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THE PHYSIOGRAPHY, DEPOSITS AND VEGETATION OF THE PLYNLIMON CATCHMENTS

(A synthesis of published work and initial findings)

by

M D Newson

PROLOGUE

From high Plynlimon's shaggy side
Three streams in three directions glide.
Trad.

Plynlimon sat on lofty height,
surveyed his lands and warming might
from a throne-carved boulder, through misty tears
he saw the ending of his years.
His long cloak torn, now faded bare
was tugged by breezes that spread his hair
from his forehead in a wild, grey mane
streaming like some squall of rain.
No son would ever take his realm
no proud heir could wear his helm
he had, but now his daughters three
and they must share his territory.

from The Song of Three Rivers (1968-74)
Ian Fearnside

After ascending the hill and passing over its top we went down on its western side and soon came to a black frightful bog between two hills. Beyond the bog and at some distance to the west of the two hills rose a brown mountain not abruptly, but gradually, and looking more like what the Welsh call a rhiw or slope than a mynydd or mountain. "That, Sir," said my guide, "is the grand Plynlimon. The fountains of the Severn and the Wye are in close proximity to each other. That of the Rheidol stands somewhat apart from both..........................

from Wild Wales (1862)
George Borrow

.... many high Hilles and plentifull Springs, which water and make fruitful the soyle every where; whofe fearching rilles with a longing defire hafte ever forward to find an increafe, and to augment their growth into a bigger body, whereof the Severne is the chiefe, and the fecond River in the Land: Whofe head rifing from the fpired mountaine Plymllimon, runneth not far without the receits of other riverets into her ftreame.

Speed's map of 1610 – Montgomeryshire.

"Plynlimon is not a popular mountain, except in geography books, which till quite recently misled generations of British youth with the preposterous assertion that it was the third highest in the Pricipality, whereas there are several, even in South Wales, of considerably greater altitude. But the ingenuous geographer, though ridiculous as a statistician, was dumbly and half consciously, and with vague intentions, groping after something like the truth. If importance had been substituted for elevation he was not far wrong in his appraisement of this lonely humpy mass ...."

The Wye (1910)
Sutton Palmer & A.G. Bradley

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PREFACE

This report is intended as an introductory background for visitors or researchers at Plynlimon as well as a reference for analysts seeking background to the hydrological data. It draws not only on the author's own work but on the published and unpublished results of others. Of the former type, the work of members of the Department of Geography, University College of Wales, Aberystwyth predominates (Drs Watson, Bowen, Taylor, Lewin et al). Unpublished help was in the form of Catchment Section mapwork supervised by Dr J C Rodda and Mr S W Smith prior to rainfall domain selection, specific mapping of soils by Mr C C Rudeforth (Soil Survey of England and Wales) and vegetation by Mr R O Millar (Institute of Terrestrial Ecology. The Vegetation survey of Wales was consulted in cooperation with Mr J A Taylor, University College of Wales, Aberystwyth and the National Library of Wales. Second Land Utilisation Survey maps of vegetation were obtained from Mr G A Sinclair, Environmental Information Services who also gave the author field advice on vegetation as did J M M Munro, Welsh Plant Breeding Station. Mr Simon Bennett-Evans kindly advised on land-use in the Wye catchment, Mr R Rogers in the Severn.

In connection with the finality of this report, it should be stressed that refinements are proceeding, particularly in respect of soils mapping and for the detailed hydrological interpretation of Plynlimon soils the reader is referred to the work of Mr J P Bell (Institute of Hydrology Report No. 8). My thanks go to John Bell for critically reviewing this report.

Finally the author's own motive for producing this report was to investigate the spatial organization of the catchments in order to formulate strategy for the integration of process studies and eventual streamflow modelling. This is seen as the geographical contribution to scientific hydrology, helping to counter the libel of Palmer and Bradley (see Prologue).

All maps of the catchments except Figures 2, 4, 5, 11 and 17 were drawn at a scale of 1:25,000 and then reduced during printing by 20 per cent.

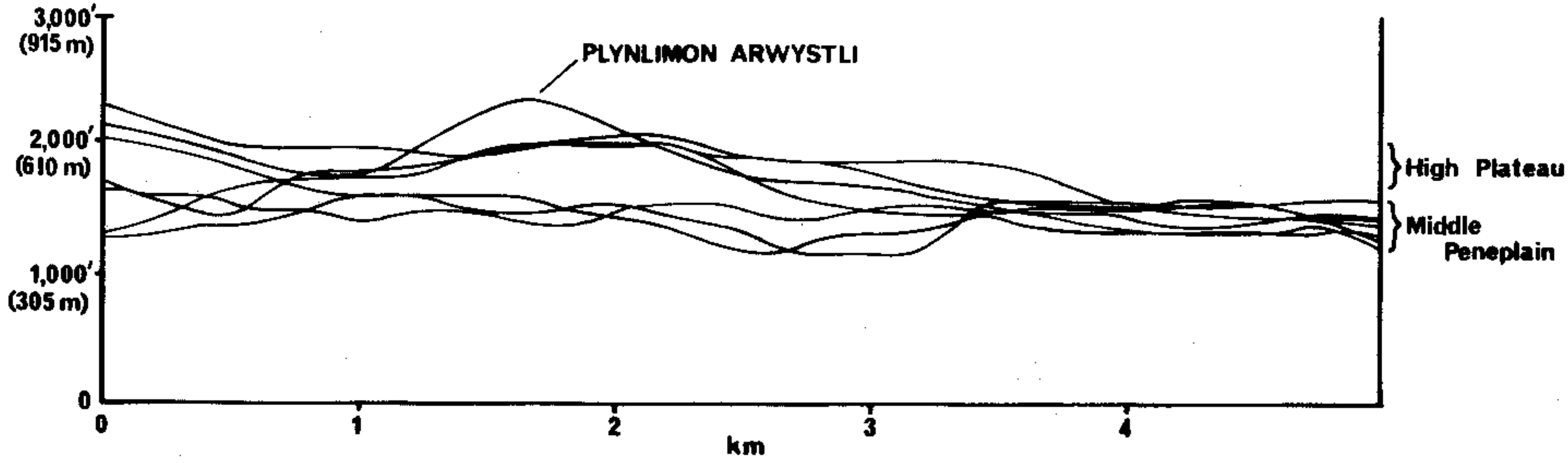


FIGURE 1 Superimposed profiles, E-W across the Plynlimon catchments

I. THE PHYSIOGRAPHY OF THE PLYNLIMON CATCHMENTS

Two aspects are investigated - the geomorphological history and deposits of the catchments and their quantitative description in terms of morphometry. The former provides information helpful to an understanding of hydrological processes and their applicability elsewhere, whilst the latter yields numerical data for comparisons within, between and outside the Wye and Severn.

The general physiography of the two catchments is similar, axiomatic from their choice for the Institute's Plynlimon experiment. There are differences, best expressed in morphometric terms, but a shared geomorphological history (even as far as being part of the same Tertiary river system!) has meant that aspects of the first section have a joint relevance.

1. GEOMORPHOLOGICAL HISTORY

Writers on the physique of Wales have been generally concerned with one of two dominating aspects: the evolution of Tertiary and older erosion surfaces (now elevated as widespread, level, rather monotonous upland country due to base-level changes), or the impact of Quaternary glaciations.

Tertiary evolution

This approach has culminated in the thorough treatment by Brown (1957,1960). Brown takes the view from Plynlimon as demonstrating the widespread High Plateau between 1700 and 2000 feet (520 m - 610 m). Plynlimon peaks rise above it (see Figure 1) as "the textbook monadnock" (a remnant of land surface not reduced to the peneplain level of the High Plateau). Plynlimon's prominence is in part due to the exposure of more resistant Ordovician rocks in the core of a structural dome. Brown suggests that the summits like Plynlimon may themselves be part of a warped "Summit Plain", an erosion surface whose projection envelopes the whole modern landscape, cutting its surface through the higher summits which represent its sole remnants. Below it, the High Plateau is found throughout Wales and is not warped as would be the case if it had been affected by mid-Tertiary earth movements. Below it are the Middle Peneplain at 1200-1600 feet (365 m - 490 m), the Low Peneplain at 800-1000 feet (245 m - 305 m) and a succession of coastal marine surfaces resulting from Pleistocene sea level changes. Rodda (1970) confirms the three-fold division of peneplains using trend-surface analysis. Brown reconstructs drainage patterns responsible for the three major peneplains following emergence from a Cretaceous cover. In this respect his remarks on the Wye and Severn (1960) are worthy of quotation.

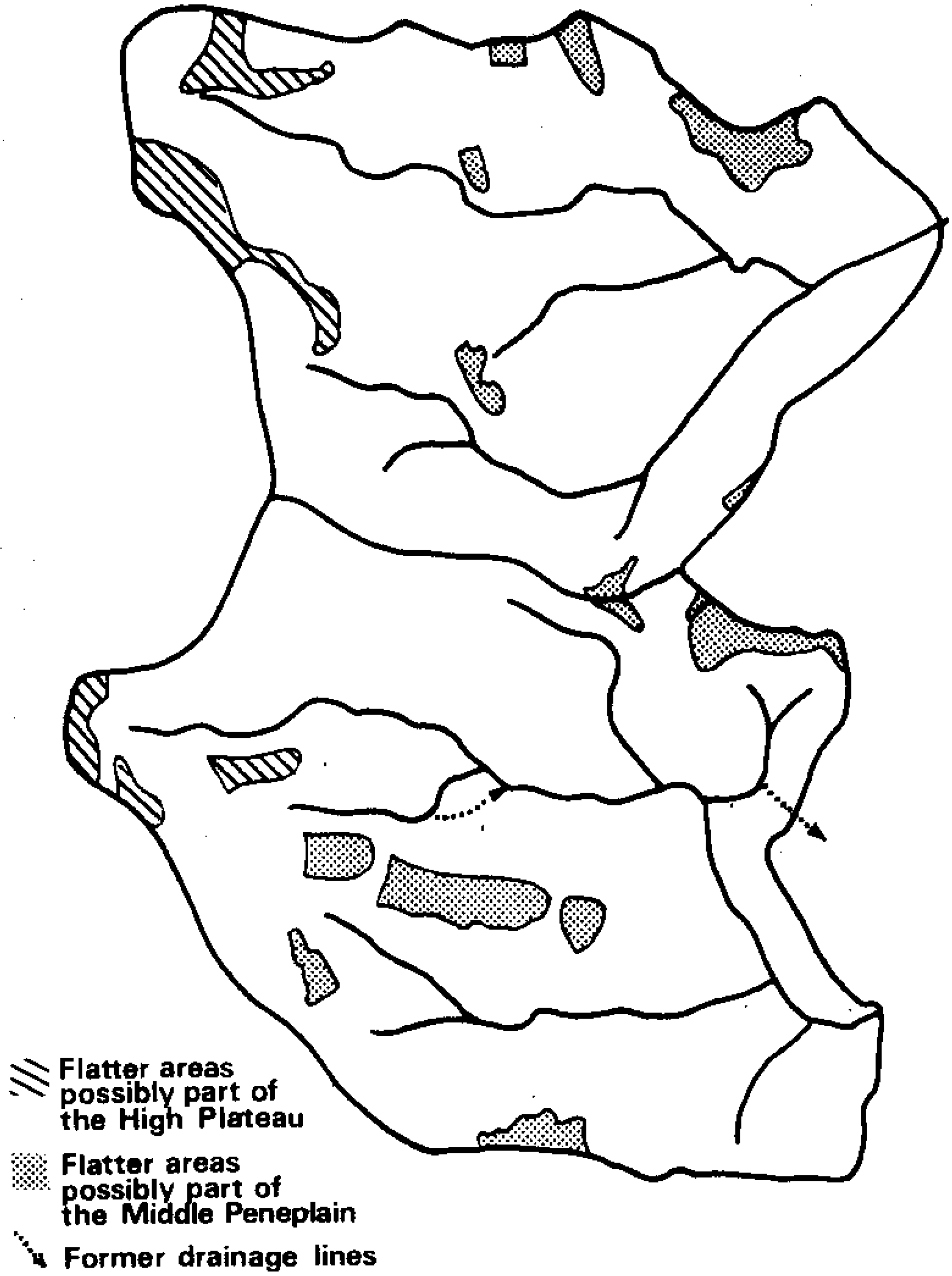


FIGURE 2 Location of plateau remnants, Plynlimon experimental catchments

"The tributaries of the Wye have suffered a considerable amount of capture since the Low Peneplain Stage. The Severn and Clywedog above Llanidloes at this time were probably tributary to the Wye via the Marteg and the gap at Pant-y-dwr, 969 feet O.D., (295 m)."

Brown depicts the original drainage pattern of Wales (Figure 3) as radial with the Severn and Wye both flowing off south-eastwards from a divide of which Plynlimon was a part. Since that time glaciation and further negative base-level changes have intervened. Consequently, "more adaptation and capture is attributable to the present cycle than to any previous one".

The remnants of peneplains are unequally distributed on the catchments (see Figure 2), the Wye showing the 'summit plain' but not so much High Plateau as the Severn. However, the Middle Peneplain dominates interfluves in both catchments. All surfaces have an important positive influence on the cover of blanket peat which is sensitive to erosion on moderate to steep slopes.

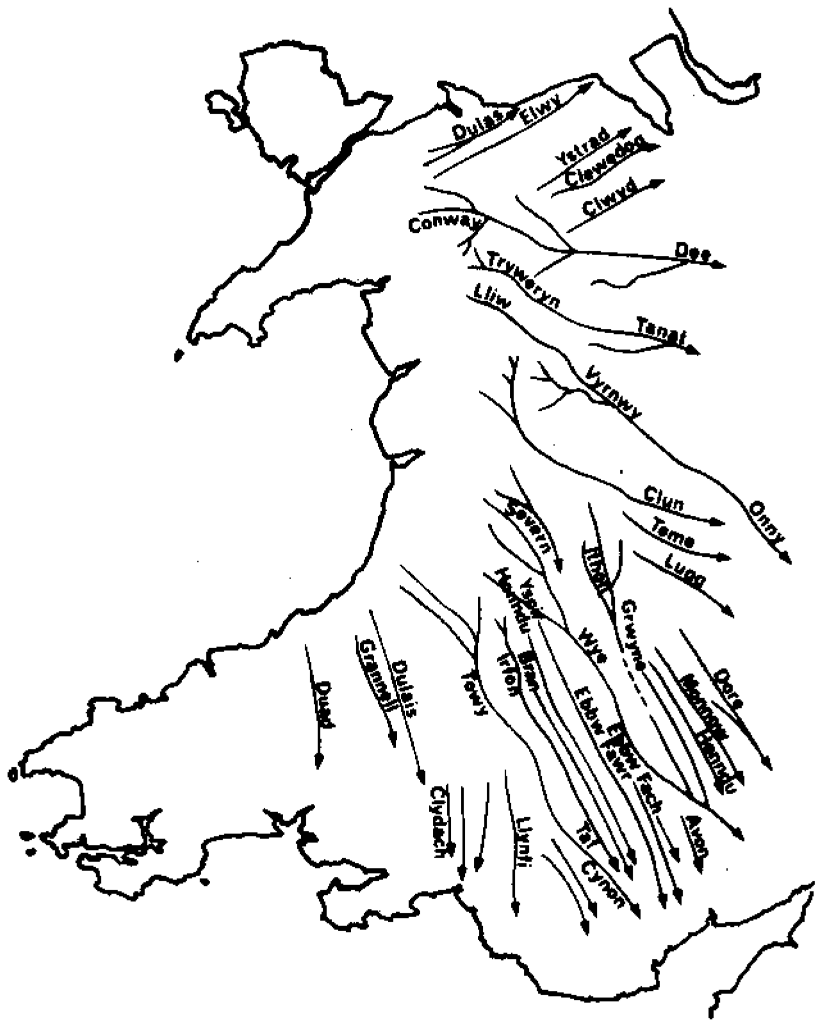
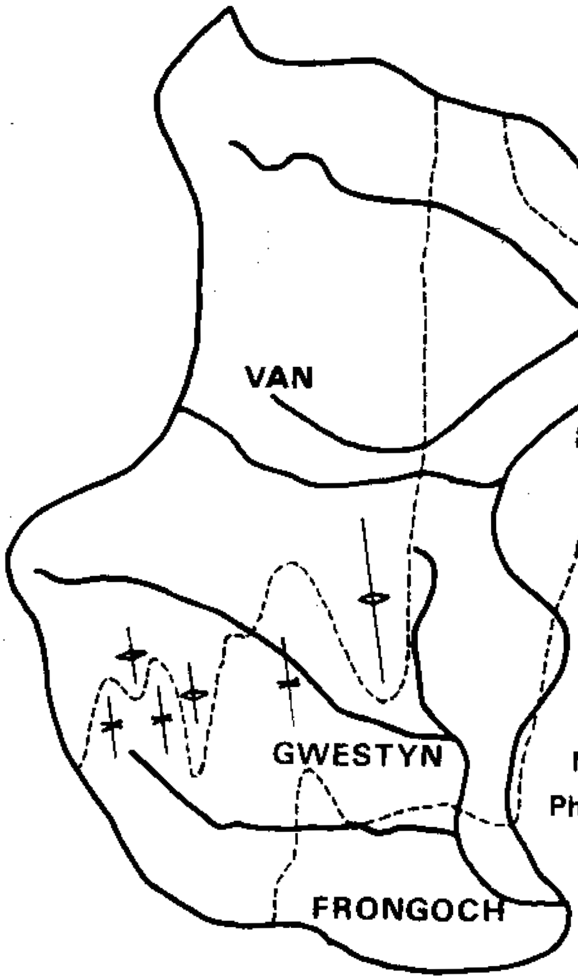


FIGURE 3 The original drainage pattern of Wales (after E H Brown, 1960)



Map taken from Ph.D. Thesis, B.J.Knapp

LOWER SILURIAN UPPER VALENTIAN	Frongoch formation		Shales & mudstones with some thin sandstone or siltstone bands
LOWER & MIDDLE VALENTIAN	Gwestyn formation		Shales & mudstones with some siltstone & impure limestone bands
UPPER ORDOVICIAN	Van formation	Upper	Soft blue shales & bronze weathering mudstones
		Lower	Massive grits, mudstones & conglomerates

FIGURE 4 Geology of Plynlimon experimental catchments

Drainage patterns at Plynlimon are in some cases due to bedrock controls where the drift mantle has been incised but in two obvious cases the drift mantle itself has caused diversion (the Nant Y Gwrdy joins the Wye where its more natural course to the Nant Cwm-y-Foel is blocked by drift and the Nant Gerig's former downstream junction, prior to formation of the Gerig gorge, is now but an undistinguished trickle). (See Figure 2).

Bedrock control shows up notably in the most incised reaches of channel where alternately the bedding, cleavage or faulting of the Silurian shales are followed. The main structural and lithological axes run NE/SW and are picked out, for instance, by the deeply incised right bank tributaries of the Cyff. Right bank tributaries of the Nant Iago anomalously flow across the slope by excavating structural weakness although an ice marginal mechanism may partially explain their position. The experimental area of the upper Nant Gerig also curves round northeastward. Structural and lithological trends also shape the upper slopes of the catchments, particularly the Wye where ridges and steps are characteristic (especially between the Upper Cyff and Upper Wye where folding axes in the Van and Gwestyn formations (Jones, 1922) are very close - see Figure 4). It is worth remarking that nowhere is incision of drainage so marked to the east of Plynlimon as to the west, where the rapid attainment of base level and possibly greater or later glaciation have produced very dissected topography with pronounced structural ridging. No geological surveys exist of the catchment areas apart from that by Jones referred to above. However, the lithology and structure of the Lower Silurian shales and mudstones is treated in neighbouring areas by Jones (1909), Wood (1906), Jones (1945) and Bassett (1955).

The Pleistocene

The interpretation of the glacial and periglacial geomorphology of the British Isles is still subject to controversy and Wales is no exception. Consequently, reviews such as those provided by Bowen (1973,1974) and in the book edited by Lewis (1971) are helpful. Watson, writing in the latter reference, mentions Plynlimon as a centre of ice dispersion and describes the trough-shaped valleys, typical of glaciation, which radiate from it. However, in many cases the present concave sides of the valleys are depositional; it is the drift and scree materials in this position which form a central argument in interpreting Pleistocene development. (Writing in 1968, Watson says that, "It seems probable that in mid-Wales powerful local ice streams capable of severe erosion did not exist for significantly long periods"). He says (1971) "though deposits described as till and boulder clay occur at many points in the upland valleys, those with indisputable glacial morphology, such as end moraines, are rare. In the great majority of cases the drift of the uplands takes the form of smooth terraces sloping towards the river and usually occurs on one side of the valley only, with a rocky slope opposite. Where the valley sides are of the same rock and rise to the same height the deposits are thicker at the foot of a slope facing NW, N or E than at the foot of one facing SE, S or W."

He goes on to say that the stoney clay character of the deposits signifies a solifluction origin but that the interbedded gravels were formed in intervals when slope wash predominated over solifluction.

Bowen (1974) argues against a completely solifluction origin using evidence gathered by Potts (1971). "At the centre of the controversy is the ubiquitous blue-grey stoney clay of the uplands deemed to be head by Watson (1970) but till and recycled till by Potts (1971). Watson's view is held for a combination of reasons: the clay is characterized by strong preferred orientation downslope; it consists largely of angular and subangular rock fragments though rounded and sub-rounded ones do occur; it is crudely bedded parallel to local slope, horizons of dirty gravels, silts and sands occur; the drift terrace which it forms is usually thicker when the rear backslope is highest; and, such terraces occur principally at the foot of slopes facing north-west to east."

"On the other hand, Potts maintains that sedimentological and morphometric parameters support a glacial rather than peri-glacial origin for the deposit. He noted that rounded pebbles are frequently deeply striated and in some areas the clays are apparently genetically related to spreads of fluvioglacial outwash gravels, statistical tests showed that there was no preferred orientation for the drift terraces, and he argued that when bedded this indicated redeposition downslope of original glacial drift by solifluction. Moreover, that the high relief of much of the area, the general character of the country rock and the fact that cryonival (ice/snow - M D Newson)processes are still active today lends colour to the proposition that redeposition of glacial drift in the part would have occurred soon after deglaciation".

Thus Bowen concludes that whilst the effects of periglaciation are spectacular they are to be viewed as ornamentation to a fundamentally glaciated landscape.

The Plynlimon catchments certainly exhibit the stoney clay under review and there is no doubt that solifluction has mostly removed it from all but the lower, concave valley sides. Terraces of it probably represent incision into complete valley fill but in our case it is the north-facing slopes which have retained their cover (e.g. right bank Gwy, Gerig and Hore). It is certainly well weathered, highly variable and still slumping. A redistributed glacial till origin is supported by the present author on the grounds of the stone content and the existence, in streambeds and plastered locally into fissures higher up the slopes, of a fresher, blue, more homogenous clay which is probably the original till. However, undoubtedly the Upper Severn and Wye do not exhibit the spectacularly trough-shaped valleys of extensively glaciated areas such as Snowdonia or the English Lake District and the Tertiary surfaces described earlier are surprisingly intact; thus, possibly, only shallow glaciers were responsible for the blue clay and above them periglaciation was active. This could be deduced from the relatively low level of certain periglacial and ice-marginal features as so far interpreted.

Certain exposures of the undoubtedly periglacial screes in the Severn catchment show the fresher till beneath - giving a logical sequence for glacial and periglacial events.

The stratified screes unite Bowen, Watson and Potts in the view that permafrost occurred locally when these were deposited. They consist of gravel-sized fragments of shale or thinly-bedded mudstone and can be found on upper slopes, especially those facing north or west, where they are finely gullied (e.g. Hore, Gwy, Cyff right banks) or lower down as fans spreading across valleys as at the Dolydd office which is built on such a fan: whilst the Ordovician and Silurian rocks of the area appear monotonously similar, the detailed lithology appears to be picked out by periglaciation since in other apparently suitable locations for stratified scree formation only a blocky "felsenmeer" type of accumulation occurs. This is most typical of the slopes around Plynlimon Arwystli where the presence of tougher grits is the explanation. Elsewhere, beneath a podzol profile one encounters a coarse colluvial material of shale, again much coarser than stratified scree.

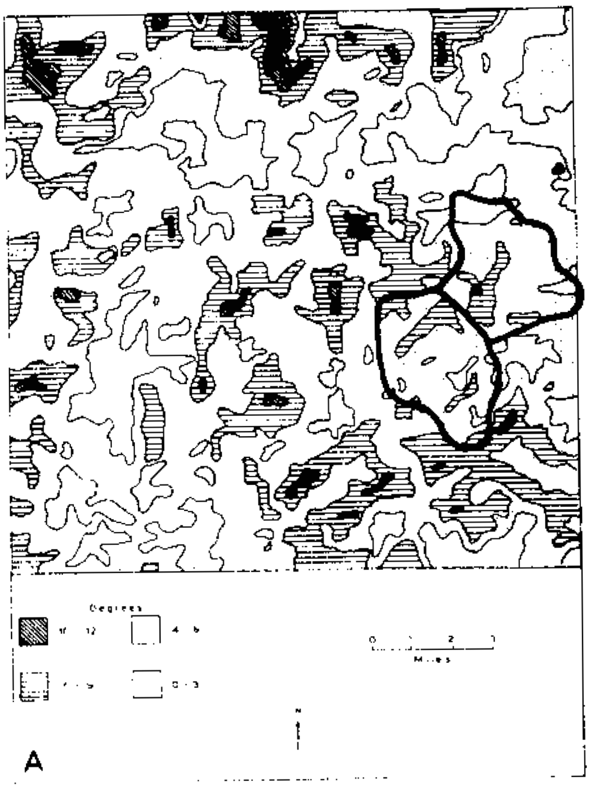
Further description of the screes is given by Watson (1965) for the Plynlimon region and by Dylik (1960) for some continental sites. Watson is able to suggest a chronology where three distinct layers of the deposit occur, relating the lower and upper unsorted gravels to Zones I and III of the Late-glacial whilst the middle, siltier, stratified screes represent the moister Zone II. In a further paper (1965 b) he describes periglacial structures in the deposits indicating the cold conditions. In the Church Stretton area of Shropshire Late-glacial (Zone III) dates are also obtained for the head deposits by Rowlands and Shotton (1971). The significance of these results is that it leaves the Devensian period in Central Wales as a possible normal glacial one rather than exclusively periglacial as suggested at one stage by Watson. Not that the Late-glacial is left ice-free; indeed late-glacial cwm glaciers have been noted by Seddon (1957) in Wales although the north-easterly aspect of the favoured sites is not that of the valley heads of the Plynlimon catchments. However, further work is required on the till at sites chosen for earth dams on the Gwy and Cyff. The latter, especially, looks remarkably like a morainic ridge across the outlet of an accumulation basin.

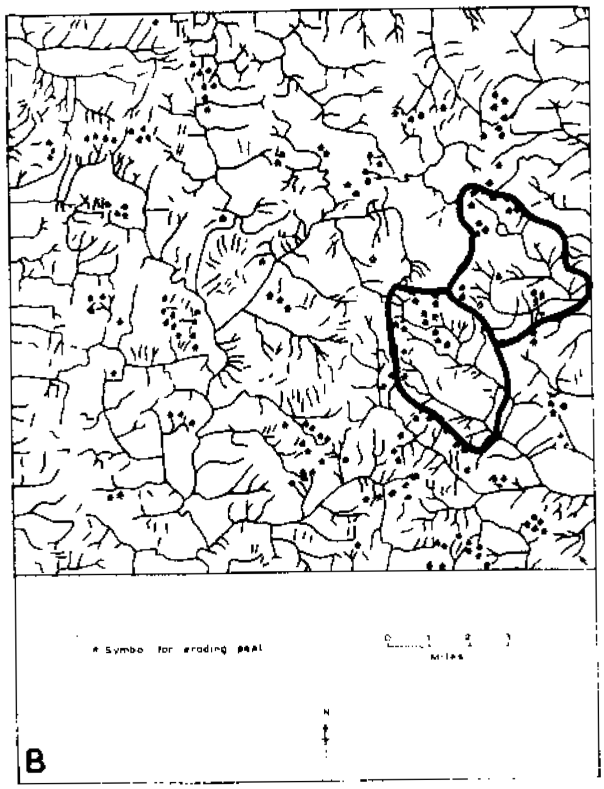
Frost action has been observed as an effective agent of erosion in the catchments, even during the recent mild winters, particularly on peat and stratified scree. It is therefore not surprising that Ball and Goodier (1970) report on currently-active periglacial forms in Snowdonia.

Whatever the arguments about chronology, the Pleistocene left the Wye and Severn mantled with stoney clay, which is found mainly at the base of slopes, and a variable shale or grit colluvium on the slopes, ranging from gravelly to blocky in texture depending on lithology. In some places bedrock is exposed through this mantle.

The post-glacial

The post-glacial period has seen the development of soils upon the bedrock, glacial and periglacial materials of Plynlimon within a dynamic system of climatic oscillations, further geomorphological evolution





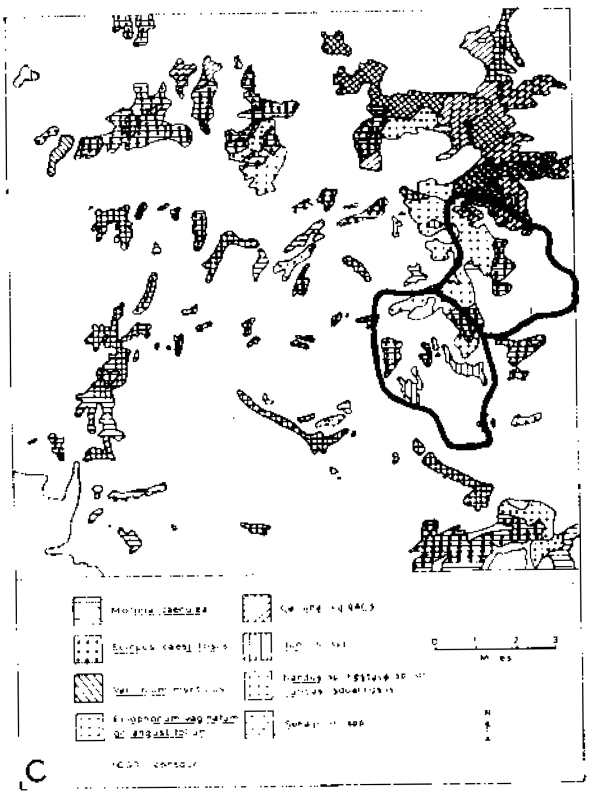


FIGURE 5 The Plynlimon area:

A - Average angle of slope

B - Stream network and eroding peat sites

C - Generalized vegetation on the peat

(after Taylor & Tucker, 1968)

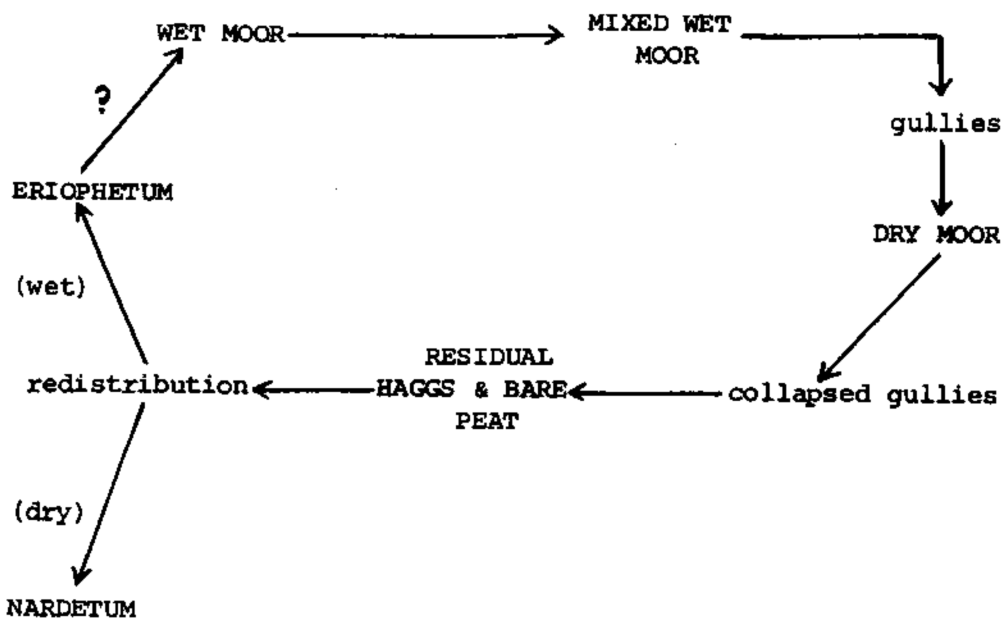
and the emergence of man. Central to the interpretation of post-glacial history has been the vegetation record preserved as pollen. The pollen is preserved in the organic deposits whose deposition and erosion form a central theme in the maritime uplands, together with the influence of steep climatological lapse rates with altitude.

A summary of results from pollen analyses and carbon-14 dating for the 14,000 years since the last glaciation is provided by Taylor (1973). Tundra was succeeded by birch, pine and finally mixed deciduous woodland which reached above the 2000 ft (610 m) contour during the post-glacial climatic optimum (5000-3000 BC). Thereafter, two important forest deteriorations mark the development of peat, the first at around 5000 Before Present (B.P.) and the second, the sub-Atlantic phase beginning around 2500 years B.P. The former may have been edaphic but the latter involved climatic deterioration. The latter phase is described in detail by Piggot (1972).

Smith and Taylor (1969) present pollen diagrams for Plynlimon and its region. The parent material for the soils they studied is generally a Zone III periglacial deposit, giving a bounding date to the profile. Around 5000 years B.P. there is a decline of tree pollen and a growth of heath on peat. No evidence is found of Neolithic man as an agent in forest decline but Bronze Age man is thought to have played a part in a further (secondary) forest decline around 700-400 BC. Moore (1968) reveals even later human influences on the pollen record of the region.

The most detailed approached to the peat deposits of Plynlimon occurs in a paper by Taylor and Tucker (1973). Maps are provided of the slope angle, erosion and vegetation of peat (see Figure 5) and correlation coefficients are obtained between aspect (r = + 0.40), slope angle (r = + 0.77) and altitude (r = + 0.06) for peat depth and erosion. The presence of the erosion surfaces (Section 1.1.1) is essential for the preservation of blanket peat. The importance of internal peat drainage for initiating the hagg topography and of wind, rain and frost for accelerating erosion is also referred to.

A flow diagram of the dynamic peat system is presented by Taylor and Tucker as follows:



Considerable controversy exists over the reasons for peat erosion and redistribution in the present phase. Bower (1962) lists four possibilities:

(a) Erosion is a natural end-point to accumulation, possibly aided by slightly drier conditions or the headward erosion of post-glacial streams on to the peaty interfluves.

(b) Erosion can occur during accumulation as evinced by bands of silt in peat;

(c) Climatic change may have altered the position of the 50" (1270 mm) annual isohyet which Bower defines as the Pennine lower limit for peat;

(d) Peat cutting, burning, drainage or air pollution may represent artificial causes of erosion.

In further papers (1960,1961) Bower advances the internal development of gullies from hummocks and pools (Type I gullying) and the headward erosion of streams (Type II gullying) as the major reasons for Pennine peat erosion. At a slope angle of more than 10^{o} deep peat is unstable and even in the highest rainfall areas no peat is likely on slopes steeper than 20^{o}.

Mosley (1972) finds no significant difference between Types I and II gullying whilst Radley (1962) sees the initiation of peat erosion partly as self-induced from subterranean drainage channels and partly as wind action, exaccerbated by human activity (right up to the present). Barnes (1962) calls some of the arguments to order.

Clearly peat is of key importance to the hydrology of the Plynlimon catchments. The deposit ranges between thick (1 m - 2 m) blanket peats, similarly thick peat in flushes and valley bottoms, and mineral soils on slopes of 10^{o}-15^{o} with a (10 cm - 20 cm) organic horizon.

Referring to the Hiraethog Soil Series (peaty gley podzol) which commonly occurs on the 10-15^{o} slopes, Taylor and Smith (1972) cite weathering and leaching, with drainage impedence in the profile as reasons for the accumulation of an A horizon of 'pedogenic peat'.

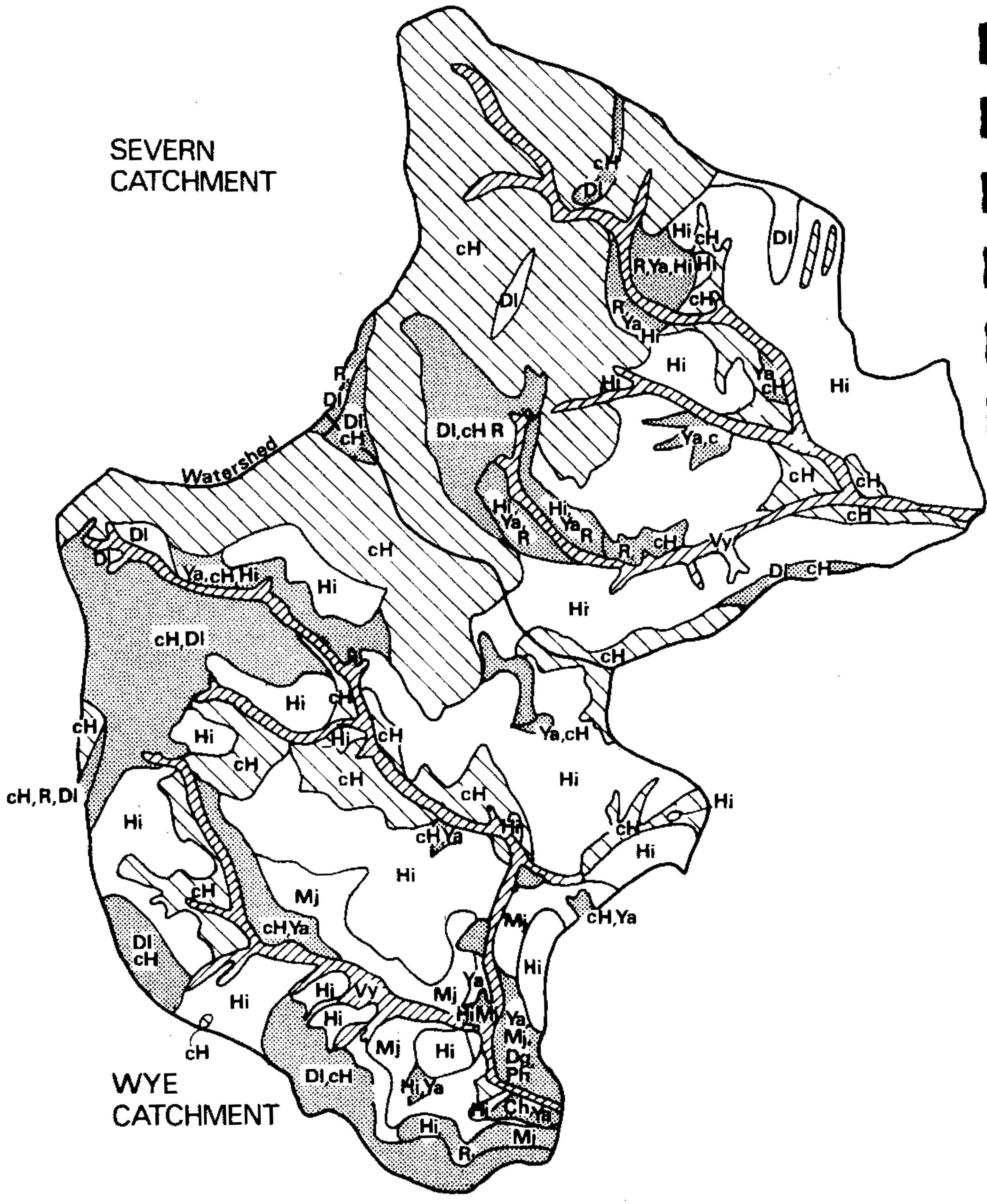
Little quantitative information will be available on Plynlimon peat hydrology until the end of the current phase of process study investigations on the catchments. However since organic deposits or soil horizons dominate the majority of both catchments, the map of soil series (Figure 6) prepared by C C Rudeforth in 1967 is instructive. The soil series are an extrapolation of those mapped for North Cardiganshire by Rudeforth (1970). Quantitative information for the soils can be obtained by reference to interpretations performed by Rudeforth and Thomasson (1970) prior to hydrological modelling of the Dee catchment. Although the occurrence of complexes at Plynlimon makes direct comparison difficult, the dominance of the Caron (peat) and Hiraethog Series (peaty podzol) allows guidance from the table below, abstracted from the Dee publication. Field experience can be used to assign all Plynlimon soils to Caron/Ynys, Hiraethog or, lower down the Wye, Manod Series (Groups 1, 2 and 6 in the Dee Study). One major drawback is that the Hiraethog* Series is known now to exhibit soil piping, whose influence is not considered by the Soil Survey. The grouping of Caron and Ynys can be justified in terms of their peat content but not position - the former caps interfluves and the latter cloaks valley floors.

TABLE 1 Properties of organic deposits of Plynlimon Soils by reference to the Soil Survey of England and Wales

Soil Group (Dee Survey)	Soil	Dominant Soil Series	Mean thickness cm	Musgrave Class	Drainage Class	Mean slope	Total pore* space (of volume)	Available water* capacity (of volume)	Gravitational pore* space (of volume)
1	Peat, peaty gley, peat over rock	Caron, Ynys	51.0	CD	Very poor	7.0°	82%	44%	7%
2	Peaty gleyed podzol	Hiraethog	24.8	CD	Very poor	10.4°	59%	30%	2%
6	Brown earth (mor)	Manod	40.5	A	Well drained	16.5°	40-82%	10-37%	7-22%

*critical horizons - see Table 7, Dee Survey
For physical properties in millimetres see Table 6, Dee Survey.

* The Soil Survey now recognizes two subdivisions of stagnopodzols, the Hiraethog with a gleyed E horizon over a thin ironpan and the Hafren which lacks the ironpan (Lea, 1974). This reduces the need to refer to intergrades (Pyatt et al, 1969) which cover large area of the Forestry Commission unpublished map of the Severn catchment.


SEVERN
CATCHMENT
WYE
CATCHMENT
Watershed
cH
Dl
Hi
R,Ya,Hi
cH,Dl
Dl,cH R
Ya,c
Ya,cH
cH,R,Dl
cH,Ya
Mj
Dl,cH
Vy

KEY

cH	CARON series	Peat generally exceeding 15" thickness, but including land from which peat has been eroded near hags.
Dl	DROSGOL association	Peaty podzolised soils usually with strongly developed thin iron pan. Sub-pan characters range from a dark brown humus-rich loam to strongly gleyed silty clay.
Hi	HIRAETHOG	Peaty podzolised soils usually with well developed thin iron pan over a diffuse ochreous horizon of stony silty clay loam.
Mj	MANOD series	Slightly podzolised acid brown soils. The steep phase is considered considered equivalent to CYMMER series.
Ya	YNYS series	Peaty gleyed soil.
Dg	DENBIGH series	Acid brown soil. Cultivated.
Ph	POWYS series	Ranker. Shallow on solid rock.
R	ROCK AND SCREE	
Vy	VALLEY complex	Includes alluvium and most of the soils of the region occurring in complex close to streams and associated with the steep sides of locally incised valleys.
(stippled)	DISTURBED GROUND	Disused mines where the workings on the surface cover sufficient area.

FIGURE 6 Soil map of Plynlimon experimental catchments (prepared by C C Rudeforth, Soil Survey of England & Wales)

2. RECENT GEOMORPHOLOGICAL STUDIES

In a symposium on rates of erosion and weathering in the British Isles the late Trevor Thomas (1965) discussed the effect of sheep in producing crescent-shaped "burrows" by breaching thin soils overlying shaley bedrock. They are concentrated on slopes greater than 12°. Between 28° and 35° Thomas suggests that sheet erosion eventually results, producing scree slopes of shale particles. Only at a few small sites on the Plynlimon catchments are such scars worthy of Thomas' interpretation, for example where the grass cover has been broken on gullied screes near the Nant Iago mine. Sheep show an obvious preference for these warm, dry areas and clearly exaccerbate erosion although it is not clear how the "burrows" first form. Elsewhere on the catchments the crescentic scars appear to be related to mass movement along seepage lines (Bunting, 1960, 1964). The term seepage steps (Hadley and Rolfe, 1955, Tuckfield, 1973) has been used for features developed upslope in flights. Whilst Bunting sees seepage lines ('percolines') as an important prerequisite of headward extension by first order channels and gullies, the most spectacular development of a first-order channel at Plynlimon was by failure of a rush flush (Newson, 1975). Rush flushes are unlike seepage lines, containing distinct roofed channels. Another difference is that seepage lines show some deepening of the solum by bedrock rotting whilst flushes are peat-filled former surface channels, eroded in bedrock. At this stage no reference will be made to soil piping on the catchments (see Gilman, 1971, 1972, Davies, 1972). Instrumental work on erosion has formed part of the Institute's programme at Plynlimon (see Painter *et al*, 1974). However, earlier work was done by Slaymaker (1972) whose slope and channel plots included the Cyff and Wye at Cefn Brwyn. Rates of soil creep recorded are 2.91 - 6.52 $cm^3/cm/year$ and both Cyff and Wye are said to be in a state of quasi-equilibrium; sediment supply to the Cyff channel is 425 $m^3/km^2/year$ and removal 397 $m^3/km^2/year$. However, in detail there are clear examples of temporary disequilibrium; Slaymaker's 1963-1967 sampling period did not include a low probability flood and the August 1973 flood showed slope failure and bank erosion which took all the following winter to remove by channels. Clearly spatial variations in equilibrium are also important. More recent work on the western side of Plynlimon (Maesnant) by Lewin, Cryer and Harrison (1974) has listed three main erosional locations: channel banks, crescentic slip scars and, dominantly, bluff faces on the other edge of solifluction terraces. The importance of frost and high flows is emphasized in promoting erosion but during the 16-month period studied the Maesnant channel aggraded with material eroded from the solifluction terrace. Solutes are mainly those derived from rainfall although significant differences result from different flow paths to the channel.

3. THE MORPHOMETRY OF THE SEVERN AND WYE CATCHMENTS

The gross scale morphometry, using catchment averaged values, may be obtained from Ordnance Survey 1:25,000 maps. The following figures were obtained for the United Kingdom Flood Studies (NERC, 1975):

TABLE 2

		WYE	SEVERN
	Area	10.55 km^2 *	8.70 km^2 *
	% forest	1.20% +	67.50 % +
	Strahler order	4	4
	Drainage density	2.04 km/km^2	2.40 km/km^2
	Stream frequency	2.88	3.60
	Outline shape (K)	1.36	1.37
(S1085)	Main channel slope	36.3 m/km	67.0 m/km
	" " length	7.32 km	4.58 km
	Bifurcation ratio	1.54	1.67

*"True areas" By 1/cos slope - angles are shown in Fig. 7.
Severn: 8.924 km^2 Wye: 10.823 km^2.

+roads, channels, 'rides' and other non-tree areas are included here.

It can be observed that general similarity is confirmed but differences in channel slope are likely to make interpretation of channel response difficult. A higher value of stream frequency and drainage density (which do not include forest ditches) in the Severn would also tend to give a quicker response.

Turning to more detailed work, morphometric data in terms of slope, aspect and altitude was prepared prior to the choice of rainfall domains. The slope angle map prepared for that study is shown in Figure 7 with superimposed channel gradients. Neither classification is purpose-built but is expedient; however, it would be possible to adopt the ground slope angles of Curtis, Doornkamp and Gregory (1965) or the land units of Dalrymple, Blong and Conacher (1968) for further work, for instance on soils (see Institute of Hydrology Report No. 8). Modal ground slopes in both catchments are 5-15° (median for Wye 10.6°, Severn 10.4°) but the Severn has almost twice the proportion of 15-20° slopes and a slightly higher proportion of 0-5° slopes, probably due to the "bowl-like" lower Severn and plateau-like Upper Severn. Moderate channel gradients are also more common in the Severn.

Hypsometric curves (Figure 8) for the catchments show apparently similar mean altitudes (450 m) although the modal value for the Wye is 450-500 m whilst that for the Severn is 400-450 m but with a secondary

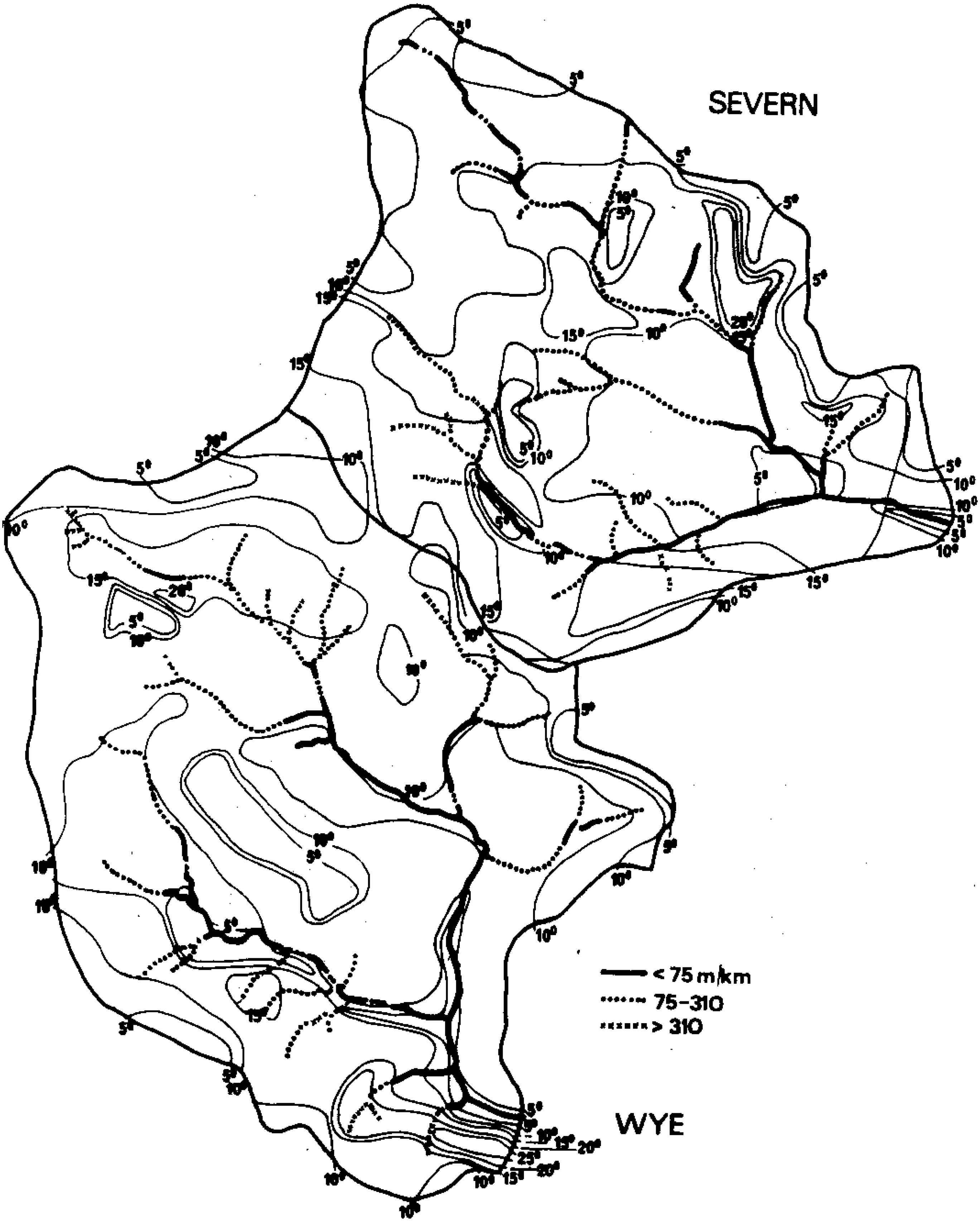


FIGURE 7 Slope and channel gradients, Plynlimon experimental catchments

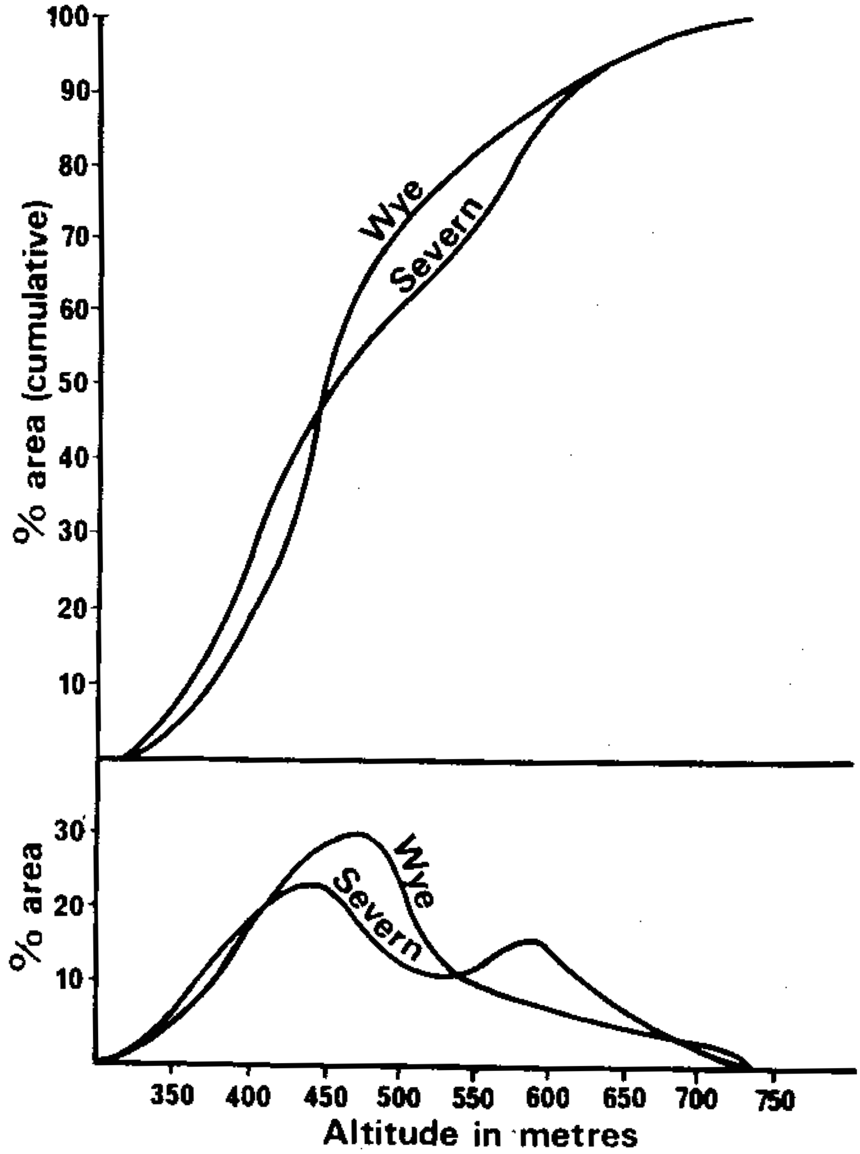


FIGURE 8 Hypsometric curves, cumulative and simple, Plynlimon experimental catchments

mode at 550-600 m, again pointing to the 'plateau and basin' shape of the Severn.

Of the gauged subcatchments, the Hore has the steepest land slope (median 14.8°) followed by Gwy (12.1°), Nant Iago (11.1°), Cyff (10.4°) whilst the Tanllwyth and Hafren are lower at 9.3° and 8.6° respectively. Table 3 shows the percentage area of each sub-catchment occupied by specific domain criteria.

The measurement of slope aspect for rainfall domains shows that the modal direction for Wye slopes is north-east with south-east second whilst for the Severn, east dominates followed by south-east.

In an attempt to use further morphometric and other variables within both catchments to choose runoff domains via principal components analysis, a 150 m grid was superimposed on the Huntings 1:5000 maps. Data on slope, aspect and channel junctions have been coded but the project remains to be completed with peat depths and possibly hydrological data such as infiltration capacities.

Re-mapping by grid squares is possible and Figure 9 shows a plot of channel links from the 1:5000 map (including artificial drains and flushes). The "no-channel" area is very prominent in the Upper Gwy, in contrast with the Upper Hore which is densely drained. In most respects, however, the two catchments are identically drained.

TABLE 3 Rainfall domain criteria and Plynlimon catchments (as % area)

	WYE				SEVERN			
	Lower Wye	Gwy	Nant Iago	Cyff	Hore	Hafren	Tanllwyth	Lower Severn
Altitude								
340-439	61.35	8.45	22.76	27.82	20.53	14.16	42.08	87.36
440-539	38.65	36.10	63.59	62.83	38.72	31.33	33.48	12.64
540-639	-	31.51	13.65	8.35	25.38	52.95	24.44	-
640-740	-	23.94	-	1.00	15.37	1.56	-	-
Slope								
0-9°	38.49	34.57	43.66	47.51	35.97	50.94	69.41	48.57
10-19°	50.59	60.18	56.34	52.49	51.03	44.63	30.59	43.60
20° +	10.92	5.25	-	-	13.00	4.43	-	7.83
Aspect								
NE	26.50	27.28	-	39.32	7.49	40.89	21.56	25.75
SE	21.87	37.82	64.93	28.50	62.66	38.39	78.44	16.17
SW	31.25	34.90	23.88	31.49	8.16	20.72	-	58.08
NW	20.38	-	11.19	0.69	21.69	-	-	-

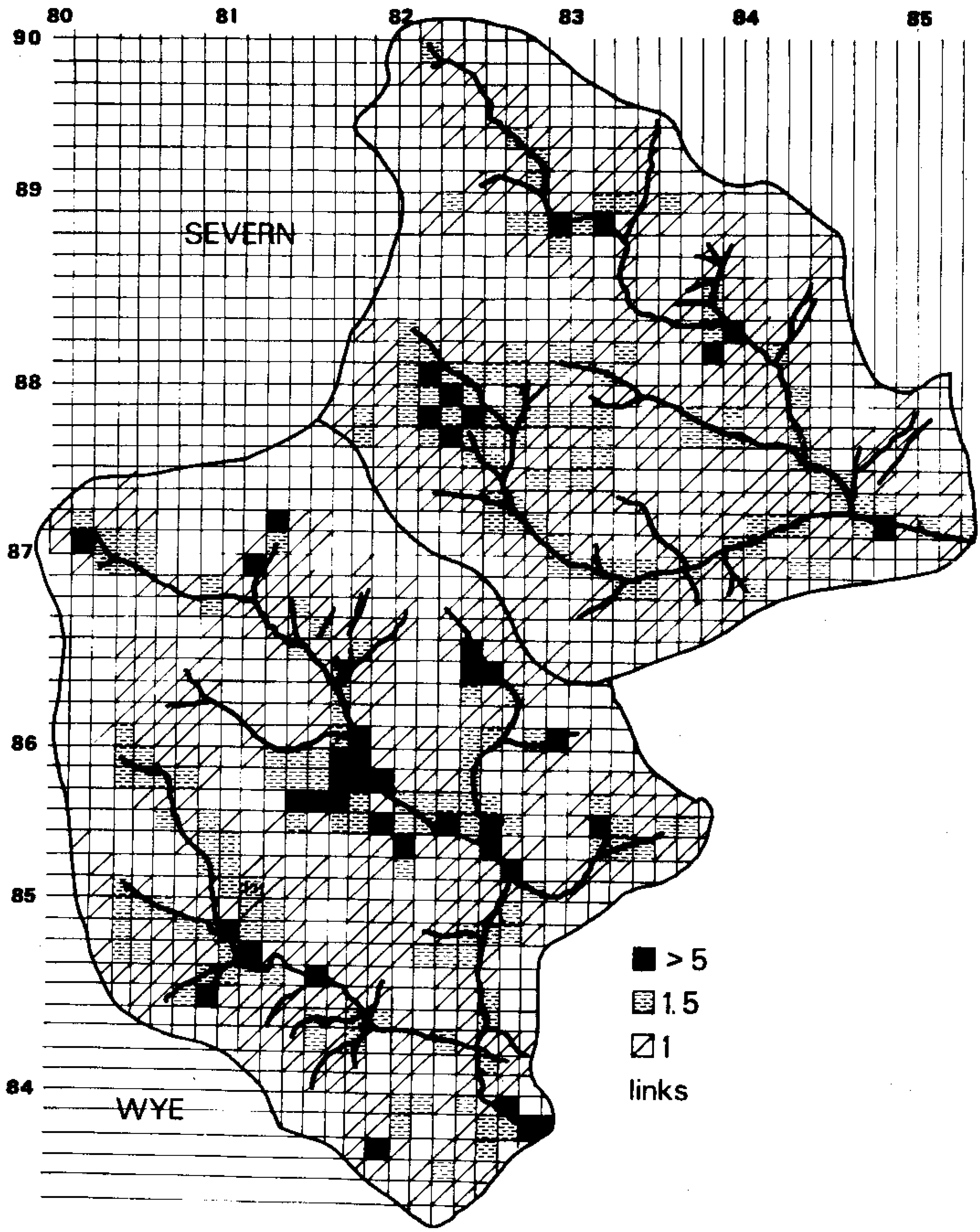


FIGURE 9 Stream frequency variability, grid sampled from Huntings Air Survey of Plynlimon experimental catchments (1:5000)

Turning to analyses of channels, interest focuses on the possible use of plotting the distribution function of drainage density relative to measured distance up the channel network from the catchment outlet.

Although the moments of such a distribution fail to predict unit hydrograph lag (U.K. Flood Studies) the mode(s) allow determination of hydrologically sensitive areas and express network shape. Figure 10 shows graphs of 100 m interval channel counts for the Wye and Severn. Forest drainage in the Lower Severn produces an early peak but the mode occurs further from the outlet in the Severn than in the Wye, whose peak is much higher. In terms of the location of the peaks, in spatial terms in the Severn it occurs at the top of the Hore and at the junction of the two branches of the Upper Hafren whilst in the Wye the Upper Cyff, Upper Nant Iago and Gerig/Gwy confluence represent the peak.

The stream frequency diagram approach is similar to the distance (time) - area diagram technique of hydrograph synthesis except that by indexing channels it assumes that slope runoff is simultaneous throughout the catchment. The distance - area concept lumps all slopes at a certain increment of main channel upstream from the basin outlet regardless of how well drained or steep they are (see Figures 11 and 12a). Distance-area graphs show that the biggest expanse of the Wye lies in its middle to upper-middle reaches whereas the Severn peaks near the middle and again in the upper reaches. The long slopes down from Arwystli to the Wye and Severn sources show up in Figure 12b which was prepared by dividing the area increments in 12a by channel lengths in the same increment. The Wye generally has longer slopes throughout,

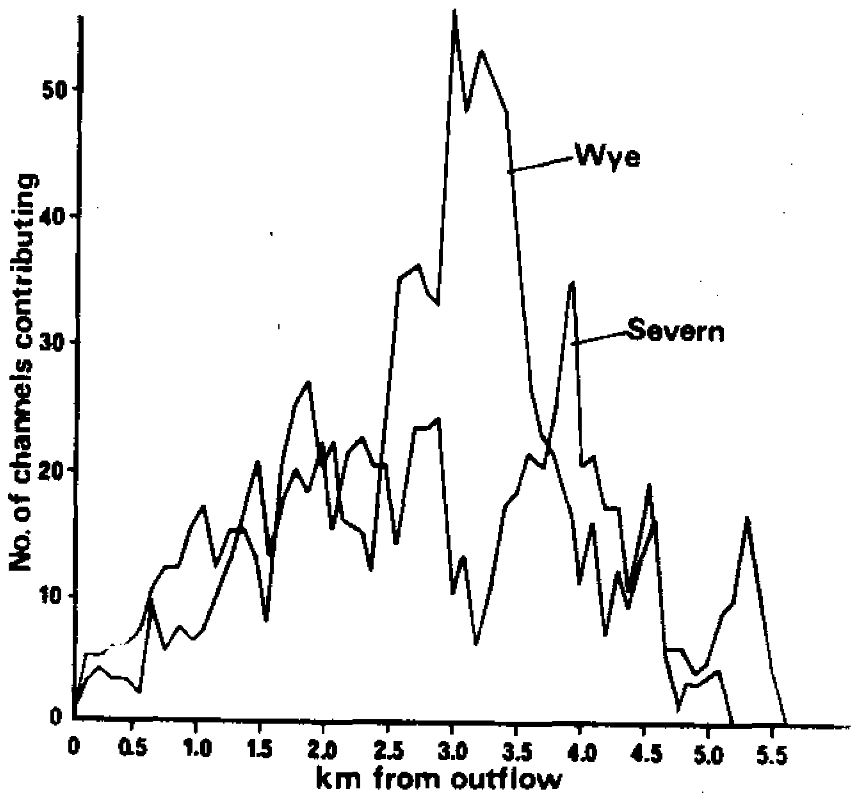


FIGURE 10 Stream frequency relative to distance from outlet, from Huntings Air Survey of Plynlimon experimental catchments (1:5000)

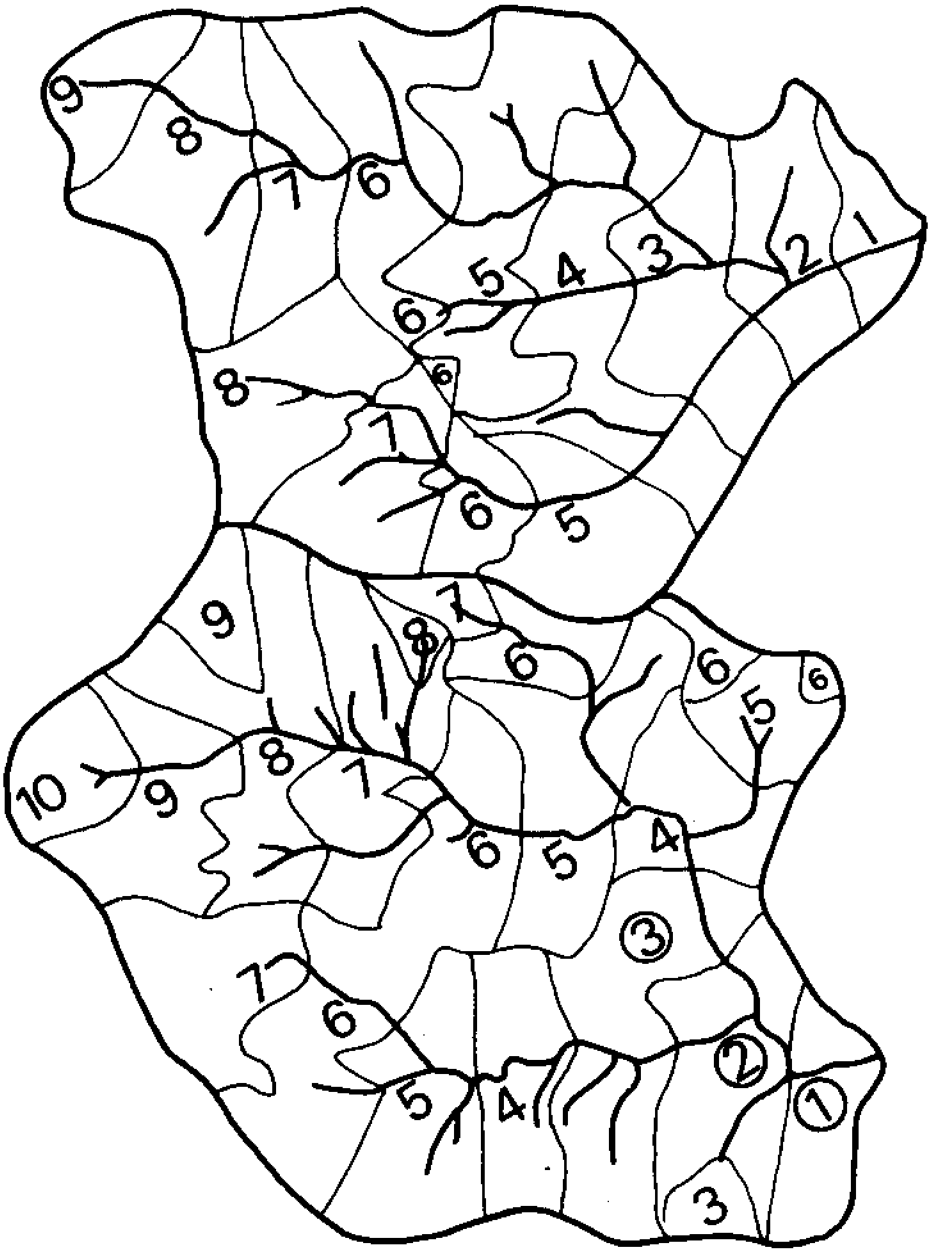


FIGURE 11 Time/area subdivision of Plynlimon experimental catchments (from 1:25,000 map)

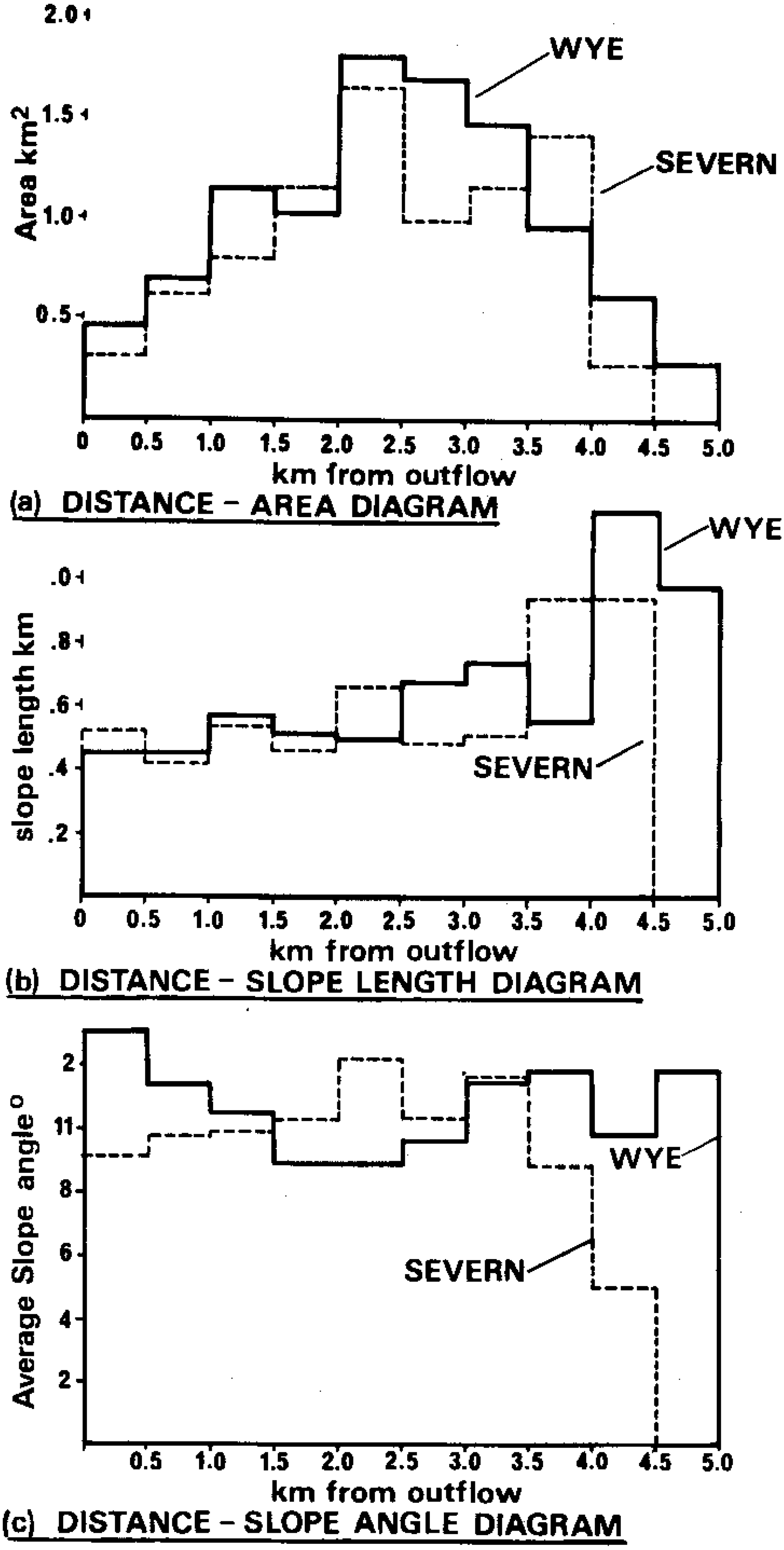


FIGURE 12 Distance/area and other distributed indices, Plynlimon experimental catchments (from 1:25,000 map)

particularly at the source. Using Figure 11 overlaid on Figure 7, Figure 12 c was constructed to index the varying average valley-side slope throughout both catchments. The lower and upper Wye are appreciably steeper than the equivalent parts of the Severn, particularly the Upper Severn. Only the slopes of the Middle Severn compensate, plus the steeper channel slopes in the Severn. Figure 13 gives qualitative information, from contour shapes, on slope configuration. The major straight slopes are named; it is thought that concavities may help to define areas of quick runoff.

Turning from channel plan to elevation, plotting the long profiles for the Wye has already been completed by Rice (1957). He extrapolates the several incomplete sections of 'graded' profile between steeper sections in an attempt to subdivide the erosional history by base level changes. He names at least four graded segments, three of which take names from the Wye tributaries; the Gerig, Nant Iago and Cefn Brwyn stages are then followed down the Wye.

Figure 14 shows long profiles for both catchments plotted from the d-mac digital contour data and the program 'STREAMSLOPES' (NERC 1975).

Table 4 tabulates derived-data from the profiles, showing the steeper gradients of the Wye tributaries, apart from an ungauged right-bank one from the lower Wye.

TABLE 4. Long profile data Plynlimon catchments

	WYE						SEVERN		
	Lower Wye	Gwy	Nant Iago	Cyff	Gwrdy	Gerig	Hore	Hafren	Tanllwyth
Simple valley) gradients	116.2	66.6	53.9	58.6	38.8	56.3	80.0	52.8	71.9
Simple stream)	115.3	66.2	53.1	58.2	38.8	54.2	79.4	53.8	79.4
USGS Slope (S10/85)	90.9	20.3	30.7	27.6	35.1	22.9	70.5	59.4	109.5
Taylor/Schwarz slope	42.1	31.2	24.4	29.4	21.7	27.5	41.1	34.8	32.0
Height range (m)	165	382	212	247	132	292	375	295	215
Length (km)	1.42	5.73	3.92	4.21	3.39	5.19	4.69	5.60	2.99

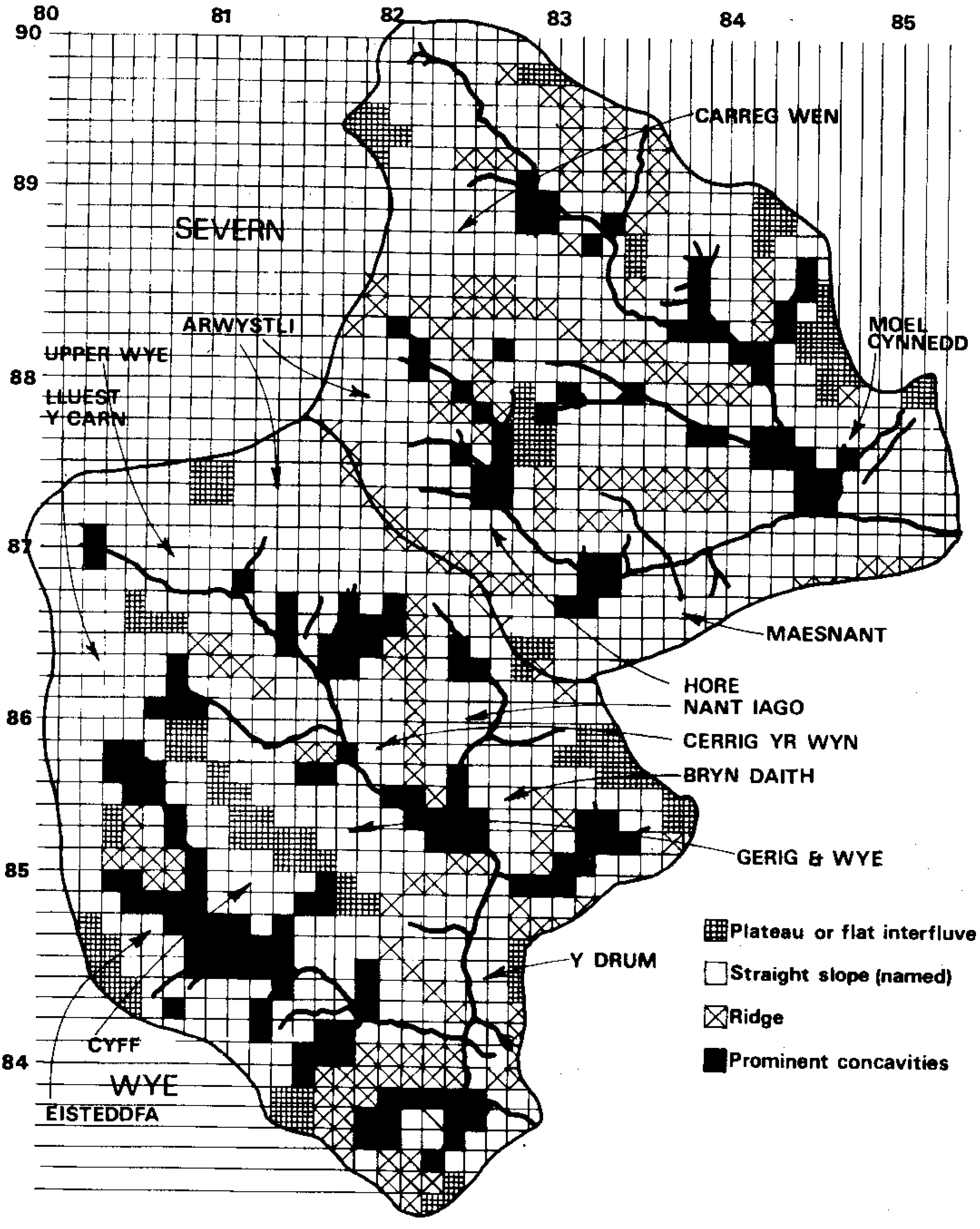


FIGURE 13 Slope type and curvature, Plynlimon experimental catchments (from 1:25,000 map)

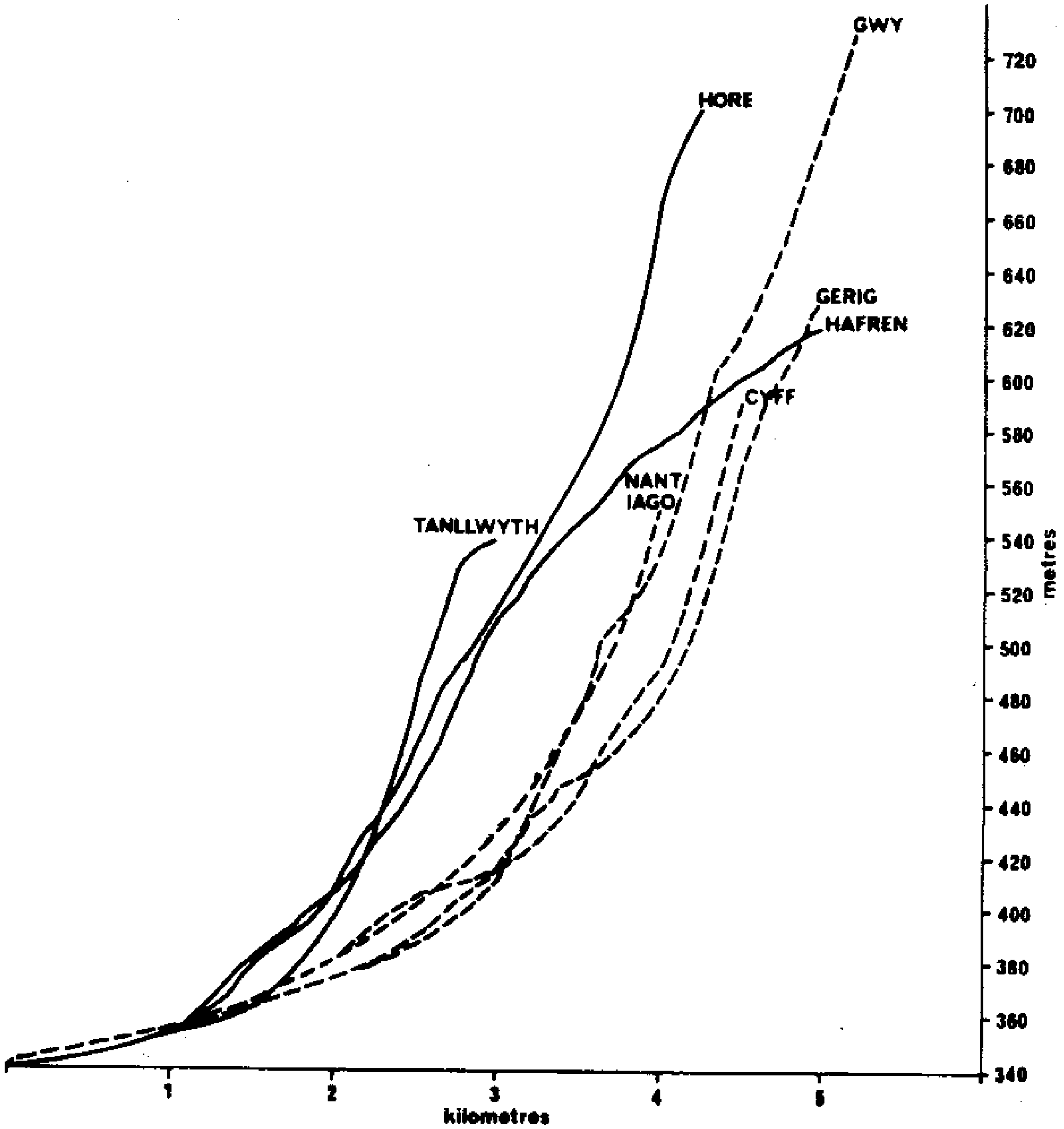


FIGURE 14 Long profile of Severn (solid lines) and Wye (dashed lines) channels (from Huntings 1:5000 survey via program 'STREAMSLOPES')

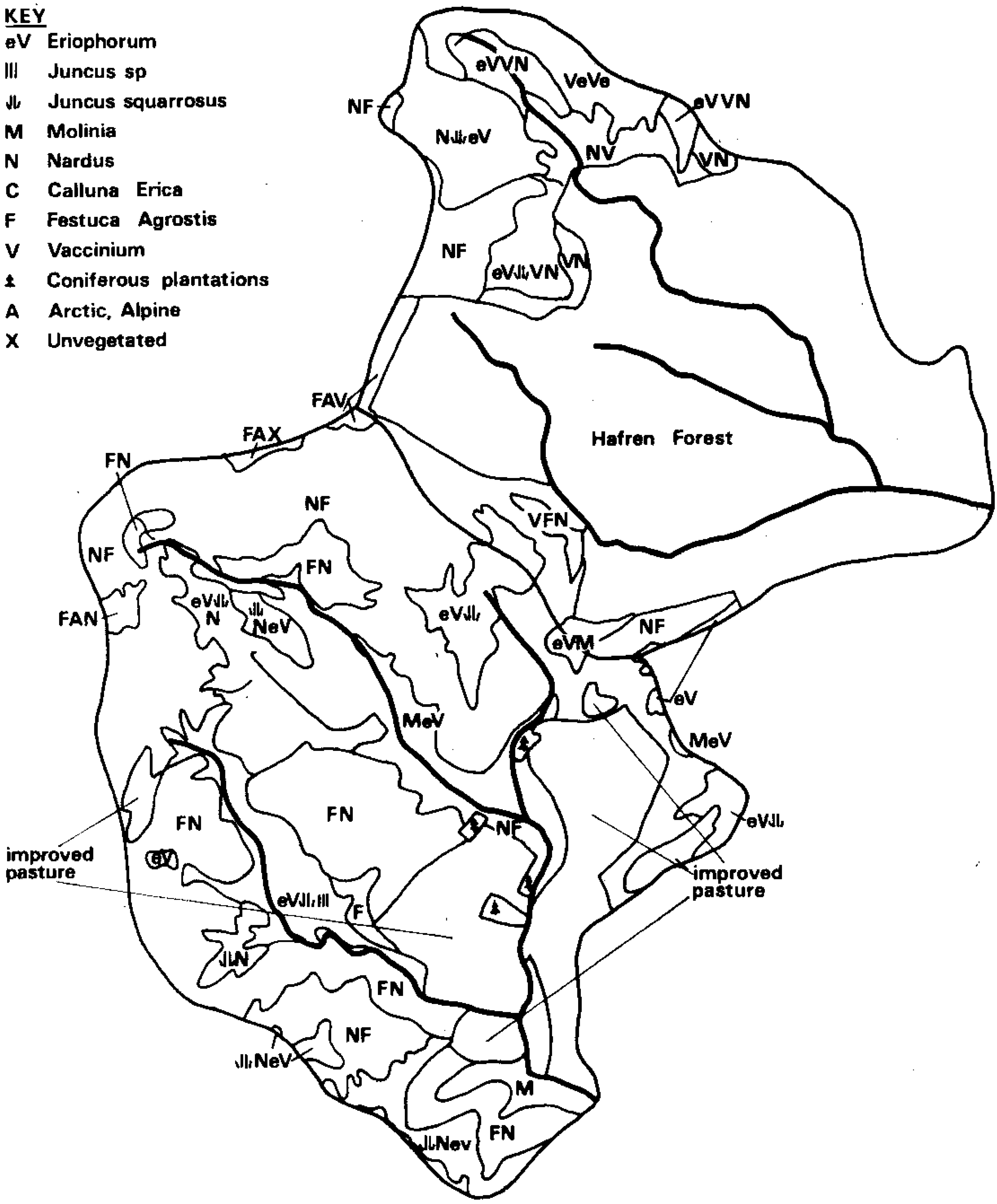


FIGURE 15 Vegetation map of Plynlimon experimental catchments prepared by Environmental Information Services, Gallt-y-Bladdur, Glaspwll, Machynlleth, Montgomeryshire

II THE VEGETATION OF PLYNLIMON CATCHMENTS

1. "NATURAL" VEGETATION

Large parts of the Severn catchment have been planted with coniferous forest and many parts of the Wye have been re-seeded with grass. However, apart from the effects of grazing, nutrients or time lags in adaptation, it is thought that natural vegetation over the remainder of the catchments has an indicator value for moisture regime in terms of soil water content and its variability. Improved pasture seldom completely masks the underlying pattern, merely altering the species of grasses. The indicator value of vegetation has already been put to use by foresters in Northern Ireland (Dickson, 1962). Rather than select individual species, a vegetation community approach is needed, within which the absence or dominance of a species may have moisture or nutrient significance. The approach also depends, of course, on an agreed field survey or mapping procedure which can be applied to new areas for which indicator information is required.

The interpretation of upland vegetation began quite early this century and a thorough guide is provided by Pearsall (1950). Widespread mapping of "the wildscape" did not, however, begin until the late Sir Dudley Stamp introduced it as part of the Second Land Utilisation Survey of Great Britain. The classification scheme used is described by Coleman (1970) and it considers the natural vegetation in relation to land-use potential (hence an indicator use is implicit). The range of genera is particularly good for upland use and field survey has been carried out for the Plynlimon catchments. Mapping units are coloured (on the original maps) according to dominant genera but annotated where a mixed or mosaic pattern occurs. Very small areas (less than 2.025 ha) cannot be included and certain key sites may need more field survey for hydrological interpretation. The maps are available at 1: 25,000 from Environment Information Services and the Surveyor, Mr. G. A. Sinclair, has been most helpful with specific interpretations for Plynlimon. Further presentation may come with a 1: 100,000 "Wildscape Atlas of England and Wales" of which sample pages are available. The 1: 25,000 map of Plynlimon provided by Mr. Sinclair is shown in Figure 15. A similar map has also been prepared for the Coalburn experimental catchments (prior to forestry).

Vegetation maps have been obtained from the National Library of Wales. Besides differences arising from the individual work of the surveyors the vegetation survey of Wales gives slightly more detail (on 1: 10,560) and, since it was prepared earlier, (1961) gives more natural vegetation for the Severn. However, generic detail is not necessary for most hydrological interpretations, preference being given to spatial detail.

Another type of vegetation map, prepared by the Montane Grassland Habitat Team of the Institute of Terrestrial Ecology, Bangor, is shown in Figure 16. The team began work in 1969 to obtain classificatory experience in upland vegetation (see Ward, 1971). A dichotomous key to plant communities based on association analysis has been used. Work has been done on Snowdon and Dartmoor, the three main community types being grasslands, mires and heaths. An application of these to Plynlimon

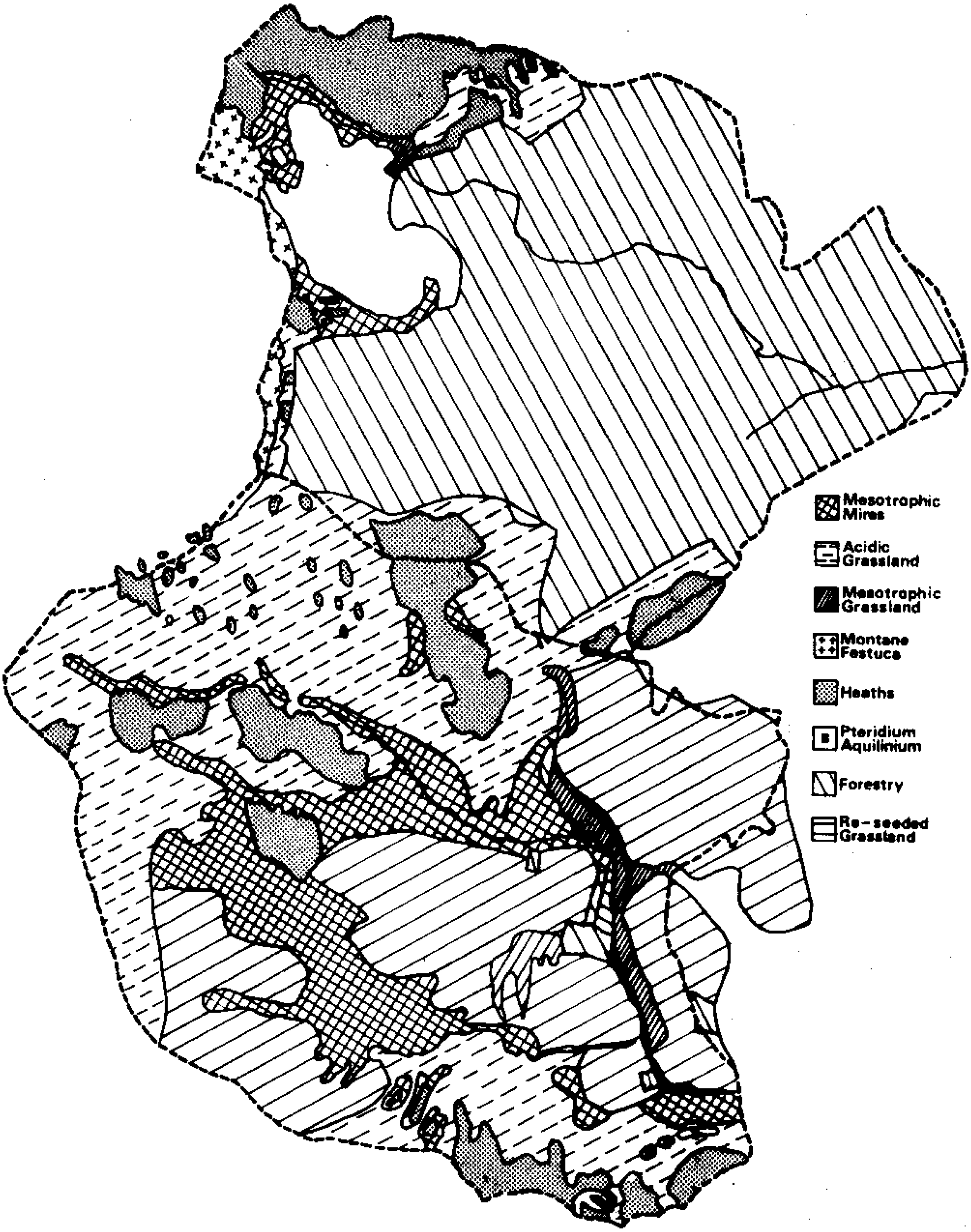


FIGURE 16 Vegetation map of Plynlimon experimental catchments prepared by R O Millar, Institute of Terrestrial Ecology, Bangor

was made by Mr. R. O. Millar on the basis of aerial photography and a field visit. Aerial photography is a powerful tool in vegetation mapping (Ward *et al*, 1970). Fortunately 1: 10,000 has been chosen in the literature as a suitable scale for vegetation mapping and the Institute's aerial survey of Plynlimon (Huntings) has been printed at this scale to add detail to a field survey by the author. Colour plates taken on the ground were also used. The result is shown in Figure 17. This map has less generic but more spatial detail than any of the other three. The vegetational communities can be summarized as follows on a three-fold basic subdivision from the Snowdon study (see also Ratcliffe, 1959, for the Carneddau): grasslands, mires and heaths.

GRASSLANDS

By far the largest area of the Wye catchment under natural vegetation consists of Festuca/Nardus or Nardus/Festuca grassland; they characterize the long, well-drained slopes with podzol soils. Other mixed communities with Festuca include arctic alpine species near the top of Plynlimon Arwystli.

MIRES

Although boggy areas do exist on the flatter interfluves, most of the true mires are located in the valley bottoms, extending upslope along the lines of rush flushes. Because of their position the nutrition of plants is mesotrophic, receiving both rainfall and drainage water. The most common species are the rush Juncus and Eriophorum; the largest extent of such vegetation occurs in the Upper Cyff, 'spilling' on the left bank into the Upper Gerig. The same community prevails at the head of the Severn. In the lower Cyff, Gwy and Wye, Molinia is more common; its tussocky appearance is obvious on the photographs and it has occasionally been burned to promote new shoots for grazing.

HEATHS

Eriophorum (cotton grass) dominates the heath communites in association with Vaccinium, Calluna or Nardus (see for instance over much of the Upper Severn). Juncus squarrosus enters on Cerrig yr Wyn and the Gwrdy whilst Molinia is present in the Nant Iago. A further area of heath on blanket peat occupies the right-hand interfluve above the Cyff (Llechwedd Hirgoed); smaller areas occupy the Upper Hore.

Given information on vegetation communities for Plynlimon and means of extrapolation it, there remains the problem of elucidating the precise indicator value of plants for hydrology. To solve it an extensive literature search has been made and field experiments designed. Only the former can be reported at this time.

Of the grassland species, *Nardus stricta* is best documented. Smith (1918) discussed the position of the Nardetum marginal to peat, a position similar to that on Plynlimon although Smith was reporting from Peebleshire. He suggests that as peat erodes and is redistributed its colloidal character and moisture-holding properties are lost,

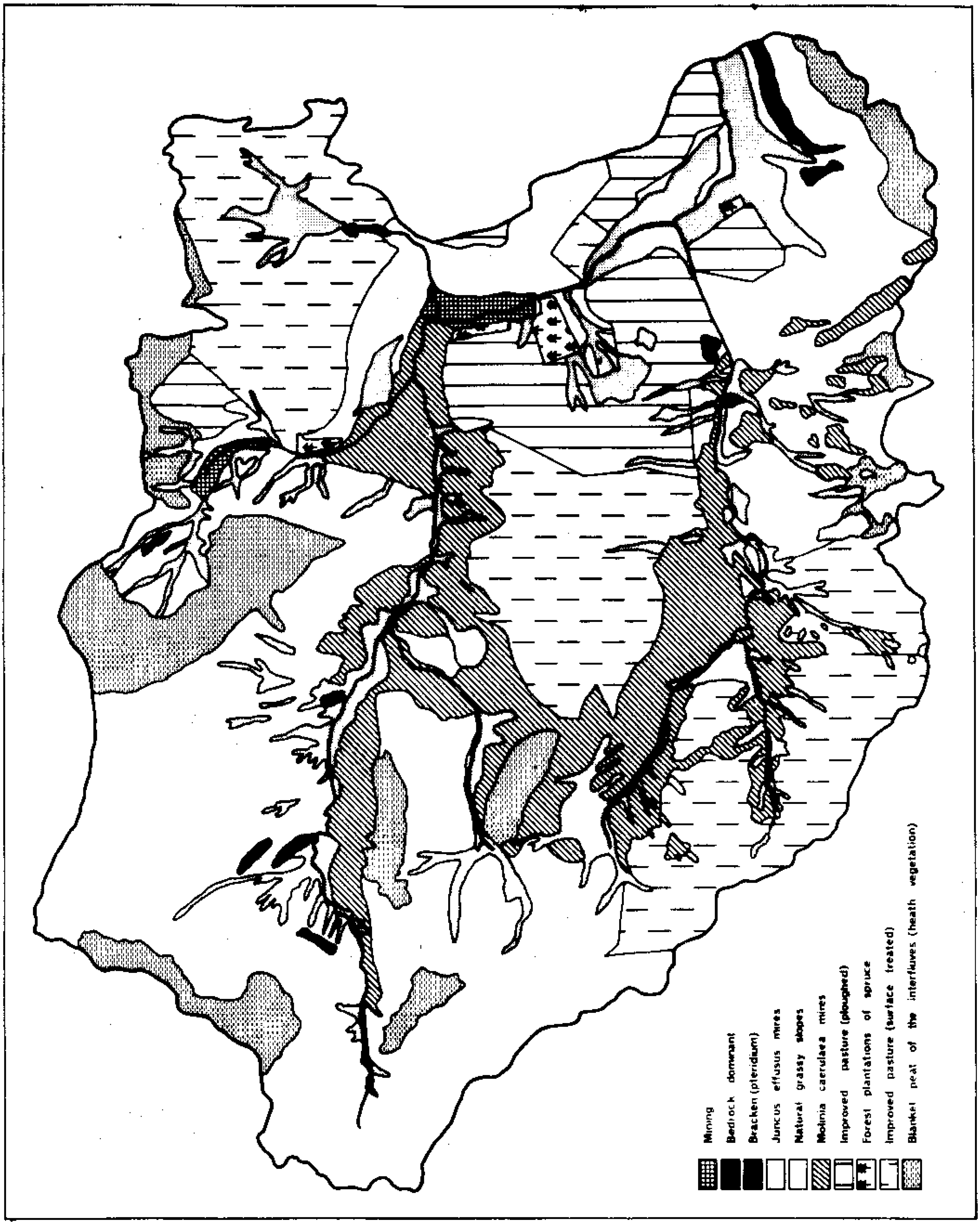


FIGURE 17 Vegetational guides to hydrology of Wye catchment (prepared by M D Newson)

suiting the drier tolerance of Nardus. "Nardus is distinctly xerophytic with its thick basal sheaths, involute leaves, thickened epidermal structures and protected stomata". Where the peat is unidsturbed Nardus gives way to Eriophorum and Trichophorum with Juncus, Calluna and Vaccinium where partial drainage has occurred. H. Jeffries (1917) mentions the exceedingly sharp boundary below the Nardetum where it gives way to *Juncus effusus* as resulting solely from the injurious effect on Nardus of winter submersion. Jeffries conducted experiments on the moisture content and texture of the substratum but found moisture content alone of little value in separating communities; however, the figure of 22.9% moisture content for the Dry Nardetum contrasts strongly with those of 60.7% (callunetum) and 77.1% (Molinietum). In places where *Mollinia caerulea* takes over from Nardus one cannot assume winter submergence - a higher proportion of organic matter and more soil water solutes are more likely reasons. T. A. Jeffries (1915) puts Molinia in a sequence of increasing wetness and acidity between Nardus and Eriophorum. Ratios of water to dry soil under each are 63, 134 and 288 respectively. He says "the distribution of Molinia depends primarily upon an abundant supply of relatively fresh water - whenever stagnation becomes pronounced so that the water is badly aerated and excessively acid, Molinia tends to degenerate". Gore and Urquhart (1966) contrast the stagnation tolerance of Eriophorum with that of Molinia. The latter species is inhibited (especially in rooting: normal Molinia roots reach down half a metre) whilst the former can actually gain by utilizing the breakdown products of Sphagnum. The leaves of Molinia are more typical of aquatic plants (T. A. Jeffries) and obviously it does require a high moisture status; Rutter (1955) correlates the fluctuation of moisture levels under Molinia with the height of tussocks produced as the deciduous grass accumulated its dead matter. Clearly some flushing action is involved, not so much of incoming peaty water but of outgoing toxic substances. This situation is clearly in keeping with the indicator value of Molinia at Plynlimon as a mire species in conjunction with the submergence-tolerant *Juncus effusus*. Further information on the differentiation of mire vegetation according to water table fluctuations (via hydraulic conductivity) is provided by Ingram (1967) who gives a nutritional explanation.

Returning to the upper border of the Nardetum, Bannister (1964) has been able to distinguish between the physiological adaptation of the heath plants Calluna, *Erica tetralix* and *Erica cinerea* to moisture extremes. Of the two Erica species, *tetralix* dominates wet areas, *cinerea* dry, while Calluna competes over a wide range of intermediate moisture ranges. Smith (1918) suggests that, once on to the blanket peat, the better-drained areas will exhibit *Juncus squarrosus*, Calluna, *Erica tetralix*, *Vaccinium myrtilis* and Empetrum whilst unbroken peat will develop the wetter Eriophrum spp., Trichophorum and the important range of bog mosses of genus Sphagnum; the latter occupy a series of wet ecological niches related to the "regeneration complex" (see Newbould, 1958) of peat bogs. The preference of Eriophorum for wetter, acid conditions has already been referred to. The presence of *Juncus squarrosus* on the better-drained peat is seen by Kershaw and Tallis (1958) as a result of preferred colonization it also co-exists with Nardus on slopes but does not dominate where drier.

The extent to which moisture status alone or other soil factors and nutrition (grazing, etc. is dealt with separately) affect plant communities in the uplands is dealt with by H. Jeffries (1917) Pearsall (1938), and Dickson (1962). Pearsall's results tend to suggest pH as an integrator of chemical effects whilst Dickson separates three main categories of blanket bog in Northern Ireland on the basis of moisture content, pH, sodium, potassium, calcium, phosphorous and iron. The categories are:

A Areas of very wet, unflushed peat occurring on flat, slightly convex or gently sloping ground.

B Areas of drier, possibly slightly flushed peat occurring on moderate - fairly steep slopes.

C Areas of peat strongly flushed with mineral-rich water of telluric (soligenous) origin.

Whilst Dickson's indicator species clearly show his restriction to blanket bog, it is quite possible to see his differentiation in the same light as the heath/grassland/mire sequence already outlined for a Plynlimon hillside. In other words an interfluve site of wet, ombrogenous species, a drier (Nardus) slope site broken by flushes from the wet areas above, and a valley bottom soligenous site which, like the flushes, receives slope drainage water in addition to rain water (see also Ingram, 1967, Perkins 1974). Ratcliffe (1959) constructs a two-dimensional matrix of communities varying with soil moisture in one dimension, biotic pressure in the other. Such subdivision has relevance to forestry, farming (see Dickson, above, and Fraser, 1933), transport and hydrology. An experimental approach remains to be taken in the latter field to quantify the frequency of high standing water levels, surface runoff and dessication of the various communities. This is being investigated by means of surface water detectors and boreholes located so as to sample the main Plynlimon vegetation communities; it is thus a hydrological approach a contrast to laboratory experiments of botanists like Bayfield (1973), Gore and Urquhart (1966) Bannister (1964) and the intriguing 'V' and 'Y' shaped drainage experiments of Smith (1918) which take the plant as the dependent variable. The rapidity of plant changes in response to drainage discovered by Smith (over one season, for instance) are encouraging to the view that time-lags in vegetation response are not great. However, artificial effects must be considered:

2. ARTIFICIAL INFLUENCES

Grazing and burning

Welch (1974) provides an ideal summary of the contradictory views that less palatable species now dominate the uplands (e.g. *Juncus squarrosus*, Molinia and Nardus) due to sheep grazing. Nardus has been mentioned as being promoted by grazing of mixed vegetation (Smith, 1918, Perkins, 1968, Chadwick, 1960) especially since the change from grazing wethers all year to raising fat lambs only between April and

September when other, palatable species are available. The nineteenth century change to sheep from cattle and ponies which were less selective for grazing was possibly equally important, especially for Molinia. Obviously dwarf shrubs are eliminated by grazing from a wide range of habitats. Calluna decline is thought to begin at sheep densities of over one per acre (not now reached at Plynlimon).

The aim of burning is less concerned with changing species than allowing animals easy access to new vegetative growth, e.g. of Molinia, Calluna. The heath vegetation of Plynlimon is not managed for grouse and consequently only the remaining valley-bottom Molinia sites are now burned in dry springs.

The indicator value of vegetation is thus clearly one which changes with management. However, apart from the re-seeding of the lower Wye, it is thought that the current indicator value for moisture status is higher than would be the case without sheep farming. No effective drainage has been carried out there to alter the picture. It remains to quantity specific hydrological relationships.

Improved pasture

The Wye catchment comprises part of the 5,000 acre (20.24 km^2) farm of Messrs. Bennett-Evans, a farm specializing in the rearing of Welsh Mountain sheep. Around 4,000 ewes graze the pastures and lambs are sold in late summer for fattening elsewhere. Replacement ewe lambs are kept on lower pastures and have access to concentrated feed and shelter at night. Hill-pastured ewes are fed with bought-in hay and feed-blocks between Christmas and lambing.

Welsh Black cattle are also kept for beef to balance the selective grazing of sheep and aid fertilizer input to improved pastures. Of the improvement techniques available, the farm was early to experiment with drainage, ploughing, liming, slagging and re-seeding with ryegrass and clover. Sir George Stapledon, writing in 1933, says, "With the Caterpillar tractor you can plough the open hill all right - we have in fact ploughed nearly 100 acres on the foothills of Plynlimon thanks to the lion-hearted endeavours of my friend Captain Bennett-Evans."

Whilst ploughing was practised on the early plots this has proved less successful than techniques involving less disturbance, mainly because of the clay pan (podzol B horizon) which results near the surface with ploughing. Consequently surface runoff is a common phenomenon, for instance beside the "Gerig Track" and by the Nant Iago road. The ploughed pastures are moss and rush infested to a greater extent than those re-seeded by surface treatment. Surface treatment leaves the podzol or brown-earth profile almost undisturbed. Soil pipes are not all destroyed. No tile drainage has been done on the catchment; in this way the pasture is untypical in view of the enormous post-war spread of tile drainage and newer plastic drains in Mid-Wales. The Cyff and other valley bottom bogs were drained in the 1950s by Cuthbertson plough but the drains have not been maintained as they were considered a danger to sheep. Burning of the valley-bottom bogs was formerly an annual practice, together with Molinia-clad slopes, before pasture improvement.

Fertilizer in the form of basic slag is spread at the rate of 10 cwt. to the acre every two or three years and lime was applied at the time of reseeding. Re-infestation of rush is occasionally controlled by spraying but is allowed in some degree as shelter for lambs.

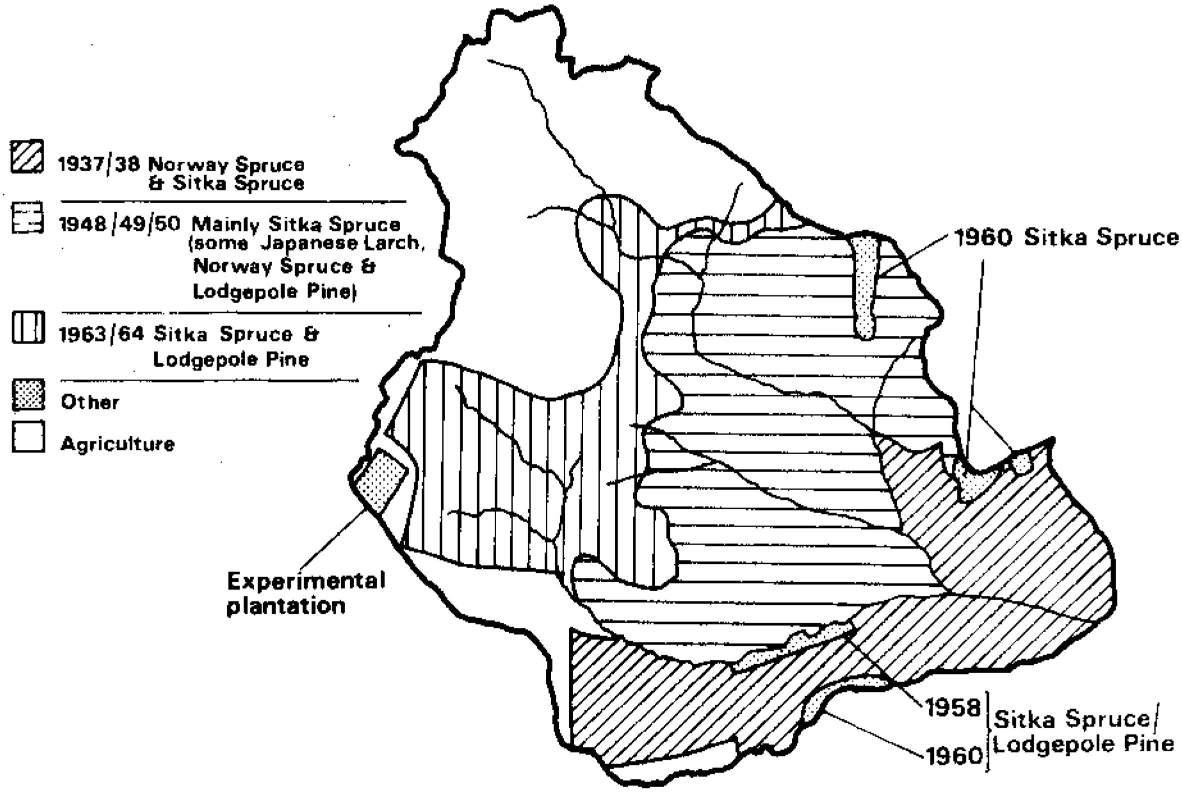
Access for feeding and shepherding is provided by a series of roads, built to Forestry Commission standard and off-roading is possible by means of Land Rover under dry conditions in better drained areas, or modified "bog-trotter" Land Rover to tackle peat bog or steep slope. Both Messrs. Bennett-Evans and the Institute operate the latter vehicles. Access to the blanket peat was formerly practised for extracting fuel and there are peat diggings near Eisteddfa Gurig (Llyn y Fawnog) and near the Nant Iago mine which used peat extensively. In the dry summer of 1975 peat was once more extracted from Esgair Y Maesnant.

Nant Iago mine operated between 1846 and 1917 producing 3638 tons of lead and zinc ores, with a peak of 176 tons of lead ore in 1875. Silver was also obtained. Water was pumped from the mine using power from an overshot water wheel (See Rees, 1969 Plate 19) and extra water was conducted for this purpose, and to drive a pelton wheel at the crushing plant, from the Upper Wye via a dam and leat constructed in 1860. The dam is now breached as are similar earth embankments in the Cyff and Gwrdy. The Nant-y-gwrdy and West Wye valley mines are located lower down than the Nant Iago and were worked between 1865 and 1885. The hydrological implications of mining are not great - leakage does not occur between catchments as a result (Biggin, 1970) but short underground sections of stream (e.g. Nant Iago, Gwrdy and in the Severn catchment at Nant-Yr-Eira) do influence channel travel times on a local scale. Mining activity in the Wye catchment appears as "disturbed ground" in Figure 6.

Hafren Forest, within the catchment of the River Severn

Originally the Severn catchment was rough pasture for sheep grazing from the farmsteads of Blaen Hafren and Hore. The depressed state of farming in the late 1920s and 30s led to State purchase and the earliest planting within the I.H. catchment (See Figure 18) is that in the Hore, mainly on the true right bank where Norway Spruce (*Picea abies*), Sitka Spruce (*Picea sitchensis*) and mixtures of the two species were planted in 1937/8. Most of these early plantations were hand dug for turf planting and fairly sparsely drained (again by hand) because of their naturally well-drained situation. The 1940s saw the introduction of tractor ploughing. The earliest plantings have now been thinned. Two later plantings in the Hore were of Sitka Spruce and Lodgepole Pine (*Pinus contorta*) in 1958 between the Miners' Path and the river and of a similar mix on Esgair y Maesnant in 1960.

A major planting of Sitka Spruce was carried out in 1942 in the lowest, left bank area of the Severn (although Norway Spruce was planted between R10 and the river). At the same time Norway/Sitka mixed were



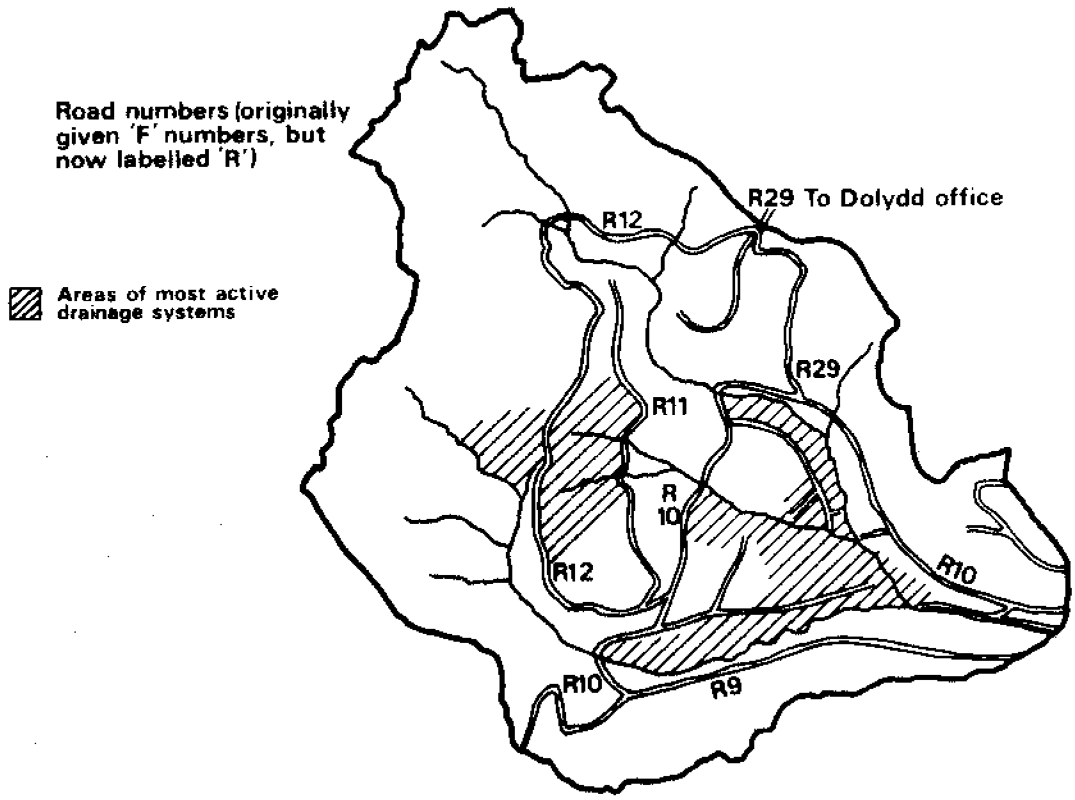


FIGURE 18 The Severn experimental catchment, its afforestation, roads and drains

planted on the left bank of the Hafren and around the Moel Cynnedd met. station. Sitka and Scots Pine (*Pinus sylvestris*) strip plantations divide this part of the catchment up into a mosaic. Sitka was planted on Banc Gwyn in 1945 but the next major phase of planting did not take place until 1948. Further mosaic planting occurred on the left bank above Blaen Hafren, mainly of pure Sitka and pure Norway but also of Japanese Larch (*Larix kaempferi*) with Lodgepole Pine mixed here and there. 1949 and 1950 saw the large expanse of the middle of the Severn basin planted with Sitka Spruce, by then proven as the most successful coniferous species except in the most difficult locations. Improvements in drainage machinery allowed basin areas to be tackled and these plantings are intensively drained (See Figure 1a). It was to even more severe locations that planting turned in 1963 and 1964, particularly in the Upper Hore (mainly Sitka) which includes, near the summit of Plynlimon Arwystli an experimental plantation at one of the highest altitudes ever tackled by the Commission. Lodgepole Pine also became a feature of planting in the Upper Tanllwyth and Upper Hafren areas in 1964. Certain difficult areas were also planted in the main body of the forest.

Drainage has proved a successful procedure in these severe areas but exposure is thought to be the major reason for poor performance of the higher plantations. The experimental plantation has been a complete failure. Whilst the growth rate of Hafren Forest as a whole was boosted by aerial applications of potash (200 Kg./ha.) and phosphate (375 Kg./ha.) in September - November 1974, some problem areas are seriously "in check" or "unusable". These areas are of three main types: thin soils (e.g. around the Hore mine) exposure and poor nutrition (e.g. near the top of Arwystli and Graig Wen in the Hafren valley) and boggy ground (such as parts of the Tanllwyth).

III CONCLUSIONS - A MODELLING STRATEGY

Flow prediction for ungauged catchments needs the application of statistical relationships between flow parameters and mapped catchment characteristics (eg The UK Flood Study approach), the application of theoretically-structured mathematical models (in which case the whole hydrograph may be predicted), or by gauging (in which case a real-time facility, using modern instrumentation, may be worth the investment). The author anticipates that applied hydrology will make increasing use of the first and last of these options whilst research will assess its findings on the basis of modelling.

The transfer of modelling to applied hydrology has been proved easy if the model is simple and can be calibrated (for instance by optimization on any available data). However, the application of physically-based models, calibrated from catchment physiography, soils, channels and other information in the office awaits proof that such models have equal or greater predictive ability and can be worked with equal or less expense than current methods.

This report hypothesizes that the conversion of rainfall to storage and runoff is a process which is likely to be spatially variable. The "domains" in which significant variants of the process take place are mappable and the most immediate impression of their extent in the Wye catchment can be thought of as a tank rather than part of a slope/ channel continuum. Peat aids the tank concept through its distinctive behaviour. Tank dimensions and performance may be hypothesized from laboratory tests, although these are few and far between, or by very simple short-term instrumentation.

The network of channels of all sizes integrates the domains and is worthy of separate treatment. Having established a possible method for calibrating a Wye model there remains the tank of extrapolating it to other grassland catchments and also of predicting the effects of forestry. Extrapolation can be thought of as initially restricted to the typical upland reservoir catchment. Unpublished vegetation surveys exist for all British uplands, in advance of soil maps of similar standard. Spatial detail may be added by a day's field survey. Tank and channel properties may be inferred.

The effects of forestry are especially well suited to the tank concept since interception may be considered as a tank and forest drains clearly influence the soil tank's state/discharge relationship. Drains are also part of an imposed channel network although forestry tends to destroy the buried channels of grasslands.

Geomorphology is the background and continuing framework of the whole scheme which is summarized as a cascade:

1 TERTIARY: <u>PLATEAUS</u>
2 BLANKET PEAT WHEN COMPLETE
3 WET VEGETATION, DRYING
4 RAPID PEAT EROSION

  1 GLACIAL/PERIGLACIAL <u>VALLEY SIDES</u>
  2 PEDOGENIC PEAT/SOILS
  3 DRY VEGETATION
  4 PIPING, GULLYING, SLOPE FAILURE

    1 GLACIATED <u>VALLEY BOTTOMS</u>
    2 PRODUCTS OF PEAT AND SLOPE EROSION
    3 WET VEGETATION
    4 CHANNEL ENCROACHMENT/SLIPS

      1 INCISED <u>CHANNELS</u> (RECENT)
      2 BEDROCK/GLACIAL BOULDERS/GRAVEL
      3 FALLS/POOLS, GEOMETRY
      4 SELECTIVE TRANSPORT/BANK EROSION

<u>Key</u>

1 ORIGIN AND FORM
2 MANTLE
3 INDEX OF HYDROLOGICAL STATUS
4 CURRENT MORPHOLOGICAL TREND

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APPENDIX A

THE GEOLOGY OF THE PLYNLIMON CATCHMENTS

The catchments lie just to the east of the Plynlimon Anticline, a prolongation northwards of the Teifi Anticlinorium. Just to the east is the Central Wales Synclinorium main axis. The former is manifest in the "Plynlimon Dome" of Ordovician rocks showing through the Lower Silurian. These structures reflect the prominent NE-SW Caledonian trend of orogenesis which uplifted sediments first deposited in the Lower Palaeozoic geosyncline, a deep trough centred just west of Plynlimon. The sediments deposited in the geosyncline were mainly deep water, fine-grained silts and muds which, when lithified, produced the characteristic shales and mudstones of Central Wales.

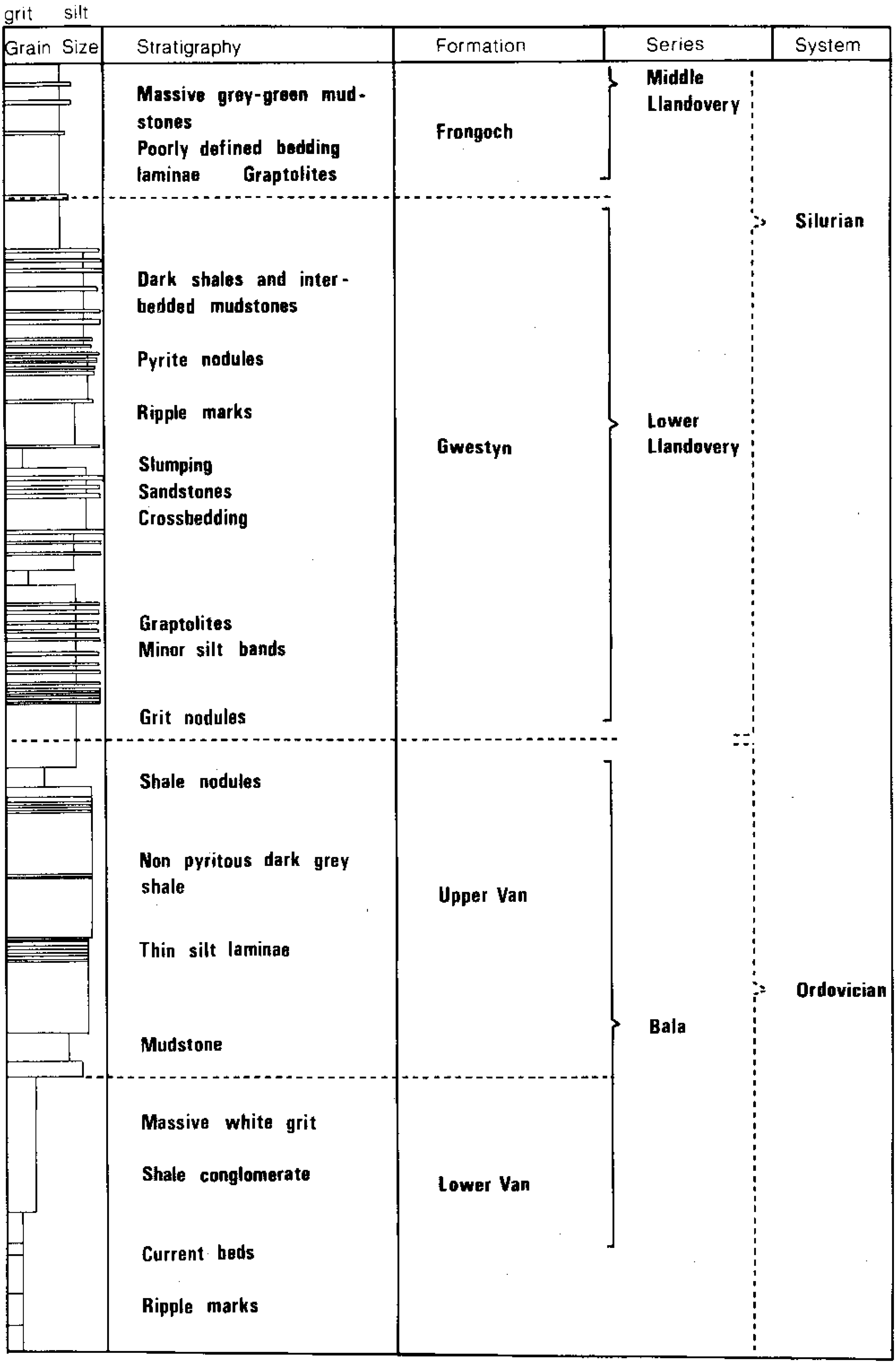
The lowest formation of the succession in the area has been called the Lower Van (Ordovician - Bala); in contrast to the shales and mudstones of the rest of Plynlimon it is dominated by grits. It forms the crest of Plynlimon's flat ridge, where periglacial activity has weathered it to a coarse, blocky "felsenmeer". The Lower Van is thought to represent a submarine fan of coarser material swept into the geosyncline. It shows, too, shale conglomerates in places and channel features.

The lithological change to Upper Van shales marks the beginning of prominent river incision in the Severn, Hore and Gwy valleys. The shales of the Upper Van are fairly massive, hard, dark and grey and represent turbidite deposits, the results of sediment-laden currents reaching the lower parts of the geosyncline. At the top of the Upper Van formation are found occasional shaley nodules but the transition to the Gwestyn formation is marked by a band of more siliceous nodules (see, for instance, just downstream of the Gwy flume). Whilst the mudstones of the Gwestyn are fairly massive (e.g. in the Gerig gorge) the shales, finely interbedded with sandstones are structurally weak to erosion and the Gwestyn outcrop corresponds closely with the bowl-shaped valleys of the lower Severn, middle Wye and Upper Cyff. As well as showing the characteristic "fining - upwards" sedimentology of turbidites there are structural forms such as sole marks and slumping, mainly of the sandstone members.

The Frongoch formation has no sedimentary structures and is once more a massively bedded grey/green mudstone which must have accumulated in shallower, more oxygenated water. It contains far more graptolite fossils and these can be collected in a quarry on the R10 forest road (Severn catchment). The resistance of the Frongoch is manifest in the hills of Moel Cynnedd (Severn) and the steep slopes opposite Cefn Brwyn (Wye).

As well as the main anticline/syncline structure, the area exhibits a number of subsidiary folds, three anticlines and three synclines; these are in fact periclines, dipping at each end of their axes. Furthermore, there are drag folds associated with them and small chevron style folds too. All beds in the catchment are, however, "right way up" (discovered

FIGURE 19 Stratigraphy of the Plynlimon bedrock



from worm burrows, sedimentary structures) and it is fairly simple to pilot the major directions of bedding, jointing and clearage (Figure 2).

The major faults are those of the Nant Iago (N.N.E. - S.S.W., downthrow 30 m to E.) and Gwrdy, although a further fault has physiographic expression in the Cyff.

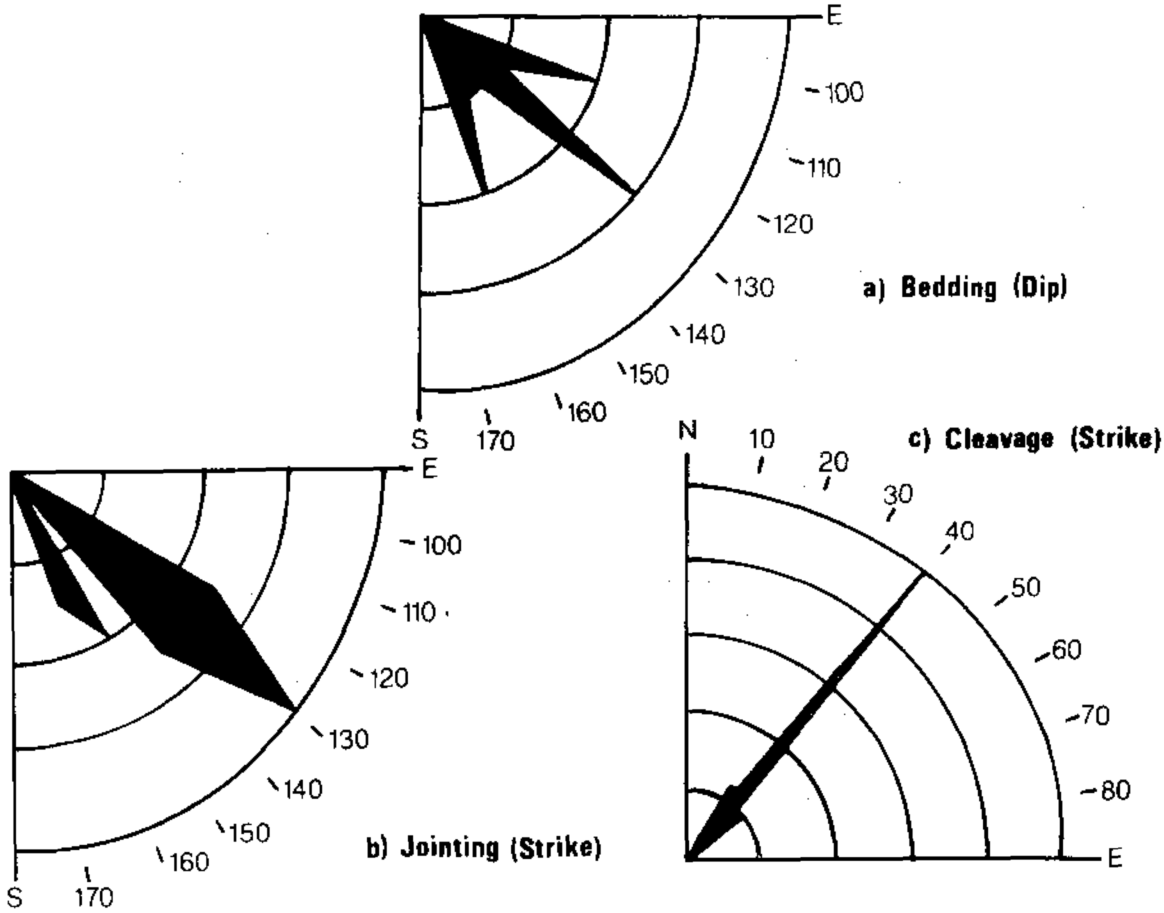
References

In addition to those references already given, the account above is indebted to two undergraduate geological surveyors,

R. Bradford (1969) and S. Kerry (1974).
To the latter we are indebted for Figures 19 and 20.

A further recent reference which includes a new coloured geological map of the area is, 'Preliminary mineral reconnaissance of central Wales' by T.K. Ball and M.J.C. Nutt, published by I.G.S. (Rept. 75/14, 1976). Figure 21 is taken from this survey.

FIGURE 20 Cleavage, jointing and bedding directions of the Gwestyn formation



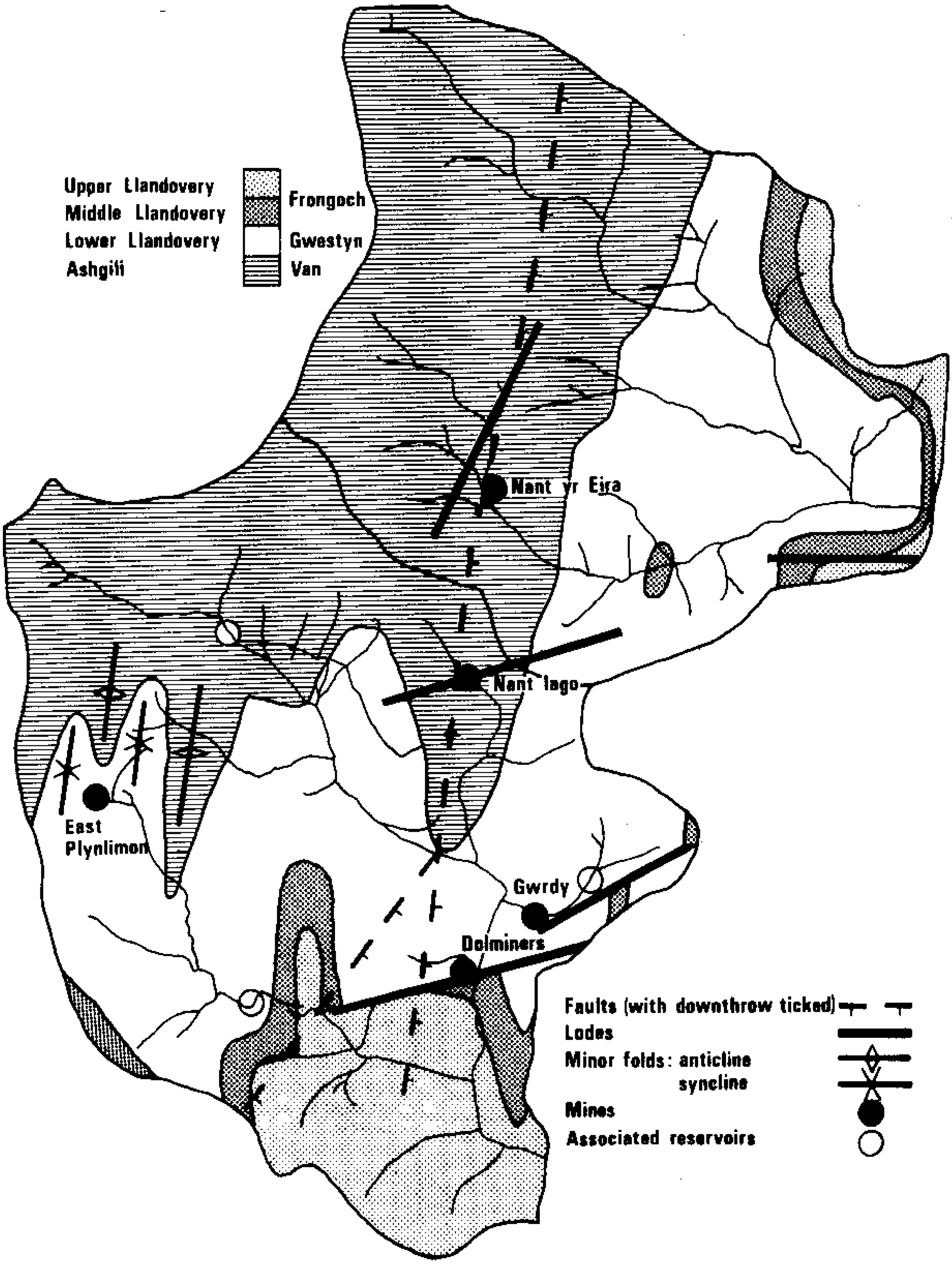


FIGURE 21 Revised geology map of the Plynlimon catchments

Mines in the Plynlimon catchments

Faulting which accompanied the Caledonian orogeny also resulted in mineralization and the presence of the ores of lead, silver and zinc in quantities which, in the 19th century, were economically worthy of extraction. The NNE - SSW faults are little fractured, brecciated or mineralized but those of an ENE - WSW trend are much more important as lodes, forming part of the major West Montgomeryshire/East Cardiganshire ore-field. The Van formation is mainly affected on the Montgomeryshire side.

Four groups of mine adits and shafts occur in the experimental catchments:

East Plynlimon	(1866-1895)
Nant Iago	(1846-1917)
Wye Valley -	
Gwrdy	(1865-1884)
Dolminers	(1877-1880)
Nant yr Eira	(Roman? 1859-1883)

Flooding of workings was a considerable barrier to extraction and elaborate water engineering schemes were constructed, for example an earth dam on the Gwy with a leat to Nant Iago, a similar system between the Cyff and Dolminers and a smaller scheme on the Gwrdy. On the Hore, water was elaborately diverted to the mine workings at Nant Yr Eira. A 38 foot (11.6 m) water wheel is recorded for the site; at the Iago the wheel was 18.3 m in diameter and at Dolminers 12.2 m. The present-day flooding of the workings and drainage of water from adits at all the sites led to early doubts about the water-tightness of the catchments as defined by surface topography. As early as 1964, therefore, reconnaissance was made of the mines with speleological exploration, water tracing and chemical analysis of water.

Specially dubious appeared to be the relationship between the East Plynlimon mine in the upper Cyff and the main Plynlimon mine to the west in the catchment of the Tarenig. However, the East Plynlimon "mine" turned out to be no more than a 300 m trial adit (bearing 325°). Water draining from it (baseflow less than half a litre per second) is chemically distinct from that in the Plynlimon mine and no Rhodamine tracer placed in the latter appeared at the adit.

Another doubt surrounded the fault line connection between Nant Iago in the Wye catchment and Nant yr Eira in the Severn (Hore). However, the flow emerging from the Iago adit is equal to that of the Nant Iago above the shaft, down which it disappears. This shaft descends 30 m to water level but the total depth of the workings is 135 m so a considerable volume of flooded galleries must occupy the short plan distance between shaft and adit. Water tracing revealed a time of travel of more than three hours (to peak dye retrieval) through the workings, although the first dye came through in less than an hour. The "tail" of the trace was very long delayed.

The drainage adit at Iago is at 430 m; the Nant yr Eira workings are at 480 m. Two factors, besides the comparable flows of the Nant Iago above and below the mine, suggest that drainage south along the fault does not occur. Firstly, the NNE - SSW faults are narrow and little-fractured. Secondly, Nant yr Eira workings are very small and although the Hore is re-routed through them it does not enter the workings or diminish in flow.

There have occasionally been other doubts about the natural water-tightness of the catchments. It is true that small springs do occur whose steady flow regime (especially persistence in drought) and steady temperature regime suggest a moderately deep source. During the 1976 drought summer it became obvious that these springs are mainly a feature of the Lower Van grits at the head of the Severn and Wye. Since these areas also have blanket peat covers the source of the steady flow may lie in the peat; however, it is thought more likely that the storage supplying the springs lies in the grit felsenmeer which mantles the Plynlimon summit plateau. Catchment leakage is therefore most unlikely. Even if the Van formation springs have a storage in the superficial bedrock the catchments are consequent with the regional dip.

Confidence, *a posteriori*, in the water-tightness of the catchments is further strengthened by the established water balance of the Wye (83% runoff coefficient, similar to neighbouring catchments) and the fact that the coefficient of the Severn (62% for the forested area) can be explained independently by measurements of the interception of rainfall on the forest canopy.

The mines and water quality

Geochemical sampling carried out by IGS ("Preliminary mineral reconnaissance of Central Wales") is published in map form. Totals for zinc between .07 and .14 ppm are recorded at the Hore and from sites in the Cyff. The Nant Iago revealed 0.2 ppm of lead and .01 ppm copper; Cefn Brwyn also yielded .01 ppm copper.

The Wye River Division also analysed water in the Gwy and Iago in November 1976. Significant values are:

	Gwy	Iago
Cadmium	.0013	.0043 mg. l^{-1}
Copper	.004	.0047
Iron	.121	.097
Lead	.008	.012
Manganese	.0353	.0343
Zinc	.0249	.550

Analyses of water in the Cyff in June 1975 yielded .05 - .07 mg.l^{-1} of zinc.

APPENDIX B

RADIO-CARBON ANALYSES OF ORGANIC MATERIAL FROM PLYNLIMON

Thanks to a period of profitable cooperation with the NERC Radio-carbon Laboratory, East Kilbride, it has been possible to obtain 20 C^{14} dates for wood and peat samples drawn mainly from within the experimental catchments. Sampling was guided by a desire to establish chronologies for the post-glacial period to compare with regional chronologies (variability in the uplands is an established feature) but especially to investigate the post-glacial development of the slopes and channels of the two catchments.

The largest number of samples (9) has been taken from the Cyff subcatchment of the Wye where, in the valley bottom, a number of "fossil" tree stumps (Pinus) are apparently *in situ*. Nearby, a land drainage ditch, severely gullied by flooding (5/8/73) exposes in its side a mineral/organic stratification of slope deposits at the edge of the valley floor.

A second concentrated sampling programme (5) was centred on the Cerrig Yr Wyn "flush" study plot in the Gwy sub-catchment of the Wye. Here the same flood (5/8/73) also exposed a stratification of mineral and organic deposits by causing the flush to "burst". The flush features are of debatable origin but if formerly open channels, how and when did they fill in? Nearby, soil pipes are under study and a sample of peat was taken from the wall of one to establish an 'oldest possible' date for these features. Nearby, too, one of the only large pieces of "fossil" timber to be found on a plateau in the Plynlimon area (as opposed to plentiful occurrence in valley bottoms) was sampled for C^{14} analysis.

Three samples were taken from channel banks to assess the post-glacial history of the open channels of the area in separate fluvial zones - the Upper Severn, middle Severn and from a floodplain borehole in the Rheidol valley at Llanbadarn.

Two samples were taken from peat on "solifluction terraces" in the area. Two more were taken from forest ditches dug across valley-bottom bogs in the Severn catchment (Tanllwyth). These were to check on local and regional chronologies.

RESULTS (REFERENCE FIGURES REFER TO RADIO-CARBON LABORATORY NUMBERS)

(a) <u>Cyff bog series</u>

The prominent tree trunk of *Pinus* sampled from the valley bottom (SRR-1112) gave an age of 6,399 ± 45 bp, corresponding with the *Pinus* maximum and optimum conditions in upland areas. The peaty layers immediately surrounding (and partly burying the root) yielded a date of 4655 ± 60 bp (SRR 1293). Of the two phases of upland peat formation, the Neolithic (anthropogenic) and sub-Atlantic (climatic deterioration) the former is most likely, given this date. Peat obviously formed *in situ* around pine roots anchored, as they still are, in mineral soils.

Moving to the gully nearby. Figure 1 shows how the basal peat in the section, overlying the solifluction deposit (undated - Late Glacial or Devensian) gives a date of 3005 ± 45 bp (SRR 1290) whereas the macrofossils (*Pinus* and *Betula*) it contained yield dates of 4097 ± 45 and 4143 ± 45 bp (SRR 1111 and SRR 1110 respectively) at the base and 3278 ± 45 and 4417 ± 50 bp (SRR 1109 and SRR 1108 respectively) at the top. Possibly these smaller, mainly birch, fragments represent a phase of mainly scrub woodland during continuing peat accumulation. However, the irregularity of the dates may mean that the fragments are not *in situ*. Taken with the mineral layer above, in which an organic lens gave a date of 2625 ± bp (SRR 1292), it is possible that the two layers represent an inverted profile eroded from the slopes above. This erosional phase may have occupied a rather restricted time period, say, from 3005 to 2625 bp - at the time of the sub-Atlantic climatic deterioration. Sample SRR - 1291 suggests that the present, mainly peaty, soil is as recent as 350 ± 40 bp.

(b) <u>Gwy flush series</u>

Samples from the upper layers of the flush peat, either side of a pronounced mineral layer (SRR 1294 and SRR 1295) were analysed as "modern", clearly not part of the zone VII b erosive phase. The Oh horizon of soil around the soil pipes bordering the flush yielded an earlier date - 620 ± 35 (SRR 1296).

(c) <u>Other samples</u>

Both pairs of samples taken from valley-bottom peat bogs and solifluction indicate similar dates to the Cyff valley bottom deposits and that profile reversal may have occurred. At the Tanllwyth the *Betula* from 1 m depth (SRR 1114) was dated 1841 ± 55 bp whereas that from 0.45 m was dated 4.758 ± 45 bp (SRR 1115). The Rhiwdefeitty and Nant Iago samples of *Betula* (SRR 1132 and SRR 1131) yield dates of 4045 ± 45 and 2605 ± 40 bp respectively.

The river-bank samples reveal a fairly stable channel course near to its source (SRR 1116 - 1420 ± 45), more mobility in the meander belt in mid course (SRR 1117 - 450 ± 40), and great antiquity of wider floodplain deposits (SRR 1113 - 4807 ± 45).

<u>Interpretation and problems of interpretation</u>

The interpretation of broadly unstable slope conditions following the Zone VII b/VII climatic decline casts doubt on those hypotheses developed for the rest of Zone VII. Apart from the *in situ* tree remains of the lower Cyff and the suggestion that peat began to grow over their roots around 4655 bp, the other samples may represent a complex mixture of

TABLE 6 The Late and Post-Glacial climate, vegetation and morphology of Plynlimon

PERIOD	POLLEN ZONE	DATE*	CLIMATE	LOCAL EFFECTS
Sub-Atlantic	VIII	- 500 BC	Cold, wet marked deterioration	Erosion of Plynlimon slope peat. Further accumulation in bogs.
Sub-Boreal	VII b	500 BC - 3,000 BC	Warm, dry	Man deforests Plynlimon? Peat begins to accumulate; Birch scrub.
Atlantic	VII a	3000 - 5,500 BC	Warm, wet CLIMATIC OPTIMUM	Cyff pines grow in mineral soil.
Boreal	VI V	5,500 - 7,600 BC	Warmer, drier	
Pre-Boreal	IV	7,600 - 8,300 BC	Sub-Arctic	
	Younger Dryas			
	III	8,300 - 8,800 BC	Minor glacial advance	
	Allerod			
Late Glacial	II	8,800 - 10,000 BC	Warmer	
	Old Dryas			
	I	10,000 - 12,000 BC	Tundra	

in situ peat growth and slope erosion. Much of the peat and tree debris accumulating in valley bottoms and terraces may therefore be redeposited and it requires more detailed sampling, or a more detailed technique such as pollen analysis, before the stratigraphy of these sites can be interpreted. Following the phase of erosion/deposition there appears to have been quite a gap before the peaty horizon of slope soils developed (350 to 620 bp).

To conclude, an attempt at a 'broad brush' treatment of physiographic, soil and hydrological developments during the post-glacial has been frustrated by the sensitivity of organic terrain to climatic fluctuation (for instance, the slope soils are now suffering erosion once more from dessication-induced piping) and by the spatial variability this introduces to organic/mineral stratigraphy.

APPENDIX C

DETAILED SLOPE PROFILES FROM THE WYE CATCHMENT

As part of an investigation of contributing areas to the storm hydrograph in the Wye catchment, Miss Sandy Stachowicz measured 13 long slope profiles using a 'pantometer', a quadrilateral of alloy rods equipped at one intersection with a protractor and spirit-level. A path was followed from divide to stream bank following the line of greatest slope. Vegetation composition and soil type/depth were also recorded on each profile; however, since quadrat sampling and detailed soil analyses were not used, we refer here mainly to the slope angle profiles.

Humid temperate slopes are typically convex/rectilinear/concave, with the convexity often forming more than half the profile. Young (1963) proposed a sequence of development of slopes on Palaeozoic rocks in Britain; the profiles surveyed in the Wye (especially the longer ones, mid-catchment) closely resemble Young's model (Figure 22) with the convexity occupying between 29% and 83% of the profile (Table 7).

TABLE 7 <u>Slope Profile Sequences</u>

<u>KEY</u>

X	Convex element	curved sections of the profile
V	Concave element	
S	Segment	straight section of the profile
M	Maximum segment	
N	Minimum segment	

Above concave elements maximum segments and minimum segments are shown mean slope angle values.

Below each set of profile data are the relative proportions of the slope that each slope shape takes up.

SLOPE PROFILE SEQUENCES

PROFILE 1

```
 21   22
X V X X V X
    V = 0.174          X = 0.826      S = 0
```

Contd

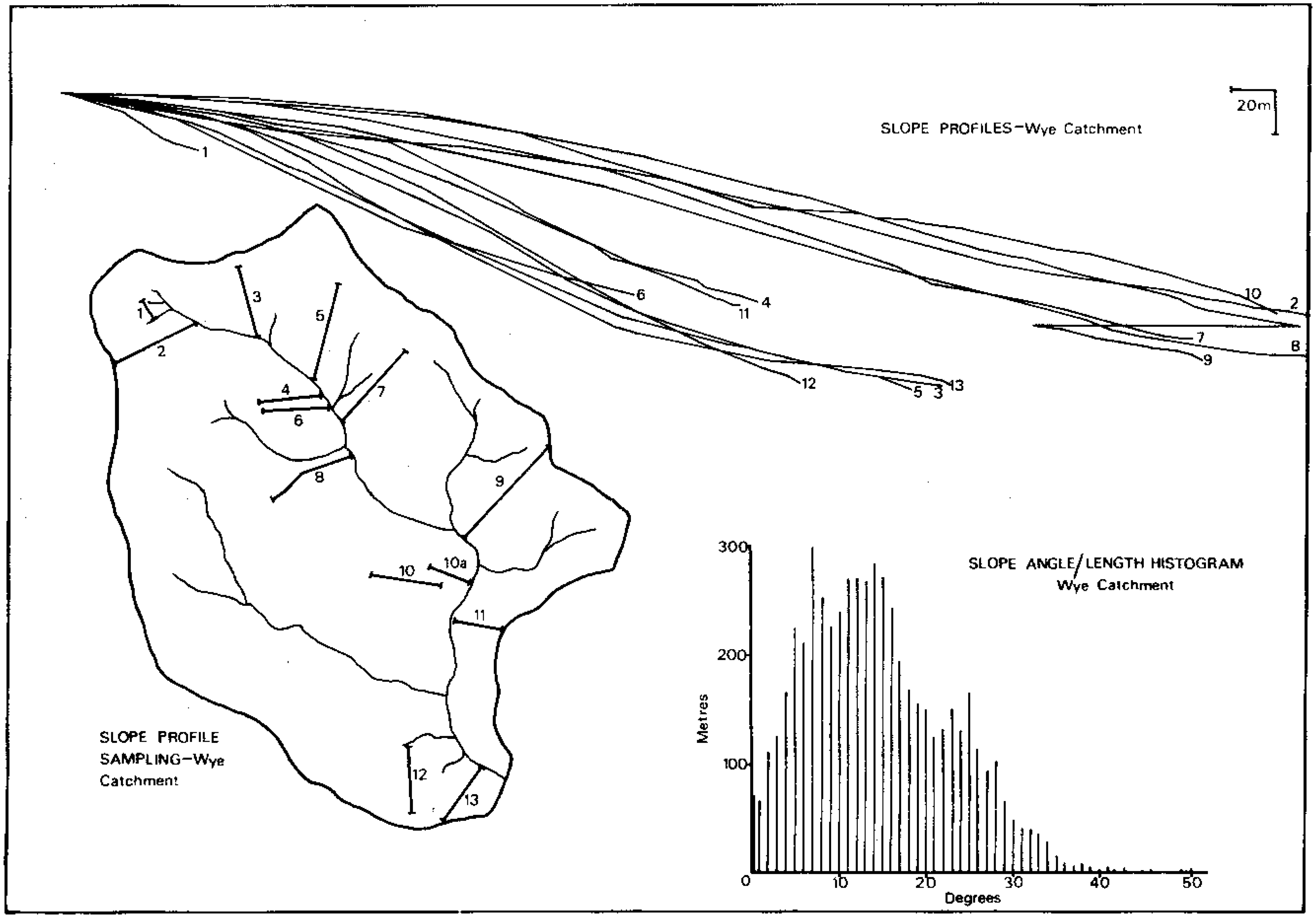

SLOPE PROFILES–Wye Catchment
20m
1
2
3
4
5
6
7
8
9
10
11
12
13
SLOPE PROFILE
SAMPLING–Wye
Catchment
10a
SLOPE ANGLE/LENGTH HISTOGRAM
Wye Catchment
Metres
100
200
300
Degrees
0
10
20
30
40
50

FIGURE 22

PROFILE 2

1.5 2 10 18 18 18 5 1 7 6 2 8 13
N X V S X V S V X V X S X X V V X V X V X V X V X V X X V
8 14 11 9 24 27 29
X V X V X S V X V X V X V M
V = 0.45 X = 0.328 S = 0.220

PROFILE 3

11 15 26 25 24 8 12 8
V X X V X V X M X V S V S V X S V N X
V = 0.320 X = 0.29 S = 0.387

PROFILE 4

4 9 8 143815
X X N V/X V/X X X S X V M V X
V = 0.453 X = 0.372 S = 0.175

PROFILE 5

12 9 31 18 17 9
X N V X X X S X M S V X V X S X V X
V = 0.219 X = 0.537 S = 0.243

PROFILE 6

1 4 2617 16 13
N X S S V X S X S X M V X V X V
V = 0.198 X = 0.487 S = 0.315

PROFILE 7

2 7 12 1917 18 11 11 11
N X X S X V X V X M V X V X V X V X V X S
V = 0.378 X = 0.481 S = 0.141

PROFILE 8

7 1717 13 13 8 6 4
X V/S X V M X V X X V X V X V N X
V = 0.302 X = 0.521 S = 0.177

PROFILE 9

1 2 11 15 10 17 14 16 15 6 16 14 14
N X V/X X V X X V X V X V X V X M X V S X V X V X V X V
16 4 11 35
X V X S X V X S V S X V
V = 0.315 X = 0.548 S = 0.136

Contd

PROFILE 10/10A

```
2  10   5       7     9     8     15          11   7  15
N X V S V X S S V X S V X S V X X M X S X S X V X V X V
          2   1
         N X V X
     V + 0.266     X = 0.330    S = 0.402
```

PROFILE 11

```
 3   7    9        24  2420    26
N X V/X V X S X S M X V V X S V
     V = 0.260     X = 0.319    S = 0.410
```

PROFILE 12

```
  5    8    8  13  15  32  29              22
X V X V X V/X N X V X M X V S X S X S S X V S X
     V = 0.211     X = 0.434    S = 0.354
```

PROFILE 13

```
 3          30  27  11   7   6
N X X X X X V X V X V S M X V X
     V = 0.426     X = 0.392    S = 0.182
```

The concavity at the base of the slope occupies between 17% and 45% of the slope length but the most variable is the straight segment, a prominent feature of the longer mid-catchment slopes but absent at the very head of the Wye where rapid gully incision is occurring. The segment occupies between 0% and 41% of slope lengths.

The distribution of slope angles recorded by Miss Stachowicz may underestimate at the low end; using a pantometer between peat haggs on the Plynlimon plateau surface proved difficult and, since the bias of the study was hydrological, the longer segments of plateau were not surveyed; an estimation of the true length of slope between 0^o and 5^o has therefore been made (Figure 22). The complete slope angle histogram closely resembles that for central Wales drawn up by Young (1961), with maxima between 5^o and 10^o, 10^o and 15^o and at 25^o.

A correlation between peat depth and slope angle shows a high degree of variability but a general tendency to 30 cm or less on slopes steeper than 15^o, increasing to 100 cm or more on slopes less than 6^o. Other mapping of peat depths in the Tanllwyth by Biggin and in the Gerig by Gerrard show the pattern as already discussed - peaty plateau and valley bottoms.

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POSTCRIPT

"Plynlimon, or less correctly Plynlimmon, is a plateau of grits and shales overlaid with bog, and is well described as 'a sodden dreariness'. The view from the highest point, Pen Plynlimon-Fawr (2,469 ft) is immense but somewhat featureless. Plynlimon is the 'Mother of rivers', for the Wye, Severn and Rheidol, besides the Llyfnant, Clywedog, and other smaller streams all rise on its slopes. It was Glendower's lair in 1401, whence he issued forth to harry the land.

On the whole, Plynlimon may well be given a miss."

Wales for Everyman. H.A. Piehler.

J. M. Dent and Sons, 1935.