Cwm-du, Cwmystwyth, Ceredigion

[SN 813 740]

Introduction

Cwm-du is a large, north-facing hollow on the south side of the Afon (river) Ystwyth. It is fronted by a large fan of debris showing some stratification and a number of physiographical 'terraces'. Several types of mass movement have been involved in the production of these forms. Opinions differ as to their genesis, and concerning the relationship of the fan to the hollow which, in part, it occupies.

Some sites have been included in the GCR for mass movements because they have become classic sites for research and learning, and are, relatively speaking, well understood (e.g. Folkestone Warren, Mam Tor, Black Ven). Cwm-du is selected for a different reason: it is not well understood, and is the subject of continuing disagreement about the role of the mass-movement processes at work. Mass movements are certainly envisaged as having been instrumental in its development, but their precise nature, and their relationships to the surface forms present, remain unclear.

Description

General description

The large, north-facing hollow of Cwm-du, on the south side of the Afon Ystwyth (Figure 3.2) and (Figure 3.3) is 2 km east of Cwmystwyth. It is in the Aberystwyth Grits, a series of greywackes and mudstones of the Llandovery Series. The floor of Cwm-du is elongated like the floors of many glacially eroded basins (500 m x 300 m). The hollow has a spectacular backface (Graig Ddu) more than 50 m in height. It is 180 m lower in altitude than typical glacial hollows in the area and it shows none of the erosion features associated with them. It has a fan-shaped, terrace-like front without an enclosing moraine or rampart. It was first described by Keeping (1882) and has been studied in detail by Watson (1966, 1968, 1970, 1976) and Watson and Watson (1977).

Instead of a moraine, which would be expected if it were a glacial cwm, the basin of Cwm-du is fronted by a drift scarp 18 m high in the centre, which resembles a moraine when viewed from downslope but is in reality the front of a terrace consisting of head deposits. The main stream in the hollow, Nant Cwm-du, has cut a deep gully parallel to this front but instrumental levelling in the area of the profile J-K ((Figure 3.4)a,b) shows that the top of this scarp is lower than the floor of the hollow (Watson, 1966). The gully reveals up to 18 m of head without the bedrock being exposed and there is a smooth slope rising up to the headwall of the hollow.

The long-axis of the hollow is south-west–north-east and its floor falls in the same direction. The angle of elevation from the front of the drift platform at the stream exit to the top of the backwall in its south-west corner is 13°. The smooth curve of the floor of the lower part of the hollow is replaced towards the head by a drift accumulation that fills the south-west corner of the hollow. The streams falling steeply into the hollow have filled in the area behind this accumulation at its southern end with bouldery alluvium, but downstream (at profile R–S, (Figure 3.5)) it is seen to be composed of head.

Surface topography

The south-west corner of the hollow contains an accumulation of drift, denoted 'Stage V' by Watson (1966) (see (Figure 3.4)). The drift encircling the basin of the hollow (IV, see (Figure 3.4)) appears to be the highest and most continuous member of a series that is developed across the surface of the drift fan below it. This series, marked 'I', 'II' and 'III' on (Figure 3.4), gives the fan a stepped profile. These steps, or scarps, are not continuous across the fan so profile J-K does not give the complete series; profiles L-M and N-0 restore the missing steps in the general picture. The upper scarp of the series, III, is parallel to the terrace front of the hollow, IV, and, like it, falls in elevation towards the east. Unlike IV, it appears to have been worn down at two points as if erosion had lowered the top of the scarp. Scarp H extends as a continuous scarp to the east of the Nant Cwm-du gully except where it is cut by the unnamed stream. West of this stream it appears to have been eroded as in the case of scarp III. Scarp I exists only on the flanks of the fan; in the central area the fan gives the appearance of having been built up so that there is a continuous slope from scarp H to the limiting bluffs of the fan, which are due to erosion by the Afon Ystwyth.

Deposits

The drifts in Cwm-du consist of two types of head (Watson, 1966). One is a tough bluish-grey silty deposit containing angular and sub-angular rock-fragments of all sizes from fine gravel to great boulders. The other is a yellowish-grey, loose deposit, containing similar debris but with a smaller proportion of finer material so that it may often be described as a muddy angular gravel. It often shows rusty mottling and, in the more open beds, manganese staining.

The exposures in the gully of Nant Cwm-du (15–18 m deep where it leaves the hollow) suggest that these beds form the whole of the deposits, occurring in distinct layers between 0.3 m and 1.0 m thick. The bluish-grey type is typical of the solifluction deposits on the greywackes and mudstones of the region, and the yellowish-grey type is probably basically the same except that it has suffered some degree of washing during deposition.

Stage V has many boulders scattered over its outer slope, and exposures show the two types of head; on the profile line R-S (Figure 3.5) 3.5 m of the loose yellowish-grey type overlies 0.6 m of the compact bluish-grey type, above 5.2 m of talus.

The main exposures of the deposits making up the Cwm-du fan are shown in (Figure 3.6). The interbedding of tough bluish-grey head and loose yellowish-grey head seen in the floor of the hollow also occurs in the fan just behind scarp II at exposures 2 and 3. At other points, for example 11 m upstream of exposure 3, the west side of the gully shows only the blue-grey head and at exposure 5 only the blue-grey head is seen for 7 m above the stream.

In front of scarp II, small-calibre water-laid gravels (clast long-axes less than 5 cm) are interbedded with thin layers of grey silt at the top, from the lower 3 m of exposure 1. Again, in front of scarp III, exposure 4 shows blue-grey head overlain by 2 m of similar small gravels capped by 0.5 m of sand and silt, on top of which is blue-grey head. Exposure 5, in front of scarp IV, shows 0.7 m of water-laid sands, gravels and silts resting on the blue-grey head of scarp III. These are overlain by a stony, bouldery yellow-grey head (in places a muddy gravel) which thickens when followed upstream (Figure 3.7). Exposure 4 at the top of the sequence also shows a gravelly head, roughly stratified parallel to the present surface and showing similar conditions at stage II to those of stage IV.

An exposure new in 1974 (Watson and Watson, 1977), almost at the mouth of the gully, consists of grey clay 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, indicating pressure along the fan axis. A bed of clay, sand and small gravel is torn out along a plane that curves upwards and outwards, suggesting thrusting.

Interpretation

Watson (1966) considered the hollow to be due to nivation associated with inert masses of névé and ice that were not thick enough for plastic deformation and flow. This conclusion is supported by many of his detailed observations on the deposits present, since it provides interpretations of their genesis. For example, he attributes the yellowish tinge of the yellowish-grey deposits as being due to post-glacial weathering accompanying a more ready percolation of water. He suggests that the water-laid sand and silt layers in the succession in front of scarp III might be older than the step behind, having been laid down during a recession phase when summer melting was more pronounced, and having then been overwhelmed by the solifluction deposits of the snowpatch of the succeeding cold phase. They might also represent meltwater deposits laid down while the step behind was being built up. The former explanation, he continues, supports the sequence at exposure 5, in front of scarp IV, where the bouldery head that tops the sequence would appear to be material that has been partly washed by snowmelt as it flowed down the face of the scarp.

The 1974 exposure caused him to revise his view. Interpreting it as a glacial deposit, he suggests that glacial ice played a part in the earlier stages of the development of the fan, incorporating this view by suggesting that an ice advance from the hollow was followed by a period of nivation that is responsible for the present surface form (Watson and Watson, 1977).

It is worth noting that he cites Flint (1957) to the effect that for slow plastic deformation 'the minimum thickness of ice and fern required is not known'. He envisaged a large snowpatch, covering the interior of the hollow from the backwall to the crest of scarp IV This snowpatch would have sloped from the south-west corner towards the present stream exit. The upper limit of the snowpatch would be lower than the top of the backwall so that the surface of the snow would be less steep than the angle of 27° between the top of the drift accumulation which fills the south-west corner of the hollow, and the head of the backwall, measured along line R–S (Figure 3.5). The absence of a protalus suggests that no superficial debris reached the foot of the gently sloping snow surface in Cwm-du.

Botch (1946) produced a block-diagram (Figure 3.8) of the features associated with typical snowpatches in the Ural Mountains which, unusually, shows debris accumulating under the lower part of a snowpatch and moving on subaerially down the slope as a series of solifluction terraces. Watson (1966) suggests that the exposures of the floor of the hollow (stage IV) may have been built up in layers in the way shown in Botch's block-diagram. The exposures on the outer edge of the Cwm-du hollow may represent deposits laid down at the margin of the snowpatch, which might account for the increased washing of some of them, a further parallel with Botch's block-diagram.

The building up of such a platform of drift could be due to the fact that the ground below the snowpatch is affected by summer thaw only to a very shallow depth and that as the debris derived from the weathering of the backwall moves as a solifluction layer beneath the snow-patch it tends to thicken as the gradient lessens. In winter this muddy accretion is frozen to the permafrost below and never thaws out again fully so that summer after summer it is added to. The abrupt limit to the deposit, represented by the scarp 18 m high, seems to imply that the actual front of the snowpatch fluctuated relatively little, otherwise the thawing out of the uncovered ground must have been accompanied by soil flow.

The similarity between Botch's block-diagram and the situation at Cwm-du suggests that the steps of the fan may be solifluction terraces, but Watson (1966) came to believe that these scarps, I, II and III, are similar in origin to scarp W at the mouth of the hollow and that they mark earlier snowpatch limits.

His argument against the view that the scarps are sub-snow solifluction terraces is their arrangement in plan. They do not form a series concentric with scarp IV but appear to enclose a series of lobes that have a progressively changing axis. The lobe enclosed by scarp II has an axis running west of north (about 350°); the axis of the higher lobes swings clockwise until in the hollow (the area enclosed by scarp IV) it runs NNE (about 025°). This would be consistent with an area of snow emerging from a gully which was being extended towards the south and west as freeze-thaw made its maximum attack on the backwall on these sides (Figure 3.9). However, while he did not ascribe the surface form of the fan to solifluction, he believed that the 18 m minimum depth of head, and the smooth slope rising across the hollow from terrace IV to the headwall, point to the deposit as a whole being due to solifluction, accumulated beneath the putative snowpatch.

The position of the stream, Nant Cwm-du, on the centre line of a convex fan that is not of its own construction but predominantly of head, favours the view that the scarps of the fan mark snowpatch limits. Inside the hollow, Nant Cwm-du and the stream to the east occupy positions which would have been sub-marginal to the snowpatch of stage IV, and leave it at its lowest point, where one would expect meltwater to escape. The present stream appears to be a direct descendent of such a meltwater stream, having become entrenched in later times. Downstream of scarp IV the stream passes through the lowest point of each crescentic step so that the stream course cuts across the fan to a central position where it joins the Afon Ystwyth.

Watson (1966) made an attempt to reconstruct the evolution of Cwm-du and its fan by advancing the backwall of the hollow to compensate for the building of the fan, along the profile J–K of (Figure 3.4). One of the difficulties he found was the fact that the hollow was not extending along the axis of the fan. Only a fraction of the material laid down at stage IV came from the backwall on the profile J–K. The bulk of it came from the south-west corner of the hollow. This is less true of the earlier stages, but the reconstruction in any case is only very approximate. The 'initial' profile shows a nick-point just above 275 m above OD. Though no rock is seen in the stream bed, the Nant Cwm-du gully is shallowest at this point, only 8 m deep compared to more than 16 m upstream and downstream of this, and the steepest stretch of the present stream profile in the fan occurs just below this.

From the elevation of the High Plateau here and the position of scarps I, II and III, it seems impossible that a snowpatch extending to them could fall into the steeply sloping class. On the reconstruction shown in (Figure 3.10) the angles from the rim of the backwall for scarps I, II and III are similar to that for scarp IV which is 18°. This is in harmony with the fact that each suggested snow limit is marked by a terrace front and not a protalus rampart.

Estimates of the thickness of snow at these stages, on the basis of (Figure 3.9), show that the maximum thicknesses, if the hollow was filled to the top of the backwall, would be 82 m, 82 m and 72 m respectively, for stages I, II and III (75 m for stage IV). In this respect, the problem of stages I, II and III is the same as that of stage N: the question of the thickness reached by snow and ice before it begins to behave as a hollow glacier.

With this escape of meltwater from the snow limit of stage IV, may be associated the fluting of the face of scarp IV suggesting wide shallow gutters leading down to scarp III. This drainage probably escaped by a shallow channel that breaches scarp II. It may be pointed out that this drainage and the deformation of the scarps is developed on the western, 'warmer' side of the fan.

The exposures in Nant Cwm-du gully show that the material in the fan has been laid down in several stages and that the scarps are not a series of terraces formed contemporaneously with the build-up of the platform of head at stage IV The water-laid gravels and silts seen in three places, each a short distance from a scarp, suggest that the building of the steps may have followed on milder climatic interludes.

The drift accumulation, V, which fills the south-west corner of the hollow, has the stream passing behind it, between its rear and the back-wall of the hollow, in a space which the stream has partly filled with bouldery alluvium. This suggests that after the snowpatch had disappeared from the hollow, it re-formed, filling only the south-west corner, and built up this drift as a protalus. The angle of elevation from the top of the protalus ridge to the rim of the backwall on profile R–S is 27°, indicating that this final snowpatch belonged to Botch's steeply sloping class.

The question arises as to whether the volume of the 'fan' is sufficient to account for the volume of material removed to create the hollow. Clearly, Watson believed this to be the case, so justifying his classification of Cwm-du as a 'nivation cirque' (i.e. a hollow formed by nivation). There is, however, a difference between a hollow formed by nivation, and a hollow (of glacial origin) in which nivation has taken place. There seems little reason to doubt Watson's argument that the fan at Cwm-du is a periglacial deposit, particularly in view of his many carefully reported observations at the site. His reconstruction of events may well be correct, but there is another possibility.

Thorn (1976, 1979, 1988) has questioned the efficacy of nivation alone to produce such large landforms. He has shown (Thorn, 1976; Thorn and Hall, 1980) that nivation processes operate at extremely slow rates, suggesting that large features may be in some sense 'inherited', and merely modified by subsequent nivation and frost-action processes. Thorn's work was concerned with large cryoplanation terraces, but similar considerations apply to the notion that nivation may form or develop large hollows ('nivation cirques').

Cwm-du seems a prime candidate for the situation envisaged in general terms by Thorn (1976): in this view, Cwm-du may be seen as an 'inherited' glacial hollow that has been modified by nivation. There is little evidence from which its original genesis may be deduced. It may be inferred that like some other hollows in the hills of mid-Wales, it originated as a glacial cirque. However, there is much evidence that hollows like this may be due to landslides.

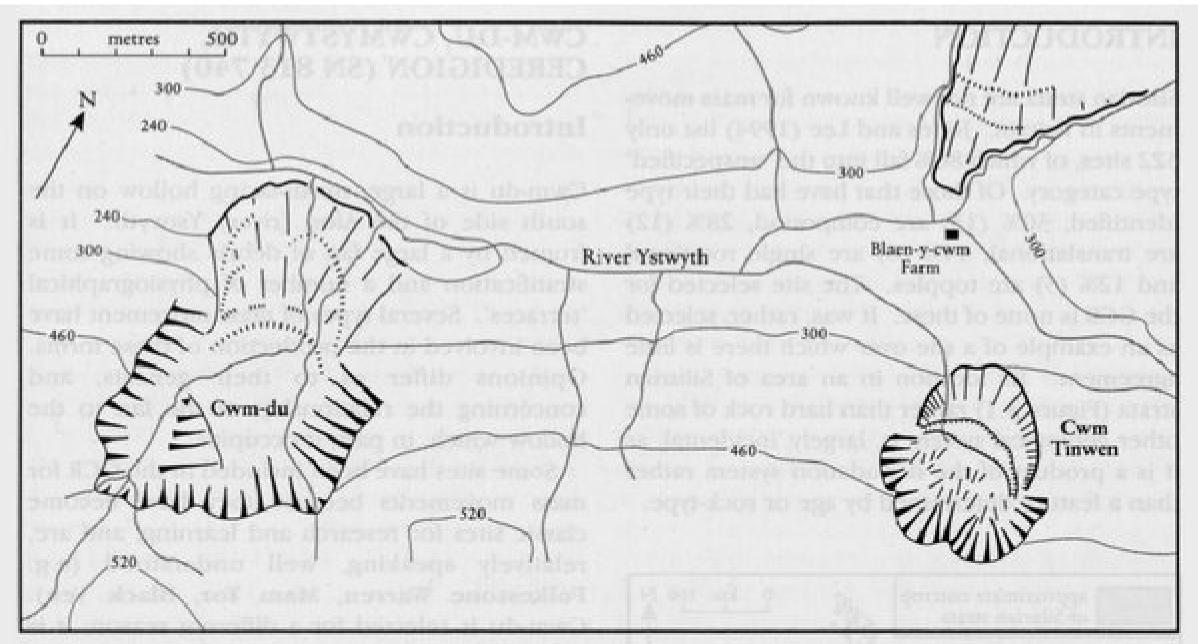
In a detailed critique, Ballantyne and Harris (1994) point out that Watson's argument rests on the lack of evidence for glacial erosion in the hollows that he studied (Cwm-du and the nearby Cwm Tinwen). Instead, he invoked frost-sapping of headwalls, meltwater transport, sub-nival solifluction and the movement of debris across steep snowpatch surfaces to explain their development. Both hollows are fronted by thick drift accumulations up to 18 m deep. The drift is a tough diamicton with occasional looser layers deficient in fine-grained materials, and was interpreted by Watson as a solifluction deposit partly modified by meltwater eluviation. Watson's interpretation has attracted scepticism (see discussion in Watson, 1966). A particular difficulty (Ballantyne and Harris, 1994) is posed by the thickness of snow or névé required to produce a slope on the snow or névé steep enough to permit the sliding of debris over its surface. With gradients greater than 23° (Watson, 1966) the thickness would be such that unless densities markedly lower than that of ice are assumed for the accumulated névé, the basal shear stresses must have exceeded 1 bar, so that the 'snowpatch' would have moved as glacier ice. Although the snow surface gradients indicated by Watson are maximal, lower gradients would not have permitted movement of debris over the snow surface in the manner envisaged by Watson. Observations on active protalus ramparts (Ballantyne, 1987b) suggest that gradients of 23° and 25° are too low to permit this to occur (Ballantyne and Harris, 1994).

However, these strictures really apply only to that part of Watson's notion that the whole of Cwm-du owes its origin to nivation. The origin of the fan, the terraces upon its surface, and the distribution and properties of the head require explanation. At the very least, Watson's observations on the fan and its surface form and composition, pose a problem which is not solved by demonstrating that nivation cannot have been a major process in its genesis.

Conclusions

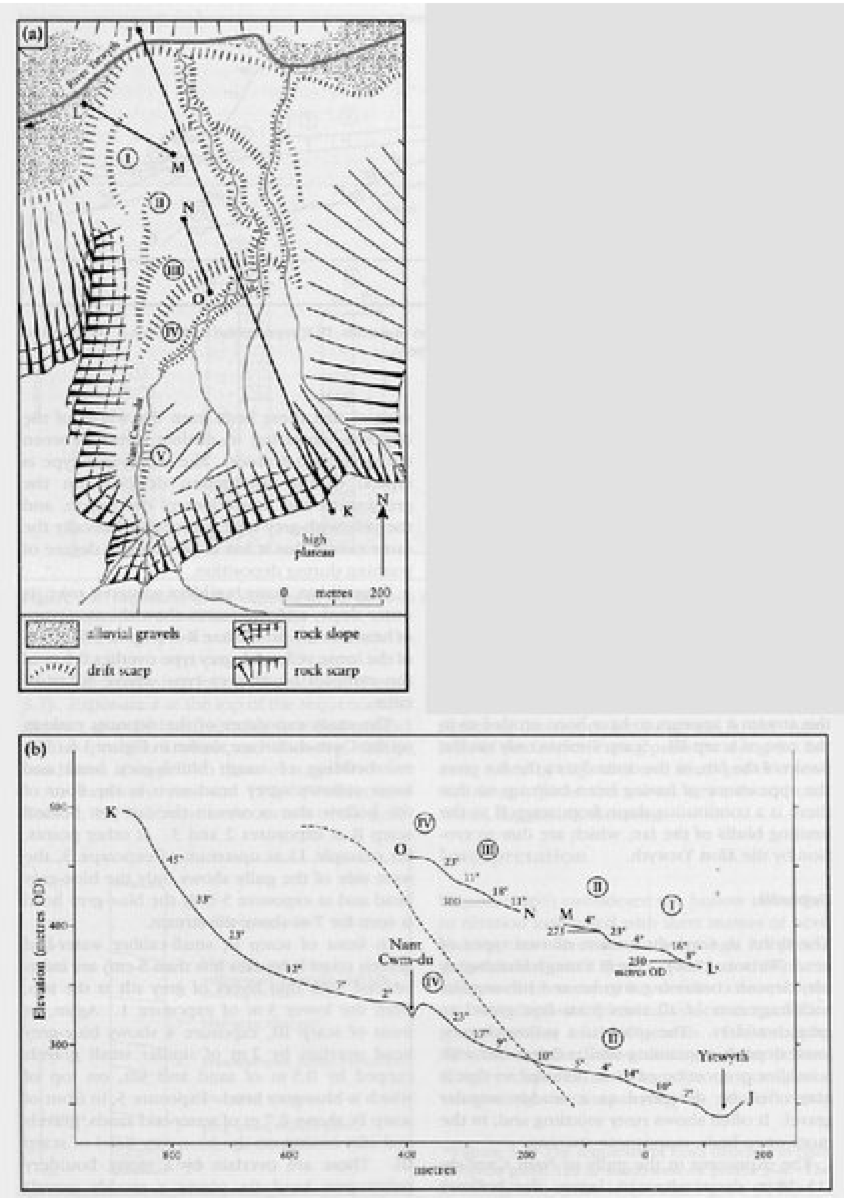
Two main means of mass movement have been invoked to explain, at Cwm-du, the transport downslope of material arriving as debris from rockfalls at the backwall of the hollow. The chief type of mass movement suggested by Watson (1966) is solifluction, unusually suggested to have taken place under a covering of snow. He also suggested sliding of debris over a snow surface; this has been proved not to be possible in this particular case, which leaves the apparent protalus in the south-west corner of Cwm-du unexplained. A further possibility is that the terraces could have reached their present positions as a result of landsliding, a process certainly capable of producing the features shown in (Figure 3.9). This site's conservation value relies upon its protection so that it remains available for future scientific research.

References

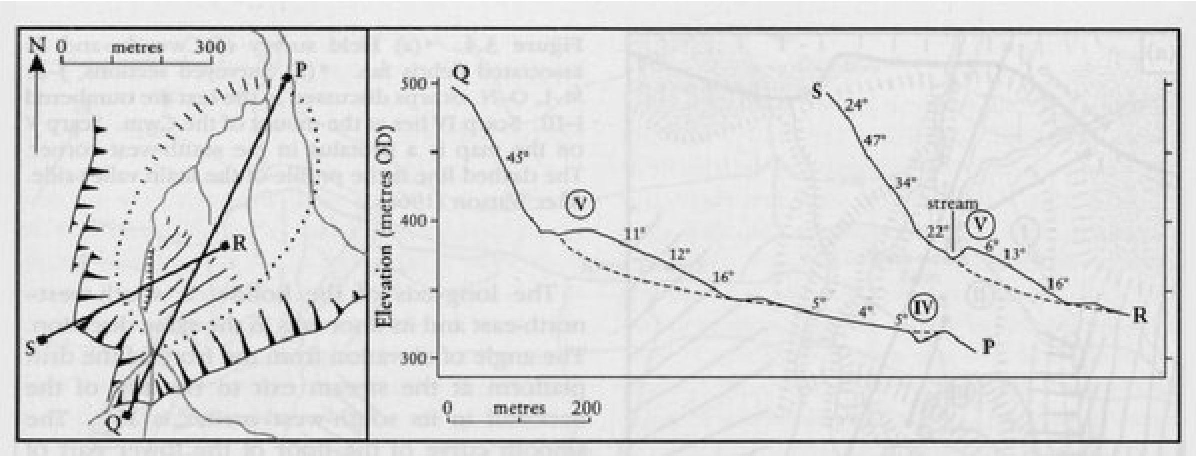


(Figure 3.2) The location of Cwm-du in the Upper Ystwyth valley. Contours are in metres. After Watson (1966).

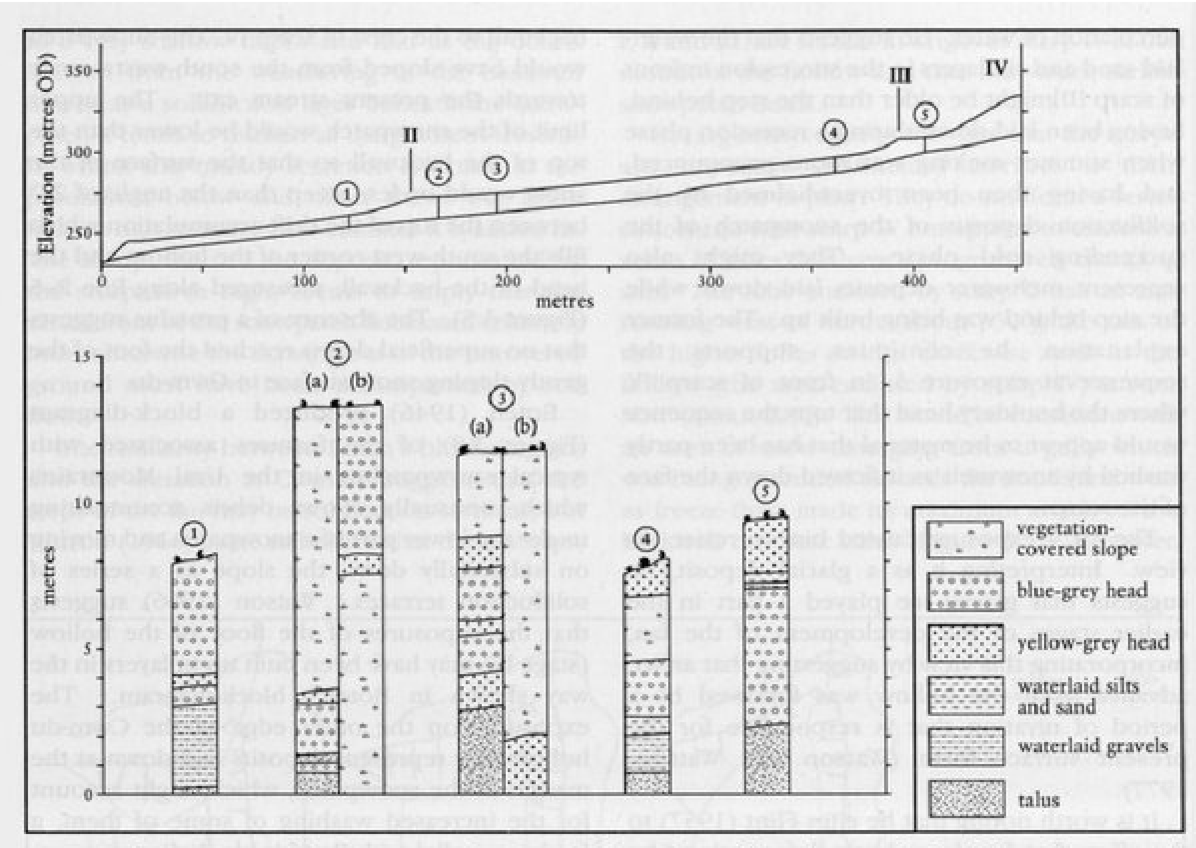
(Figure 3.3) View across the Upper Ystwyth valley looking southwards into Cwm-du, up the extensive 'drift' or landslip debris incised by an 18 m-deep gully. (Photo: S. Campbell.)



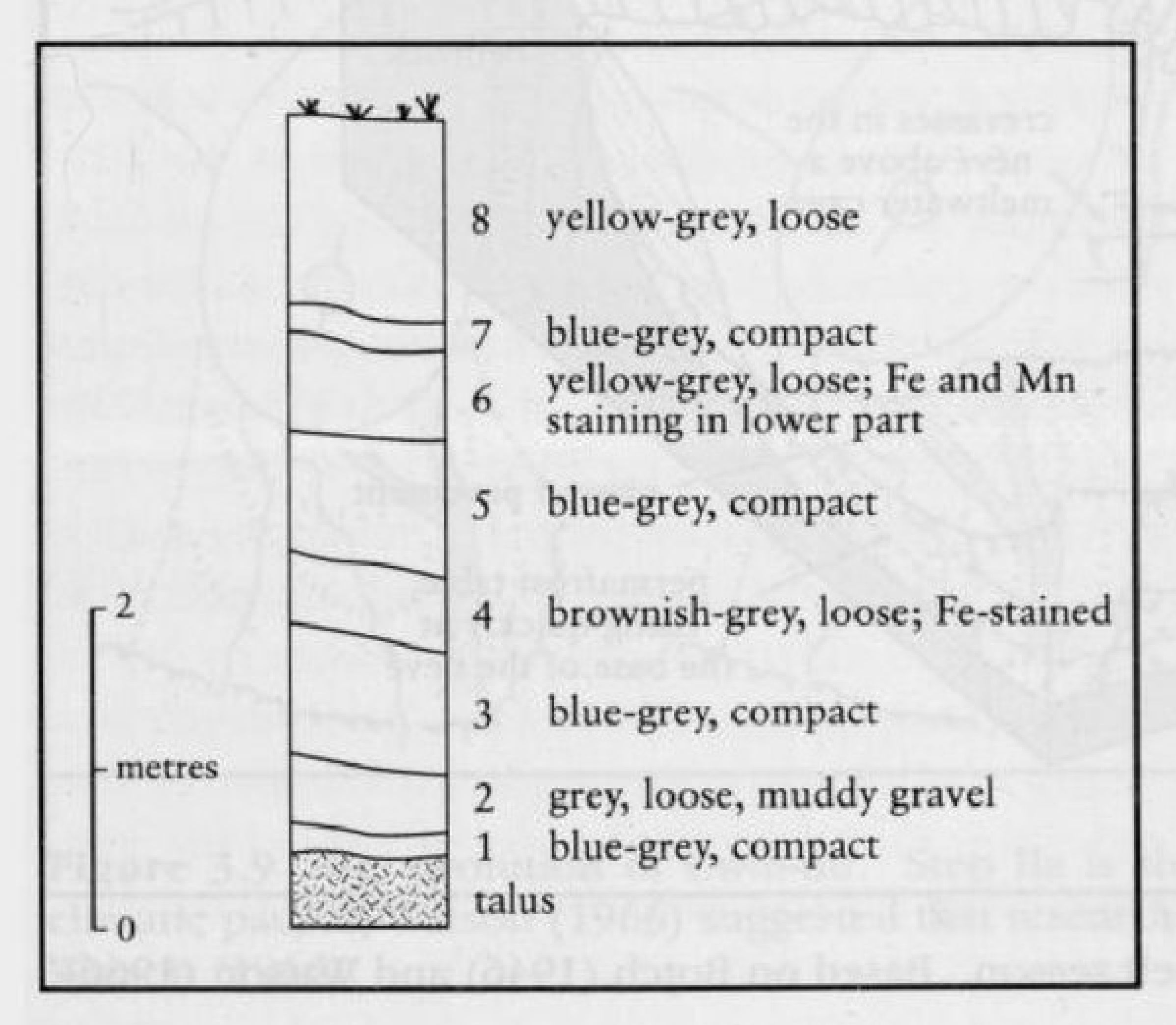
(Figure 3.4) (a) Field survey of Cwm-du and its associated debris fan. (b) Surveyed sections, J–K, M–L, O–N. Scarps discussed in the text are numbered 1–111. Scarp IV lies at the mount of the Cwm. Scarp V on the map is a protalus in the south-west corner. The dashed line is the profile of the main valley-side. After Watson (1966).



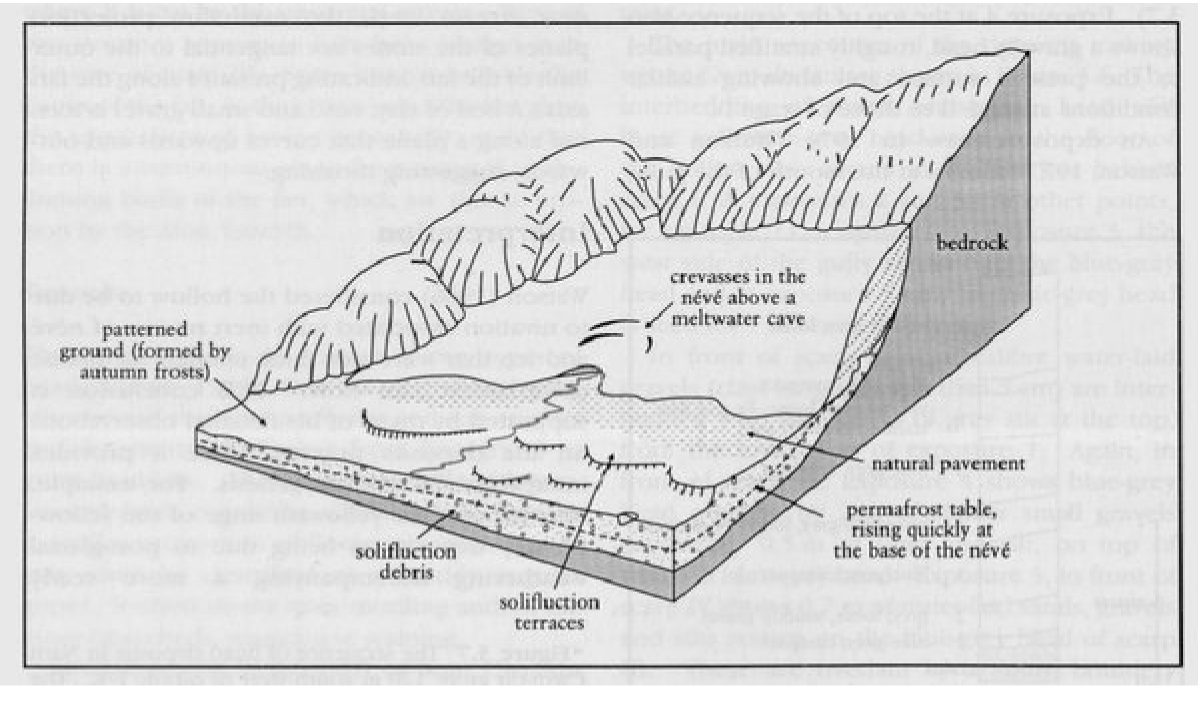
(Figure 3.5) Profiles (P–Q, R–S) through Cwm-du. Roman numerals, IV V, correspond to (Figure 3.4). The dashed lines reconstruct the floor of the cwm. After Watson (1966).



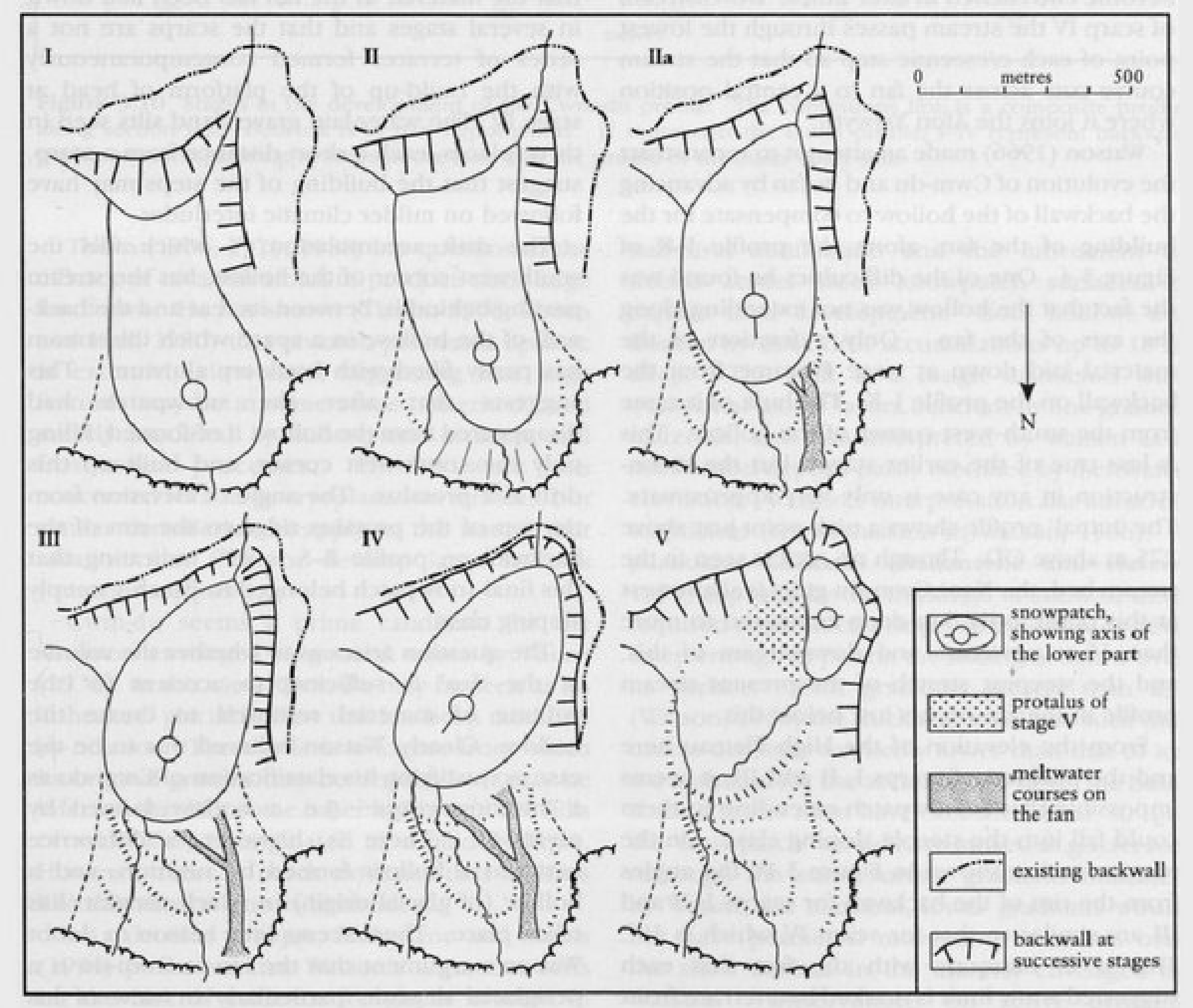
(Figure 3.6) Exposures of the deposits in the Cwm-du fan. The profile is the west bank of the gully projected onto section J–K. After Watson (1966).



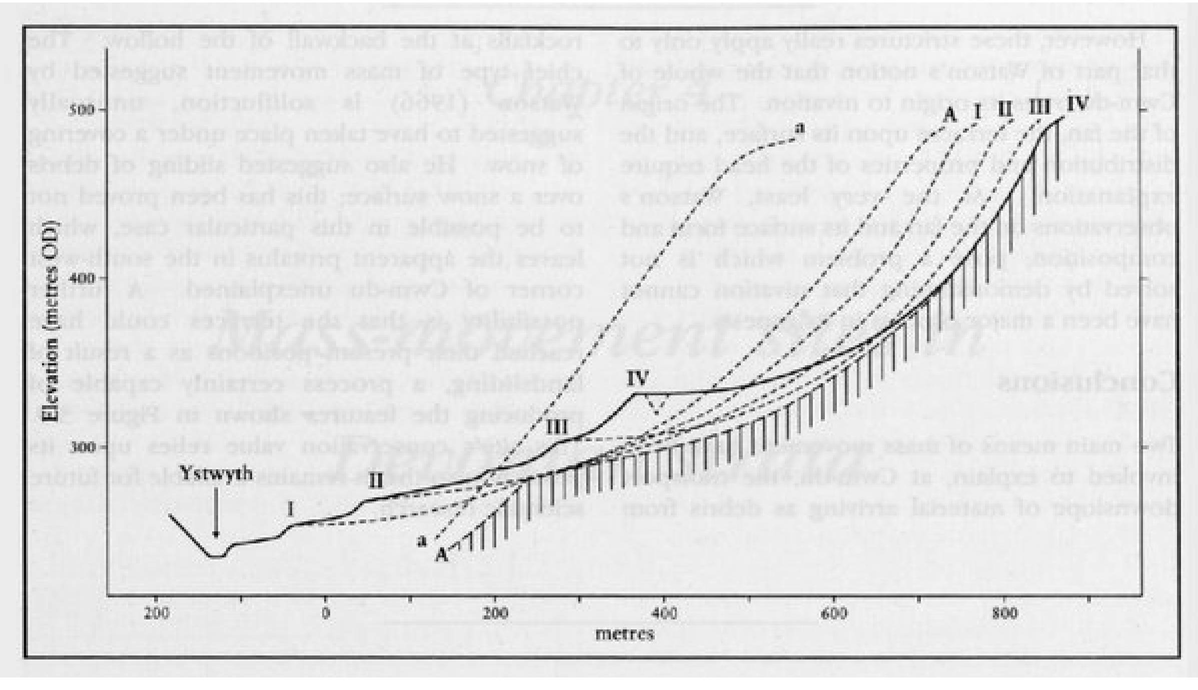
(Figure 3.7) The sequence of head deposits in Nant Cwm-du gully, 120 m south-west of profile J–K. The scale begins at stream level. After Watson (1966).



(Figure 3.8) Block-diagram of a snowpatch during the melt season. Based on Botch (1946) and Watson (1966).



(Figure 3.9) The evolution of Cwm-du. Step Ha is shown as marking a snow limit. If these steps represent climatic pauses, Watson (1966) suggested that research elsewhere in Wales may help to decide its status. After Watson (1966).



(Figure 3.10) Stages in the development of the Cwm-du profile. The continuous line is a composite profile along section J–K. Bedrock is in part hypothetical. 'A' represents the initial profile; I–IV represent backwall positions corresponding to steps in the fan; 'a' is the profile of the main valley-side.