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THE SLOPE DEPOSITS IN THE NANT IAGO VALLEY NEAR CADER IDRIS, WALES

Abstract

The rapid deepening of a small tributary valley has exposed a sequence which occurs elsewhere in drift terraces in the upland valleys of Mid-Wales. The beds are interpreted as slope deposits formed by solifluction and slopewash because the bedding and the long axes of the included stones are parallel to the slope. The imbrication of the interbedded gravels also indicates deposition by water flowing down the slope. Such an origin is in agreement with the topography; the terrace is developed on the north-facing side of the valley only. The sequence, which may be compared with that of the screes in the same area, may represent the deposits of the later Würm.

The Nant Iago which rises 5 km SSE of Cader Idris, joins the Dysynni from the south, 2.5 km southwest of Tal-y-llyn lake. From a relief point of view, its valley may be divided into three parts. In the first, which is above 1100 feet, (335 m), above sea-level, several small tributaries, barely incised, descend steeply in rocky beds. The second, between 1100 feet and 615 feet (335 and 187 m), above sea level, has the lowest gradient, averaging 1 in 17.5 between 700 and 1000 feet (213 and 305 m); the Iago though frequently on rock, has only small falls and rapids. At 187 m, the stream enters the third section plunging over a waterfall into a narrow rocky gorge which continues down to the Dysynni floor, the gradient between 600 and 200 feet, (180 and 60 m), being 1 in 7.5.

In the uppermost of these three sections, the rock is everywhere near the surface, but where the gradient flattens at about 340 m, a terrace of superficial deposits begins abruptly on the south side (Fig. 2 and Pl. 2). Downstream of this, these deposits are virtually continuous to the knickpoint at 187 m, in places forming bluffs which rise 12 m above the stream. By contrast the slopes on the north side show frequent rock outcrops and only shallow patches of superficial debris (fig. 4). In the gorge section below, the slopes on both banks become more rocky as they steepen. The Iago which flows westwards above 180 m, gradually turns northward in the gorge section. As the left bank turns to face northeast it steepens (average slope, 40—45°) and takes on

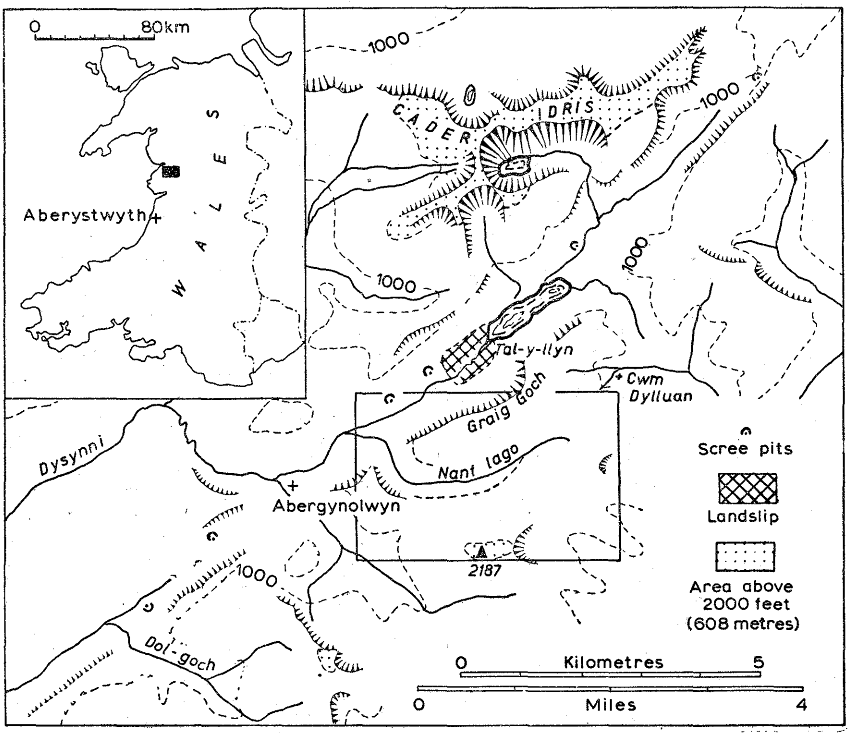


Fig. 1. The location of the Nant Iago valley
The black rectangle in the inset map shows the area covered by the main map, and the rectangle around Nant Iago shows the area covered by Fig. 2. Contours are in feet. For scree pits see Watson, 1965a, Fig. 1

a character unlike that found in the rest of the valley. The steep head of the slope is scored by a series of parallel V-gullies which lead down to screes (Pl. 1). These scree gullies resemble those of present-day Sub-Arctic areas such as Iceland and Spitsbergen.

The middle section with which this paper is chiefly concerned, is a relatively deep valley with fairly steep sides (averaging 20—25°). On the southern side is a well-marked bench which in the first instance is probably related to structure (Figs. 3 and 5). The steep rocky slope below the bench is mainly developed on the Broad Vein, "pale blue, thickly-bedded mudstones ... hard and resistant to weathering", (J e h u, 1926, p. 472), while the bench itself is largely on the R e d V e i n, "more thinly-bedded dark

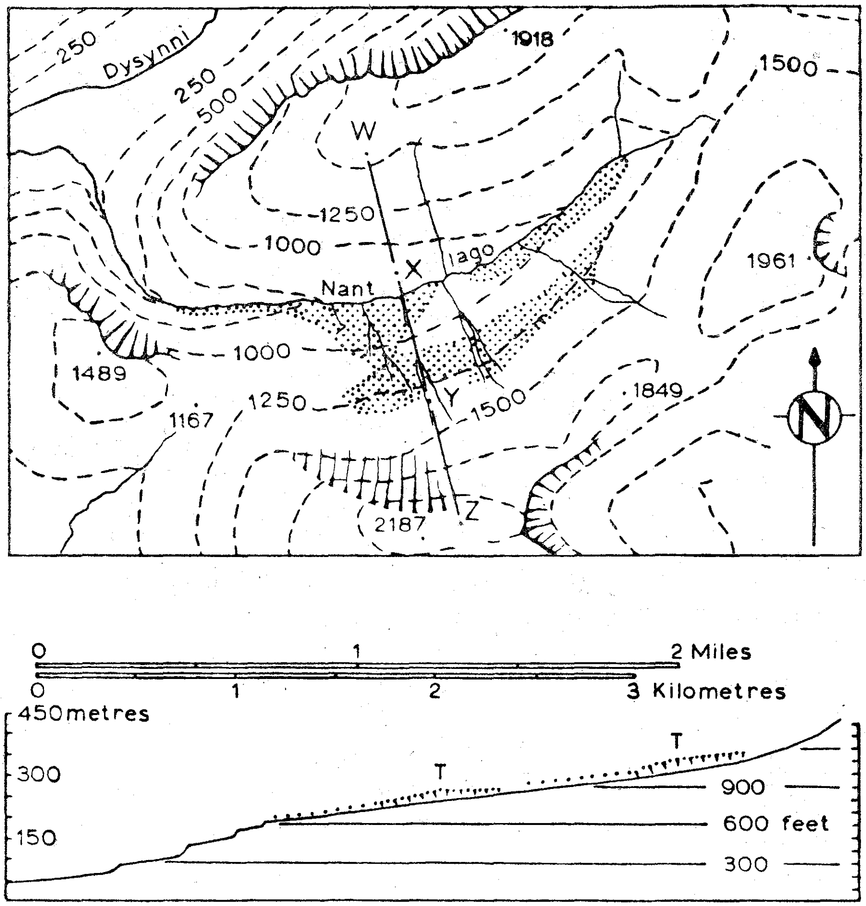


Fig. 2. The relief of the Nant Iago valley

Below, the longitudinal profile of the stream. The stippled areas on the map indicate the main areas of head; the dots along the stream profile, its distribution along the south bank, the greatest thickness being at T. WXYZ is the line of the cross profiles in Fig. 5

blue mudstones ... fairly soft" (*idem*, p. 473). The rugged slope to the rear of the bench consists of the G a r n e d d W e n B e d s, thick blue mudstones interbedded with grits, some of which are massive (*idem*, p. 477).

The most striking development of superficial deposits occurs where this bench is best developed and they are in fact continuous across the bench and over the brow to the terrace on the valley floor in the neighbourhood of stream B (Fig. 4). Where the bench

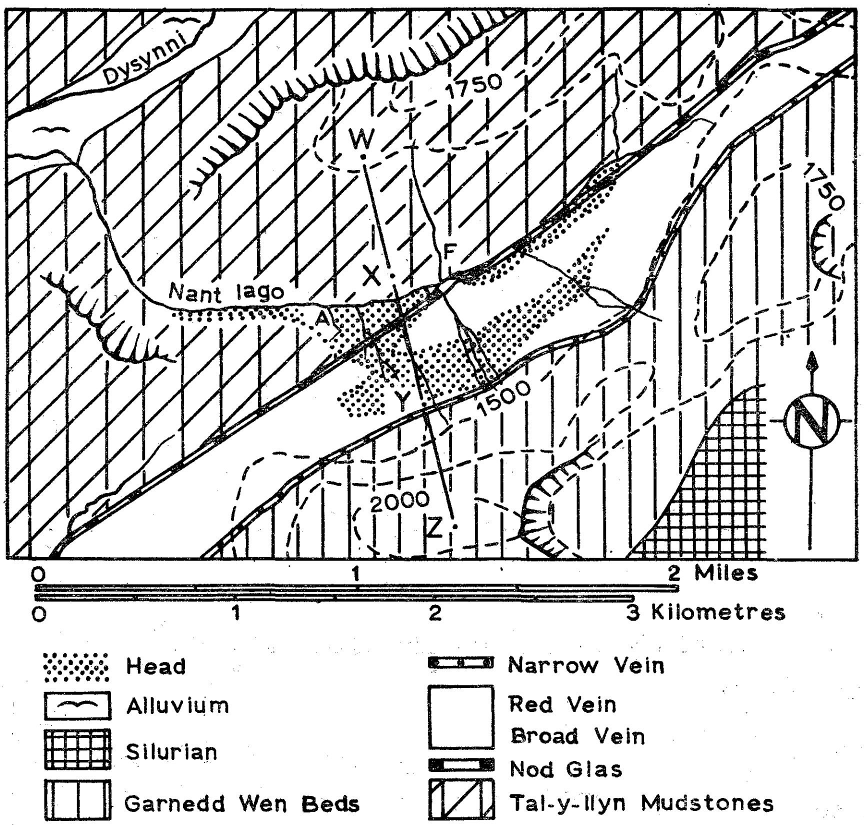


Fig. 3. The geology of the Nant Iago valley, after R. M. Jehu (1926)
WXYZ is the line of the profiles in Fig. 5

is again marked, at stream E, the superficial deposits appear to have accumulated on it rather than on the valley floor. Upstream of this, as the bench tapers away, the main deposits occur on the bank of the Iago as a well-developed terrace (Pl. 2).

THE SEQUENCE OF SUPERFICIAL DEPOSITS

On the terrace below the main bench a drain was cut straight down the slope and this has developed into a relatively straight gully (A on Fig. 4). Because of its rapid excavation it gives a continuous exposure of the deposits forming the upper part of the terrace. The valleys of the other streams which cut through the deposits, although sometimes more than 6 m deep, have slopes

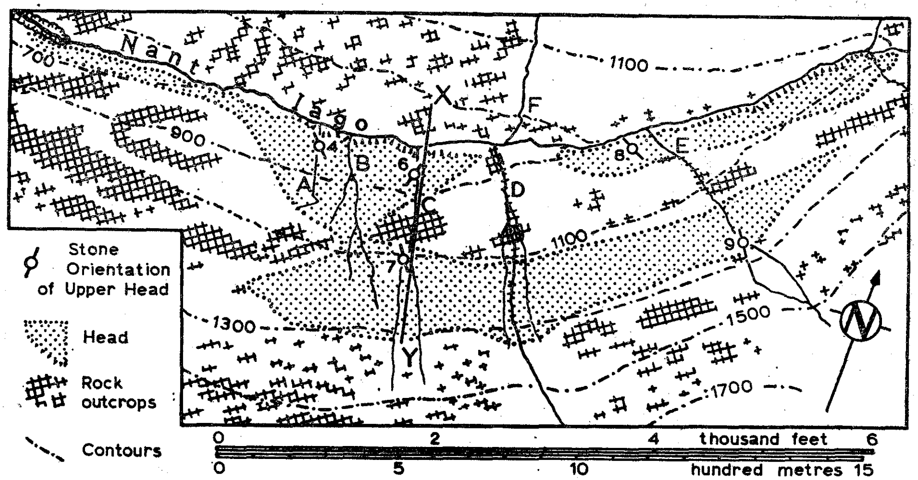


Fig. 4. The distribution of head in the Nant Iago valley
A, B, C, D, E and F are the streams referred to in the text; 4, 6, 7, 8 and 9 refer to the stone orientation roses shown on Figs. 7 and 9. XY is the line of the upper profile on Fig. 5

almost completely covered by vegetation and only rare and very limited exposures occur.

In gully A, 45 m upstream from its confluence with the Iago the following sequence occurs (reading from the bed of the stream upwards, Fig. 6). The term *head* is being used for some of these deposits as the evidence presented here leaves no doubt but that they are slope deposits.

THE LOWER HEAD (A)

The lowest deposit, A′, which is exposed in the stream bed, has a yellow-grey compact silty matrix with a good deal of small angular gravel (less than 10 mm), a fair number of stones 50—150 mm long and an occasional block of 200—250 mm. In several places it shows a rough stratification dipping downstream at 18—20° (Pl. 4). Overlying this is about 0.6 m of looser head, A″. This has a large proportion of small gravel, with very little debris exceeding 15 mm. No structure or bedding was observed.

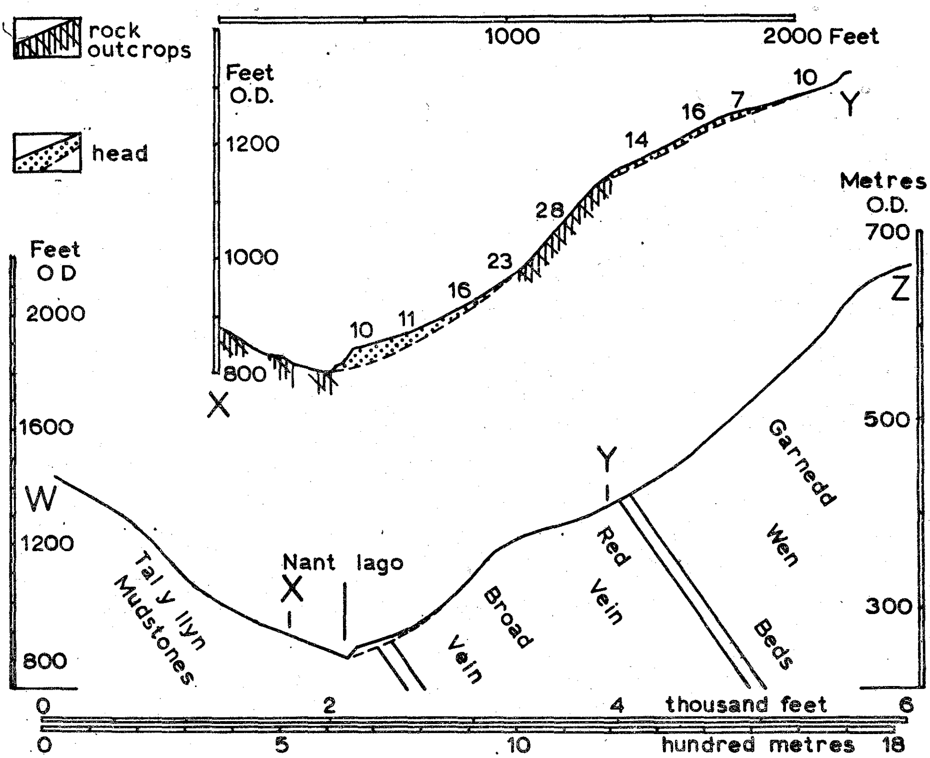


Fig. 5. Cross profiles of the Nant Iago valley along the line shown on Figs. 2 and 4

THE LOWER GRAVELS (B)

The base of these is the sharpest and most regular of all junctions in the section (Pl. 5). Along the section face in figure 6 it slopes downstream at about 15°. These gravels are rounded, up to 150—220 mm long but mostly 15—75 mm. They are fairly well washed, loose and iron-stained. Some short lenses of gritty sand and small open work gravel occur but generally they are poorly sorted.

THE UPPER HEAD (C)

The Lower Gravels pass upwards without a clear break into the Upper Head. The lower part (C′ on Fig. 6) consists of about 0.5 m of very muddy gravels, of similar calibre to B, and showing a weak stratification, with iron-stained gravelly bands and grey muddy lenses. The change to C″ is marked by an increasing size and angularity of the debris, there being a considerable amount of 150—300 mm fragments, though a great deal of 5—25 mm debris is present. In C‴, these larger fragments become much scarcer. The Upper Head is yellowish-grey in colour but compared with the Lower Head it is looser, and more gravelly.

THE UPPER GRAVELS (D)

Overlying C is a much coarser looser deposit of angular to edge-rounded stones and cobbles, much of it 150—400 mm, in a mass of small gravel and grit, but occasionally open-work. These gravels vary in calibre and thickness, but they overlie C, with interruptions, in the gully sides for a distance of some 110 m. The junction with C is not so sharp as that between A and B, though loose, coarser debris often contrasts with more compact and smaller debris in C (Pl. 6).

MODERN FLOOD GRAVELS (E)

In the years immediately after the cutting of the drain, it was too shallow to accommodate flood-waters which spread out over the lower part of the terrace burying the vegetation and soil (Pl. 6). These gravels are similar to D, angular to edge-rounded fragments up to 200—300 mm, with much in the 100—200 mm range, packed in silty, gritty, small gravels.

As shown in figure 6, the bedding of all these deposits is sub-parallel to the existing surface and to the stream bed suggesting a series of slope deposits. The dip decreases downslope and there appears to be a thickening of at least some of the deposits. The Lower Gravels, B, thicken in 12 m from 0.5 to 1.0 m while the upper part of the Lower Head, A, increases from 0.6 to 1.2 m. Because of the steepness and regularity of the base of the Lower Gravels, B, they cannot be former deposits of the Iago, but like the Upper Gravels, probably have an origin comparable with the modern flood gravels, E.

OTHER EXPOSURES

No comparable section occurs elsewhere in the valley; shallow exposures at several points show only the Upper Head, C, and the Upper Gravels, D. This is also true of the upper part of gully A, which shallows rapidly above the section on figure 6, so that the Lower Gravels are not seen for more than 4.5 m upstream. The rust-mottled yellowish-grey Upper Head overlain by loose coarse gravels (with boulders to 0.6 m), continues for 100 m or so. At the lower end of gully C (Fig. 4), 1 m of angular to edgeworn boulder gravels, up to 1 m long and packed in loose small gravels, underlie the soil in both banks, and are probably the Upper Gravels. The other gullies just above their confluence with the Iago 137 m, 231 m and 310 m northeast of stream D, show 0.6—1.5 m of gravelly grey head, (the Upper Head?), while at stream E, a similar head (with much 50—125 mm debris), underlies a bouldery gravel (up to 375 mm long) which in turn is covered by peat.

On the valley bench, stream C is sunk between bluffs 4.3 m high just above the valley shoulder. These bluffs show up to 2 m of head above stream level. This is loose, full of 3—10 mm gravel and stones to 225 mm, rust-mottled and containing lenses of muddy iron-stained gravel. Exposures near the top of the bluffs show 0.5—0.7 m of loose open gravels, with occasionally some discontinuous bedding and sorting. These two deposits suggest the Upper Head overlain by the Upper Gravels. These deposits appear to shallow eastwards for the three tributaries forming stream D are bordered by bluffs only 2 m high and the streams are frequently on rock. Exposures are few, but show gravelly head. Stream E has cut down through 6 m of deposits on the bench but only the top part is exposed, to show 0.75—1.0 m of coarse gravelly head with debris up to 350 mm long. Northeast of this the bench tapers away but two streams to the east of E show up to 2 m of head. Between these deposits on the bench and those on the valley bottom, is a steeper slope showing many areas of outcrop of the Broad Vein.

THE PREFERRED STONE ORIENTATION

The preferred stone orientation was determined in Gully A for the lower and upper parts of the Lower Head (A′ and A″ respectively), for the Lower Gravels, B, and for the Upper Head, C″; (for a discussion of the method, see Watson, 1967, p. 428—9).

As the lower part of the Lower Head, A′, was poorly exposed in the area of figure 6, the readings were taken about 20 m downstream (near the site of Pl. 4). The result (Fig. 7: 1), shows a fairly close grouping with a median between 340 and 350° N which is in very close agreement with the surface slope, 350° N.

A site in the upper part, A″ (2 on Fig. 6), gave a slightly less close grouping but the median, 330—340° N, is also close to the orientation of the surface slope.

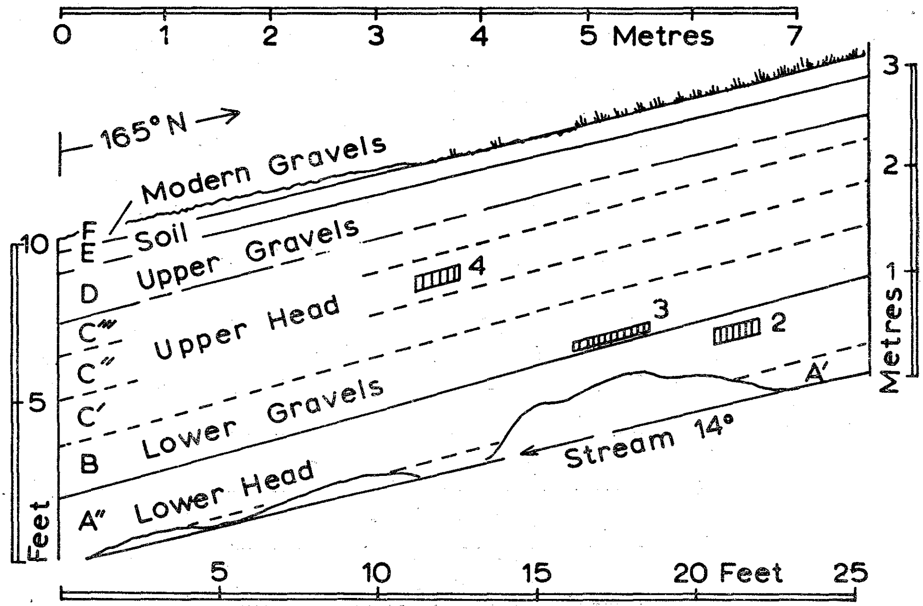


Fig. 6. The deposits exposed in gully A

The sites of three of the stone orientation counts on Fig. 7 are numbered 2, 3 and 4

In the Lower Gravels, B, 100 readings were taken at site 3, (Fig. 6). The resulting rose diagram, (Fig. 7: 3), shows a majority of the readings in the sector 300—360—40°, no 10° sector having more than 10%. The median of this 100° sector lies between 340 and 350° N, closely parallel to the surface slope. The remaining 80° sector of low readings has a marked secondary maximum approximately at right angles to the median of the major grouping.

It has been pointed out that in the early stages of the development of the gully, flood gravels were spread on the surface of the lower part of the terrace. But more and more they were spread in front of the terrace as the gully deepened. A relatively fresh and bare surface of these offered a ready chance to determine the orientation pattern of gravels where the direction of flow is known.

Table I

The stone orientations at the Nant Iago sites

Azimuth	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	N	P	S
Lower Head	1	8	6	4	6	4	0	0	0	4	0	0	0	0	5	7	8	7	7	50	165	345°
	2	6.5	6.3	1.5	1.5	3.1	0	3.1	3.1	1.5	1.5	1.5	3.1	7.7	15.4	12.3	14	9.3	9.3	65	155	345°
Lower gravels	3	6	7	7	8	2	3	3	4	5	2	0	4	9	10	8	10	7	5	100	165	345°
Modern gravels	5	8.8	7.2	8.8	6.4	4	0.8	4	3.2	1.6	4	3.2	6.4	7.2	5.6	7.2	7.2	8	6.4	125	165	345°
Upper Head	4	5	3	0	3	2	1	0	0	0	0	1	9	19	20	17	7	9	4	100	135	345°
	6	12	16	14	6	4	2	6	2	2	0	0	2	0	4	6	8	8	8	50	15	350°
	7	4	4	2	4	0	2	0	0	4	8	2	6	10	10	20	12	6	6	50	145	340°
	9	0	0	0	2	2	4	0	2	4	8	18	20	10	10	8	6	6	0	50	115	315°
	9	6	2	0	0	0	0	0	0	0	0	2	10	12	18	16	14	12	8	50	145	305°

The sites are numbered as on figs. 7 and 9, showing the percentage in each 10° group. N, the number of readings in the sample; P, the preferred orientation, is the mid-point of the 10° group containing the median; S, the direction of the surface slope.

The pattern resulting from 125 readings (Fig. 7: 5), is very similar to that of the Lower Gravels. A 110° sector has continuously more than 5% but less than 10% per 10°, and the median of this group is 340—350° N. Approximately at right angles to this is a weak secondary maximum in the low sector, (i.e. with less than 5% per. 10°). The bearing of this site from the mouth of the gully is 350° N, so that this median is sub-parallel to the direction of flow.

The relationship of the preferred orientation of the long axes of pebbles in deposits laid down by running water to the direction of flow has been found to vary, (Johansson, 1965, p. 10), and a seminar held at Bloomington, Indiana, concluded that in such deposits "current direction can best be obtained by finding the average maximum dip direction of the maximum projection plane", 25 readings being enough to establish this (1965, p. 281). The azimuths of the maximum dip of 35 pebbles, 3—14 cm long, were taken at two sites in the Lower Gravels, B, the first (site 10), being 5 m, and the second (site 11), 12 m below site 3 on figure 6. The results plotted on equiareal polar graphs (Krumbein, 1939, p. 681—5), show that the 180° sector with the maximum grouping of dips is the south (with 23 dips against 12 in the north at site 10, and 28 against 6 in the north at site 11, Fig. 8). In addition, since these dip angles are measured with reference to the horizontal and the bed dips north at about 15° some of the pebbles dipping north at less than 15° actually dip south in relation to the bedding. This imbrication implies a flow downslope, a conclusion already drawn from a comparison of the preferred stone orientation of the Lower Gravel with that of the modern flood gravel. The evidence as a whole is clearly against the view that the Lower Gravels were laid down by the Iago.

The azimuths of 100 stones in the Upper Head, C″, (Figs. 6 and 7: 4), gave a close grouping with a median between 310 and 320° N, slightly oblique to the surface slope, so that the preferred stone orientation in all four horizons exposed in gully A favours the view that they are all slope deposits.

In other parts of the valley, the Lower Head and the Lower Gravels are not exposed, so the preferred stone orientation of the Upper Head only was determined. This was done at two sites on the valley floor (6 and 8 on Fig. 4), and two on the valley bench (sites 7 and 9). Each consists of 50 readings and the patterns are generally similar with a maximum for a 10° sector of 15—20%

as at site 4 (Fig. 9). All indicate deposition by movement parallel to the slope, and it is of note that the obliquity of the preferred orientation to the slope at 4 is balanced by an opposed obliquity

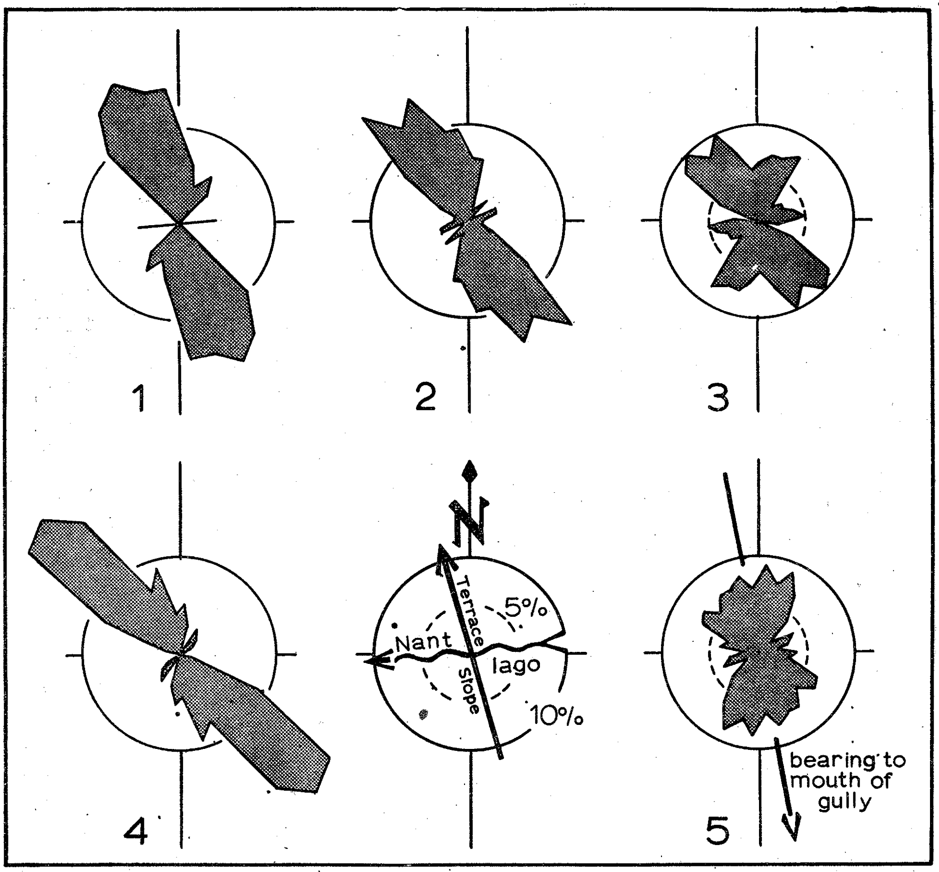


Fig. 7. The preferred stone orientation of the deposits in gully A
1. the Lower Head, A′; 2. the Lower Head, A″; 3. the Lower Gravels, B; 4. the Upper Head, C″; 5. the modern gravels at the mouth of the gully. The diagrams are numbered as in Fig. 4 and Table I

at 6, for these two sites are on the western and eastern sides of a fan-like accumulation of deposits (Fig. 4 and Pl. 3). The evidence suggests that the Upper Head and the Upper Gravels were formed on the north-facing slopes on which they lie. As they moved downslope, some lodged on the bench, the remainder accumulating on the valley floor.

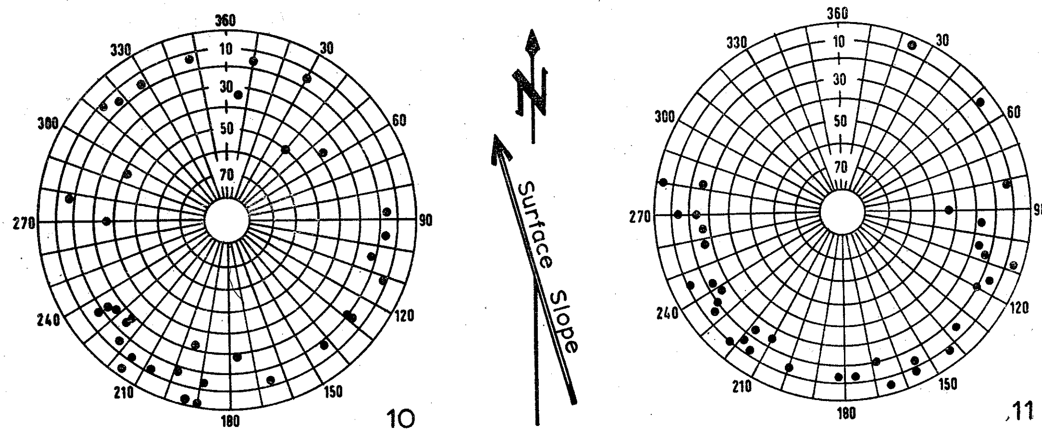


Fig. 8. The maximum dip of the maximum projection plane of 35 pebbles at each of two sites in the Lower Gravels, B

THE DISTRIBUTION OF SUPERFICIAL DEPOSITS

The argument for a slope origin of these deposits, based on stratification and fabric, is reinforced by their distribution. This is characterized by a concentration on the north-facing side of the valley, and by close relations between their thickness and the height of the slope to the rear.

The maximum height reached on the south side of the valley is 2187 feet (667 metres) O.D. The northerly face of this hill is the steepest where it faces due north, becoming less steep as it turns towards the northwest. This steepening of the higher slopes to a maximum where they face northeast is typical of the area. It is probably due to snow drifts on the shaded face melting out only slowly in summer and providing moisture for frost shattering over an extended period. On the valley bench the deposits, are, as has already been pointed out, thickest to west of XY (Fig. 4), that is below the steepest slope, and thin out to east of this. The thick deposits west of XY continue over the valley shoulder to where the thickest accumulation on the valley floor occurs, (between streams C and D, on Fig. 4).

Downstream of stream A the head on the valley floor thins and loses its terrace form. This coincides with a fall in the height of the watershed above, which declines to 1167 feet (355 m) O.D. immediately upstream of the gorge head on the Iago (Fig. 2).

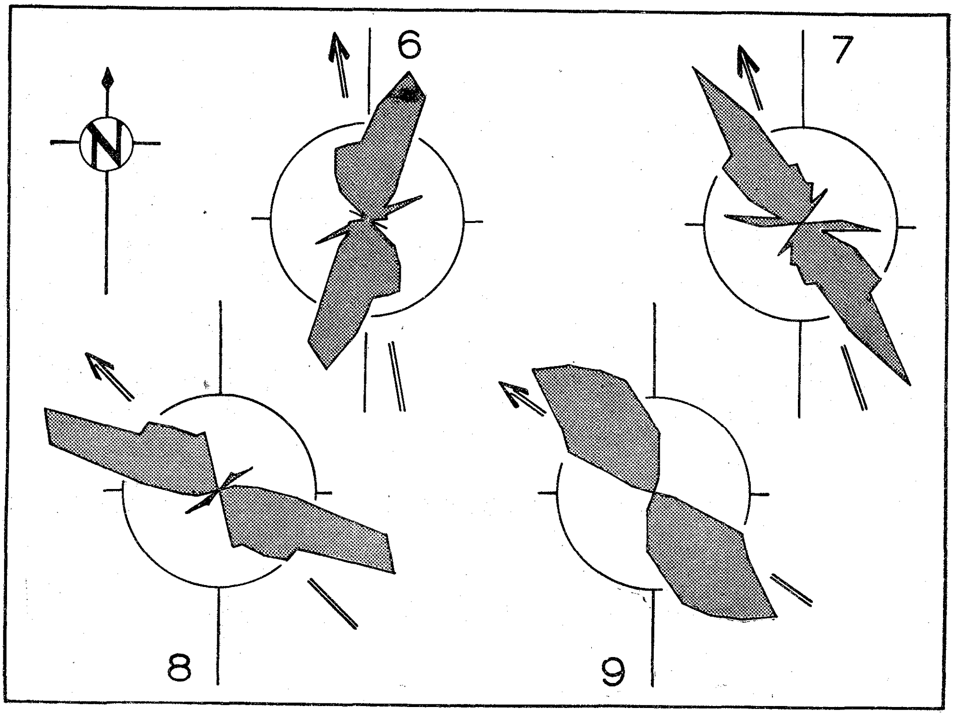


Fig. 9. The preferred stone orientation of the Upper Head
The diagrams are numbered as on Fig. 4 and Table I, and the arrows show the direction of the surface slope

Upstream of stream C there is a break in the valley-floor terrace at stream D, but the completeness of this break seems due to a purely local factor. The rock slope bulges outwards there as the base of the Broad Vein reaches the Iago bank.

In the area of stream E, the relatively slight development of the valley bottom solifluction terrace is due to the lowering of the watershed and also to the lodging of a thick accumulation on the valley bench. As this bench tapers eastwards and the watershed rises, the solifluction terrace on the valley floor becomes increasingly pronounced.

CONDITIONS OF DEPOSITION

Morainic forms are entirely lacking in the valley and there is no indication of ground-moraine in the deposits exposed. The lowest bed, A, exposed for a maximum thickness of one metre at the lower end of Gully A, is compact and has some resemblance to glacial till but the rough stratification and preferred stone orientation indicate that it is a slope deposit. Towards the top of this bed, the debris becomes smaller in size, suggesting a more thorough disintegration by freeze-thaw. This might be due to a greater frequency of the freeze-thaw cycle but might also be due to increased moisture. Such increasingly moist conditions might have culminated in a dominance of slopewash over solifluction resulting in the deposition of the Lower Gravels. These gravels pass upwards without a clear break into the Upper Head. This second solifluction phase was terminated by a renewed dominance of slopewash which lasted until the slopes were stabilized by vegetation and a soil developed.

This succession of changes recalls that suggested by Jean Alexandre for the central Ardennes, the change from periglacial to temperate conditions there being marked by three phases:

(1) solifluction; "la solifluction était l'agent d'érosion principal";

(2) run-off; "la ruissellement concentré jusqu'alors peu efficace devenait prépondérant";

(3) soil formation; "une phase tempéré, sans activité autre que pédologique" (1960, p. 63).

In the Iago valley the solifluction phase represented by the Lower Head, A, is followed by a slopewash phase in which the Lower Gravels, B, were deposited. There is however, no evidence for soil formation succeeding this. Instead the transition from Lower Gravels to Upper Head suggests a reversal to solifluction. The partial cycle A—B was followed by a complete cycle in which the Upper Head, C, was succeeded in turn by a second slopewash phase, D, and then by soil formation, E, which presumably marks Post-glacial conditions. In the absence so far, of organic material for pollen analysis or radio-carbon dating, one may compare this sequence as with the Late-Glacial and early Post-Glacial:

Deposit	*Process*	*Pollen Zone*
E	Soil formation	IV onwards
D	Slopewash	III—IV transition
C	Solifluction	III
B	Slopewash	II
A	Solifluction	1

Deposits B and D suggest an amelioration of conditions which parallels the pollen record in zone II and the early zone IV. Compared with the latter part of zone IV, a closed woodland cover would not have been established; compared with zones I and III there was probably an increase in run-off as well as a rise in mean temperatures. Alexandre suggested that in the slopewash phase there was an increase in precipitation in the form of snow: "une neige plus abondante que pendant la phase précédent entraîne un ruissellement intense" (1958, p. 318). A characteristic of such a nival régime would be the concentration of run-off in the summer season following the general thaw, when debris broken off the higher rocky areas by frost in a climate still marked by severe winters, may have been washed down the relatively steep slopes. If one considers the Lower Gravels in isolation one might think of them as derived from the erosion of the Lower Head on the bench above, but the fact that the Upper Gravels occur on the valley bench suggests that they may be to a large extent a deposit derived from the higher rocky hill-sides and laid down on the underlying head. This would imply that the dissection of the head on the bench (as elsewhere in the valley), is a Post-Glacial process.

COMPARISON WITH THE SCREE SEQUENCE

In the more deeply trenched valleys such as that drained by the Dysynni-Fathew (Fig. 1), the typical slope deposits are screes. In many exposures these show a three-fold succession, which has been compared with that of the Nant Iago terrace (Watson, 1965a, p. 23). Wedge structures occur in the screes (Watson, 1965b, p. 458—9), and in one case cut all three divisions of the scree (see Photo 1a, Watson, 1965a). Since it seems highly unlikely that scree was not forming on slopes such as the sides of the Tal-y-llyn valley in Pollenzone III of the Late Glacial and since wedge structures in Scotland (Galloway, 1961, p. 185), and in south Sweden (Hoppe, 1956, p. 55), are believed to date to Zone III, it is probable that the Upper Scree is Zone III in age and that the soil overlying it marks the vegetation and stabilization of the scree in Post Glacial time.

Iago Terrace	*Screes*
Soil	Soil
Upper Head, C	Upper (unsorted) Scree, III
Lower Gravels, B	Stratified Scree, II
Lower Head, A	Lower (unsorted) Scree, I

The dominance of solifluction in the more open upland valleys such as the Iago, suggests a minimal snow cover during phases A and C; the coarse scree of phases I and III may likewise be due to relatively dry conditions (as may the wedge structures). The replacement of solifluction by slopewash in the Iago valley in phase B may reflect increased snowfall as well as less severe conditions. This change may have favoured the development of stratified screes (*grèzes litées*) which, as Y. Guillien has forcibly argued, are associated with snow banks (1964).

The conclusion presented here that the deposits in the Nant Iago valley are all of slope origin, formed by solifluction and slopewash is based on their distribution, bedding and fabric. From the evidence so far available, the sequence of deposits appears to be normal for the upland valleys of central Wales. It is seen in the next valley to the northeast near the site of Cwm Dylluan farm (Fig. 1 and Pl. 7). It has been studied by the author in the upper Rheidol valley, some 15 km east of Aberystwyth, (unpublished), and the evidence of preferred stone orientation there supports the conclusions reached here. The correlation of the solifluction sequence with that of the screes and of the Post-Glacial still awaits the discovery of the material for absolute dating.

References

Alexandre, J., 1960 — La succession probable des phases morphologiques au cours d'un cycle climatique quaternaire en haute Belgique. *Biuletyn Peryglacjalny,* no. 9, p. 63—72.

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

Guillien, Y., 1964 — Grèzes litées et bancs de neige. *Geologie en Mijnbouw,* 43, p. 103—112.

Hoppe, G., 1956 — Rapports de la Comm. de Morph. Périglac. de l'U.G.I. *Biuletyn Peryglacjalny,* no. 4; p. 55.

Jehu, R. M., 1926 — The geology of the district around Towyn and Abergynolwyn (Merioneth). *Quart. Jour. Geol. Soc. London,* vol. 82; p. 465—489.

Johansson, C. E., 1965 — Structural studies of sedimentary deposits. *Geol. Fören. Stockholm Förhandl.,* vol. 87; p. 4—61.

Krumbein, W. C., 1939 — Preferred orientation of pebbles in sedimentary deposits. *Jour. Geol.,* vol. 47; p. 673—706.

Watson, E., 1965a — Grèzes litées ou éboulis ordonnés tardiglaciaires dans la région d'Aberystwyth. *Bull. Assoc. Géogr. Franç.* no. 338—9; p. 16—25.

Watson, E., 1965b — Periglacial structures in the Aberystwyth region of central Wales. *Proc. Geol. Assoc. London,* vol. 76; p. 443—462.

Watson, E. & S., 1967 — The periglacial origin of the drifts at Morfa-bychan, near Aberystwyth. *Geol. Jour.,* vol. 5; p. 419—440.

(Anon.) 1965 — Gravel fabric in Wolf Run. *Sedimentology,* vol. 4; p. 273—283.

DISCUSSION

Professor Hoppe: I agree with the general result of the reinterpretation. However, I wish to ask two questions: (1) does this mean that you think that the area under consideration was not covered by the last inland ice? (2) Cannot the whole sequence have been deposited just after a deglaciation, when slope processes would be very active, and during a rather short time?

Dr. Watson: There is no direct evidence of the age of these beds, but as I indicate in the full text of this paper, I think the deposits exposed in the Nant Iago section may be younger than the Würm maximum. Only a small part of the Lower Head is exposed. Nevertheless, the complete absence of moraines or other glacial deposits here and in the main valleys leads me to question the presence of Hauptwürm ice in this part of Wales.

Professor Rudberg: I wish to raise a general problem which is not to be regarded as a criticism especially aimed at Dr. Watson's paper. When giving a detailed interpretation of a section it is necessary to take into account the great local differences which are known to occur in areas where present-day periglacial processes have been studied. Most important is what was happening above the site studied. Strong solifluction might be caused by the addition of water from a persistent snow patch above, or if there is a rock face, greater quantities of coarse material might be produced intermittently by rockfalls than would otherwise be present.

Dr. Watson: I agree completely with Professor Rudberg that a failure to take into account the effects of local conditions may render completely false the general conclusions drawn from a single exposure. I should like to emphasize that the interpretation I have offered is not based on this one exposure. The sequence found here occurs elsewhere in central Wales; it occurs in the next valley to the northeast and I have studied it at several points in the upper Rheidol basin, some 20 km. away. The Lower and Upper Gravels do not occur continuously but in lenticular beds probably due to slope wash being locally concentrated by the configuration of the slope. I have selected the Nant Iago exposure for a detailed description because the whole sequence of the beds is exposed in a long dip section so that the dips of the beds are clearly shown. The presence of the modern slope wash gravels is, I think, also instructive.

In one respect the Nant Iago section is not typical. The surface inclination of the slope deposits on the valley floor is unusually steep. At the upper end of the gully exposure, this reaches 19°; usually the surface inclination of these valley floor slope deposits on mudstones in central Wales does not exceed 10°. The steep surface slope in this case seems to be due to the fact that the bulk of the material was derived from solifluction deposits on the valley bench above; it seems to have poured over the valley shoulder and to have been partly banked against the valley side below. This is, I think, a clear example of the effects of local conditions, such as Professor Rudberg refers to.

Dr. Rapp: I think the deposits called solifluction beds by Dr. Watson can be interpreted as mudflow beds, due to: (a) texture, (b) particle orientation, (c) bedding structure, (d) topographical situation. All these four factors suggest repeated rapid flows of thin sheets.

Dr. Watson: I confess I have not considered a mudflow origin, and I am grateful to Dr. Rapp for his suggestion. However, I must state that the bedding he referred to, is seen here only in the Lower Head, and in only part of that. This bedding is very unusual in the Lower and Upper Head in the central Wales uplands; normally these are much less obviously stratified so that I think the mudflow explanation is not generally true. The question, whether it is true here, due to local factors, such as the persistence of snow drifts on the steep north-facing slope above the valley bench producing saturation of the solifluction debris on the bench and to its flowing over the valley shoulder and down the valley side below, seems worthy of investigation, once the fabric of contemporary mudflows has been clearly established.

Pl. 1. The downstream limit of the Iago terrace

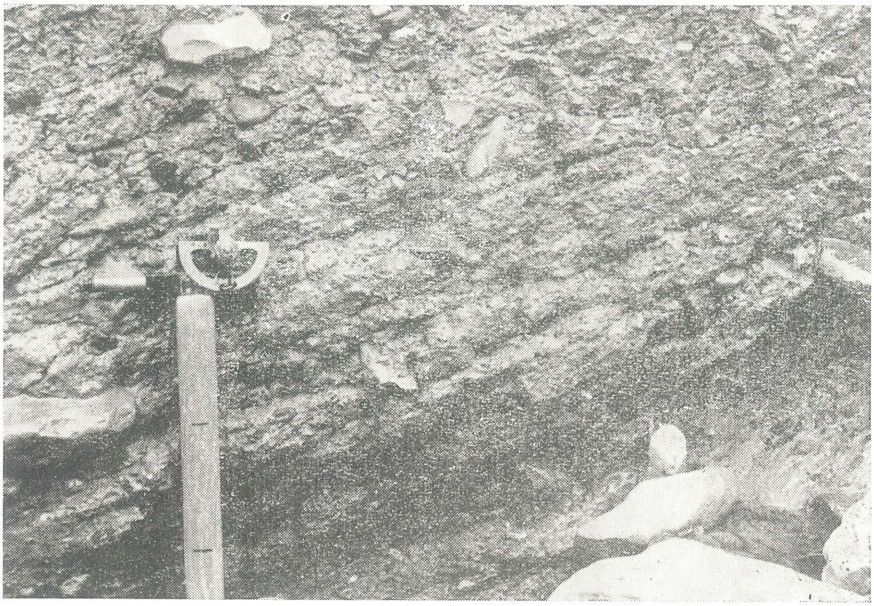
The near left-bank is covered by thin solifluction deposits which cease to have a distinct terrace form. These give way to a gullied rock slope with gravity screes at its foot when the stream enters the gorge section. At the gorge head the valley turns so that this gullied slope faces northeast, and as the gullies are not developed on the southwest-facing slope they are probably due to aspect. All slopes are developed on one rock, the Tal-y-llyn Mudstones

Pl. 2. The upstream limit of the solifluction terrace on the south bank of the Iago

This begins immediately below (to the right of) the sheepfold, S. The streams above it and on the north bank are in shallow rocky incisions

Pl. 3. The solifluction terrace from the west

Streams A, B and C as in Figure 4. The valley bench lies above the crags to the centre and left, but the head is continuous down to the valley floor between B and C, where the terrace reaches its maximum development



Pl. 4. The stratification of the Lower Head in gully A

The Abney Level is horizontal, and the marks on the hammer shaft are 10 cm apart

Pl. 5. The sequence of deposits in the valley-floor terrace

Oblique view of the upper end of the exposure shown on Fig. 6. A, the Lower Head; B, the Lower Gravels; C, the Upper Head; D, the Upper Gravels. The modern flood gravels are seen on the terrace surface on the left. Stick: 90 cms long

Pl. 6. The lower end of the gully of stream A

B, the Lower Gravels is, in turn, covered by C, the Upper Head; D, the Upper Gravels; E, the soil and F, the modern flood gravels. Stick: 90 cms long

Pl. 7. The terrace of slope deposits at Cwm Dylluan. The terrace is on the south side facing a rocky slope on the north