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Aberystwyth

FIELD EXCURSIONS IN THE ABERYSTWYTH REGION
1—10 July 1975

REPORT BY THE DIRECTOR

During the symposium at Aberystwyth, the following field excursions were held:
3 July — Remains of round and linear pingos in the Cledlyn and Cletwr basins
4 July — 1. Coastal periglacial slope deposits at Morfa-bychan
2. Cryoturbation structures at Llanon
6 July — 1. Superficial deposits of the upper Rheidol basin
2. Large cryoturbation steps in the Carno area
7 July — Nivation forms and deposits in Cwm Ystwyth
9 July — Periglacial forms and deposits in the Tal-y-llyn valley

Excursion 1: Thursday, 3 July

REMAINS OF PINGOS IN THE CLEDLYN BASIN

In the Cledlyn basin is one of the best preserved of the numerous groups of rampart forms in Cardiganshire (Watson, 1972) which have been interpreted as the remains of open system pingos (Watson, 1971; Watson and Watson, 1972). Members of the symposium went to Cwrt Newydd, (National Grid Reference SN 489479) and the first stop was made on the minor road 1600 m to the west. This gave a view of a group of the ramparts, L, M, N and P which occupy the foot of the long gentle slope (3-4°) on the south side of the Cledlyn (Fig. 2). The director drew attention to the characteristic level tops of the ramparts, none of which completely surround the basin. This is characteristic of the Cardiganshire ramparts which are typically on sloping sites. Pingo L, the largest, has a basin about 135 m across, an external diameter about 200 m, a rampart 6 m high with a maximum slope of 18°.

The group next visited pingo U, which in the director's opinion is the most impressive rampart in Wales known to him, with its remarkably level top and smooth cross-profile, steepest slope 23° and height, 5 m. He also pointed out the level tops of ramparts R and S across the stream and stressed this feature as distinguishing these forms from kettle holes. An auger sample was taken from the junction of the organic

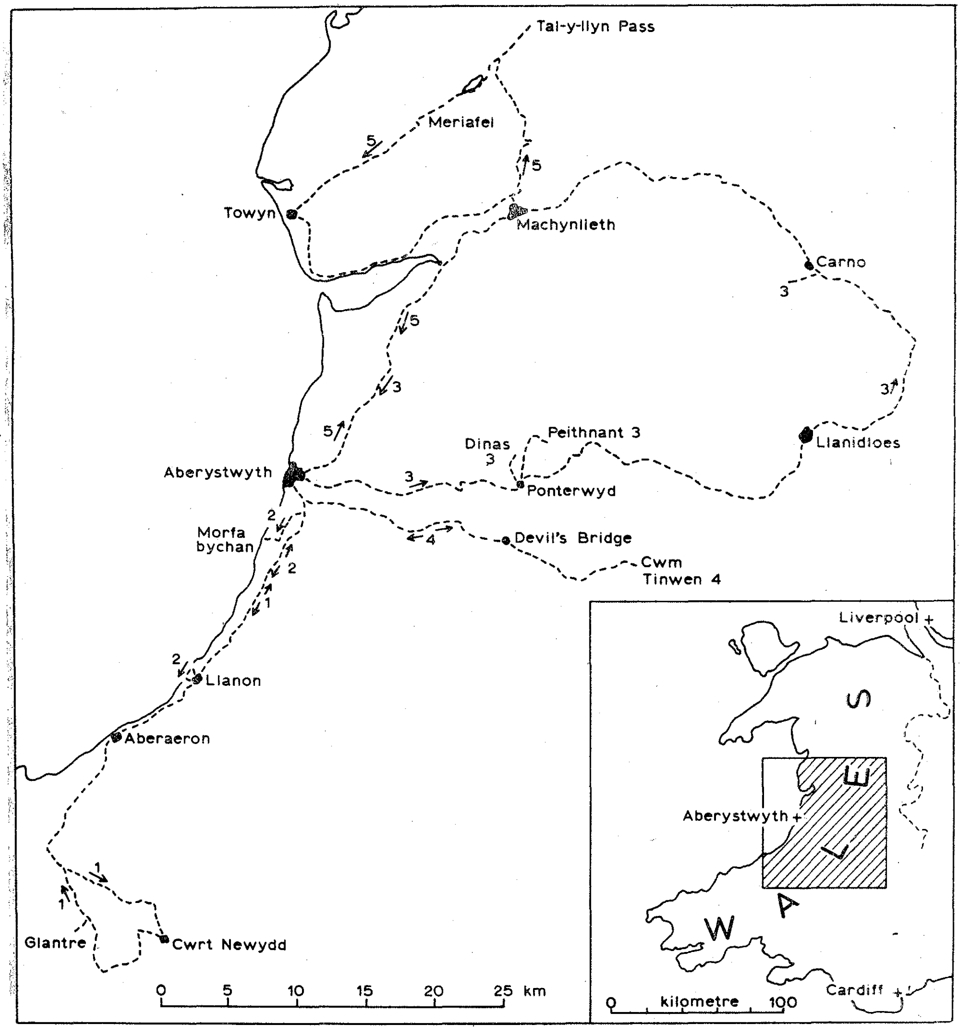


Fig. 1. Routes followed by excursions

Excursions numbered as in text

deposits and grey clay in the basin (Fig. 3). Great interest was shown in the smooth grey clay and searches made by hand recovered a few particles of fine gravel (which are usually found scattered through it; WATSON and WATSON, 1972). The director stated that a hand auger had not reached the base of the clay at 11.77 m below the basin surface.

Discussion centred around two main points, the open plan of the ramparts and the origin of the grey clay in the deep basins. On the first point it was asked if the festoon or garland form of the ramparts on the lower hillslope might not be explained by the fact that they were snow moraines, which show a similar pattern. The director replied that the depth of some of the basins, such as U, is against this. These are not surface features; the base of the clay is more than 8 m below the stream bed (Fig. 3a). The depth of this basin seems also against the view that it represented a palsa, a theory that none of the Scandinavian members who were familiar with palsas, supported.

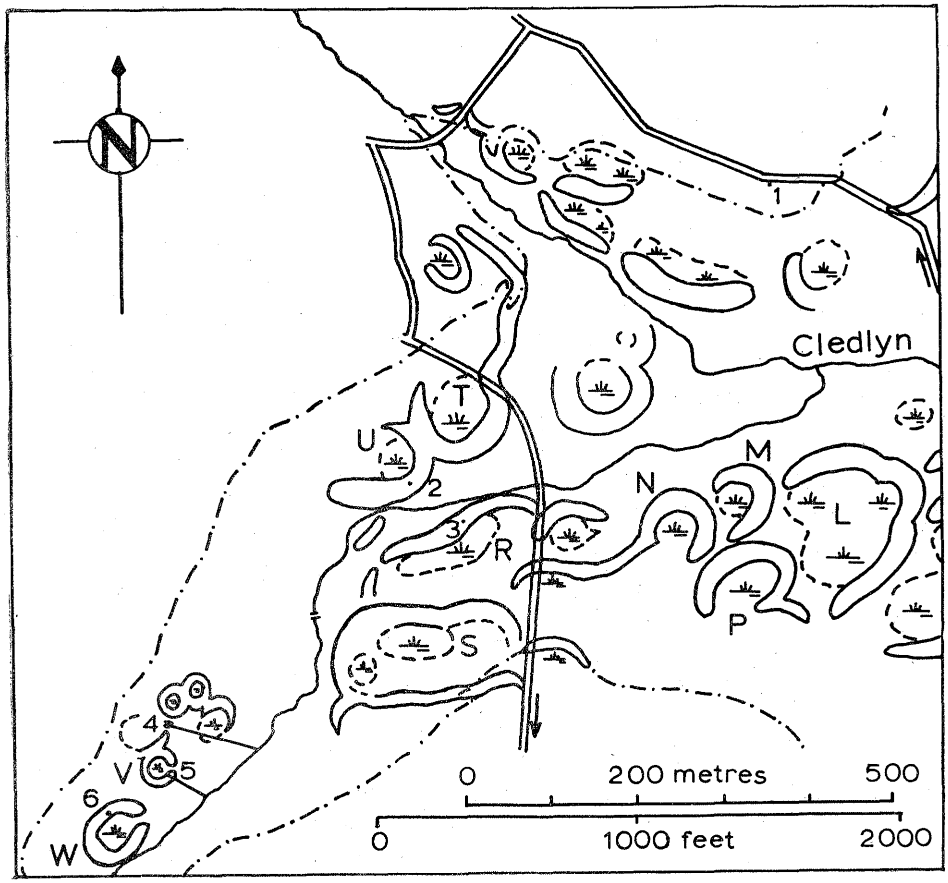


Fig. 2. The Cledlyn pingos

For letters and numbers, see text. Contour at 700 feet (213 m)

The slope-foot siting seems typical of the open system pingos of central Alaska, and on the evidence of Holmes, Hopkins and Foster (1968) there are collapsed pingos there whose remains form a crescentic or horseshoe rampart. The director had seen them in the southern Yukon. He felt that it is likely that some may not have been recognized as pingo remains. What is needed as a study of *collapsed* pingos in the central Alaska—southern Yukon area. It was asked if pingos on a slope would have an upslope rampart at any atage; by the time collapse of the skin inwards had ceased, the upslope side might have reached ground level. The director agreed that this was possible especially on steeper slopes, but in this area the basins behind open plan ramparts are asymmetrical, and deepest at the downslope end. This suggests that more material has collapsed into the basin from the upslope side than from the downslope side. It seems a reasonable assumption that this additional material is the missing rampart.

It was suggested that the grey clay had not been precipitated in a pingo pond but had already existed at depth before the frost mounds, now represented by the ramparts, developed. This silt-clay would readily form cores of segregated ice which subsequently melted leaving the clay. The director confessed that the source of this volume of grey clay was a problem. Loess had been suggested, but the grain size, often 95-98% smaller than 0.02 mm does not support this and the absence of loess outside the basins (e. g. banked against ramparts) rules it out. He had considered the possibility of injection but a sample taken almost 10 m below the surface in pingo W to see if diatoms were present, yielded no diatoms, but plant tissue and pollen. This suggested that the basin of W was open to the atmosphere at this depth. It is hoped to take samples from considerable depth in other basins to see if this is general.

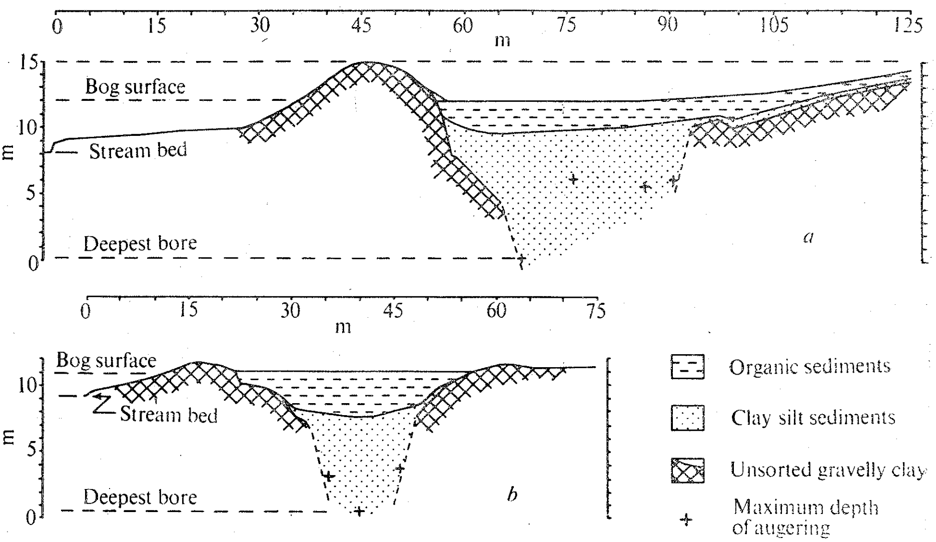


Fig. 3. Levelled profiles of two of the Cledlyn pingos: (a) pingo U and (b) pingo W

Continuous subsurface boundaries are based on contacts determined by augering, broken boundaries on the auger depths shown (+), which give minimum slopes to these boundaries. From *Nature*, 236, p. 343

Pingo R was next examined. This is elongated perpendicular to the slope. The basin is 160 m long and its maximum width 45 m, though it is only 20-25 m wide for most of its length. There is no rampart on the upslope side and the basin is asymmetrical. The interest of R is that the height (3 m) and surface slope (11°) of the lower rampart are the same where the basin is shallow as where it is deep. This suggests that the basin depth is not related to external form but to differences in the core, which the director suggested was of clear ice in the central basin but ice-lensed sediments elsewhere.

After lunch on rampart R, the group moved towards pingo W. An exposure in a drain at 4 on Fig. 2 showed the grey stony clay which appears to form most of the ramparts. It was also seen again in a shallow drain cut in rampart V. V, which is on the valley bottom is an almost circular closed rampart, with a small breach on the downslope side which probably drained the pond. W, some 20 m away is also a closed rampart form with a breach on its northeast side.

Ramparts V and W resemble those of the collapsed pingos of the Arctic plains. They are on a slope of less than 2°; this is true of other closed forms in Wales, as in the Cletwr (WATSON and WATSON, 1974) and near Llangurig (PISSART, 1963), which are on the valley bottom. The basin of V, like W (Fig. 3b) is symmetrical. This, said the director, is the negative case of the theory that the open plan ramparts are due to siting on a slope. Where the slope angle is low, there is no rampart collapse. The basin is steep-sided; measurements in V indicate that its sides slope at about 70°. In the centre of the basin of W, the bottom of the grey clay was not reached at 10.13 m below the bog surface, and the clay was still remarkably well sorted. Of the fraction smaller than 2 mm, the percentage smaller than 0.02 mm is respectively, at 4.0 m depth, 98; at 5.25 m, 98; at 6.05 m, 97; at 8.60 m, 97 and at 9.95 m, 96.

One member asked if the ramparts could be the crater rims of mud volcanoes but another argued that, in this case they would be composed of clay. Here the director stated that samples from the ramparts, including W, consisted of gravelly clay similar to that just seen in the drainage ditch at 4. The $<$ 2 mm fraction included about 40—50% of material coarser than 0.02 mm, compared with the very low values in the basin clay (*cf.* WATSON and WATSON, 1972, p. 220).

REMAINS OF LINEAR PINGOS IN THE CLETWR BASIN

The remainder of the afternoon was devoted to a visit to a group of ramparts believed to be the remains of linear pingos, sited at Glantre farm about 5 km west of pingo W (SN 424486, as Glan-rhyd-y-dre). However, site levelling for new buildings at the farm and the excavation of new drains gave an opportunity to look at the slope deposits of the area as well.

The farmer kindly drew attention to exposures at the back of a new silo (Fig. 4: 1), where the deeply shattered bedrock was exposed. As is usual in the area, the steeply dipping cleavage planes curve into conformity with the surface and the platy mudstone fragments become aligned parallel to the surface slope. Excavation on the north side of the farm (Fig. 4: 2, lower down the hillslope), shows the same orientation of the rock debris, which is mostly angular but includes a few worn and split pebbles and cobbles in a silt-clay matrix. The thickness of this very stony clay is about 1.5 m, resting on rock. The drains which are in the "poorly drained land" of Fig. 4, show this same deposit, 2 m thick close to the slope foot at 3, and 1 m thick, 150 m out at 4. At 5, it rests on water-worn gravel and gravel fragments. The director thought that the last ice in the area had become stagnant: gravels occur *in situ* on the wider plateau surfaces and in the valley bottoms. On most of the summits and slopes they

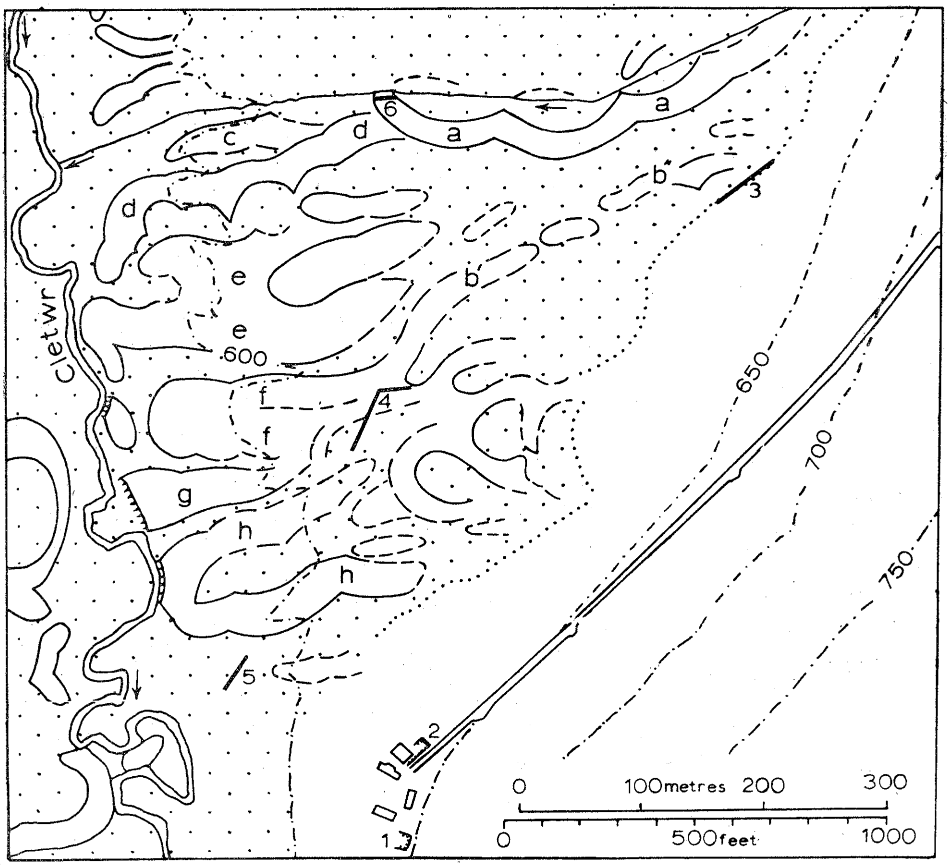


Fig. 4. Linear pingo remains in the Cletwr valley at Glantre

Dotted area, poorly drained land. Letters and numbers as in text. Contours at 600, 650, 700 and 750 feet (183, 198, 213 and 229 m)

have been removed. On gentle slopes of the plateaus, slope deposits up to 1.5 m thick, containing some worn pebbles and an occasional erratic, are found. On the steeper slopes the rock is close to the surface, as at site 1, while at the slope foot deposits similar to those at sites 2, 3 and 4 are usual. In this instance they could be seen to thin on lower ground.

A stop was made on rampart h (Fig. 4) which the director suggested is the remains of a linear pingo. Contemporary linear pingos, described as being like eskers or moraines occur in the Arctic and some have been shown to have ice cores. Some have developed axial depressions and it has been suggested that as they grow they rupture along their crest line and the subsequent melting of the core produces a pair of parallel ramparts as here (see PISSART, 1967). These ramparts are parallel to the slope. At the lower end where the two ramparts curve inwards to meet, there is a breach, presumably caused by water flowing down the central depression. Augering showed that the deepest part of the central depression is at the lower end where the underlying gravelly clay is 3.30 m below the surface (WATSON and WATSON, 1974). The ramparts, like those of the Cledlyn, are most impressive at the downslope limit and decline in relative height as the slope rises. Some members who knew the linear forms in the Ardennes stated that they were similar.

The group moved along the lower ends of ramparts g, e and d (Fig. 4), which form impressive ridges up to 7 m above the Cletwr flood plain, but breached at intervals. Though the ramparts are generally of the same character, difficulty was found in visualizing the individual pingos but the director emphasized that one is dealing

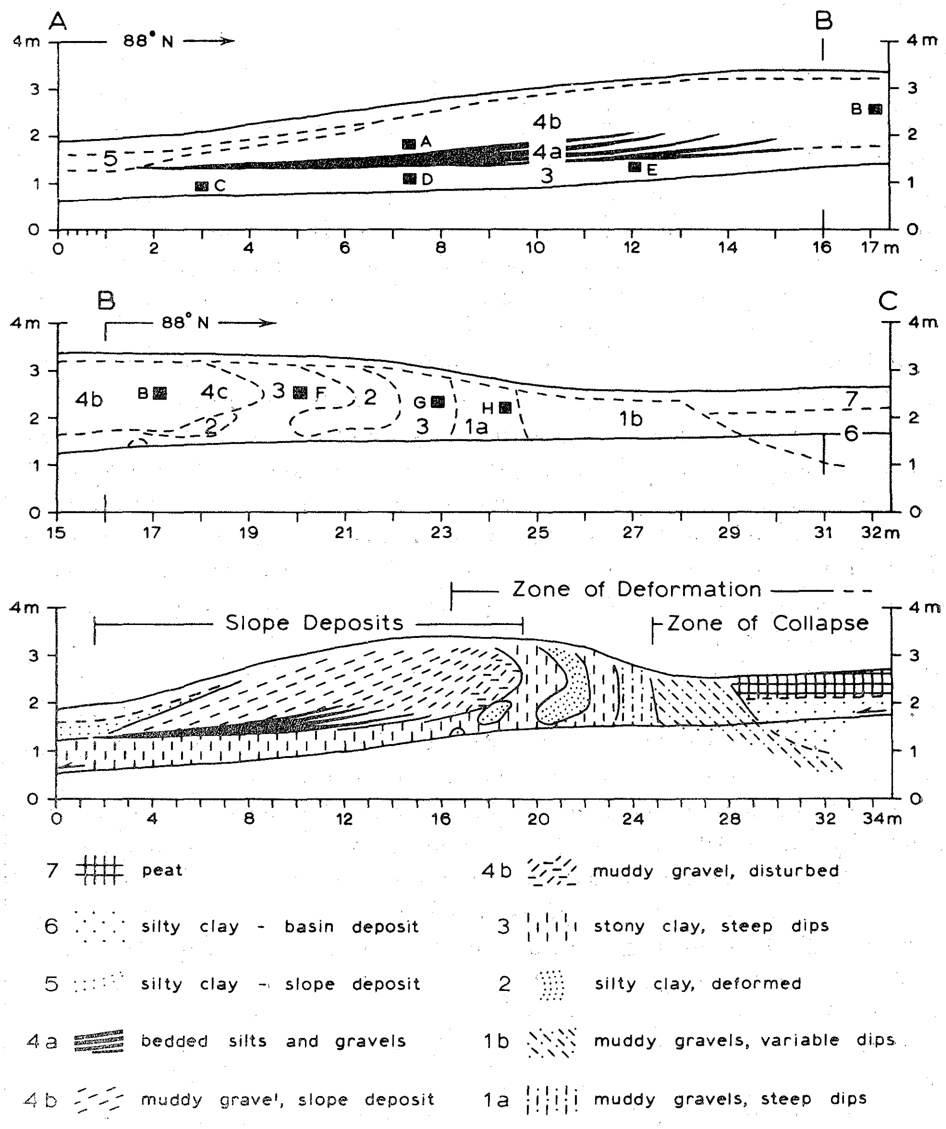


Fig. 5. Profile of pingo rampart north of Glantre

The location of the trench is shown as 6 in rampart a on Fig. 4

with repeated regrowth on the same site, as appeared to be the case in some areas of round forms. The linear forms in Wales appear to be of comparable width to round forms but as individuals covered a greater extent of slope, the possibilities of overlap would be greater. To the question whether there was any difference in slope values between areas with round and linear forms, the director doubted that there was any significant difference. In the Cletwr basin where groups of both forms occur, the slope at the limit of discernible forms is around 3°.

At the next stop, at 6 on rampart a, through which a drain had recently been cut, the director pointed out the main features of the section before members entered the trench. The most striking deposit is the interbedded silty clay, silt and fine gravel (4a on Fig. 5). The gravel bands in it thin and die out downslope so that at 8 m the silty clays form a single laminated deposit. Underlying these is a stony clay (3) in which the elongated stones appear to be vertical, and overlying them is a more stony clay (4b) in which the platy stones consistently dip downslope. Upstream of 17 m the pattern changes. In stony beds, the stones appear to be vertical, up to the soil. The silty clay (2), containing a thin organic clay band is bent into a recumbent fold. This is more clearly shown on the opposite face (not shown on Fig. 5). Above 25 m the stones in the gravelly beds have steep but variable dips, before passing under the silty clay and peat of the pingo basin.

In discussion, the director stated that counts in bed 3 (at C, D, E, F and G on Fig. 5) show that the flat pebbles may have their a or b axis vertical; the important feature is that the maximum projection planes are tangential to the rampart crest, and he suggested that this reflected pressure from the pingo basin. Count H in bed 1a which is more gravelly than 3 gives the same result. On the other hand, counts in bed 4b at A and B show the a-axis dipping downslope at low angles, the three-dimensional fabric at A is typical of a slope deposit of platy debris. He regarded the silts and gravels (4a) as the distal part of these slope deposits, the silts being laid down by rain or snow meltwater. On the site, he compared them with the thin deposit of silt laid down at the foot of the spoil bank (taken from the trench), by the rain of previous winter. He agreed that some of the clays in 4a appear rich in organic matter and that it may have been derived from the outcrop of the organic band in bed 2 when the rampart was higher.

Members pointed out that similar deformations had been seen in ramparts in the Hautes Fagnes in Belgium and in contemporary pingos in the Canadian Arctic. The director stressed the need for deep sections through ramparts: a drain of 1 m deep, which was the depth of the older drains showed only the forward dipping material of the slope deposit and the top of the deformation. In such cases he had been inclined to interpret the forward-dipping material as tilted by the pressure of the growing ice core. He recalled the exposure in the rampart R cut by the Cledlyn which had been examined in the morning. The exposure, which is parallel to the rampart crest, shows

3. a very stony clay with the platy stones lying parallel to the rampart slope,
2. thin beds of fine muddy gravel and more open work gravel,
1. stony clay, down to stream level.

He thought a section perpendicular to the trench here at 10 to 11 m would be comparable.

The trench also gives a section along the central depression of the pingo. As has been found in the Ardennes the basin is shallow, the bottom of the grey clay being reached less than 3 m below the bog surface. The structures in the rampart are consistent with thrusting outwards from this basin and several members felt that this is a strong argument for regarding the rampart as the remains of a pingo.

Excursion 2: Friday, 4 July

SLOPE DEPOSITS AT MORFA-BYCHAN

The coastal strip at Morfa-bychan forms a bench 30—45 m above sea level. Thif bench is clearly a bedrock feature 350 m north of Morfa-bychan and between Morfas -bychan and Cwm-ceirw where the present cliff is formed of rock (Fig. 6). South o-Cwm-ceirw, rock is not seen until 800 m south of Ffos-las, but mapping of the shore platform indicates that the deposits shown on Fig. 7 form only a thin cover against a steep rock face (*cf.* Pl. 1). The structure of these deposits is typical of slope deposits. There is consistent dip towards the sea (Pl. 3), and in strike section the beds appear horizontal or very gently dipping (Pl. 2). Individual beds are concave, the dip decreases downslope, and the dips of a series decrease upwards vertically at any one point (Fig. 7).

Members of the group walked southwards from Morfa-bychan along the cliff top to see the upper part of the deposits. At A, the view southwards shows the concave surface which is typical of coastal terraces of head in southern England and northern France. From the headland above Cwm-ceirw gully (290 m on XY, Fig. 8), the cliff at A and the narrow shore platform of Aberystwyth Grits could be seen. The director pointed out that the Aberystwyth Grits, consisting of siltstones and sandstones interbedded with cleaved mudstones of Silurian age are the only rock outcropping on this coast and for some 7 km inland. The very large blocks of bedded Aberystwyth Grits present at the base of the Yellow Head at many points could also be seen along the outer edge of the shore platform, with their bedding dipping steeply seawards though the bedding of the shore platform is nearly horizontal. The director stated that the base of the Yellow Head is unquestionably below the level of the existing shore platform which truncates superficial deposits and rock. It is difficult to see the rock platform as an exhumed surface. In Cwm-ceirw gully the buried rock cliff against which the Yellow Head rests was seen (Pl. 1), and from this to point D a series of gullies in the cliff edge shows the sequence of Blue Head, Gravels, Brown Head, and Loess. The Gravels thicken seawards and sorting and bedding improve as beds of fine gravel, sand and silt increase in number. At D a descent was made into the upper part of a gully to examine the Brown Head and Gravels (profile D, Fig. 8).

The Brown Head consists of unweathered, angular rock debris in a brown-grey muddy matrix (Pl. 4). This matrix is relatively low in clay and silt (Table I, nos. 4, 5

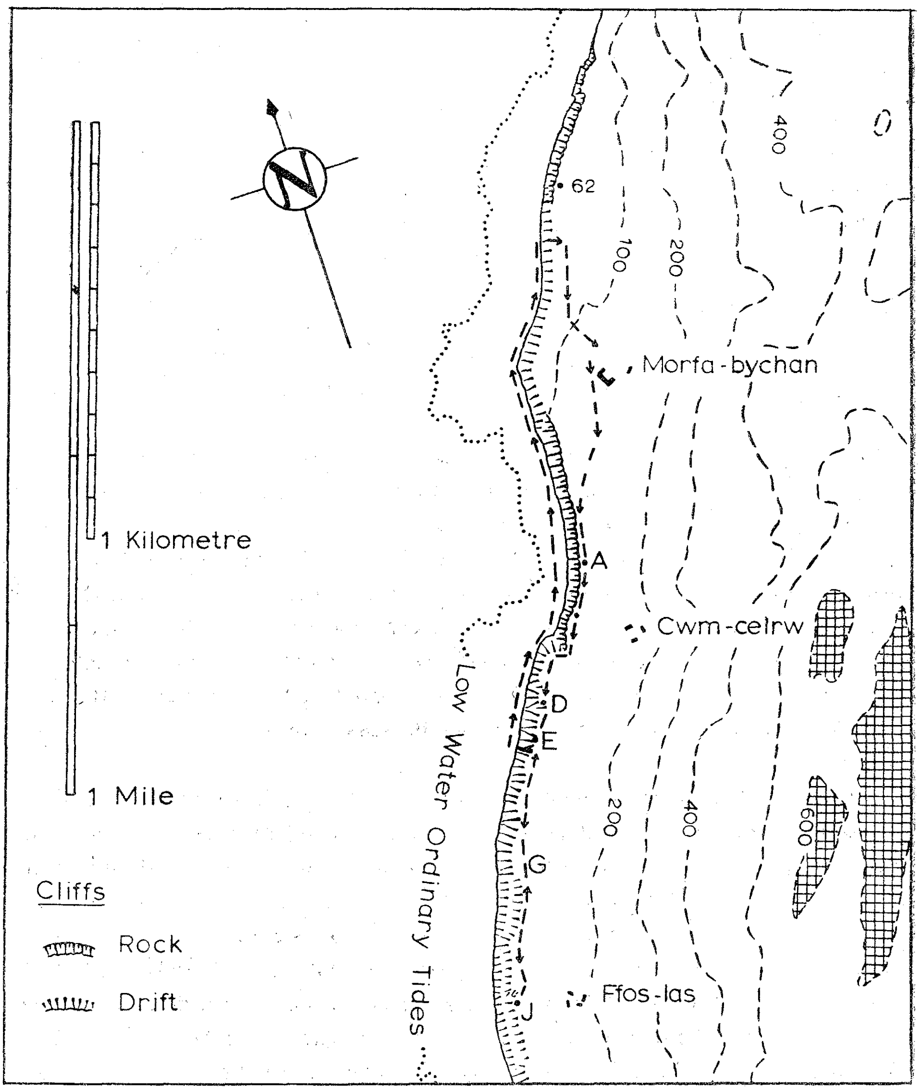


Fig. 6. Excursion route at Morfa-bychan
Letters as in text and Fig. 8. Contours in feet

and 6). The material is unsorted though there are variations in the maximum size of the debris; though there is no consistent sequence, the upper part is generally finer than the base. The surface zone around the gully shows vertical cracks, some of which have been open fissures filled by the overlying Loess (*cf.* Table I, nos. 3 and 4 where the coarse sand fraction present in the Brown Head is absent in the fissure). Two round-bottomed wedge-like structures attracted much attention and it was agreed that they are not ice-wedge casts as the typical internal collapse pattern is absent (Pl. 4). The Brown Head was pronounced "typical of the colluvium of Alaska".

Beneath the iron-panned base of the Brown Head is the upper of the two interbedded stony clays (see profile D, Fig. 8). These are similar to the main mass of the Blue Head. The gravelly beds which form the greater part of the deposit consist of coarse edge-rounded to angular gravel, poorly washed and poorly sorted. Associated with them are thin beds of washed fine gravel, sand and occasionally, laminated silt. The director interpreted these as laid down by slope wash, pointing out that they

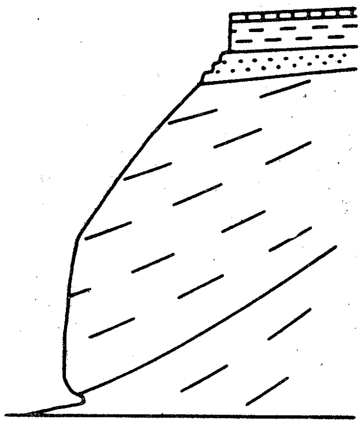


Fig. 7. Sequence of beds at Morfa-bychan
Dips and relative thicknesses of the beds are those in the area E—F

occupy a depression in the Blue Head surface between the high rock area at A and the highest point on the Blue Head at J, and that they thicken towards its centre (Fig. 8). They are found again north of A and south of J.

The top of the Blue Head was also examined. This consists of debris of the Aberystwyth Grits of all sizes, which is rather angular, though some edge-rounding occurs (Pl. 5). Angular boulders of 0.3 m are common and some exceed 1 m in length. The larger particles are embedded in a dark grey compact matrix which is also unsorted (Table I, Nos. 7—11). The material is always fresh and unweathered.

A field bank had been constructed at the top of gully D and the surface disturbed, so the Loess was examined at the top of gully E, where it is about 1 m thick and consists of a gleyed silt, about 70% being fine sand and silt. It is unbedded, has a rough vertical cleavage, the coarse sand does not exceed 5% of the fines, and it lacks small gravel, though as is common in loess near hill slopes, it contains flat angular stones, sometimes in layers. Members agreed it does not meet the generally accepted standards for loess in that it has 20—25% clay, the 0.01—0.05 fraction is only 30—40% (Table I) and it is non-calcareous. It was suggested that it is a slope deposit, but in this case it is difficult to explain the scarcity of fine gravel and sand which is abundant in all of the underlying drift deposits.

The route from E to G gave repeated views of the Blue Head and two points were generally agreed. First, there is a marked unconformity between the Blue Head and the overlying gravel; the base of the latter truncates the steeper bedding of the Blue Head. Second, though when seen at close hand at D, the Blue Head appears massive and unbedded, from a short distance, a seaward dipping stratification is everywhere apparent. This appears to be due partly to variations in the size of the coarser debris, and partly to beds of washed sand and small gravel, whose beginnings could be seen some distance below the cliff top and which thicken downslope. They are sometimes

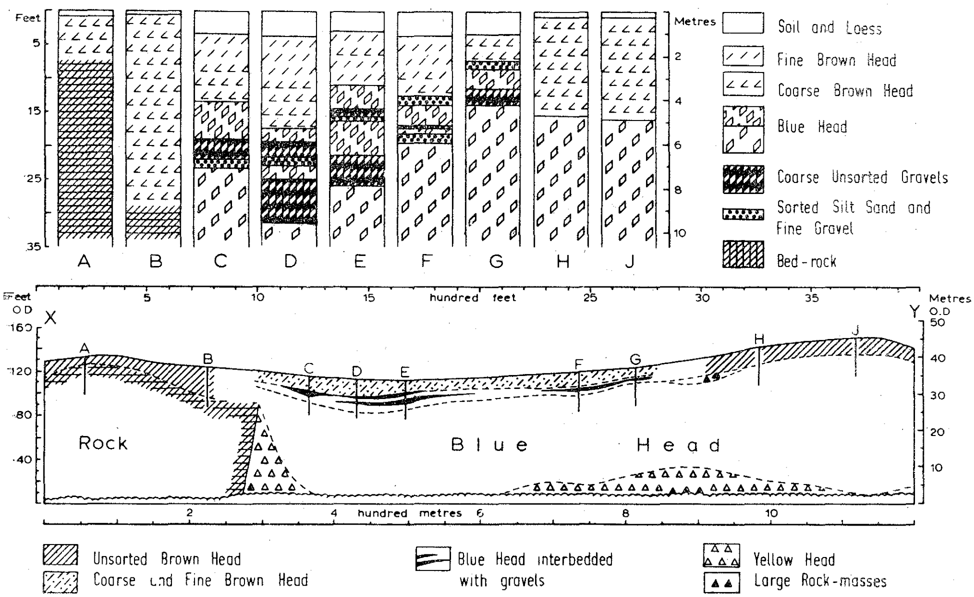


Fig. 8. The Gravels and Brown Head between Cwm Ceirw and Ffos-las

Letters as in text and on Fig. 6. The vertical scale is five times the horizontal. From the *Geological Journal*, 5, p. 424

clearly lenticular within the area of a single gully, thinning laterally from a central maximum (*cf.* Pl. 2, view from beach 150 m south of E). The discussion on the Blue Head centred on whether it is a gelifluction deposit derived from the hill slope at the back or a glacial deposit from inland Welsh ice reaching the edge of the Coastal Plateau at the top of the slope.

At J the deposit shown as Brown Head differs from that seen further north. The surface horizon down to a depth of about 2 m consists of erected pebbles or vertical stones containing involutions of brown loam. This development may be related to the fact that the surface here is almost horizontal, as vertical stones with involutions seem to occur only with very low surface slope angles. The director said he doubted the "Brown Head" here is a slope deposit, but instead is the weathered top of the Blue Head which has been cryoturbated. Further north the Brown Head has the fabric of a slope deposit, here the fabric is unknown as the exposed face is quite inaccessible. In the deep gully at J the Blue Head structure is again clear, and shows thin beds of sand and fine gravel thickening downslope (*cf.* Pl. 21 E in WATSON and WATSON, 1967).

The group retraced its steps to a gully 40 m south of E and descended to the beach to examine the lower part of the Blue Head. In the 2—3 m above the beach the large grit blocks seen at higher levels are absent and there is a dominance of stones less than 20 cm long. These are frequently discoloured and easily broken, in contrast to the fresh material in the mass of the Blue Head. Some of this may have been picked up from the underlying Yellow Head but frequently it is less angular. Between 400 and 450 m on XY (fig. 8) much worn, even well rounded material is present and the director suggested that glacial or fluvio-glacial material had been incorporated. This was probably derived from superficial deposits formerly on the bench, and was the first material to come down when slope processes affected the upper slopes.

At about 350 m on XY (Fig. 8) the Yellow Head appears at beach level and forms an increasing part of the cliff northwards. In most places the surface of the Yellow Head is covered by a grey muddy wash derived from the Blue Head above, so that its upper limit can be seen only after cliff falls. The Yellow Head consists of very angular rock fragments, frequently weathered, in a yellow-grey clay-silt matrix (Table I, nos. 12 and 13) which sometimes completely envelops the clasts as in the Blue Head, though the coarser beds are sometimes open-work. In the basal beds the large bedded blocks were seen, at the foot of Cwm-ceirw gully and again north of Morfa-bychan near the path leading up from the beach.

To sum up the discussion, both the Yellow Head and the Brown Head were accepted as gelifluction deposits. The group generally agreed with Mellard Reade (1896, *in* Watson and Watson, 1967, p. 419), that the Blue Head has "a sloping stratification as if tipped over the cliff". One view expressed was that the material is glacial in origin, on the grounds that striated stones are present and are not confined to the basal zone. Against this, other members argued that the large blocks would not be

Table I

Grain size of typical Morfa-bychan sediments

	Percentage of fraction < 2 mm				
	2μ	10μ	20μ	50μ	200μ
1. Loess-like silt — 1500 m	23	40	48	74	96
2. Loess-like silt — 3500 m	23	47	61	87	98
3. Loess-like silt in "frost crack" — 1700 m	20	42	55	75	96
4. Brown Head surrounding No. 3 — 1700 m	17	34	41	63	85
5. Brown Head — 1500 m	10	26	33	64	82
6. Brown Head — 2100 m	11	25	36	52	75
7. Blue Head, top — 700 m	21	43	52	61	75
8. Blue Head, bottom — 700 m	16	37	48	58	72
9. Blue Head, top — 2150 m	16	43	54	70	80
10. Blue Head, bottom — 2150 m	22	48	57	72	82
11. Blue Head, basal — 1500 m	25	49	55	68	80
12. Yellow Head — 800 m	21	52	59	67	71
13. Yellow Head — 2200 m	18	48	63	80	90

so fresh and angular in a glacial deposit. In reply to a question the director stated that no erratics have been found in the deposits but that ice from the east might not have carried anything diagnostic. He pointed out that the striated stones found are soft mudstone and he believed the striae were probably produced by slope movement. The large grit blocks scattered thoughout the main deposit appeared to be fresh joint blocks.

CRYOTURBATION STRUCTURES AT LLANON

In the afternoon the group went to Llanon where a series of involutions and vertical stones is continuously exposed in low coastal cliffs for nearly 3 km. These were examined between the rivers Peris and Clydan (Fig. 9) where they are developed mainly in fluvial gravels, and for 300 m south of the Clydan where they are developed in glacial deposits. The involutions are of the festoon type, consisting of clay-silt cores in gravels or very stony till. They are therefore not *load deformations.*

The history of this area may be summarized as follows:

1. Deposition of till, of local non-calcareous material in the lower part and calcareous till with Northern erratics in the upper.

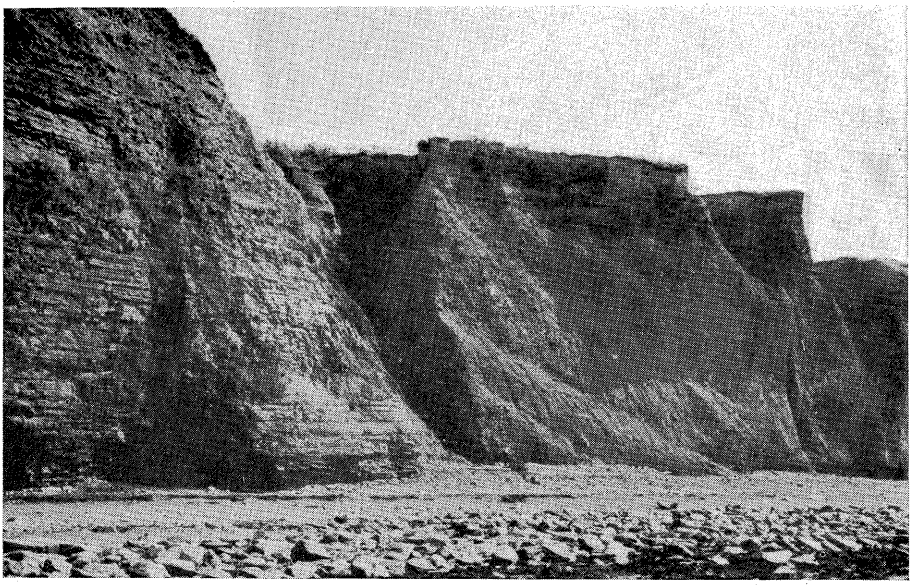
2. Erosion by the Peris and Clydan where they debouched on to the coastal "drift platforms" and the deposition of boulder gravels on the truncated till surface. These gravels extended as far south as 550 m on Fig. 9. South of this the till still formed the surface at the end of this episode.

3. Intense cryoturbation of the surface zone of both deposits, producing the striking development of vertical stones and involutions of the *Lower Cryoturbated Horizon* of the alluvial gravels (Fig. 9) and further south, of the till. The lower limit of cryoturbation is nearly horizontal and lies near the top of the modern beach gravels. Below it the deposits are undisturbed, the fluvial gravels retain their imbrication, while in the till the boulders dip at low angles and have a preferred stone orientation almost parallel to the coast (Fig. 10). The lower limit of cryoturbation is interpreted as a fossil permafrost table.

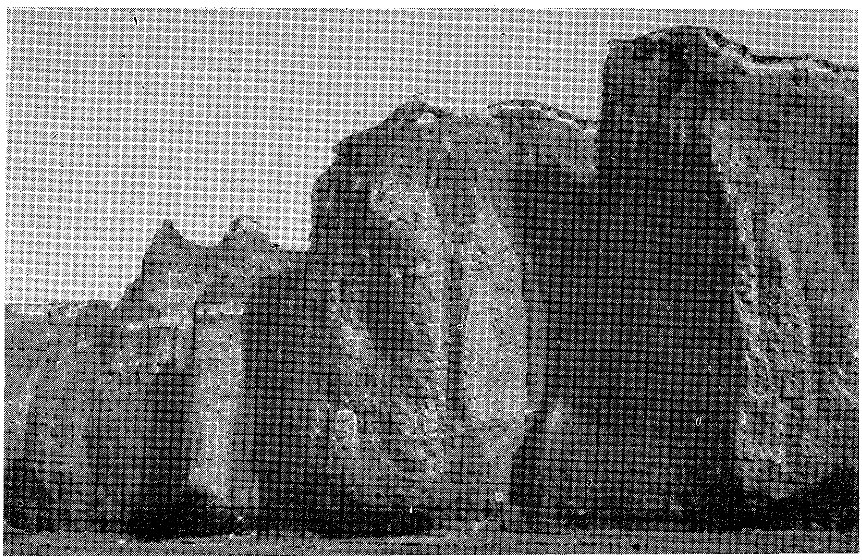
4. A second period of erosion by the two rivers, removing the upper part of Lower Cryoturbated Horizon and depositing more gravels, of smaller calibre than the Lower Horizon, as well as silts and sands. River action affected a wider area than in the earlier fluvial episode, so that the cryoturbated till north of 720 m was truncated; south of the Clydan, the till still formed the surface zone.

5. A second period of cryoturbation less intense than the first, producing festoons in areas of interbedded gravels and silts but the clean coarser gravels of the main channel areas were unaffected except for a shallow surface zone. There is some evidence in the outer parts of the Peris-Clydan fan (400—550 m on Fig. 9) that this second period consisted of two separate episodes of cryoturbation following on two periods of fluvial activity.

The party first examined the stretch between 140 and 200 m where the coarse platy fluvial gravels at the top of the beach frequently have a visually clear imbrication

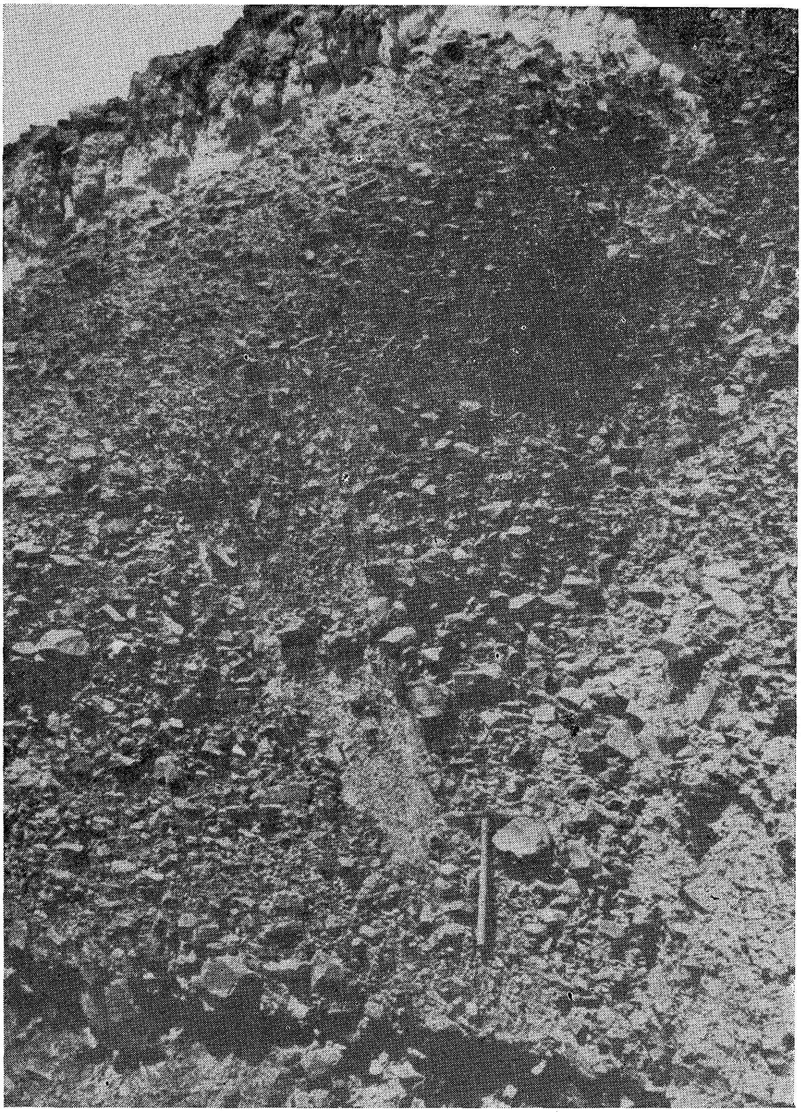


Pl. 1. Morfa-bychan. Slope deposits dipping off the fossil cliff, west of Cwm-Ceirw (between A and D on Fig. 6). Cliff, 36 m high



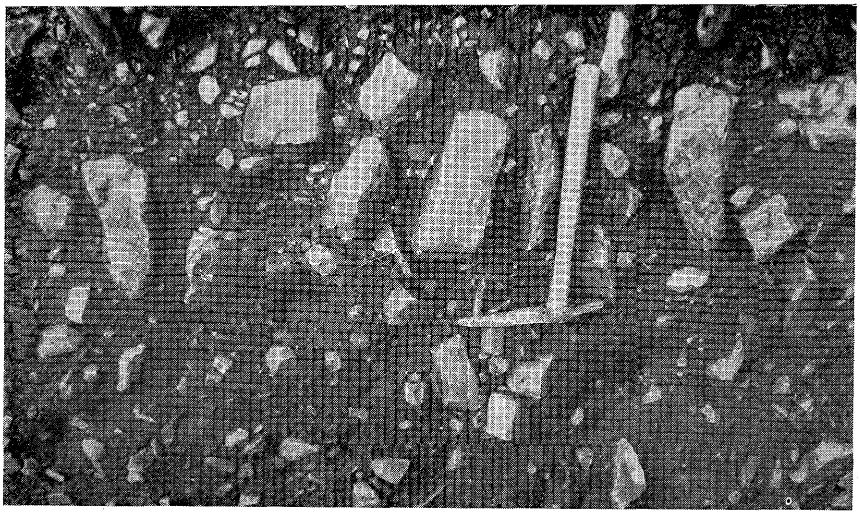
Pl. 2. Morfa-bychan. Strike exposure of Blue Head, 150 m south of E on Fig. 6. Cliff, 33 m high

Pl. 3. Morfa-bychan. Dip exposure of slope deposits, 240 m south of J on Fig. 6



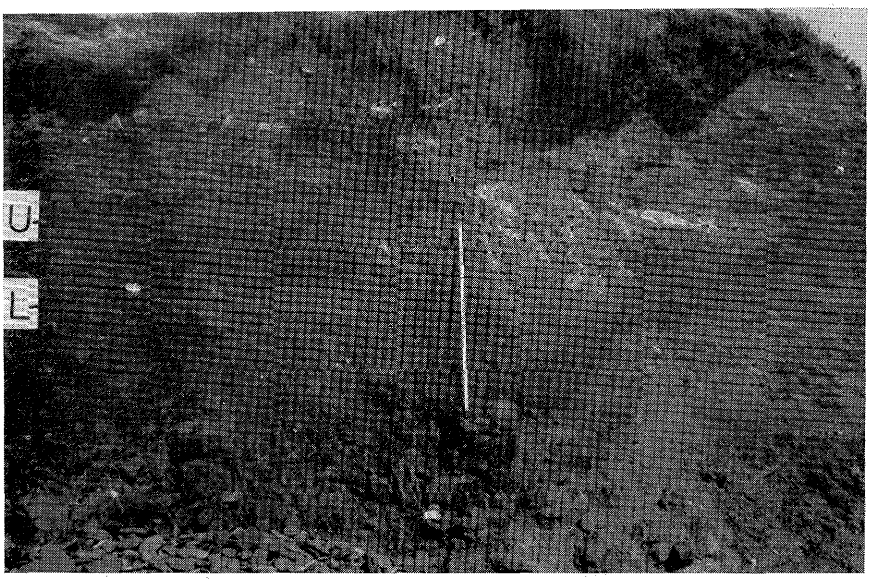
Pl. 4. Morfa-bychan. Brown Head at the top of gully D showing wedge-like structure

Hammer, 45 cm long



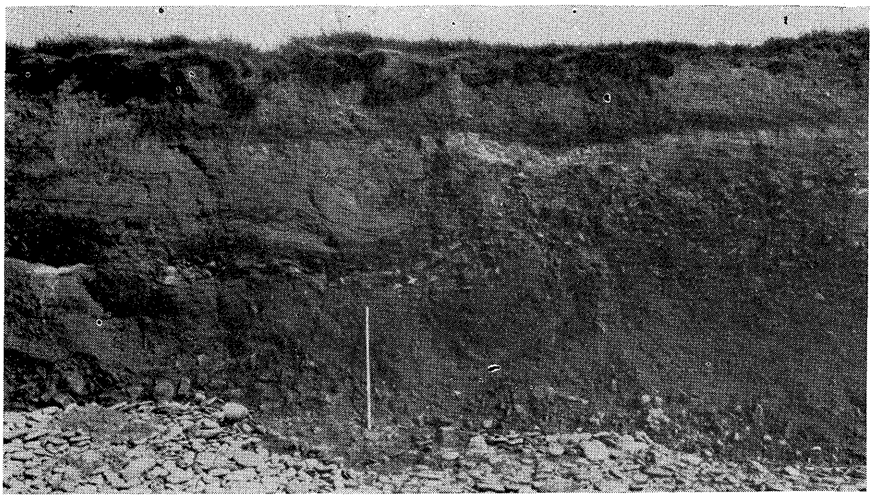
Pl. 5. Morfa-bychan. Exposure of Blue Head on shore platform

Hammer, 45 cm long



Pl. 6. Llanon. Lower Cryoturabation Horizon below line LL and almost undisturbed upper gravel above line UU. The gravel between the two contains festoon structures. At 260 m on Fig. 9

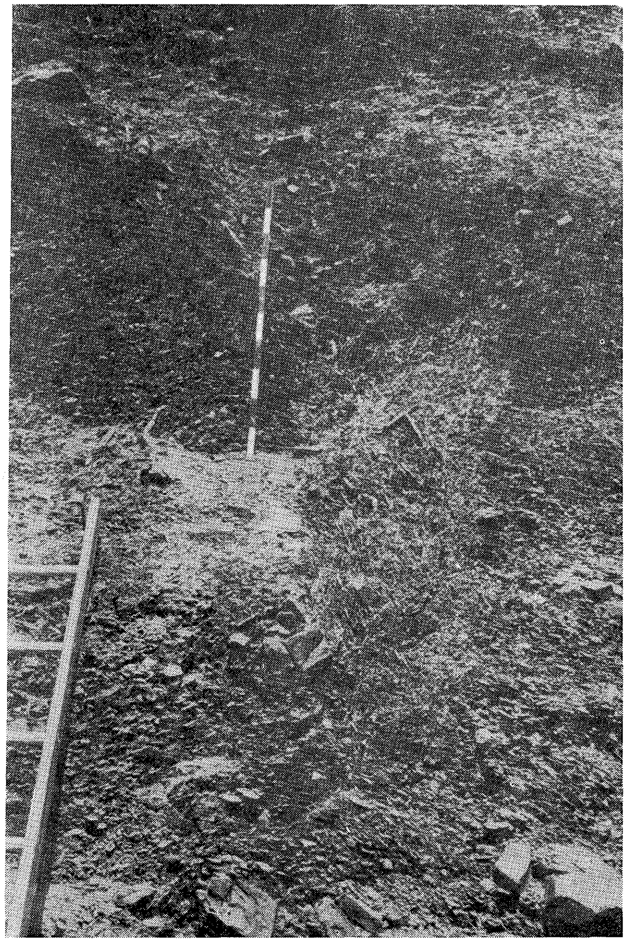
Stick, 1 m long



Pl. 7. Llanon. Two cryoturbated horizons at 550 m on Fig. 9. In the involution above the metre-stick the deformed bedding of the silt and sand is seen

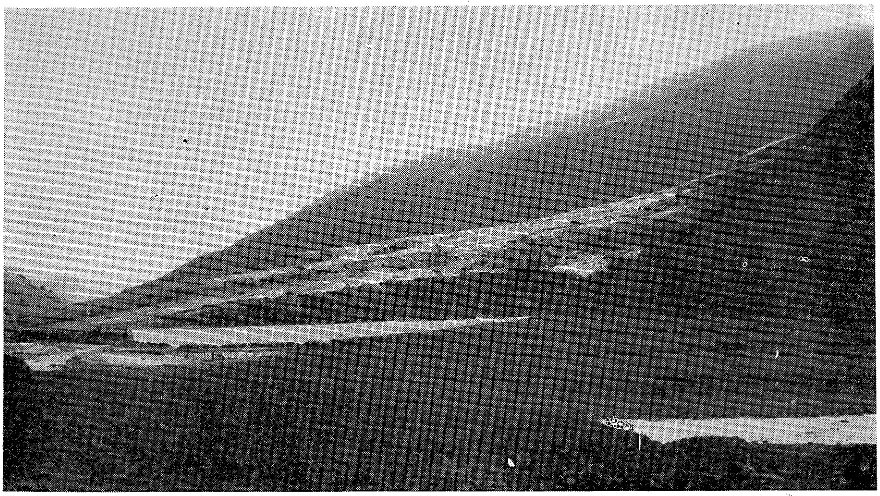
Pl. 8. Llanon. At 670 m on Fig. 9, the metre-stick rests on decalcified Irish Sea Till which formed an involution core. Above are almost undisturbed silts, sands and gravels

Pl. 9. Upper Rheidol. Exposure at H on Peithnant (Fig. 11)
Stick, 90 cm long stands on base of bed B

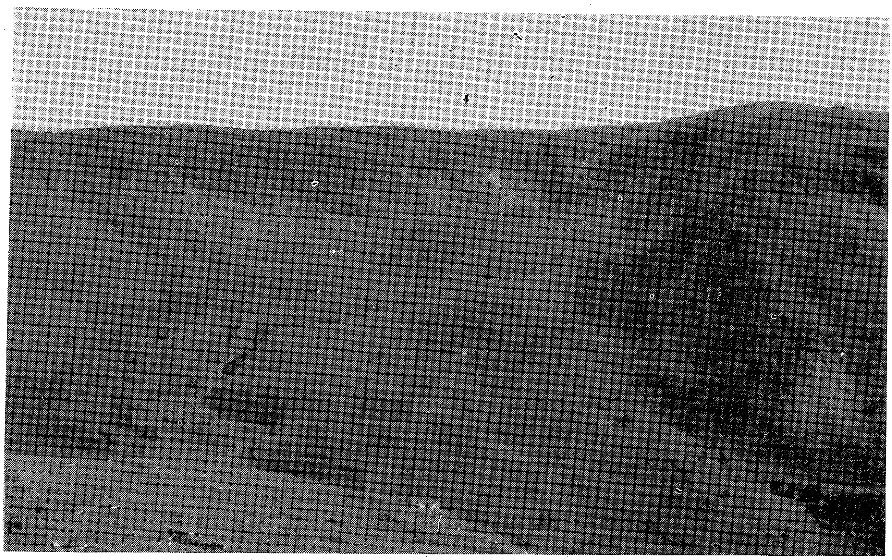


Pl. 10. Wedge structure 4 km N. E. of Ponterwyd

The stick measures 1 m



Pl. 11. Cwm Ystwyth. The debris fan from Cwm Du on the right closes the Ystwyth valley (Fig. 12)



Pl. 12. View of Cwm Du from opposite side of valley. The protalus is clearly seen in the right hand corner of the cirque (see Pl. 13)

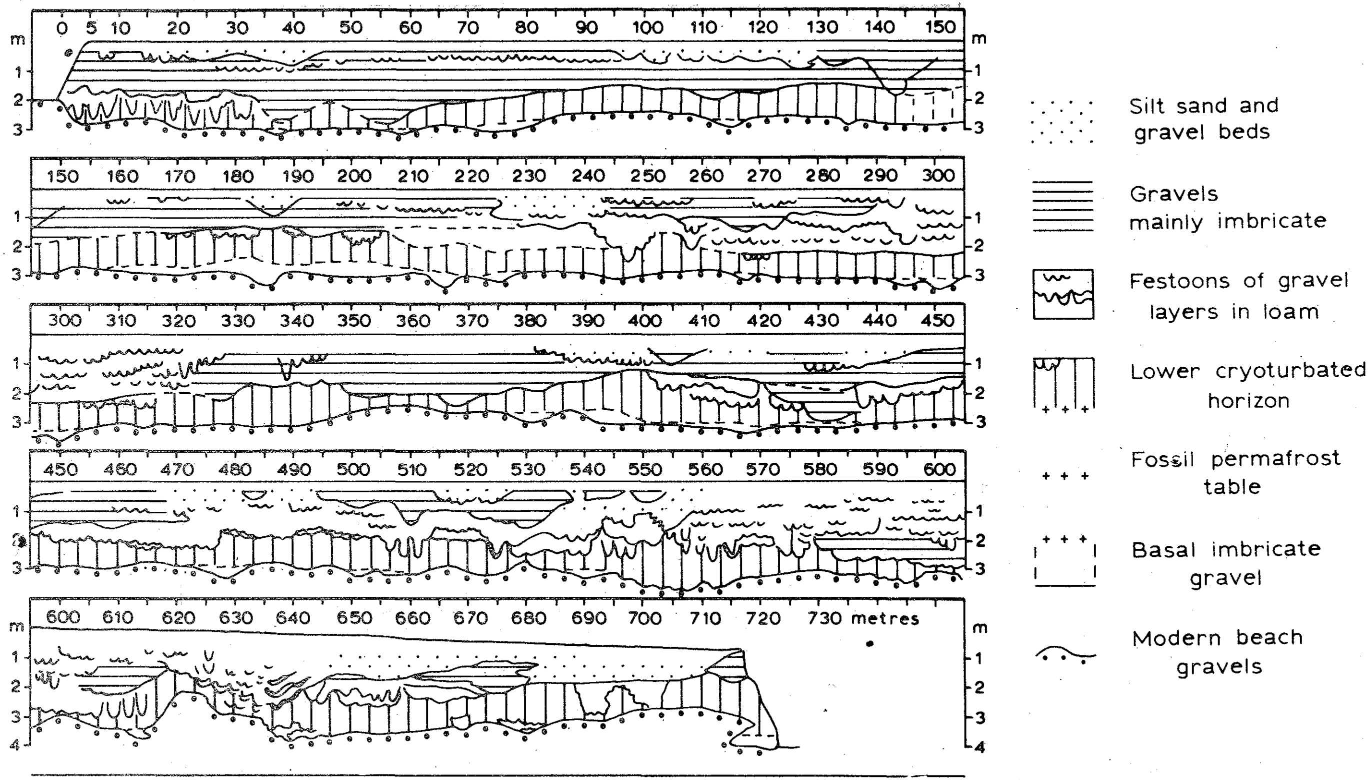


Fig. 9. Cryoturbated deposits between the Peris and Clydan Rivers, near Llanon

Profile trends SSW from the Peris valley at 0 to the River Clydan at 725 m indicating flow off the land. The director added that the maximum dip of the maximum projection planes (Anon. 1965), between the Peris and 480 m suggested flow parallel to the present flow direction of the Peris and Clydan. Above the presumed fossil permafrost table, the gravels are disturbed and in places have a marked vertical orientation. South of 170 m shallow pockets of clay-silt occur, both they and the vertical stones being truncated by a surface which marks the base of an upper series of imbricate gravels. The maximum dip of the maximum projection planes indicate the same flow direction as in the lower gravels. The director believed that these pockets are only the bottoms of involutions and that the active layer would have been thicker than the metre which remains. It was noted that the involution cores contain variable amounts of gravel which is small and often angular in contrast to the boulder gravels enclosing them, but like them often vertical.

It was asked whether the involutions might be explained as channel forms produced by the streams, with subsequent collapse of the banks producing the festoon character. The director replied that the retreat of the cliff during the last 15 years showed that the festoons are plug and not linear forms. This is also borne out by observations 6 km to the southwest where the involutions are truncated by the shore platform and may be seen in plan (WATSON, 1965, Plate 14c). Some members familiar with involutions in river terraces in the Low Countries and Hungary thought they were similar to those seen here.

The section from 0 to 200 m was the main area of erosion and deposition by the Peris in the second period of fluvial activity mentioned above, but between 200 and 320 m there was less erosion of the Lower Cryoturbated Horizon so that more impressive involutions survive. There was some discussion amongst members as to how many periods of cryoturbation are represented. The higher part of the cliff also shows well developed festoons in contrast to the relatively undisturbed upper gravels between 140 and 200 m. These festoons occur in relatively thin beds of gravel in silt which was deposited between the main areas of deposition by the Peris and the Clydan. The section between 320 and 470 m was the main area of erosion by the Clydan in the second fluvial phase, so that there was deep erosion of the Lower Cryoturbated Horizon (which was completely removed at 430 m) and the pattern is generally similar to that between 140 and 200 m. South of 470 m the evidence indicates less vigorous fluvial erosion; the involutions in the Lower Cryoturbated Horizon are more completely preserved than in the sections examined to the north, so the details of structure can be more closely observed. In some, the core has a bedding concentric with the base, showing that the fine materials of the cores are not produced by progressive sorting but consist of materials which were in some cases previously sorted and bedded. The other point of interest was that there appeared to be evidence for the deformation of earlier involutions, suggesting fluvial deposits thinner than the active layer so that seasonal freeze and thaw extended down to and involved deposits already cryoturbated. Here again there was speculation about the number of periods of cryoturbation; there appeared to be evidence for three, though some felt that more detailed study might reveal more.

South of the Clydan, the beach covered the base of the vertical stones except in limited stretches where the full sequence could be seen. This is shown in Fig. 10, 210 m south of the Clydan:

2. above a fairly horizontal base, local stony till with elongated stones and boulders on end, up to the base of the soil (3 on Fig. 10). In the upper part, festoons mainly of red-brown clay (4);
1. emerging from beneath the beach gravels, undisturbed local till (2).

There was some discussion as to whether the festoons were due to downthrusting of the core or upthrusting of the surrounding material. Some points seem to favour

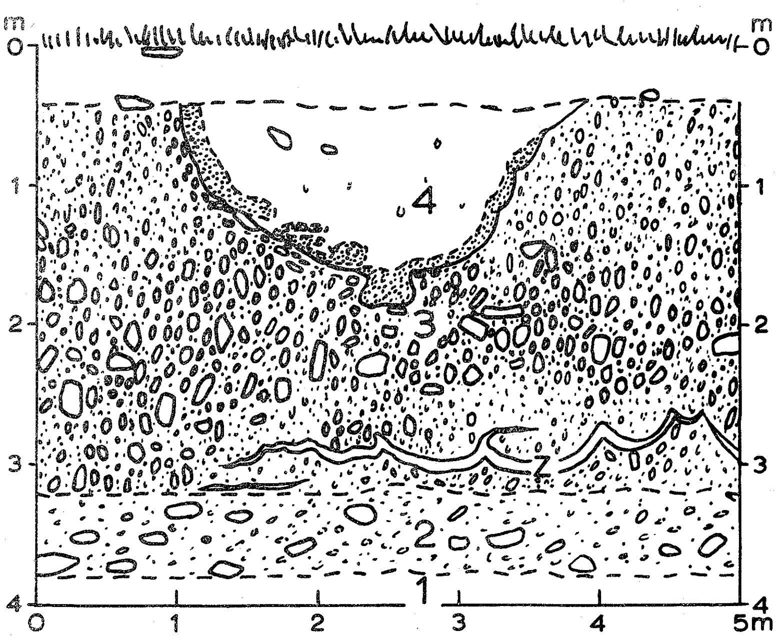


Fig. 10. Festoon in vertical stones, 210 m south of the River Clydan

1. modern beach; 2. undisturbed local till; 3. cryoturbated local till; 4. festoon of decalcified Irish Sea till surrounded by a deformed layer of gravelly coarse sand; z. deformed lens of silty clay and sand

downthrusting of the core; on Fig. 10 the fine gravel outer layer of the festoon appears to have burst into the underlying vertical stone layer at 2.5 m. The slightly irregular base of the festoon (better developed in other examples), suggests divergent thrusts outwards. Generally it was felt that both downthrust of the core and upthrust in the surrounding material occurred. The suggestion was made that the vertical stones might be due to glacial drag but since the same structures occur in the fluvial deposits with the presumed permafrost table at their base and may be followed from fluvial to glacial deposits it seems more likely that the process was unrelated to the deposition of the till. The cliff is higher here than to north of the river and the depth of the presumed active layer exceeds 3 m. Some argued from this that more than one till (in terms of deposition) and more than one period of cryoturbation was involved. There was general agreement that in view of the depth of weathering of the till and of the complexity of the processes in the Peris-Clydan gravels, which followed its deposition, that the till must be older than the last glaciation.

Excursion 3: Sunday, 6 July

SUPERFICIAL DEPOSITS IN THE UPPER RHEIDOL BASIN

On reaching Ponterwyd (SN 750808) the minibus followed the minor road on the west side of the Rheidol to stop A (Fig. 11) overlooking Dinas Power Station (access by kind permission of the Central Electricity Generating Board). The director drew attention to the asymmetrical character of the valley; the group were on the

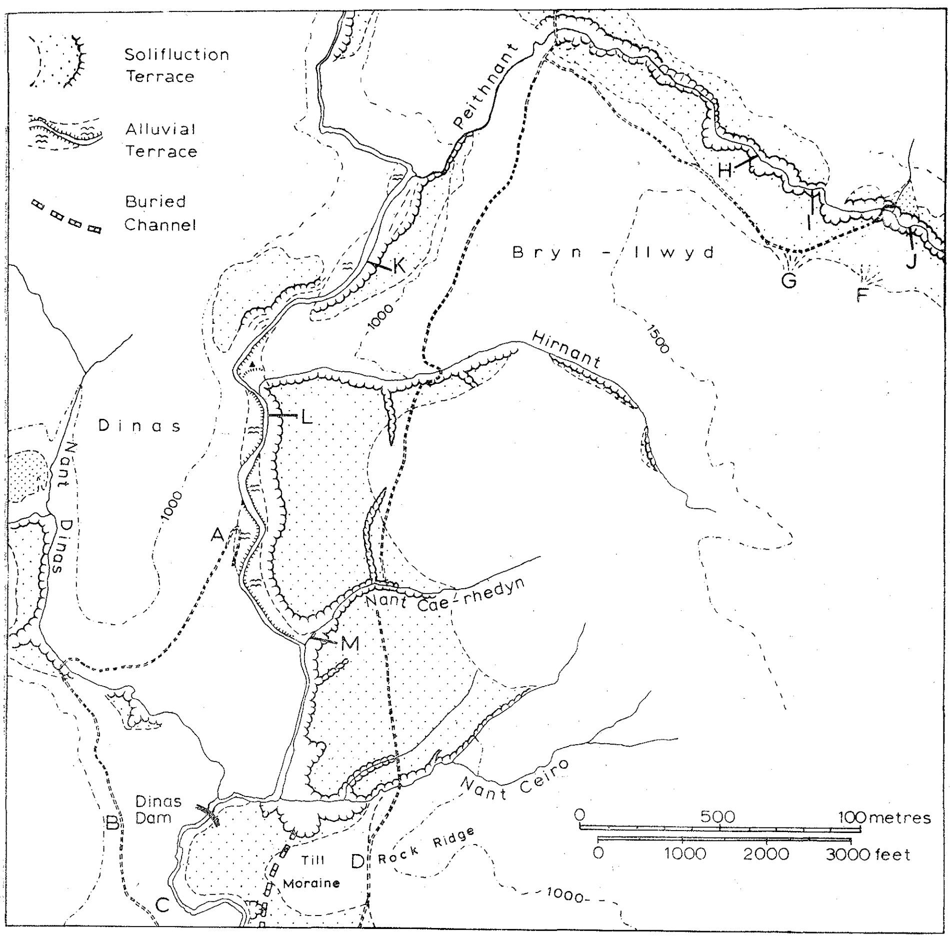


Fig. 11. The superficial deposits of the upper Rheidol valley between Ponterwyd and Peithnant
Letters as in text. Contours at 1000 and 1500 feet (305 and 457 m)

steeper rocky western side, while opposite, a long slope ends in bluffs up to 30 m high, overlooking the river. Exposures in the bluffs show a stony grey clay, but this gives a false impression of the volume of superficial deposits. As at Morfa-bychan, thick deposits are limited to a narrow belt, in this case along the river. This is shown by the profiles of the tributaries, Nant-cae-rhedyn, Hirnant and Peithnant which fall steeply over rock to the Rheidol, a very short distance behind the bluffs. Upstream of these falls, they flow down the long drift slope in shallow valleys some 3 m deep. The belt of river terraces along the Rheidol is about 85 m wide (Fig. 11) and on the outside of each meander the Rheidol has cut into the rock sides of a partly infilled valley. The asymmetry of the upper Rheidol valley (up to Nant-y-moch Dam) is a bedrock feature. The drifts moved down the long rock slope on the east side and formed a talus against the steep side of an incised valley.

Returning south, brief stops were made at B and C to view the endmoraine at Dinas Dam in cross profile (Fig. 11). This and the ridge immediately below Ponterwyd are the only endmoraines in the Rheidol valley. The ridge which crosses the valley here consists of three parts. To the east of D it is bedrock. The endmoraine forms an extension westward of this ("Till moraine" on Fig. 11); it is a smooth, rather subdued ridge without any surface irregularities. To the west it falls in a smooth concave slope extending into the Rheidol meander. Jones and Pugh (1935, p. 244), suggested that this moraine was responsible for the diversion of the Rheidol into the rock meander channel and that the buried valley ran across the meander neck (Fig. 11). A line of bores along the moraine in the 1950's confirmed its existence (Adams, 1961) and that the ridge west of D is in fact till.

After crossing the Rheidol at Ponterwyd the minor road on the east bank was followed as far as D, on the crest of the endmoraine. The surface of the solifluction terrace was seen as far as the Hirnant, together with the steep rocky slope of the west bank. The director suggested that the smooth continuous slopes were due to slope processes, stating that the surface slope of the solifluction terrace is mostly between 4° and 8°, values that are typical not only for the rest of the upper Rheidol valley but for mid Wales in general. The upper bed of the deposits, which the surface form reflects, has a preferred stone orientation parallel to the slope no matter what is the orientation of the slope.

The branch road up the Peithnant valley was followed to a place directly above site H (Fig. 11), at the upper limit of a gently sloping drift surface (3—6°). It was agreed that the surface form here and the main valley indicated a modelling or remodelling of the surface by solifluction. The director's use of the term "solifluction terraces" for the features being discussed, was questioned. The director replied that he used the term in the same way as alluvial terraces, where a gently sloping sheet of debris is dissected to produce a steep scarp or bluff at its lower margin. He agreed that he was advocating sheet solifluction (*solifluction en nappe*) as the origin.

At H, the following succession was exposed in the river bluff (Pl. 9):

E. Dark grey silty clay containing much small gravel and sand, and scattered 7—20 cm stones 1.5 m

D. Yellow grey, very gravelly stony clay, with much ironstaining 0.9 m

C. Grey silty clay, stony, not so compact as A 1.4 m

B. Iron-stained boulder gravel in muddy, small gravel matrix; unbedded 1.4 m

A. Compact dark grey stony clay (base not seen) 2.0 m

In his introduction the director explained that this profile had been chosen partly because the whole thickness is exposed and partly because the usual variations in the top bed are shown at one site. The basal bed in the drift terraces in most cases is an unsorted grey clay similar to the two samples from bed A, Table II, with a variable content of stones and boulders. In some localities the preferred stone orientation indicates movement down valley but at others it is parallel to the slope, so that it probably consists of *in situ* till in some places and a slope deposit containing reworked till in others (WATSON, 1967). At H the preferred stone orientation has been determined at five separate places, all of which give a median between 85° and 95°N, indicating a probable movement down the valley (whose general direction is 125°N).

Bed B has been seen at a number of places and has been interpreted as a slopewash gravel. Its base always slopes towards the river, and the preferred orientation and imbrication indicate movement downslope. Here the base of B slopes at 29° towards the Peithnant and the top at 15°, showing that the bed is thinning rapidly away from the stream; the same measurements taken in 1962, 3 m upstream, where the main erosion face was then, are 27.5° and 14.5°. This is much greater than the values obtained in the main valley.

Bed C is of similar composition to A, and is interpreted as a solifluction deposit derived from A higher upslope beyond the limit of bed B. The preferred orientation is 250°N which is close to the azimuth of the surface slope.

Bed D has a more sandy gravelly matrix, but has none of the characters of a water-laid deposit. Because of difficulty of access here its preferred stone orientation has not been determined, but at other sites it is parallel to the surface slope.

In bed E, the fine fraction is comparable to that of A, but it is less compacted and its preferred stone orientation is parallel to the slope.

At most places either C, D or E overlies B, and they always have a preferred stone orientation parallel to the slope.

In discussion, it was suggested that from its appearance E is a till. The preferred stone orientation is against this; the readings are closely grouped, unlike those of A, and the median is almost at right angles to that of A. The long axes of the particles plunge upslope: this is visually clear in the case of the larger clasts and is confirmed by sampling. As was pointed out in the case of the Brown Head at Morfa-bychan, this upslope plunge is found in mid Wales where slope deposits are inclined at low angles. Another member thought that bed B is rather muddy for a water-laid deposit. The director said that the clay-silt content is very low and that the deposit consists essentially of boulders in a gravelly, gritty matrix. It should not be compared with a modern fluvial gravel. The pebbles are appreciably more worn than those in beds A, C or D which on the CAILLEUX and TRICART roundness index give values of 60—70 against 120 for B. The values for contemporary fluvial gravels in the mid Wales area is around 200. The interpretation of the long axis orientation of these gravels was questioned. The director agreed that the long axis orientation is perpendicular to flow in many cases, but that it has also been found parallel to flow (see JOHANSSON, 1965). He based his interpretation on the fact that in the modern gravels of the Rheidol and Ystwyth the long axis orientation has been found to be parallel to flow. Where imbrication counts have been made in Bed B (Anon., 1965) the results agree with this interpretation (see WATSON, 1967).

The group next examined site I, some 300 m upstream where the following sequence occurs:

5. Peat	0.5 m
4. Humose boulder gravel	0.7 m
3. Grey, very gravelly clay containing pockets of coarser, looser gravel	1.6 m
2. Thin lenticular beds of silty sand, clean sand, gravelly sand, and clay-silt with scattered fine gravel	1.2 m
1. Medium gravel, often heavily iron-stained	0.5 m

It was generally agreed that the gravels in beds 1 and 2 are edge-worn and well enough sorted to suggest deposition by water. Bed 2 attracted much attention. The director stated it is a type of deposite which occurs elsewhere, a series of fine gravels and sands, often muddy, interbedded with what he interpreted as thin mud-flows. Some situations suggested sheet flow from persistent snow banks. This might be the case here as there is a hollow in the valley side directly upslope, at G (Fig. 11). This still tends to channel run-off and there is a fan below it. A feature which caused much speculation was that silt bands in bed 2 clearly dip upslope by as much as 25°. Some thought that this must be due to rotational slipping but there is no supporting evidence for this. The director thought the involute structure of bed 3 might be explained by load deformation, coarser overlying gravels having sunk into the gravelly clay. It is uncertain how far down the effects of such loading might extend — it might be responsible for the upslope dips in bed 2. Only the clearing of a larger section would resolve the problem.

The director stressed the change in the upper bed, 4, from that of the previous section, H. The abundance of large grit boulders, which is limited to a stretch of about 100 m along the stream, must be linked to grit outcrops at G. Above site H, the slope above the road showed clearly that the valley side is composed of mudstones, and the absence of grit boulders at H supported the local derivation of Bed E.

In summary, these two sites, H and I show a variation in deposits coinciding with changes in local slope conditions, of rock type and slope morphology (as it affects run-off). A still different sequence might be seen at site J (Fig. 11). This local variation applied most clearly to the upper beds. Bed A (not exposed at I) is the least variable. It is almost always compact and "till-like". Where not *in situ* till, it probably contains a considerable proportion of reworked till, as evidenced by the presence of till stones (smoothed, striated and shaped).

WEDGE STRUCTURES NORTHEAST OF PONTERWYD

After lunch, a short stop was made 4 km northeast of Ponterwyd where roap (A44) widening had exposed three wedge structures at 345 m above S. L., (SN

Table II

Grain size of deposits at site H, Peithnant valley

	Percentage of fraction < 2 mm				
	2μ	10μ	20μ	50μ	200μ
Bed E (I)	16	40	46	57	70
Bed E (II)	19	55	64	75	84
Bed D	8	18	32	42	55
Bed C	24	53	61	72	82
Bed A (I)	24	50	58	70	80
Bed A (II)	19	50	58	69	80

785829). Bedrock, finely cleaved mudstones and shales of Silurian age, is overlain by a head of unsorted angular rock debris in a matrix of fine gravel, sand, silt and clay. This is succeeded above a sharp junction, by loose small angular slaty gravel. All three wedges are in this loose gravel; two stop at its base, the third, stops 50 cm above it (Pl. 10).

The latter wedge shows the flaring top common in Mid Wales. Its identification is based partly on the uniform character of the "fill", the gravel being generally looser than that outside. It appears "streamed" down into the structure; near its sides dips are downwards and inwards. In the upper wider part, dips are less steep and in the centre suggest collapse structures (Pl. 10).

The gravels in a narrow surrounding zone show a marked deformation resembling that seen around present-day ice wedges in well bedded materials, and is consistent with the development of horizontal pressures. This deformation zone is widest around the upper half where the wedge is widest.

The group was impressed by the clarity of the structures and the palaeoclimatic implications for mid Wales. In reply to a question, the director stated that the surface slope above the wedges is 21° at the western wedge and 26° above the eastern. It is not uncommon to see them on slopes up to 25°. Wedges in mid Wales occur in two types of location, on slopes, in deposits of small loose angular gravel as here, secondly in flat ground in alluvial gravels. One member noted that there appeared to be indications of upheaval beneath the wedge structure and suggested that this may have been associated with the initiation of the fissure. Similar indications of the arching of bed 1 occur below the left hand wedge. The director said he would certainly look for similar indications at other wedge structures; he would like to see them in more regularly bedded material.

LARGE CRYOTURBATION STEPS NEAR CARNO

The party drove on without further stops to the Carno area where large terraces or benches of superficial debris are well developed. These are a feature of the northeastern parts of the central Wales plateau, especially in the valleys of the Afon Carno and Afon Banwy, tributaries of the Severn. They are almost unknown in the western parts around Aberystwyth.

Some 500 m southeast of Carno (SN 963964), the minibuses left the main road (A489) and followed the minor road up the Gerniog valley to where the road ended at 300 m above S. L. Here Professor PISSART assumed the direction of the excursion.

As the group followed the track to Hafod farm two large terraces were seen on the hillslope to the north. South of the farm the group turned east to ascend the main slope, crossing two of the terrace treads, 200 and 300 m wide and climbing the scarp, more than 10 m high, between them (see Fig. 2, PISSART, 1963). The scarp has a multiple lobate front. The traverse ended in view of the high scarp of the uppermost terrace at 420 m above S. L. Professor PISSART stated that the lobate front and fresh appearance of the scarp is typical (80% have a slope of 20—25°). The maximum height he had measured is about 15 m. He believed the terraces to be formed of superficial debris, a grey stony clay with fairly frequent grit boulders. This is seen in outcrops in all parts of the area, though none of these is very large or deep. He had not seen any rock outcrops in the scarps, nor a concentration of boulders there.

In this area the general slope faces east. The majority of slopes with these terraces face northeast, less frequently, southeast and rarely north or south. In no case are they found on a west-facing slope. The terraces here are very largely perpendicular to the slope but locally they are oblique to it and in some cases parallel to it. He thought them periglacial in origin from their many points of resemblance to other terrace forms in present day periglacial regions. But because the scarps are at times parallel to the slope and because they tend to face east, he thought they were initially formed by transverse snow banks. Drift terraces had accumulated beneath the snow banks but at a later stage, movement *en masse* occurred producing the convex lobate forms of the scarps.

The participants were impressed by the size of the terraces and some wondered if they had not some structural control. Professor PISSART replied that there was no evidence for this: the mudstones and grits which form the area are tightly folded. Where streams flow down slopes with terraces, there is no indication that the rock sub-surface is benched.

Some thought that the parallel series of terraces in succession down the slope and the lobate nature of their fronts suggest simply movement *en masse*. It was also argued that nivation should produce concavities along the front and not convexities. Professor PISSART agreed that on an east facing slope such as they were on, with the terraces perpendiculat to the slope, movement *en masse* would be an adequate explanation. The problem is that in some areas the terraces are parallel to the slope and therefore cannot be explained by movement *en masse*. Another process must have played a part: in his opinion the most probable is nivation. Dr. WATSON added that he had recently revisited the valley of the Afon Golwyn, 3 km to the southeast. There the ridges and valley trend west—east and the terraces cross the valley parallel to one another but often parallel to the slope. The north—south trend of the terraces is maintained in spite of slope direction (see Fig. 4, PISSART, 1963).

Excursion 4: Monday, 7 July

NIVATION FORMS AND DEPOSITS IN CWM YSTWYTH

CWM TINWEN

After a brief scenic stop at Devil's Bridge the group drove to Cwm Tinwen in the upper Ystwyth valley (Fig. 12), 4 km east of the village of Cwmystwyth (SN 790740). Cwm Tinwen shows a feature which is widespread in the mountains of Wales, consisting of a moraine-like ridge fronting a narrow basin elongated parallel to this ridge. They are found in strongly shaded positions, usually some 200 m below the floors of typical cirque basins, i. e. elongated perpendicular to the backwall, with a rock basin closed by a moraine. The Cwm Tinwen ridge has been interpreted as a protalus rampart (WATSON, 1966).

Members climbed up the slope on the eastern limit of the drift accumulation enclosing the linear basin. This accumulation begins as a double ridge, but only the inner one continues across the front of the basin; the outer appears to pass into a slope. It was also seen that there is a double ridge at the western end, visible in profile on the west bank of the gully which drains the basin. The director suggested that there had been two ridges formed in succession in front of the basin but that the older outer ridge had been deformed before, or during the deposition of the younger. The ascent was continued some distance round the east end of the basin to where a good view of the basin and its enclosing ridge was obtained.

The director pointed out that the inner ridge is thickest in the centre so that its inner margin is convex towards the basin. This is unusual; he did not know of another in Wales, but he thought it might reflect a maximum accumulation of debris on the névé foot at its centre (*cf.* Fig. 6; 3a *in* LEWIS, 1970). It is not the lateral moraine of a glacier in the Ystwyth valley as has been suggested in the past, since both ends turn into the valley side and the rampart is clearly localized around the niche.

The deposits exposed in the gully draining the basin at the west end were next examined. These consist largely of grey or yellow-grey stony clay. In the outer part there is, in places, a rough stratification dipping outwards, approximately parallel to the surface. This is produced by coarser bouldery beds, by short lenses of muddy grit and by thin beds of yellowish silty clay. Compared with published accounts of protalus ramparts, this abundance of fines is unusual. Such ramparts consist of coarse openwork debris, as do most of those known to the director in Wales. The other Welsh examples however, consist of debris of igneous rocks or massive sandstones; the nature of the material here may be related to the composition of the rock in the headwall, the mudstones and sandstones of the Aberystwyth Grits.

The main points arising in the discussion concerned the size of the accumulation and the possibility that it is due to ice rather than névé. Many thought it too large for a protalus. The director replied that it was higher than most in mid Wales but some of these have a separate inner and outer rampart. If this ridge represented two stages as he thought, the comparison was complex. On the central profile line the total height of the accumulation is 44 m (145 feet) and his estimate for the stage I rampart 25 m (82 feet) and for stage II 19 m (63 feet) (WATSON, 1966, Fig. 4). The range of heights of protalus ramparts given by BLAGBOROUGH and BREED (1967) is 10—80 feet, so that these would be at the higher end. Admittedly their position is marginal in terms of these figures. At stage II he estimated that the greatest likely thickness of névé would not exceed 30 m, the depth often quoted for the

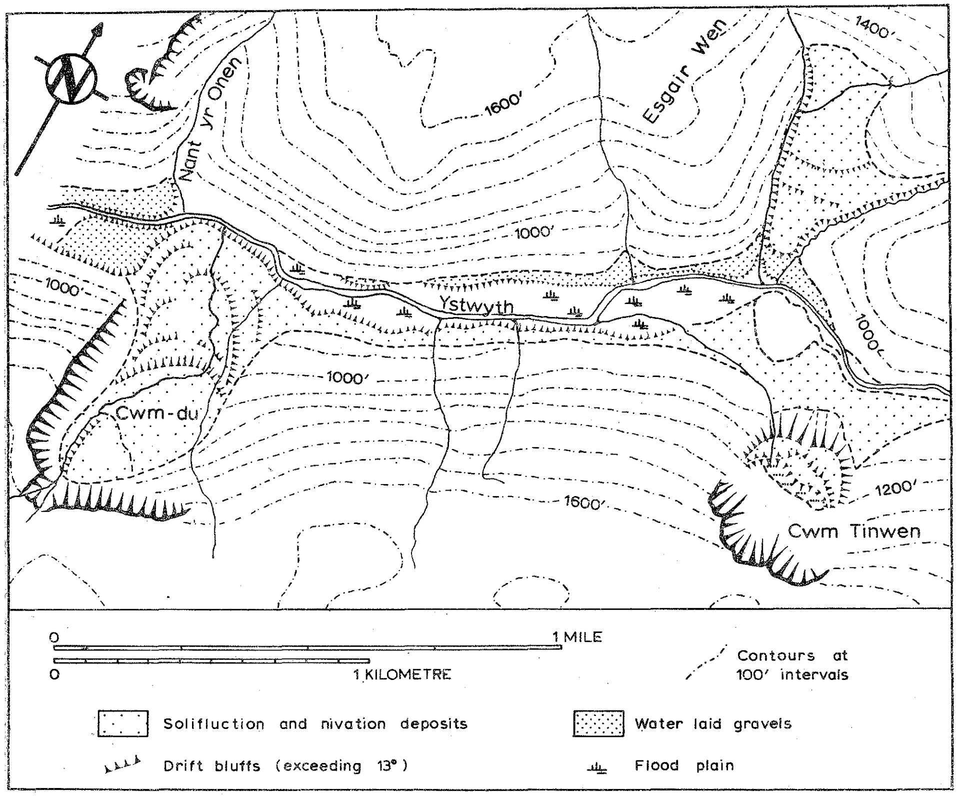


Fig. 12. The superficial deposits of the upper Ystwyth valley. From WATSON, 1968, p. 42

transformation of névé into ice. Plastic deformation and flow would require a greater thickness, so he favoured formation by névé with probably static ice in the lower parts.

To the suggestion that the rampart is a moraine and the convex plan of its inner edge may be explained by the fact that the ice consisted of two lobes one on either side of the thick middle section, the director replied that if the thick centre is due to two lobes, the rear (proximal) edge of the moraine should consist of two concave sections separated by a sharp prow and the crest of the rampart should be parallel to this proximal edge. The crest line showed no relationship to the rear edge. Again the headwall consisted of three large niches; there should therefore have been three lobes and two rearward bulges in the moraine.

Another argument advanced in favour of a glacier origin was the presence of shaped striated boulders in the deposit, in addition to small scratched mudstone fragments. The director thought this true of the upland area in general (as had been seen in the Peithnant section the previous day). The problem is one of differentiating between *in situ* till and slope deposits containing till material. He thought this aspect of these deposits required further investigation. If striated boulders proved to be more common in the rampart than outside it, the case for their production within the rampart boundary would obviously be very strong.

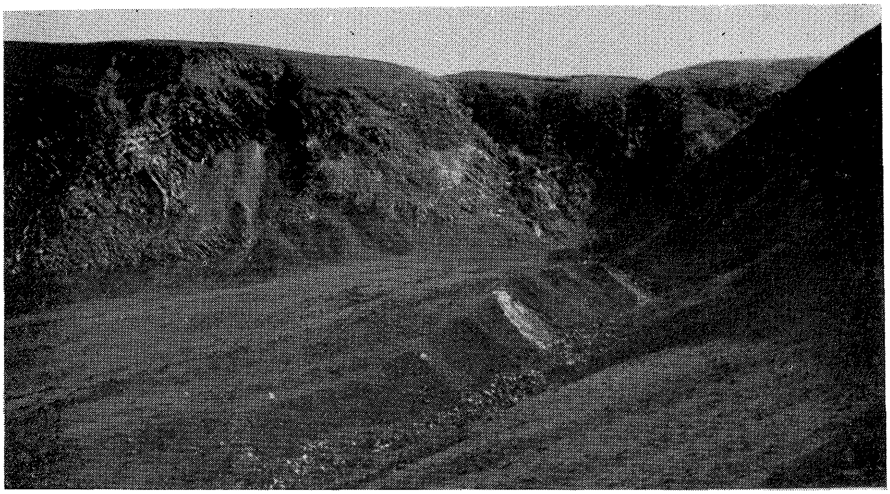
It was also argued against the protalus hypothesis that fines would not slide or roll over a snow surface. The director admitted that this had long troubled him. His present position had not been reached from a consideration of this example alone. He has seen many other examples, some as high as 20—25 m, composed of angular blocks derived from massive rocks. He felt that lithology had a strong influence on the detail of the rampart. He planned to begin a study of a glacial cirque moraine and nearby ramparts of the same lithology, from which he hoped to establish some of the differences between the two forms. In his final remarks he drew attention to the lack of slope deposits on the backwall which appears to have been protected by névé until a late date. In Tae-y-llyn, another rampart would be seen but the backwall is covered with slope deposits which he believed to be contemporary with stage II here.

CWM DU

The group next moved to Cwm Du (Fig. 12). This is a cirque form, with its basin elongated along the main axis, which is over 500 m compared with a width of 300 m (Pl. 11). From it a large fan has emerged, blocking the main valley (Pl. 12). The upper step at the mouth of the cirque is fresh and continuous, except for two gullies by which the streams leave. The view from the northwest shows the steps on the fan are fragmentary on the west side, but on the east side they are continuous, with fresh fronts or risers up to 23°, and concave treads sloping between 9° and 4°. The greater preservation of form on the east side as compared with the west was also observed in the Cwm Tinwen accumulation.

The route followed was by farm road and track across the steps on the east side of the fan to the northeast edge of the cirque floor. This edge forms a giant step some slopes upwards at 4°—5° along its central axis, and at its lower limit the stream has cut through some 18 m of superficial deposits without reaching bedrock. About half way along the front of the cirque a section of these deposits had been cleared. They form a succession of grey stony clay and yellow-grey less compact clay which in places passes into a dirty gravel with iron and manganese staining. The director said that these two types of deposits occur in most of the cirque floor exposures and the fan; he regarded the more open yellow-grey deposits as partly washed residues of the grey clay.

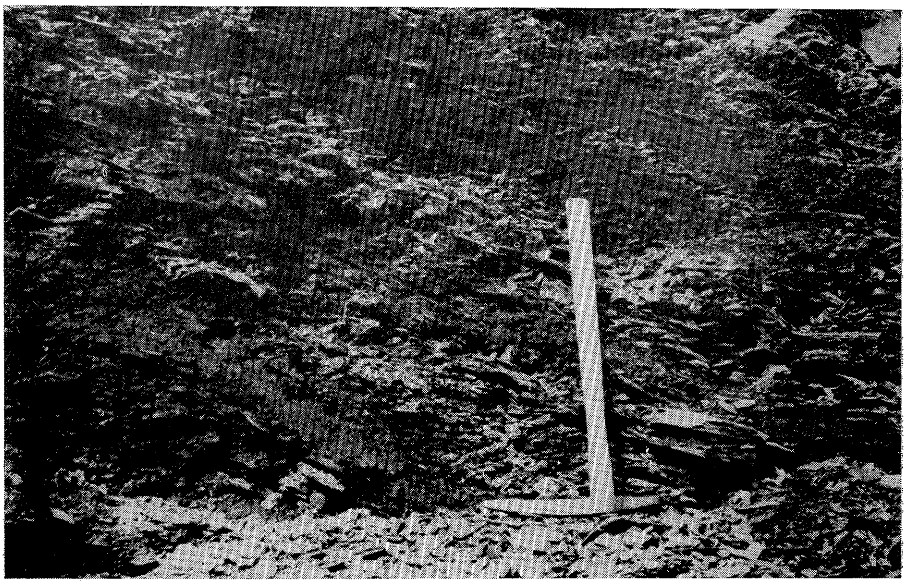
The route continued along the outer edge of the cirque floor to the rock slope on



Pl. 13. Southwest corner of Cwm Du showing the top of the protalus deposit

Pl. 14. Tal-y-llyn. Protalus rampart in Tal-y-llyn Pass (at E on Fig. 13)

Pl. 15. Tal-y-llyn. Landslide scar with debris impounding lake



Pl. 16. Tal-y-llyn. *Grèzes litées* at Maes-y-pandy, (G on Fig. 13)
Hammer, 45 cm long

Pl. 17. Tal-y-llyn. Amphitheatre and convex debris fan (B on Fig. 13)

the west side. Here curved rock surfaces rising from the cirque which, at a distance suggested glacial erosion, were shown to be concentric with undulating bedding planes below the surface. It was agreed that no striated surfaces could be seen here though Professors JAHN and WASHBURN found striae beneath the soil some distance above, on the spur between the cirque and the main valley.

From the northwest limit of the cirque floor the accumulation of debris which slopes from the west side of the cirque could be seen, almost in profile (Pl. 13). This rises some 38 m above the main cirque floor. The director thought this to be a type of protalus, which he had correlated with stage II of Cwm Tinwen. However, it raises the same problems as the latter, the large volume of debris and its nature which is largely stony clay. Its structure is not exposed but the preferred stone orientation near the crest, indicates movement perpendicular to the crest, in agreement with a talus structure.

The group next descended into the main gully reaching the bottom just in front of step 3 (WATSON, 1966), where an exposure showed grey stony clay at stream level. It is overlain by 2 m of small worn gravels and then by 0.5 m of sand, silt and clay. Above this again is grey stony clay. These small calibre gravels, sands and silts, with the bedding dipping at low angles have also been seen in front of the scarps limitting steps 2 and 4 (WATSON, 1966). The bedding in the upper levels of each step appears to be downslope at 15°—30° and the director concluded that the steps advanced outwards by accretion on the scarp, of material which moved across the tread by solifluction. These fine washed beds were the materials washed from the advancing front and later buried by its advance. One point of major significance is that the undisturbed nature of these bedded sands and gravels shows that the fan was built up bed by bed and is not the product of a catastrophic event.

The next stop was an exposure on the left bank of the gully about 250 m from the Ystwyth. This shows the same types of material as higher up the fan, grey stony clay, yellow-grey clay and small washed gravels and silt. But here the bedding dips upstream. This might be due to rotational slipping in the frontal area of the fan, but another section 100 m downstream, exposed in 1972, suggests that glacier ice was involved. The greater part of the exposure consists of grey clay containing large glaciated boulders and in much of it, especially near stream level, the maximum projection planes of the stones are tangential to the outer limit of the fan suggesting pressure down its axis. A bed of clay, sand and small gravel is torn out along a plane which curves upwards and outwards, suggesting thrusting. Unfortunately the detail of the thrust could not be seen as the face which had been cleared for the excursion had collapsed in the interval. The dips of the blocks and their glacial character was clear, however, and were accepted as evidence that a small glacier from the cirque had, at one stage reached the outer limit of the present fan.

At various stops members generally felt that glacier ice had been present during the formation of the cirque and fan. As in Cwm Tinwen, this was partly based on the size of the features and partly on the presence of striated stones. The director thought there is evidence for ice in Cwm Du in the earlier stages, but the forms and later deposits are of slope origin. Further research may show this to be also the case in Cwm

Tinwen. All the views expressed agreed that the deposits at Cwm Tinwen and Cwm Du are composed of debris from the cwms and that there was no valley glacier in the Ystwyth at the time of their formation.

Excursion 5: Wednesday, 9 July

PERIGLACIAL FEATURES OF THE TAL-Y-LLYN VALLEY

DEBRIS FAN

Members of the group travelled to Minffordd in the Tal-y-llyn valley (SH 733115) and continued on the A487 towards the head of the valley. The first stop was made 150 m south of the southwest limit of the debris fan (B on Fig. 13), where a good view of the long profile of the fan was obtained. The head of this profile is formed by a funnel-shaped amphitheatre surrounded by cliffs of acid volcanic rocks (Ordovician). The steep slopes descend with decreasing gradient into a debris fan whose centre line continues the concave slope towards the stream in the valley bottom.

The next stop was opposite the centre line of the fan, from which it could be seen that the convex fan begins at the mid point of the long profile. This coincides with the wall at the lower limit of the mountain pasture (Pl. 14). Above this the deposits in the funnel-shaped upper basin are dissected, as well as the underlying bedrock. The lower end of the convex section is markedly asymmetrical as its southern extremity is drawn out in the direction of the fall of the main valley.

The convex surface of the fan is strewn with many large blocks and the surface layer contains abundant blocks which are open-work in places, so the fan has formerly been described as a blockstream (Watson, 1968, p. 46). Closer examination shows this is true only of the surface; the underlying material consists of closely packed unsorted debris containing much silt and sand. This is true of the dissected material above the mountain wall (samples 1 and 2) and in the lower fan (samples 3 and 4, Table III). Recently the director has been considering the possibility that this is a slushflow fan, a "whale-backed fan of predominantly non-sorted debris ... which can be remarkably till-like, the particles ranging from fine sand to boulders" (Washburn, 1973, p. 166; *cf* Table III). Snow might be expected to accumulate in the amphitheatre but there are no indications that it was perennial. The amphitheatre faces southeast and being open receives sunshine into the afternoon; this may have promoted the "intense thaw in spring which produces more meltwater than can drain through the snow" (*idem*).

One of the group doubted that it was necessary to attribute the growth of the fan to slushflow and suggested normal avalanching would produce it. The director thought that the very considerable distortion of the foot of the fan down the main valley suggested a fairly fluid movement of material.

It had been intended to walk, later in the morning, from the valley head along the contour into the amphitheatre and to examine the morphology and exposures on a traverse down to the valley bottom, but heavy rain led to this being abandoned.

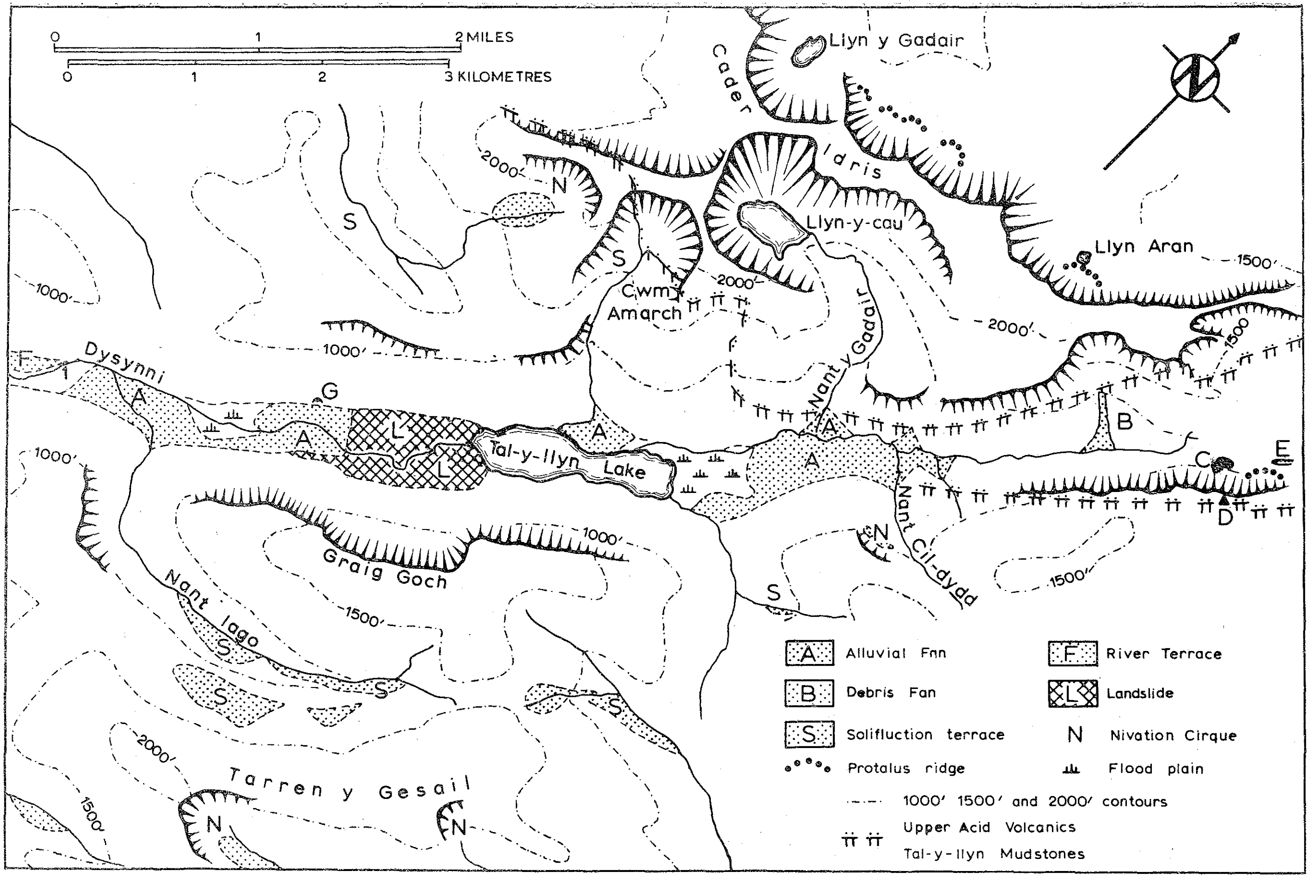


Fig. 13. The Tal-y-llyn valley

Letters and numbers as in text. Contours in feet

Table III

Grain size of deposit in Tal-y-llyn debris fan

	Percentage of fraction < 2 mm				
	2μ	10μ	20μ	50μ	200μ
1.	4	13	24	49	63
2.	5	18	25	41	57
3.	8	21	30	42	51
4.	8	19	26	38	51

SLOPE DEPOSITS ON VOLCANIC ROCKS

A quarry near the head of the valley which showed the slope deposits formed from the volcanic rocks was visited next (C on Fig. 13). The debris is angular and unsorted, the larger rock fragments having a packing of finer debris. A rough stratification is produced by varying proportions of coarser and finer debris, the slope concavity is slight. One question raised here was whether a bleached zone some way below the present surface represented an old surface. The director was not prepared to give an opinion but promised to examine the suggested surface more closely.

PROTALUS RAMPART

The party ascended the footpath leaving the road on the southeast side at the col. From this a good view of the protalus rampart in cross profile was obtained (Pl. 15). The rampart at its centre, rises 22 m above the surface outside (which is at 275 m above S. L.). This compares with the estimated height of the stage I rampart in Cwm Tinwen (25 m), and like it the ends of the rampart curve into the hillside, but unlike it there is no linear depression separating it from the slope at the rear. On the rampart, however, there is a slope of 11° back to the hillside from the crest. The director suggested that the rampart is the equivalent of stage I in Cwm Tinwen but there was no perennial snow at stage II so that the back slope (which has very little debris cover in Cwm Tinwen), became covered with head which almost filled the linear depression. There are no exposures in the hill slope below the crag line but slope angles are similar to those at the quarry in the deposits of the same slope (C). Some members asked why perennial snow should be located at this site; it is not below the highest part of the valley side. The director pointed out that it is sited NNE of the highest crags (D on Fig. 13). If, as he suggested, névé were present at the earlier stage and absent at the later stage, its location would probably be marginal. A member suggested that the ridge might be a landslide; this would account for the hollow in the hillside as well as the form of the accumulation. The director thought that the volcanic rocks here would produce large rock masses in a slide; when the surface of the accumulation was later examined, the suggestion was withdrawn. A further solution advocated was that the accumulation represented a slide of head from the hillside;

this would also account for the hollow, the ridge and the character of the material. The director admitted the possibility of this solution on the evidence here. Nevertheless this ridge has a rounded crest which turns into the hillside at each end, and taking it in a broader context, there are five such ridges formed of debris of igneous rocks on the north face of the Cader Idris escarpment; three are separated from the hillslope by depressions; the two smaller are not but appear filled with slope debris as he suggested here. He would require further evidence before making an exception of this case.

THE SLOPE DEPOSITS ON THE TAL-Y-LLYN MUDSTONES

Owing to the effects of the Tal-y-llyn fault which runs along the valley bottom, the southeast facing valley side consists of Tal-y-llyn Mudstones (Ordovician). A quarry opposite the protalus rampart (E, Fig. 13), shows the slope deposits formed from these finely cleaved mudstones which split into thin plates, in size from coarse sand upwards. The thin plates lie parallel to the slope giving a more bedded appearance than in the head derived from the volcanics. The southeast end of the quarry formerly showed a fine dip section (Fig. 3, WATSON, 1965b) with three divisions:

3. Unsorted platy head.

2. Alternating thin beds of coarser and finer debris, the coarser being generally the thicker. The finer beds are silty and coherent, the coarser free running and often open-work, so that they resemble the *grèzes litées* of GUILLIEN (1964).

1. Unsorted platy head with blocks to 30 cm near the base.

The face showing this sequence had unfortunately collapsed but the three divisions can still be seen. Members examined the lower outer part of division 2, and agreed that water must have taken part in its deposition (*cf.* GUILLIEN, 1964). A downpour cut short the discussion, and the group retired to lunch, knowing that another chance to examine the succession would occur lower down the valley.

TAL-Y-LLYN LANDSLIDE

When Tal-y-llyn Lake was reached the rain ceased and members proceeded to examine the bar impounding the lake. This was long interpreted as a moraine from its undulating to hummocky surface, but nowhere can debris which might be described as moraine, be seen. The roadside exposures on the south side of the lake show intensely shattered mudstones along the width of the bar. The director pointed out that the cleavage of the mudstones which dips southeast and strikes between 40° and 50°N (approximately parallel to the valley), here strikes 85—95°N and dips southwest. In the area behind this (southwest of the church), some large outcrops of rock are seen, showing a variable cleavage direction, as well as much broken rock. A small pit behind the church proved to be dug in a mass of small angular rock fragments.

In this, the northeast quadrant of the slide, the strike of the fallen rock masses is across the valley but on top of these and against the valley side there is a mass of debris resembling a deformed terrace which, the director suggested, had come down at a later stage, after the main fall. From this area, the position of the northeast limit of the scar in the hillside directly above the limit of the slipped mass was appreciated.

A brief stop in the centre of the northwest side of the bar showed that the slide scar falls into two parts, the southwestern which has a well-vegetated slope deposit up to a high level, and the northeastern where the slope deposit is less stable and only partly vegetated. The latter is directly above the terrace-like mass of debris which the director had suggested was later than the main slide. Finally, as the bus reached Maes-y-pandy pit (G on Fig. 13), the abrupt moraine-like front and its relation to the southwest limit of the hill scar was seen (Pl. 16). Agreement amongst members that the bar represents a landslide, appeared to be complete.

GRÈZES LITÉES AT MAES-Y-PANDY

The roadside pit (G, Fig. 13) shows very clearly and accessibly, in dip section the alternating finer, muddy, coherent beds and the loose angular gravels (*cf.* Pl. 17) which members familiar with the *grèzes litées* of France and Belgium accepted as resembling them. As in France, they rest on coarser unsorted head. To a question on slopes the director replied that the slope is about 23°. This is steeper than GUILLIEN usually found in France (1964), but in mid Wales slope values are often in the 20°—25° range, though much lower values have been recorded (*cf.* Table I in WATSON, 1965b).

THE FOOT OF THE SLOPE DEPOSITS AT MERIAFEL

The group next went to Meriafel (F, at the left-hand edge of Fig. 13) to see the outer limits of the slope deposits. For most of the valley these are derived from the Tal-y-llyn Mudstones and produce smooth concave valley sides. At Meriafel they rest on an alluvial terrace which is being undercut by the river so that their base may be seen. On the road above site 1, a coarse head (a large proportion is 5—15 cm long, with many slabs to 45 cm) is exposed below a slope of 24°. The slope decreases steadily down to the terrace edge, where the slope is 0.5° measured over the lowest 15 m. The river cliff shows the following:

3. Up to 1 m of flat angular mudstone debris, much 5—10 cm in unsorted smaller, slightly muddy debris; very scattered volcanic pebbles.
2. About 0.75 m of generally smaller, more muddy angular gravel, this is composed of impersistent beds of finer and coarser material. Rounded fluvial pebbles of mudstone and volcanic rocks occur throughout, but especially in the lower part.
1. Up to 2.75 m of horizontally bedded fluvial gravels and sands; volcanic pebbles and cobbles present.

The director explained that bed 2 represented the outer limits of the earlier slope deposits, laid down as they advanced across the fluvial terrace, and 3 the later deposits. In the coarser lenses in 2 the preferred stone orientation shows a very tight grouping of azimuths parallel to the surface. The rounded fluvial pebbles and cobbles he thought were picked up by the slope material as it moved across the fluvial terrace.

He admitted that this implied that the slope deposits were entirely later than the fluvial terrace, but the majority of the group would not accept this, arguing that bed 2 represents an interdigitation of slope and fluvial deposits which were laid down contemporaneously. This argument was supported by the observation that downstream, where the terrace extends further from the valley side, the slope deposits appeared to have thinned away completely, a feature explained by the fact that river processes would be more important towards the centre of the valley and slope deposits more likely to be incorporated in the river load. The director agreed that the top of the gravels rises visually towards the centre of the valley and that this presented difficulties for the interpretation he had suggested.

A wedge cast was formerly exposed in the gravels when the rivers was undercutting the site (1 on Fig. 13; see WATSON, 1965a, Pl. 16b), but this is now concealed by a talus. Only the upper part is visible, which it was agreed, showed collapse structures, but it was felt there was not enough clear evidence for an ice wedge. On moving 100 m upstream, where the terrace is being undercut, a small wedge structure in the fluvial gravels with an infill of the same material on end, was seen. At this point too, large worn boulders, some of acid volcanic rock occur and there was some speculation whether the origin of these and some of the cobbles scattered through the fluvial gravels might not be derived from a glacial deposit now concealed by the fluvial gravels and slope deposits.

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