CONTRIBUTIONS TO THE PLEISTOCENE GEOMORPHOLOGY

OF THE

MIDDLE AND LOWER USK VALLEY

By

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In accordance with regulations 6 and 14 for the Degree of Philosophiae Doctor of the University of Wales, it is certified that the dissertation "Contributions to the Pleistocene Geomorphology of the Middle and Lower Usk Valley" is the result of the candidate's own investigations, and that the dissertation has not been accepted in substance for any degree, and is not being concurrently submitted in candidature for any degree.

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ABSTRACT

An investigation of the landforms of the Middle and Lower Usk, based primarily on morphological mapping.

Three glacial advances are recognised: an 'Upper Usk Maximum' (probably composite); a 'Vale of Gwent Maximum'; and a 'Last Glacial Advance', the equivalent of the 'Newer Drift' advance of Charlesworth. The Vale of Gwent Maximum is marked by a thin, featureless drift extending to Llangybi. Its position relative to the present valley form suggests that the advance responsible was separated from the Last Glacial Advance by only an interstadial. The Vale of Gwent Maximum and the Last Glacial Advance are therefore ascribed to the Early and Late Weichselian, and the Upper Usk Maximum to the Gipping. There is no sound evidence for an 'Older Drift' ice advance in the Vale of Gwent.

Previous theories to account for anomalies in the Usk drainage are reviewed. It is suggested that an early subsequent drainage concentrated on the Middle Wye was disrupted by transfluent ice erosion during the Upper Usk Maximum Glaciation. The route so established through the Fforest Fawr/Black Mountains scarp was deepened

fluvially during the Ipswichian, and sufficiently well developed to confine the Last Glacial Advance, which was essentially a valley glaciation, leaving the Llangorse - Llynfi Basin as a largely unglaciated enclave.

Above Llangybi river terraces have been largely removed by glacial activity, but terrace mapping downstream enabled correlation with the Severn terrace sequence, and lent support to the suggested two-phase Weichselian advance of the ice into the Vale. Collation of bore-hole records from about the river mouth enabled plotting of the rock-head contours, and discussion of the overlying superficial deposits.

An Appendix discusses the glacial morphology of part of the Middle Wye (Llyswen - Hay-on-Wye), with particular reference to terraced outwash deposits and meltwater channels. The contrast with the Usk suggests that the Wye was a more significant ice distributary.

PREFACE

The initial work in preparation for this thesis was carried out during a period (1957-60) of post-graduate study in the Department of Geography of the University College of Swansea under the supervision of Miss G.E. Groom. I was assisted financially by the award of a State Studentship by the Ministry of Education, and for a short period by an award from the Welsh Church Disestablishment Fund administered by the Monmouthshire County Council. I would like to record my appreciation of this assistance.

The problems raised during this period of full-time research seemed more overwhelming than those solved. After appointment to an academic post in 1963 I was able to spend a further period in the field, whilst writing-up was facilitated by a sabbatical term spent at the University College of Swansea in the autumn of 1966. Residence in West Africa since 1963 has, however, meant that particular problems which might profitably have been investigated further in the field, have had to be ignored. Access to certain relevant publications has also been a problem,

whilst analysis of the Pleistocene Glaciation of a part of Britain acquires a certain unreality - even irrelevance - in the tropics!

Of the numerous individuals who assisted at various times, I should like to mention the Rev. L.S. M'Caw, who kindly loaned his one-inch geological map of the Black Mountains for copying; Mr. T.R. Owen of the Geology Department, University College of Swansea; Dr. R. Absalom of the Newport Borough Museum; Dr. F.J. North and Mr. Emlyn Evans of the National Museum of Wales, Cardiff; and Dr. Isles Strachan of the University of Birmingham.

The information upon which Chapter 12 is based was kindly supplied by officials of the Central Electricity Board (Midlands Project Group); Newport Borough Engineering Department; Newport and South Monmouthshire Water Board; Richard Thomas and Baldwins, Ltd., Spencer Works; Mott, Hay and Anderson (Consulting Engineers for the George Street Bridge); Sir Owen Williams and Partners (Consulting Engineers, Newport By-pass Road); and the South Wales Docks Office, Barry. Fig. 22 is based on information supplied by Rendel, Palmer & Tritton, Consulting Engineers for the 'Heads of the Valleys Road' (Stage 1).

Figures 37-43 and 45 were redrawn by Mr. S.J.A. Nelson, Cartographer in the Department of Geography, Fourah Bay College. All others were drawn by the author. The photographic work was carried out at Swansea by Mr. K. Jones and Mr. E. Price, and the typing was done largely by Miss S.C. Heathcote Smith. I am grateful for the help of all these people.

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CHAPTER 1

INTRODUCTION.

The area covered in this study is shown in fig 1. It lies in the south eastern part of Wales, and includes the greater part of the drainage basin of the river Usk downstream of Brecon, whilst an Appendix V deals with a sample area of the middle part of the adjoining valley of the river Wye.

The field work upon which this study is based was commenced in the spring of 1958. The research project as initially envisaged was a study of the denudation chronology of the Usk valley in the fashion that the neighbouring upper Wye had been studied by Rice (1954), and the Vale of Glamorgan by Driscoll (1953). Denudational studies had previously been made of parts of the Usk drainage basin by M'Caw (1936), Clarke (1936) George (1942) and O.T. Jones (1951). In general these works had only dealt with the area in a summary fashion, lacking detialed field analysis (e.g. O.T. Jones), or had been confined to upland regions drained by tributary streams (e.g. the Black Mountains, studied in detail by M'Caw), and were not, therefore, representative of the Usk as a whole.

Experience gained during the first field season showed that the research project, as originally conceived, could not be carried out. The contribution of the Pleistocene Glaciation to the present day landforms had been underestimated, and detailed field mapping showed that evidence of pre-glacial denudational episodes was extremely fragmentary at the lower levels within the Usk valley, and that of its major tributaries, and subsidiary in importance to landforms of glacial origin. As a reconnaissance survey of the erosion surfaces of the region had been made by Brown (1956), and in the writer's opinion further, detailed study of the higher level erosional features would tend to be negative in their findings, it was decided to concentrate the enquiry on the Pleistocene development of the region, to which virtually no attention had been given for most of the area since the work of Officers of the Geological Survey at the turn of the century.

Work commenced in the region about Abergavenny, the small Clydach valley, confluent with the Usk at Gilwern, a few miles upstream, having been the subject of the writer's Bachelor's degree dissertation (Williams, 1957).

Initial confusion as to the objectives of the work, and the relatively slow extension of coverage of the detailed field mapping, made it obvious that the original plan to survey the whole of the river basin would not be feasible, and work was first concentrated on that part of the valley extending downstream from Brecon to the limit of the 'Newer Drift' deposits, as mapped by the Geological Survey, which lay in the vicinity of Usk (fig. 9).

A reconnaisance of the valley below the 'Newer Drift' margin showed, expectedly, that the landforms there were of a quite different character to those previously mapped within the Newer Drift spread, and it was at first decided not to extend the study downstream of Usk to the river mouth. Conclusions based on mapping upstream of Usk were found, however, to be unsatisfactory, and the area to the south was re-examined in the summer of 1963, in addition to the collation of bore-hole records for the area about the river mouth. Although field mapping below Usk was not as exhaustive as earlier mapping had been, mapping being more selective, it enabled the establishment of a riverine erosional sequence for that part, tied in as far as was possible with events in the upper part of the basin, which, combined with evidence of sea level flustuations indicated by the buried channels and superficial deposits at the river mouth (Chapter 12), could be tentatively correlated with the sequence established by Wills (1938) and elaborated by Beckinsale and Richardson (1964) for the lower Severn valley.

The approach of this work is essentially morphological. This is in part a reflection of the period in which the project was commenced, when geomorphologists were much concerned with techniques of morphological mapping, and the quantitative techniques currently favoured had not been widely used: nor was equipment generally available. Even so, it is still considered that the preparation of a distribution map showing the major morphological characteristics of the area under study is a prime task of the geomorphologist engaged in regional studies, although the importance of quantitative techniques is recognised, and it is regretted that greater use of such methods was not possible.

Morphological mapping was carried out at a scale of 1:10,560 in the field, the morphological and distribution maps which illustrate this work being reduced directly from that scale. The style of mapping adopted was a development of a style used during undergraduate training at the University College of Swansea. The technique and style of morphological mapping developed in the south Pennines by members of the Sheffield Department of Geography and outlined by Waters (1958) was initially used, but discarded in favour of the simpler, personal style. The disadvantage of Water's scheme may be summarized briefly.

1. The scheme is so detailed, including classification of slope, and the mapping of inflexions of slope* that the area which might be covered using this technique by one person, was relatively limited. The returns from the use of this technique did not seem to justify the additional expenditure of time involved.
2. The major weakness of Water's scheme was considered to be the inclusion of slope inflexions. Experience showed that the plotting of such inflexions was extremely difficult and time consuming in the field, and that the finished map is, as a result, highly subjective. The number of slope inflexions that would be identified by two, equally capable

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* A curved segment of slope (or morphological discontinuity) bounding a slope facet. Waters suggests (1958, 13) that it should be shown "by means of a broken line bisecting the linear zone over which the discontinuity extends".

observers would vary according to individual assesment of the importance of minor slope changes, and also according to the direction of approach in the field to the unit of land being surveyed. To carry out a survey of this detail as objectively as possible, several observation points are needed for each line of slope inflexion plotted on the map.

3. The finished map produced according to Water's scheme was considered to contain such a mass of detail that major morphological contrasts were lost, and interpretation was only possible after detailed and close study. The scheme adopted in this work, it is hoped, gives a quick, graphical impression of the landforms under review, without commensurate loss of detail.

4. Although Water's scheme, with the disadvantages outlined above, worked reasonably well in upland areas, especially where structural control of relief was evident (and it had been developed initially in such an area), in areas where glacial deposition had been dominant, the scheme broke down altogether. Deposits of 'hummocky moraine' characterised by ever changing angles and aspect of slope defied definition by the Waters' scheme, and experience showed that such

areas were best shown on a map by plotting the crest lines of individual ridges by means of a single line. The orientation of the ridges became clearly evident using this method, although the lateral extent and height of individual ridges was not defined. An attempt to plot the lateral extent of each ridge was made, but except where ridges were developed in relative isolation, distinct from each other, and this occurs in only a minority of cases, this method proved impractical. In areas of hummocky drift especially, the definition by crest lines was much preferred. In retrospect, the absence of any categories of ridge height was probably a mistake, although difficulty in applying any classification in areas of hummocky drift can be foreseen.

The system of morphological mapping to be described in detail in Chapter seven (introductory section) was therefore used in preference to published schemes available when field work was started. Although the scheme initially developed at Sheffield has since been elaborated, and its use extended to certain other parts of Britain and overseas by its adherents, it has not been felt necessary to qualify any of the reservations held in 1958. By increasing the complexity of the mapping schemes, the possibility of producing a morphological map coverage of the British Isles, and of non-professional interest and participation in the scheme, appears to have been lost, whilst the interest of geomorphologists generally has turned to more obviously productive fields. Glacial morphology is, however, receiving an increasing amount of attention, and a genetic system of landforms mapping is being widely used in this field (e.g. Sissons, 1958 (a), Price 1960 & 1963). The pressing need here would seem to be for standardisation of symbols and mapping techniques, without the move towards refinement and complexity which seems to have retarded progress in morphological mapping generally.

It might be stressed at this point that the writer is aware of certain features which do not admit of an entirely satisfactory explanation. The aim of the fieldwork was in the first instance to produce an accurate map of the morphology of the area. Whilst genetic considerations were always in mind in the field, many features could not at that stage be easily 'pigeonholed'. They were, nevertheless, mapped, and appear on the morphological maps illustrating this work. The origin of some became evident with increasing familiarity with the terrain, but others remain problemmatical, and as such are discussed in the text.

A factor which has undoubtedly contributed to the problems of interpretation has been the location of the study area fairly close to the southern limit of Pleistocene Glaciation in the British Isles. Observations in other, more northerly, parts of Britain have shown that glacial landforms - both depositional and erosional - are far more bold there than in the Usk, and for this reason, interpretive problems in the study area have been more serious than might have been the case elsewhere. This matter has been generally highlighted by the morphological approach which was used.

Finally, as a geographer it might be well to emphasize the point that although geomorphologists are turning increasingly to more quantitative studies of process and form, the importance of regional studies based on descriptive mapping remains.

It has not been possible to indicate all the place names referred to in the text on the accompanying figures, and the relevant one-inch Ordnance Survey maps (Sheets 141 (Brecon); 142 (Hereford); 154 (Cardiff); and 155 (Bristol and Newport)) should be available for consultation. However, an extract from the 1:250,000 map

(Sheet 12) covering the whole area of study is provided (fig. 58), whilst an extract from the One Inch to One Mile map covering the Middle Wye (fig. 50) illustrates Appendix V. The 1:250,000 extract has been placed at the end of the second volume, and so cut that it may be left unfolded with the most relevant parts visible whilst other sections are referred to.

CHAPTER 2.

RELIEF AND DRAINAGE.

1. GENERAL.

The Usk rises on the fretted north-facing scarp of the Fforest Fawr uplands of Carmarthenshire, and follows an arcuate course to the south-east, to empty into the Severn Estuary near Newport. Its main tributaries derive from the uplands of south Brecon-shire and Carmarthenshire. Its drainage basin, shown in fig. 2 (672 sq. miles), has a strange constricted shape, being most extensive in its headwater section and near its mouth. This underlines the fact that the Usk is in certain respects ill-defined as a valley, its watershed in many places running across low-level cols, testimony to former episodes of river diversion, whilst elsewhere it strides along mountain ridge and scarp edge.

The Usk valley can be divided into three major sections (fig. 4):

1. The Lower Usk (Vale of Gwent);
2. The Middle Usk, between Abergavenny and Brecon;
3. The Upper Usk, above Brecon.

This thesis will be concerned only with the Middle and Lower Usk, although in certain respects the basin is better treated as a whole, and in the introductory sections, reference will thus be made to the wider area. An attempt has been made (fig. 4) to make a regional subdivision of south-east Wales which will form the basis for discussion of the relief and drainage of the area.

2. RELIEF.

Below Brecon the Usk is running through an interior lowland area which stretches north-east from the foot of the Brecon Beacons through to the Middle Wye and on to the Plain of Hereford. The Usk-Wye watershed is here a low range of hills, reaching a maximum height of 1,250 feet in Allt yr Esgair, and rising directly from the valley floor. Low cols, 250-300 feet above the valley floor lead over into the Llangorse Basin which is drained by the Llynfi into the Wye. To the south there is a stepped rise to the Brecon Beacons (Pen y fan, 2906 ft.), part of the Fforest Fawr range, the scarp of which is continued in the western and northern faces of the Black Mountains to the east. The Beacons show a deeply dissected scarp-face with impressive cirque-heads to the valleys draining off it. The scarp of the Black Mountains shows a lesser degree of dissection, although the stepped form of the scarp is here more apparent, with treads developed at approximately 500, 1,000 and 2,200 feet (crest). The Black Mountains, rising to a maximum height of 2,660 feet in Waun Fach, is a much more extensive area of high ground than the Beacons, with a series of deeply-incised south-easterly draining valleys, separated by high flat-crested ridges. It is a dissected plateau, broken in the south by the narrow cross vale extending from the Usk valley near Crickhowell to the Monnow valley in the east. To the south of this is the Sugar Loaf (1,995 feet) towering above the Usk at Abergavenny.

The Usk at Crickhowell is flowing in a deep but wide valley, separated from a similarly wide part of its valley downstream of Brecon by a gorge-like section (Llandetti - Penmyarth) developed where the river crosses the line of the Fforest Fawr - Black Mountains scarp. To the south of this lies the uplands of Mynydd Llangynidr and Mynydd Llangattwg, rising to between 1650 and 1800 feet and forming the north-eastern part of the South Wales

Coalfield. The Coalfield scarp bounds the south side of the Usk valley between Llangynidr and the Afon Lwyd valley at Pontypool, and in that distance is cut by only one valley of importance: that of the Clydach, draining eastwards to the Usk from Brynmawr.

At Abergavenny the Usk enters the Vale of Gwent. This is another internal lowland, bounded by the Coalfield scarp in the west, the Trellech Plateau and Wentwood ridge (South Monmouthshire Uplands) in the east and south, and the North Monmouthshire Uplands to the north. The centre of the Vale is occupied by a hill area of resistant rocks, cut by the river into the Bettws Newydd and Llandegfedd Hills, lying east and west of the river respectively. The Llandegfedd Hills are the most extensive, and are deeply dissected by the Sor Brook and its tributaries. These hill areas rise to between 400 and 600 feet O.D.

The rise to the North Monmouthshire Uplands is gradual and it is not easy to define the margins of this sub-region. Much dissected, although with generally open valleys, the highest points are the Ysgyryd Fawr near Abergavenny (1,596 feet) and Craig Syfyrddin, overlooking the Monnow valley (1,389 feet). In the east, the Trellech Plateau is but part of the larger Forest of Dean Plateau and has an undulating surface between 800 and 1,000 feet O.D. The scarp has a general south-westerly trend, although with a massive semi-circular sweep at the head of the Pill Brook near Wolvesnewton. The high ground is continued in the Wentwood Ridge, part of the South Monmouthshire Uplands, which tapers eastwards, loosing height towards Newport. It has a steeply-scarped north-east face, and rises to a maximum of 1,013 feet in Wentwood itself. There is a rapid fall in height southwards, and a zone of mainly low-lying land is followed by the A 48 trunk road, although broken hill country continues south of this for several miles before the Caldicot Level is reached.

The south-eastern part of the vale is crossed by the Afon Lwyd, whilst the gap between the Coalfield scarp, here swinging west, and the continuation of the Wentwood Ridge at Newport is filled by a zone of hill country with ridges showing east-west alignments.

The Levels of Wentloog and Caldicot are tracts of artificially-drained estuarine marsh, only 20-25 feet above Ordnance Datum.

3. DRAINAGE

The main tributaries of the Usk rise on Mynydd Eppynt (Honddu, Yscir, Bran and Cilieni) and on the Fforest Fawr range (Crai, Senni, Tarrell, Caerfanell, and Crawnon). Only two streams of importance drain off the Coalfield (Clydach and Afon Lwyd), whilst the drainage of the Black Mountains is equally divided with the Wye, the Usk receiving the Grwyne Fawr, Grwyne Fechan, Rhiangoll, and the misfit Gavenny. The only other tributaries of any size are the Olway, Berthin and Sor Brook, the first two being confluent with the Usk near Usk, the latter at Caerleon.

Most of the larger tributaries are therefore confluent with the main river above Abergavenny where the river is flowing through upland areas receiving high rainfall totals. Where, too, resistant rocks outcrop, forming upland regions, a consistent south-easterly or southerly trend is displayed by left-bank tributaries, whereas the drainage patterns of lowland areas of less resistant rock show trends which conform more closely with structural patterns. The Usk itself cuts obliquely across the south-easterly trending (consequent) drainage over most of its course, and this, combined with the limited development of the south bank tributaries, has raised problems of the age and origin of the Usk as a major river.

CHAPTER 3.

GEOLOGY.

1. GENERAL.

Knowledge of the geology of the middle and lower Usk varies considerably. Whilst the early maps of the Geological Survey concentrated on the Coalfield area (one-inch sheets 232 and 249), mapping by Walmsley (1959) of the Usk Silurian Inlier, and the publication of sheets 233 and 250 (1960 and 1958) of the Geological Survey One-inch series has contributed considerably to our knowledge of the structure and lithology of the pre-Carboniferous strata of the Vale of Gwent. For the area north of the Coalfield, including the greater part of the Black Mountains, the only published geological maps available are the 'Old Series' hand coloured sheets published in the late 19th Century, although McCaw, using unpublished work of the late Wickham King, has included in his thesis (M'Caw, 1936) a sketch map of the geology of the Black Mountains on a one-inch scale.

2. STRUCTURE.

In south-west Britain, three main lines of folding are evident, Caledonoid (NE/SW); Armoricanoid (E/W) and Malvernoid (N/S), and these are evident in the north, south and east of the Usk drainage basin respectively. The oldest of these is the Caledonoid, being the result of earth movements at the end of the Silurian, whilst the Armoricanoid and Malvernoid are the product of the Hercynian orogeny at the end of the Palaeozoic period.

During the Hercynian orogeny, two relatively stable blocks existed in this area, formed by the Towy anticline and the Malvern ridge, a north-south barrier of pre-Caledonian age. The intervening wedge of land was protected by these from severe folding during the Hercynian, and is today characterised by gently dipping and near horizontally disposed strata, mainly of the Old Red Sandstone Series. The structure of this area is shown in fig. 6 .

The South Wales Coalfield, immediately to the west of the Vale of Gwent is an Armoricanoid structure, elongated east-west. Essentially a basin structure with a number of minor anticlinal axes arranged <u>en echelon</u>, the south-facing scarp swings northwards near Risca to form the fine east-facing scarp overlooking the Vale of Gwent.

To the east of the Vale of Gwent lies the smaller Forest of Dean Coalfield, a structural basin which lies near to the intersection of the Armoricanoid and Malvernian folding axis, although the Malvernoid trend is dominant.

Separating these two Carboniferous basins is the Usk anticline, which culminates in a faulted pericline near the town of Usk, bringing up the Silurian strata of the Usk inlier, the outcrop of which is shown on fig. 5. This anticline, having a north-south Malvernian trend within the Vale, is considered by George (1955) to continue uninterruptedly into the Roath pericline near Cardiff, one of a number of east-west folds arranged _en echelon_ in the older strata of the Vale of Glamorgan. Although the major phase of movement responsible for this upfold was the Hercynian, George has shown that movement along this line can be detected before this, and suggests that the fold was significantly advanced in growth before the end of Carboniferous times. He points to the fact that on the Trellech plateau the Quartz Conglomerates

(Upper Devonian) transgress in places across the Brownstones to rest in one area on the sandstones of the St. Maughan's Group. On the west side of the anticline, overstep of the Carboniferous Limestone by the Millstone Grit (on the Blorenge near Abergavenny the Millstone Grit transgresses the whole of the Avonian Main Limestone, only the Lower Limestone Shales remaining), and the increasing thickness of the coal measures as traced south-west from the north-east of the field suggests not only the continued subsidence of the Coalfield basin, but movement also along an anticlinal zone to the east of the Coalfield.

In this one example we have seen that although for convenience we can date major folds by the orogeny in large measure responsible for them, movement along those lines was often recurrent over a long period of time. Upfold of the Palaeozoic rocks along the Usk anticline, associated as it was with faulting, created a zone of weakness exploited by streams, a process greatly accelerated with the uncovering of the marls of the Lower Division of the Old Red Sandstone Series.

In the Vale of Gwent, the structural picture is fairly simple with the Old Red Sandstone Series dipping off the anticline. Dips are greatest near the Usk inlier, the anticline being less pronounced in the north, reflected in horizontally disposed strata north of Llantillio Crosenny. Southwards the anticlinal axis approaches closer to the steeply dipping south crop of the coalfield, and steeper dips are present in the Old Red Sandstone, reflected in a number of narrow, elongated hills in the vicinity of Newport.

To the north of the Vale of Gwent the Old Red Sandstone shows a south-easterly dip away from the Towy anticlinal axis. The dip is low, generally in the region of 10-20°, although measurement is difficult due to false bedding. The merging of the two dips, westwards off the Usk anticline, and south-eastwards from the Towy anticline seems to occur about the Sugar Loaf in the south of the Black Mountains. Here the structure is complicated by the presence (so far not mapped in detail) of an extension of the Vale of Neath Disturbance, although the existence of a synclinal structure between Llangynidr and Pandy has been suggested by several workers (McCaw 1936; Clarke 1936).

The density of the faulting pattern would appear to vary according to the intensity of mapping, as can be seen from fig. 5, which shows details of the mapping of the Old Red Sandstone within the Vale of Gwent (faults shown on this map include those mapped as 'uncertain' on the One-inch map). The two recently mapped one-inch sheets (233, 250) show a complex pattern of faulting, whereas the western sheets (232, 249), during the mapping of which most attention was devoted to the Carboniferous, show few faults, apart from those mapped by Walmsley about the Usk Silurian inlier. This suggests that detailed mapping of the Devonian will reveal a fairly complex pattern of faulting, the nature of which we can at this stage only surmise.

In the area lying to the north of the Coalfield series of One-inch sheets little information exists regarding the faulting pattern, although morphological evidence suggests that some of the faults mapped in the Coalfield may continue across the Old Red Sandstone of that area. The alignment of a series of river captures and cols with the Vale of Neath Disturbance early suggested an extension of it north-eastwards into the Borderland, although an attempt was made to explain these in other ways, due to the difficulty of locating a major fracture in the drift encumbered valleys which mark its course (M'Caw 1936; and Clarke 1936). O.T. Jones (1951) first suggested this extension, and Tucker (verbal communication) claims to have traced it in a reconnaissance survey through to the Woolhope area of south Hereford. Its inclusion in many sketch maps (Pringle and George, 1945, 5; Anderson 1960) indicates the general acceptance of this major fracture crossing the southern part of the Black Mountains. The course of the Disturbance has not, however, been mapped in detail, although morphological evidence suggests (fig. 6) that it takes a more easterly line in its crossing of the Usk valley and southern part of the Black Mountains before returning to its former trend in its Herefordshire section.

The other major fracture zone which appears to continue from the Carboniferous Basin across Devonian country towards the Welsh Border is that of the Tawe or Cribarth Disturbance. Within the Coalfield, subsequent development along this line has resulted in the disruption of an earlier, southerly-trending drainage pattern (R.O. Jones, 1931). A continuation of this coincides with the straight, north-easterly trending section of the Wye between Llyswen and Whitney. Mr. T.R. Owen (pers. comm., 1966) is in no doubt as to the presence of a major fault zone between the upper Tawe and Wye, mapping by T.N. George revealing that it crosses the main Fforest Fawr watershed between Fan Gihirych and Fan Fraith, crosses the head of the Senni valley, and controls the line of the Tarrell valley below Craig Cerrig-gleisiad, passing under Brecon, and so into the Llynfi (Wye) drainage basin. The probable course of this disturbance is shown in fig. 11.

Along the north scarp of the Black Mountains M'Caw (1936) indicates the presence of six north-westerly trending faults including one aligned between the Wye gorge and Pengenffordd Pass above Talgarth.

Within the area of One-inch sheets 233 and 250 Welch and Trotter (1961, 7) indicate three main faulting lines (fig. 5):

1. north-south faults associated with Malvernian folding;
2. north-westerly faults: parallel to a similar group in the south Wales Coalfield;
3. east-west faults.

Of these, the north-south faults appear to be dominant in the Vale, probably reflecting the proximity of the axis of uplift.

Similar fault trends are evident in the Usk Silurian inlier (Walmsley, 1959, fig.8), the two most important faults, the Little Mill and Coed y paen faults showing approximately north-south trends, whilst an important series of faults on the S.E. margin of the inlier, whilst tending to radiate from the centre of uplift, show N.W.-S.E. trends (fig. 5).

3. LITHOLOGY.

a) Silurian.

The oldest strata of the area, the Silurian Usk inlier, has recently been investigated by Walmsley (1959). His mapping reveals that, contrary to previous opinion, there is no significant break in the Ludlovian succession of the area. The presence of the Ludlow bone bed was established, this being considered to form the base of the Devonian system. His succession for the area is (Table 1):

TABLE 1 .

THE USK INLIER: SUCC[redacted]ION AND CLASSIFICATION (AFTER WALMSLEY).

			Thickness in feet.
	DOWNTON SERIES (OLD RED SANDSTONE)		
	Red Marls		
	Speckled Grit Beds:	speckled grits, gritty sandstones and siltstones	25-50
	Ludlow Bone Bed:	friable quartz grit	0-4 ins.
	LUDLOW SERIES (SILURIAN)		1050-1300
UPPER	Upper Llangybi Beds:	siltstones with decalcified bands of rottenstone	20-25
	Middle Llangybi Beds:	flaggy calcareous siltstones	112-120
	Lower Llangybi Beds:	flaggy siltstones	16-25
MIDDLE	Upper Llanbadoc Beds:	flaggy calcareous siltstones	70-150
	Lower Llanbadoc Beds:	calcareous silt-stones with bands of limestone	180-280
	Upper Forest Beds:	flaggy siltstones	
LOWER	Lower Forest Beds:	soft calcareous muddy siltstones	650-700
	WENLOCK SERIES (SILURIAN)		at least 800
	Wenlock Limestone:	massive and nodular limestones	0-40
	Wenlock Shale:	soft calcareous mudstones and micaceous sandstones	at least 800

In terms of relief the most significant of these beds are the Wenlock Limestone and the Lower Llanbadoc Beds. The Wenlock Limestone outcrop is coincident with the ridge of higher ground forming the water parting between the Berthin Brook and the Sor and smaller streams draining the southern half of the inlier. The Lower Llanbadoc Beds were mapped by Walmsley jointly with the underlying Upper Forest Beds, there being no easily defined boundary between the two. The outcrop is marked by prominent hill areas, ranging from Clytha, Trostrey and Llancayo Hills in the northern part of the inlier, to the block of high ground north of Llandegfedd, in between forming the face of the hill slopes overlooking the Usk about Llangybi. The outcrop is buried beneath the alluvium at Usk but is exposed in the cliffed and steepened valley slopes either side of the river between Llanbadoc and Llancayo. The remaining beds are either weakly resistant, tending to occupy low-lying areas, or the outcrop is so limited in extent that the effect on relief is insignificant. Of the former, the Wenlock Shale, outcropping in the central part of the inlier, might be singled out as it forms an extensive area of generally low lying ground extending from Kemeys Commander across the lower Berthin valley into the embayment occupied by the Royal Ordnance Factory at Glascoed.

b) Devonian.

Succeeding the Silurian is the Old Red Sandstone Series of the Devonian. This outcrops over the greater part of the area of study, and therefore will be considered in some detail. Unfortunately, partly on account of the great extent of the outcrop, no general account of the stratigraphical succession is available for this area, although certain problems associated with the series have received attention. Two main problems stand out:

1) the fixing of the base of the Old Red Sandstone Series, which in this area is not marked by an angular discordance.
2) the correlation of the succession of the series between different parts of the outcrop.

The latter problem arises largely due to the conditions which prevailed during the deposition of the Old Red Sandstone. During Silurian times a shelf sea environment prevailed, but the earth movements at the end of that period (Caledonoid) gave rise to entirely different conditions in which deposition occurred of deltaic, lacustrine and fluviatile sediments. The Devonian sediments accumulated in a basin which has been referred to as the Anglo Welsh Cuvette (Pringle and George, 1948, 44). This was flanked on the north-west by the recently elevated mass of St. George's Land, the source of much of the sediment accumulating in the cuvette, and some sort of barrier probably lay along the line of the present Bristol Channel, as the marine facies of the Devonian which accumulated in the area of the south-west Peninsula at this period is strikingly different as regards both its lithology and fauna. Renewal of orogenic movement after much of the present Old Red Sandstone had been deposited is revealed by an unconformity, and the increasingly 'marginal' nature of the deposits of the upper Old Red Sandstone, due to the re-elevation of St. George's Land and the proximity of the shoreline (Pringle and George, 1948, 46).

In the West Midlands the Devonian succession was the subject of many years of study by the late Wickham King, who recognised the following subdivisions:

FARLOVIAN	(Upper Old Red Sandstone)
BROWNSTONES	
DITTONIAN	(Lower Old Red Sandstone)
DOWNTONIAN	

(The right hand column shows the current terminology of the Geological Survey. It has since been proposed by Croft (1953) that the Brownstones should be referred to as the Breconian). King extended this work into the Black Mountains, although this was never published. As noted earlier however, M'Caw (1936) utilised King's unpublished work in the compilation of a one-inch sketch map of the geology of the Black Mountains. In the south various workers have studied the Old Red Sandstone Series of the Cardiff district, but only recently have detailed maps become available of the outcrop in the eastern part of the Vale of Gwent (Geological Survey sheets 233 and 250). The succession as described for the Chepstow Sheet (Welch and Trotter, 1961) will be accepted as a basis for comparison with the succession of the Brecon Beacons and Black Mountains.

In the Chepstow and Monmouth area the Survey (Welch and Trotter, 1961, 28) recognises the following subdivisions of the Old Red Sandstone:

TABLE 2 .

SUCCESSION OF THE OLD RED SANDSTONE SERIES

IN THE CHEPSTOW AND MONMOUTH AREAS.

	Thickness
UPPER OLD RED SANDSTONE	
Tintern Sandstone Group	240-500 ft.
Quartz Conglomerate	10-100
Unconformity	
LOWER OLD RED SANDSTONE	
Brownstones	2200-275
St. Maughan's Group	1250-1450
Raglan Marl Group	1500-1700
Downton Castle Sandstone	50

Regional Description.

a) The Vale of Gwent and Periphery.

A map of the Devonian strata of the Vale of Gwent is shown in fig. 5. The Downton Castle Sandstone has a very limited exposure where it forms a faulted outcrop ringing the Silurian inlier. The Raglan Marl Group follows this and is, as its name implies, largely made up of marls with, however, a tendency to sandiness. There are also, at the top of this division, limestone bands known as the Psammosteus Limestone, and thin bedded sandstones which give rise to ridges. Normally, however, the Red Marl is marked by low lying areas and exposures are limited. In the Vale the Olway Brook is exploiting the Marl exposure, whilst sandstones form low escarpments facing the Usk anticline about Cefntilla.

Succeeding the Raglan Marl is the St. Maughan's Group, which is a series of interbedded marls and sandstones, with frequent developments of conglomeratic cornstones. This group forms the face of the Wentwood/Trellech Plateau scarp, and swings round into the North Monmouthshire Uplands north of the Troddi. The summit of the Trellech Plateau and the Wentwood Ridge is formed of the resistant Brownstones. These are purple grey micaceous sandstones, with occasional marl bands, and correspond to the combined Brownstones and Senni Beds mapped in the west (Welch and Trotter, 1961, 34).

The Upper Old Red Sandstone lies unconformably on the Brownstones, overstepping them so that at Cwmcarvan, south of Monmouth, they are in contact with the St. Maughan's Group. The base is formed of a Quartz Conglomerate bed, whilst the Tintern Sandstone above is of mainly soft, buff-yellow sandstones with subordinate marl and pebble inclusions. The greatest extent of the latter is to be found flanking the incised valley of the lower Wye.

Correlation of the Geological Survey mapping to the west of the Vale with that outlined above is not easy, due to the different division of the series which has been adopted for the two sets of sheets. The classification adopted for the earlier sheets (232 and 249) is:

	Thickness (Abergavenny area)
Quartz Conglomerate Group	120-150 ft.
Red Sandstone Group	1,200 ft.
Red Marl Group	2,800 ft.

An attempted correlation of the divisions utilised in the two sets of sheets is shown in Table 3 :

TABLE 3.

EQUIVALENCE OF GROUPS RECOGNISED IN THE MAPPING OF THE OLD RED SANDSTONE IN THE VALE OF GWENT.

West (Sheets 232 & 249)	East (Sheets 233 & 250)
	UPPER O.R.S.
	Tintern Sandstone Group
Quartz Conglomerate	Quartz Conglomerate
	LOWER O.R.S.
Red Sandstone Group	Brownstones
Red Marl Group	(St. Maughan's Group (Raglan Marl Group (Downton Castle Group

The Red Marl Group of the west includes the series now divided into the Downton Castle, Raglan Marl and St. Maughan's Group. That the characteristics of these three groups is also present in the west is indicated by Robertson (1927, 12) who refers to a grey sandstone at its base "probably corresponding to the Downton Castle Series", and notes that in the higher beds of the division, especially the highest 500 feet both sandstones and cornstones become more numerous, and form a gradual passage upwards into the Red Sandstone Division. The Red Marl division typically shows dark red mudstones with micaceous sandstones interstratified, and cornstones forming prominent ridges and low scarps. This division covers the whole of the Vale below about 600-700 feet.

Above the Red Marls, the Red Sandstones correspond to the Brownstones of the east. As in the east (Welch and Trotter, 1961, 33) it comprises the Brownstones and Senni Beds, although this division is apparently more marked in the west of the Vale. Due to the absence of any 'mappable line' this distinction has not been made on the two eastern sheets, whilst in the west, although the distinction was noted in the accompanying monograph, the division is not marked on the map. The lower division, the Senni Beds, is a flaggy formation with shale or mudstone partings and frequent occurrences of conglomeratic cornstones. The upper division, the Brownstones, are massive and gritty, and cornstones are uncommon. This group is exposed along a narrow band forming the face of the Coalfield scarp, the exposure widening northwards. The uppermost division, the Quartz Conglomerate Group shows the slightest development, being only 120-150 feet in thickness, and outcropping immediately below the Carboniferous Limestone, usually along the crest of the scarp. It is formed of Quartz Grits and conglomerates, associated in places with red or greenish shale.

b) Middle Usk Valley, Brecon Beacons and Black Mountains.

An account of the Old Red Sandstone in this area is difficult to present owing to the varying classifications which have been adopted, and the absence of reliable mapping. However, the following correlation between the Brecon Beacons and Black Mountains may be suggested for our purposes:

TABLE 4.

CORRELATION OF GROUPS RECOGNISED IN THE OLD RED SANDSTONE SERIES OF THE BRECON BEACONS AND THE BLACK MOUNTAINS.

BRECON BEACONS	BLACK MOUNTAINS (Based on M'Caw, 1936, after Wickham King).
UPPER OLD RED SANDSTONE	
Grey Grits	
Quartz Conglomerate	Farlow Sandstones
Plateau Beds	
LOWER OLD RED SANDSTONE	
Brownstones* } Senni Beds }	Brownstones
Red Marls	{ Dittonian { Downtonian

* The Division between the Lower and Upper Old Red Sandstone is not always marked by a clear unconformity, and in Breconshire, unlike in the Chepstow area (p.32), the Brownstones follow the Senni Beds without a recognisable stratigraphical break, whilst marine fossils of Upper

Devonian age have been found. The junction therefore appears to lie within the Brownstones. For convenience, however, we will consider the Brownstones as part of the Lower Old Red Sandstone.

The youngest beds of the Old Red Sandstones, the Grey Grits and Quartz Conglomerates, which are the equivalent of the Quartz Conglomerate division recognised in the eastern part of the Coalfield, only outcrop to the south of the main Fforest Fawr scarp, the tabular crests of the Beacons being formed of quartzitic conglomerates of the Plateau Beds. In the Black Mountains, however, the Farlow Sandstones (Upper Old Red Sandstones) underlie the Carboniferous outlier on Pen Cerig Calch and cap the interfluve for over three miles to the north of this.

Formed of resistant flags and conglomerates, the Brownstones are by far the more important, outcropping over the highest ground of the area. They form the face of the Beacons escarpment, and cover most of the area above 1,500 feet in the Black Mountains. The combined scarps of the Beacons and Black Mountains (Black Mountains/Fforest Fawr ridge) marks the north westerly limit of the Brownstone exposure. Their absence from Mynydd Eppynt is in large measure responsible for the lack of distinctiveness of that region. King's Brownstone division in the Black Mountains appears to include both the Brownstones and the Senni Beds of the Beacons. The Senni Beds are greenish or dull red sandstones and micaceous flags which outcrop at lower elevations in the tributary valleys of the Usk to the south and east of Brecon.

The Red Marl of the Beacons is divided into the Dittonian and Downtonian according to King's classification of the Old Red Sandstone in the Black Mountains. Primarily unresistant marls, but with important sandstone and cornstone bands, they cover much of the low ground of the Usk Valley, the Llangorse Basin, Wye Valley, and the dip slope of Mynydd Eppynt. In the Black Mountains the succession is known in some detail. We may note in particular the Ischnacanthus zone of thin sandstones which forms the low and broken scarp flanking the Wye between Aberllynfi and Hay, and the Psammosteus Limestone which forms the prominent second scarp traceable all around the north of the Black Mountains, and as far east as the vicinity of Llangorse.

The base of the Old Red Sandstone is not exposed in this area: the lower Downtonian is not present in the Black Mountains, and the Tilestones, below the Red Marls of the Brecon area are exposed well to the west at the foot of the Eppynt scarp.

c) Carboniferous.

The Carboniferous strata of the Coalfield plateau is significant only in so far as it forms the western boundary to the area under study, and ice moving off it has contributed Carboniferous material to the drifts of the Usk Valley. It will not, therefore, be considered in detail in this section.

CHAPTER 4.

PRE-PLEISTOCENE DENUDATION CHRONOLOGY OF THE USK DRAINAGE BASIN: SOME THEORIES AND COMMENTS.

The Usk cuts through the pronounced Fforest Fawr - Black Mountains scarp of the Brownstone division of the Old Red Sandstone, neglecting an easier, lowland exit into the Wye across the Llangorse Basin. The reason for this is not clear. One of the earliest workers to consider this problem was Ramsay (1873) who, outlining his earlier theory (1872) that the Welsh plateau was planed by marine agencies, suggested that the Usk was initiated on a planed surface on which the Old Red Sandstone extended much further west, and the present bold form of the Fforest Fawr/Black Mountain scarp has been due to scarp retreat in the direction of dip.

Theories of drainage evolution in Wales have, however, generally invoked an early consequent drainage superimposed from a domed cover of Cretaceous strata, and thus the general discordance of the Usk to structure has tended to be regarded as evidence of its early consequent origin. Thus in his book, Britain and the

British Seas (1902), Mackinder pictured the Wye as once tributary to the Usk, its middle course along the foot of the north scarp of the Black Mountains being a more recent subsequent development. This interpretation was more recently upheld by Rice (1957) and Brown (1955) who shows the upper Severn/upper Wye/Usk as an important member of the original consequent stream pattern, but with a pronounced variation in trend from the other consequent elements of the drainage pattern (as for example, the Black Mountain, or Eppynt/Coalfield rivers). The main line of evidence used by Brown in suggesting this is the way in which platform remnants of his High Plateau, and Middle and Low Peneplains penetrate along the shoulders of the present valley. One major objection to the theory that the Usk is a remnant of the original consequent pattern is, however, the extremely constricted form of the middle Usk, contrasting markedly with its more open headward section.

An alternative theory, proposed by Miss Dewhirst (1930) considers the middle Usk to be a relatively recent development, capturing the upper Usk formerly tributary to the Wye. She explains this early north-easterly trending drainage by suggesting that the Fforest Fawr/ Black Mountains Upland projected above the deposits laid down in the Cretaceous Seas, so that when the radial drainage was initiated following domical uplift, the consequents were deflected (in this case north-eastwards) along the foot of the highest mountain masses. In many respects this is an attractive theory, explaining in particular the pronounced north-easterly trend of the right bank tributaries of the Usk between Brecon and the Llanddetti gorge (fig. 2). The main objection to this theory was the explanation of the later breakthrough by the Usk of the Fforest Fawr-Black Mountains highland to effect capture. Miss Dewhirst (1930) explains this as due to erosion of a stream cutting back along a line of weakness at a change in the mountain line, or perhaps due to its greater volume, having numerous tributaries. This theory was supported by M'Caw (1936) who further suggested that the original valley might be marked by the col at Bwlch (and thence into the lower Rhiangoll near Tretower, the present gorge course through Llanddetti and Llandynidr being a Pleistocene development.

Other writers, approaching the problem less directly, have reconstructed consequent stream systems crossing the

Fforest Fawr divide, thus implying a later, subsequent development to account for the course of the upper Usk. George (1942), for example, suggests that the initial consequents were captured by the Usk eroding as a strike stream along weakly resistant Red Marls at the foot of the Brownstones escarpment, but this does not, of course, account for the section of the Usk downstream of Brecon which is transverse to the strike.

If elements of the drainage pattern which appear to be determined by faults and other lines of weakness are regarded as more recent developments, many of the original consequent streams must have had larger drainage areas than they now possess. In the case of the Usk, if it is considered to be an old-established stream, its upper drainage basin has been progressively reduced by the development of subsequents by the Wye and Towy. Richardson (1909) was one of the first to point out the piracy of the Irfon working along the weak rocks exposed in the Towy anticline, although O.T. Jones (1924) in his study of the Towy does not appear to have considered the piracy by that river of Usk headwater streams. T.N. George (1942), however, has explored in detail the relationships of the Irfon and Towy drainage with that of the upper Usk, and concludes that they once formed one major drainage system crossing the site of the present Eppynt scarp. He recognised two stages of base levelling affecting this larger system, the Ffos Tarw and Nant Stalwyn stages. The former can be traced from the Irfon to its former confluence with the Usk at Sennybridge, and extrapolated to a base level of 830 feet at Abergavenny where George considers the contemporary shoreline to have been. At the Nant Stalwyn stage capture of the Irfon had been achieved by a Wye tributary, but upper Towy tributaries can be extrapolated to a base level of 583 feet at Abergavenny.

In its middle section the Usk appears to have suffered due to the encroachment of Wye tributaries in the southern half of the Black Mountains, although this has been made up to some extent by the piracy of its own tributary, the Clydach, which has deprived the Afon Llwyd and Ebbw Fach of their former headwaters (Strahan and Gibson, 1900).

An early reference to the Black Mountains captures is that of Howard (1903), but the first paper to deal in detail with it is that of Clarke (1936). Unable to produce evidence of structural guidance to account for the capture of the Honddu by the Monnow and the Grwyne Fawr by the Grwyne Fechan, Clarke devises a novel origin for the piratical stream elements, all of which have a NE/SW trend (or <u>vice versa</u>), regarding the "St. Devereux/ Crickhowell Vale" in which they flow as a "superimposed subsequent valley", by the rapid incision due to uplift of a subsequent vale developed in a former rock cover. In his thesis, M'Caw (1936) also examined this vale and suggested that "its comparative straightness and anomalous direction indicate a structural element in its formation", although he was unable to prove structural control, suggesting that the deep dissection of its eastern end has probably been the result of faulting, whilst the transverse valleys between the Monnow and Usk are "due to a superimposed drainage formed when the minor fold north of the Sugar Loaf was concealed by later deposits and partially abandoned when differential erosion revealed its structural formation". Nevertheless he suggested that the Grwyne Fawr and Fechan may originally have had courses over the col at Bettws (into the Gavenny valley) and the shoulder at Bellfountain (east of Crickhowell) respectively, which graded to Miller's

Forest of Dean plateau level (Miller, 1937), and that capture followed the partial development of a 700-750 ft. stage of peneplanation.

The Black Mountain captures are now thought to be the result of erosion along a prolongation of a Vale of Neath Disturbance. This was first suggested by O.T. Jones (1951), who further linked phases of capture with the 400 and 600 ft. base levels evidenced by platforms traced at this level around the South Wales coast. The existence of this fracture belt is now generally accepted, although it still requires detailed mapping (see p. 23).

Minor changes in the drainage pattern also took place in the Vale of Gwent, an area which today shows an ill-defined watershed between the Usk and Wye drainage basins (Welch and Trotter, 1961).

In Scotland, anomalous drainage patterns have been explained by Linton as due to the erosive effects of diffluent ice masses (Linton, 1949). The possible application of this theory to explain certain features of the Middle Usk will be considered in a later chapter. The effect of glaciation has in general been neglected by workers investigating the denudation chronology of south-east Wales on the assumption that the Pleistocene Glaciation did not significantly alter the pre-glacial valley pattern. The case for this will be considered later in this thesis.

Reference has already been made to the coastal platforms of south Wales, which were the subject of a number of papers in the thirties (North, 1929; Truman, 1929; Goskar and Trueman, 1934; and George 1938). In the post-war years the lower ones in the Vale of Glamorgan were carefully mapped by Driscoll (1953), and the "600 foot platform" has been traced around the whole of the Welsh coast by Brown (1952). In this respect the area of weak rocks within the Vale of Gwent have been a major problem, and it is noticeable that Brown makes no attempt to trace the 600 foot platform further east than the eastern interfluve of the Ebbw at Risca, although his mapping of the higher surfaces (Brown, 1955) extends eastwards to include the Forest of Dean. This may indicate paucity of evidence,for Miller (1935), although able to trace remnants of a 400 ft. and a 150-200 ft. platform by the use of the generalised contour technique on the dip slope of the South Monmouthshire Hills, shows no trace of any benching at the 600 ft. level. The problem is whether the sea at the 600 ft. level (the 600 foot platform is now termed the Calabrian shoreline as a result of its proved connection with Red Crag deposits in the east of England (Brown, 1960)) invaded the Vale of Usk. No evidence has yet been produced of this, although the last remnants mapped by Brown appear to be shaping to swing north along the base of the Coalfield scarp. In discussion with the writer, Brown suggested that this might be so, citing the superimposition of the Usk over the Silurian inlier as possible evidence (i.e. superimposition from a southerly-sloping platform of marine erosion), whilst George (1942) has suggested that a shoreline at the 835 and 580 feet levels might have lain in the Abergavenny area.

No detailed work was carried out on drainage evolution and erosion surfaces, although an early reconnaissance revealed the Vale of Gwent to be singularly unproductive in this latter respect. Nevertheless, two comments might be made concerning the previous work catalogued above:

1. <u>The Drainage Pattern.</u>

The age and origin of the Usk is obviously of vital importance to an understanding of the denudation chronology of the area. In fig. 7 an attempt has been made to classify, quite objectively, the main elements of the drainage pattern. It can be seen that the majority of the larger rivers are made up of segments having one of two predominant trends: south-easterly and southerly, whilst a third trend, south-westerly seems to be associated with streams showing a degree of adjustment to structure, as important fault lines and strike lines within certain areas conform to this trend. The south-easterly trending segments have usually been interpreted as relics of the original consequent systems, and the recurrence of this trend, combined with its obvious discordance with structure seems to be strong support for this. The second, southerly, trend whilst not as evident as the former, forms nevertheless a significant element of the drainage pattern. This series of southerly trending streams has, however, received scant attention from most workers. Clarke (1935) noted the north-south trend of parts of the Black Mountains' drainage, and suggested that it resulted from a southerly tilt (probably Miocene) which disrupted a pattern of earlier, south-easterly flowing consequents. Similarly, R.O. Jones (1938) noted the north-south stretches of many of the Coalfield rivers, and suggested that warping with a southerly inclination occurred here during uplift. The southerly trend is however evident over a larger area than just the Coalfield and Black Mountains. Perhaps the most significant stretch is that of the Wye in its intrenched section between Monmouth and Chepstow, although parts of the lower Usk show a similar trend. No evidence has been produced of capture by south-flowing streams rejuvenated by a tilt in that direction, although the alignment of the south-easterly flowing segments suggests disruption of an early south-easterly consequent system. This could only have arisen as a result of warping, as no structural control is present. Jones suggests differential warping, but in view of the occurrence of north-south and N.W.-S.E. aligned elements in the same area, two distinct periods of uplift with successive south-easterly and southerly tilts seem most likely. It is not unlikely that these could be linked with the post-Cretaceous and late Miocene/early Oligocene earth movements respectively proved in the south-east of England (Brown, 1960), particularly as the axis of folding accords with the postulated directions of tilt.

Three phases may therefore be distinguished in the evolution of the river system:

1. initiation of a consequent south-easterly trending drainage (probably on a Cretaceous cover);
2. tilting to the south, and partial disruption of the earlier system by piracy of left bank tributaries;
3. exploitation of structural weaknesses by subsequent streams resulting in river capture (for which evidence is usually available - especially cols and misfit streams).

Interpreted in this way, the Usk appears to have had a complex origin, as befits its present compound form, and is not considered to have existed as a unitary stream from an early date. It seems to be composed of parts of two initial south-easterly trending consequents:

1. the Honddu-Usk (Brecon to Llanddetti)-Ebbw Fawr;
2. the Rhiangoll-Usk (Crickhowell-Llanover-Llanllywel) -Cas Troggy Brook.

Linking up the disparate members to

form the present upper Usk resulted from:

1. development of a strike stream west of Brecon, intercepting the Mynydd Eppynt/ Coalfield consequents;
2. development of a left bank tributary along the line of the Vale of Neath Fault to intercept original consequent (1) above. The exact line of this fault where it crosses the Usk valley is not known, and as can be seen from fig. 6 this section diverges slightly from the supposed line of the fault. It does appear, however, to be a more acceptable theory than any previously advanced.

In that section of the Usk where it crosses the Vale of Gwent piracy has resulted in partial disruption, whilst the original south-easterly trend appears to have been lost in one section due to subsequent adjustment to structure:

a). The original south-easterly trending consequent (Abergavenny-Llanover-Llanllywel-Cas Troggy Brook) was disrupted by capture by the growth of a north-south trending stream south of Usk. Capture must have been at a very early stage in view of the absence of any marked windgap at the head of the valley of the Ces Troggy Brook. The north-south stream below Usk is likely to have flowed over the Wentwood Ridge on the site of the present Catsash Col (although not at the level of the present col, the bottom of which is far too low and constricted to have functioned in this way). The part of the Usk between Malpas and just below Newbridge appears to be structurally controlled, and is probably a recent addition to the Usk system. After capture of the proto-Usk which crossed the Wentwood Ridge, the lower part of that stream (as shown by river terraces in the Tredunnock area) has shifted south-easterly, becoming progressively more accordant with strike, and assisting in the lateral displacement of the river between Usk and Newbridge. The reason for the sharp bend of the Usk southwards to the Severn at Newport is unclear, but this section too has a marked southerly trend.

b). The north-south section between Clytha and Kemye Commander can be shown to be structurally controlled. Walmsley's mapping (1959) of the Silurian inlier shows that its western margin in this area is fault-bounded. The right angled bend in the course of the Usk appears to have enlarged progressively as the fault was exploited. River erosion is today most noticeable on this bend, and the tendency of the river to grow in a northerly direction along the fault is continuing.

Interpreted this way, the river is seen to have emerged as a major stream by the linkage of parts of earlier consequent rivers disrupted by subsequent stream development. The sequence of suggested river diversions is complex, but the problem posed is a difficult one, unlikely to be simply solved.

It should be stressed that the comment made on the origin of the present drainage pattern is not based on field work but on map analysis, combined with an understanding of the terrain. The writer does not accept the view that there is no place for comment of this nature, although the worth of any hypothesis must clearly be tested in the field.

2. Course of the 600 foot (Calabrian) Shoreline.

As outlined earlier, Brown has traced the Calabrian shoreline as far east as the flanks of the Ebbw valley at Risca, although Miller (1955) indicates no trace of benching at this height on the south-facing slopes of the South Monmouthshire Hills east of Newport. No work has been carried out on the continuation of this bench into the lower Severn Valley, so that its continuation across the Usk from the mapping of Brown around the Welsh massif would seem to be quite critical. In this way a link might be established between the shoreline feature mapped at this height over much of the south of England and the south-west peninsula. First observations suggest, however, that the tracing of the marine bench around the flanks of the Severn valley is likely to prove difficult due to the presence of extensive tracts of weakly resistant rock, combined with the effect of glacial invasion during the Pleistocene.

In the lower Usk the problem is whether or not the Calabrian shoreline entered an embayment over the Vale of Gwent, or whether the Forest of Dean formed an island in this sea, the main shore of which ran north along the eastern scarp face of the South Wales Coalfield. Today a belt of low ground extends from the Vale of Gwent into the Plain of Hereford, but it is difficult to determine the amount of recent denudation that has occurred.

The evidence for a marine incursion within the Vale is slender: the fact that the segments of this shoreline mapped by Brown appear to be shaping to enter the Vale, and the superimposition of a north-south stretch of the Usk across the Silurian inlier. As noted earlier, the later trend is a common one in this area, and could be the result of an early tilt in this direction, whilst the river is to some extent structurally controlled (north of Kemeys Commander, fig. 5).

Cartographic analysis of the Ordnance Survey sheets covering the Vale of Gwent (including altimetric frequency analysis) proved to be singularly unrewarding, and field examination of the interfluve between 550 and 750 feet along the Wentwood Ridge, thought to be the most likely area for remnants of this surface to have survived, failed to reveal any benching.

On the other hand it seems perfectly reasonable to suppose that a marine incursion at the 600-foot level took place within the Vale. The Usk anticline has brought up relatively weak strata here, and overstep of the Old Red Sandstone and Silurian strata by the Trias in the Cardiff area shows that there erosion of this anticlinal zone in immediate post-Carboniferous times was severe. O.T. Jones (1930), considers that it was likely that the sharp rise of the hills between Newport and Chepstow was "a line of cliffs on the Trias plain of denudation", implying that the Vale of Gwent was not a significant feature at that stage. If, however, we examine Brown's map of the Calabrian shoreline it will be seen that it enters the majority of the present day indentations around the Welsh massif, and there seems to be no reason to suspect that the Vale of Gwent is of particularly recent creation. The Lower Towy, shown by George (1942) to be of largely recent (subsequent) origin, eroded in weak strata, was, according to Brown's mapping entered by the sea at this level. The wide spacing of the main drainage lines in the Vale (fig. 2), (the closely spaced south-easterly consequent drainage of the uplands to the north and west cannot be traced across the Vale, although a closely spaced drainage pattern again asserts itself on the south face of the Wentwood Ridge) suggests a degree of drainage simplification, possibly due to abstraction, at an early stage which would suggest the blocking out of the Vale as a physiographic unit well before the Pleistocene.

From the admittedly meagre evidence outlined above, it is considered that the Calabrian shoreline swung north along the western edge of the Vale. The paucity of evidence is put down to the general weakness of the local rock formations (all of the hills which rise to the 600/650 level within the Vale - none project above it - are to be found on the relatively resistant strata of the Usk inlier), and to the effect of glacial modification.

The possible course of the shoreline was investigated by extracting from the O.S. One-inch maps the area of land lying between the 600 and 700 ft. contours (fig. 8). With the safe assumption that no recent warping has occurred, this diagram will at least indicate the area which formed land at that period, as Brown (1952, 304) states that the run of the coastline feature "is found between 650 and 700 feet with a marked tendency towards the upper limit". Fig. 8 shows that a large part of the Trelleck Plateau and Wentwood Ridge rose above, although the Forest of Dean Plateau to the east shows extensive planation at this level.

In the north of the Vale the North Monmouth Uplands ranging from the Skirrid in the east through Graig Syfyrddin to Garway Hill indicate an eastward swing of the shoreline, and it is noticeable that the 600/700 ft. zone shows an appreciable broadening here (as compared, for example, with the north-facing slopes of the same ridge). There is, however, an area of lower ground between this hill belt, and the isolated hill mass near Welsh Newton, north of Monmouth, and it is possible that this is the result of recent erosion, the Calabrian shoreline swinging round to complete an embayment, the Forest of Dean/Trellech Plateau areas being joined to the Welsh mainland by a belt of high ground along the lower Monnow. It seems unlikely that the Calabrian sea penetrated much farther inland in this area, despite the fact that much of the Plain of Hereford now lies below the 400 ft. contour.

It is suggested, therefore, that the Calabrian shoreline swung north along the eastern scarp of the South Wales Coalfield and North Monmouthshire Uplands, and swung south along the west face of the Trellech Plateau. The Forest of Dean might have formed an island at this stage, although it is considered unlikely. Marine erosion might have affected the higher parts of the Bettws Newydd and Llandegfedd Hills, which rise to just over 600 feet, but there has clearly been considerable modification as a result of glacial invasion during the Pleistocene. This would account for the absence of evidence of planation (at this and other levels) within the Vale of Gwent generally, whilst the deepening of the Vale in the Pleistocene has clearly been influenced by the extensive areas of soft-rock outcrops.

CHAPTER 5.

GLACIATION:

AN OUTLINE OF PREVIOUS WORK IN THE AREA.

The first significant reference to the drift deposits of the area was made by Ramsay in 1846, but as the glacial theory was a newcomer to Britain at that time, in accordance with established thinking (North, 1943), it was considered by him to be the relics of "the old sea bottoms".

Symonds, twenty years later (Symonds, 1861) is also unable to completely rid himself of the old Diluvial theory, for he, in his discussion of the drift deposits of a wide area maintains that the land was submerged beneath the sea at some former time, a sea which was traversed by bergs and floes as far south as Austria. Doubt as to the truth of this is obviously present, for he goes on to qualify this, saying that "no amount of ice floes could, I feel satisfied, effect the works we have to account for", but nevertheless states that he was "convinced that the greater part of this part of England and South Wales (i.e. the valleys of the Severn, Avon, Wye and Usk) was underneath the sea during some part of the glacial epoch. The drift of the area he divided into:

(a) high level drifts of marine origin;

(b) low level drifts, estuarine in origin (i.e. relics of broad rivers which flowed some 30-40 feet above those of the present).

Of the latter, he quotes an example from the Brecon area, where he mentions a deposit of well stratified gravel and sand 60-70 feet above the Usk at Heol hir, south-east of Llanfaes.

By 1872, with the publication of his book 'The Record of the Rocks', the Rev. Symonds seems to have finally abandoned his theory of an incursion of the sea to explain the origin of the drift deposits of the Brecon Beacons. He states (p.246): "The summit the Brecon Van is somewhat precipitous on the northern slope where the rocks rise in a bold escarpment from the coomb which we have no doubt was once filled with the ice of a small glacier which stretched for a considerable distance down the Vale. Indeed, everywhere around these hills there are vast masses of angular local drift which have been swept down by land-ice and snow, those effective agents, which throughout a long period transported large boulders and lodged them at high levels and low levels along the flanks of the hills and against the sides of the valleys, so as in some instances to form moraines." This is followed by a description of erratics at Buckland and in Glan Usk Park, and the "Old River Drifts" and "Boulder Drift" of the valley around Abergavenny: "vast quantities of glacial detritus which nearly filled the valley before it had been scooped out by river action".

The geologist Melarde Reade visited the Brecon area at the end of the last century and published the observations which he made at the time (Reade, 1895). In particular he examined and produced a plan and cross section of Llyn Cwm Llwch, the corrie under Corn Ddu in the Beacons. He noted that the moraine and lake lie under the steepest cliffs "which are so disposed that the sun's rays are shut off at that time of the day when they are most powerful". Nevertheless, he could not accept that the corrie was wholly of glacial origin, although admitting that it would be "folly to deny" that ice has had an influence in modifying the forms of these "semicircular escarpments". The other evidence of glacial action in the Brecon area obviously did not impress him although he concludes that despite the absence of distinct ice markings, there is little doubt that these valleys have at one time been filled with glaciers.

The first systemmative survey of the drift deposits of the area was contained in the Geological Survey Reports covering the one inch Sheets 249 (Newport) and 233 (Abergavenny), published in 1899 and 1900 respectively (Strahan, 1899; Strahan & Gibson, 1900). A second edition of these reports, with the section on superficial deposits unaltered was published in 1900 and 1927. The one-inch maps, subject of these reports, were the first to show the drift distribution in the area. The Geological Survey drift mapping contained on these sheets is shown in fig. 9 . The main conclusions of the reports were:

1. that a glacier passed along the Usk valley, and the main ice parting (i.e. between the Usk and Coalfield ice) corresponded closely with present day water parting: in particular, the escarpment of the Carboniferous Limestone from Llangynidr eastwards formed an insuperable barrier to the movement of ice southwards out of the Usk valley;

2. the deposits could be divided into boulder clay and sand gravel, although "there is a perfect gradation from one to the other". Two 'general laws' were stated: firstly that the boulder clay prevails near to the source of the ice flow, whereas the sand and gravels developed where the ice foot lingered. Secondly, the sand and gravel is developed best in the present valleys, which "must have been the main line of the effluents formerly". In general, the drift of the Usk valley was predominantly of the sand and gravel type, whilst that of the Coalfield valleys to the west was largely boulder clay.

3. the edge of the drift sheet could be defined. In the Usk valley it spread south as far as the Berthin Brook, and eastwards as a lobe up the Clawdd Valley, whilst in the Ebbw valley it spread southwards into the suburbs of Newport and became merged into an extensive drift deposit flanking the northern margin of the Wentloog Level. In contrast, the drift is poorly developed in the Afon Llwyd, probably as a result of ice starvation due to the diversion of the ice at its head (from the main ice parting) by the

deep gorge of the Clydach. Beyond this main drift sheet are a number of elevated gravel patches, flanking the lower Afon Llwyd valley, and on the north bank of the Usk at Caerleon.

In addition, the presence was recorded of small corries notching the eastern face of the Coalfield scarp, and the existence of a gravel fan where the Ebbw debouches onto the Levels. Attention was also drawn to the buried channels of the river mouths, earlier noted by Codrington (1898), and the presence of a persistent gravel layer under the town of Newport.

These reports were undoubtedly a very substantial contribution toward the glacial history of the area, and no doubt partly as a result of their stimulation, a series of papers, mainly localized studies by amateurs, made their appearance in the regional naturalist societies' journals at about the turn of the century.

Papers published in the Transactions of the Cardiff Naturalists' Society, for example, dealt with the glacial features of parts of south-east Wales. Howard, in 1900 was the first to point out the anomalous position of Llangorse Lake, so close to the Usk, and yet draining north-eastwards to the Wye. The lake, he stated "lies partly in a rock hollow and is partly held up by an accumulation of glacial debris and of stream deposits at the outlet end". By contrast, the anomalous valley in which the lake was situated was, he suggested, due to capture by a Wye tributary cutting back along the strike. Howard contributed the first detailed discussion of the drift deposits to the north of the Coalfield (Howard, 1903): Keeping's paper of 1881 had been concerned mainly with the area in the hinterland of Aberystwyth. He was particularly interested in the relationship of the ice of the Wye and Usk valleys. The Wye ice, he concluded as a result of the study of erratics, crossed the Eppynt, but did not surmount the north scarp of the Black Mountains, except at the low pass at the head of the Rhiangoll valley, and west of Llangorse basin. Ice also spilled into the Usk from the later area at Bwlch.

The Woolhope Naturalists' Field Club was active too, and under the direction of the Rev. Grindley were examining the drift deposits of the Wye Valley.

Meanwhile, Wood, in their Transactions (Wood, 1905), drew attention to the glacial dam between the bend of the

Honddu at Llanvihangel, and the valley of the Gavenny Brook. The original southerly draining Honddu and Monnow were diverted, he considered, by the building of the moraine, blocking the valley and causing the rivers to 'work back' over the watershed between Pandy and Pontrilas along the bed of tributaries to establish a drainage to the north-east. This same feature was the subject of a paper by Grindley in 1907.

Carter in 1906 in the course of a much more comprehensive paper also makes reference to the Llanvihangel moraine. He refers to other examples of glacial diversion of drainage in the upper Usk, namely the diversion of the main river through the gorge at Aberyscir, and the diversion of the Honddu near the Priory Church (i.e. Cathedral) at Brecon. The gorge of Cwm Coed-y-cerig near Fforest Coalpit in the Black Mountains appeared to him to be a glacial overflow caused by the damming of the Grwyne by a lobe of ice pushing up from the Usk valley at Crickhowell, although the river returned to its former course on the retreat of the ice. Erratics of Ordovician rock recorded from the upper Usk and as far east as Talybont and Llangorse point to a stream of ice from the

Llandovery area. The main scarp to the south of the Usk was surmounted by ice at the head of the Cray valley, as well as at Nant Trefil (to leave erratic evidence in the Rhymney and Sirhowy Valleys) as had been pointed out in the Survey Memoir (Strahan & Gibson, 1900, 92).

A brief summary of much of this work appears in Strahan's contribution to the volume 'Geology in the Field', which appeared in 1910 (Strahan, 1910). He concludes that despite the fact that all the valleys are deeply cumbered with drift, all the main lines were reoccupied by the rivers at the close of the glacial epoch.

Following this early interest in the glacial history of the area, attention was soon drawn elsewhere by the First World War, and it was not until the 1920's that any further published contributions appeared. Once again an interested amateur, and clergyman - the Rev. T.I. Pocock - was responsible. His first paper, published in 1926 (Pocock, 1926), was concerned with the relationship of drift and river terrace stage passing upstream into moraines, and other terraces at 40 feet and 20 feet. The presence of Silurian material from the Builth area in King Arthur's Cave, three miles north-east of Monmouth at an elevation of 300 feet above the river is noted. He comments, however, that the limits of the 'Central Welsh Ice Sheet' are unknown. The Usk valley contrasts with the Wye in having no regular succession of terraces, but instead "almost the whole length of the valley down to the tidal part is strewn with glacial detritus". The reason for this, he suggests, is that the Usk, in contrast to the Wye, closely follows the eastern side of the mountains of South Wales, and thus never goes far from the centre of ice dispersion, so that whilst gravel terraces were forming beyond the ice margins in the Wye and Severn, the Usk was still occupied by ice. Nevertheless he claimed the existence of a 20 foot terrace at Llanvihangel nigh Usk, 'opposite Bettws Newydd', and on both sides of the river about one mile north of Usk. These terraces he considered probably contemporaneous with kames in the valley south of Abergavenny "as there is no gravel terrace between them and the alluvium". The same 20 foot terrace is noted at the mouth of the Grwyne, and on the south side of the valley near Gilwern. Further terraces on tributaries (not named, but probably the Cynrig and Menascin) below Brecon pass up into small moraines. The anomalous course of the Usk through the narrow valley at Llanhamlach he attributed to blockage of the main valley by glaciers from these tributary valleys. He observes that north of Usk the termination of the 'South Welsh ice sheet' is marked by mounds of drift with many enclosed hollows which run eastwards to within six miles of Monmouth.

> "Since much of the land between them and the Wye is below 300 feet and there is evidence of ice-borne material at least 300 feet above that river at King Arthur's Cave near Monmouth, it would follow that the whole of the low ground was buried under ice at the climax of the glacial period. These moraines north of Usk may perhaps be correlated with the moraines of the Wye valley near Hereford and the drift in the bottom of the Usk Valley which seems to have been formed by the coalescence of tributary glaciers from either side of the main valley, with other glaciers connected with the 40-foot terrace of other Welsh rivers, while the 20-foot terrace and

its connecting moraines is of the same age in all of them."

Pocock extended his survey to include the drift of the Severn and Avon, and in conclusion distinguishes three main episodes of glaciation, the last two separated by an interglacial characterised by temperate fauna as established by Miss Tomlinson in the Avon valleys (Tomlinson, 1925.) The first glaciation was the most widespread and is identified today by scattered deposits in high positions, testifying to immense subsequent erosion. Ice flow was independent of the present valleys, and originated in the Irish Sea Basin and coastal waters. The next period of glaciation was confined to the river valleys, and the 100 foot and above, terraces of the Severn and Avon, and the 70 foot terrace of the Wye at Hereford is connected with this. At this stage the Usk valley was overwhelmed by ice. Following an interglacial, ice advance occurred again but on a reduced scale. The two lower terraces (40-foot and 20-foot) are associated with this. "It seems probable that these last correspond with different stages of the Wurm period, the more general glaciation with the Riss period and the maximum with the

Mindel period".

Altogether this was, for its period a most interesting piece of work, the main defect being that his observations were somewhat disjointed, and he failed to piece them together to make a coherent whole. In particular the work would have been enormously improved with the addition of a few good maps and diagrams. The interesting thing is, however, that this detailed paper and a second published in 1940, appear to have been unknown to other workers in the area, for none of the later publications referred to in this brief survey make any reference to Pocock's valuable work.

J.K. Charlesworth's paper of 1929 was essentially a synthesis and interpretation for the whole of South Wales, of earlier work and particularly that of the Geological Survey. He was the first to distinguish in South Wales remnants of two distinct drift sheets - a Newer and Older Drift (although Pocock had earlier discerned their presence in the Wye valley). The latter was not marked by terminal moraines, the drift becoming thin and discontinuous as traced south, there being evidence of it extending beyond the coast at Newport and Cardiff, and to the Bridgend area in the Vale of Glamorgan. The rarity of moraines and marginal drainage suggested to Charlesworth that the ice "vanished in place by evaporation". Of the Newer Drift he identified two important morainic spreads in the eastern area of South Wales: the piedmont moraine running from Llantrisant in the west through Llandaff and sweeping finally onto the valley slopes east of Risca, and the Usk terminal moraine banked against the escarpment on the West and sweeping via Little Mill, Bettws Newydd, Llanarth and Llangattock nigh Usk to the hill-slopes east of Abergavenny. The intervening Afon Llwyd glacier was nourished purely locally and ended near Blaenavon.

In support of his thesis of two periods of glaciation, Charlesworth admits to being unable to cite any evidence of an interglacial period, and his basis for the distinction rests mainly on the noted greater modification of the Older Drift beyond the Newer Drift margin, and the supporting evidence of a sand and gravel deposit from West Wales (Jehu, 1904 and Williams, 1927).

A paper published by Dwerryhouse and Miller in 1930 was mainly concerned with the area to the north of that at present under discussion, but an examination of the glacial deposits of the Wye valley was included. The authors established that the lower 'step' of the Black Mountains' scarp, at 1,200 feet O.D. was heavily drift covered, and that ice at the maximum in this area extended from the flanks of the Black Mountains to Allt Dderw, a spur of Glascwm Hill on the north side of the valley. Silurian erratics in the Golden Valley show that the Wye ice had overflowed into it via the col (550 feet) at its head, but not into any of the other Black Mountain valleys, the lowest col of which is at 1,400 feet (at the head of the Monnow).

Three recessional moraines were noted in the Wye valley at Stretton Sugwas, Staunton-On-Wye and Hay.

The first dissertation to deal with the glaciation of a part of the S.E. Borderland was that of B.B. Clarke, submitted for the M.Sc. degree of Birmingham University in 1934. Although its title referred only to the lower Wye Valley, its scope was far wider than this: but the only part of it subsequently published dealt with the Black Mountains (Clarke, 1936). Much of the thesis was concerned with the evolution of the drainage pattern, but a lengthy description of the glacial deposits is included. He re-examined Carter's views on the pre-glacial course of the Usk in the Brecon area and detailed descriptions of the drift deposits of the Black Mountains are given. The possibility that the constricted section of the Usk valley between Talybont and Crickhowell might be a glacial diversion is cursorily considered - for the first time - although he concludes that "it was difficult to conceive of the conditions under which such a diversion might occur". For the Wye valley he postulates two periods of glaciation, the earlier one supported by the evidence of erratics and overflow channels. The margins of the older glaciation are not stated, but he finds evidence of it as far south as Goodrich whilst ice movement is postulated in the adjacent Leadon valley in the east as far as Rudford, not far from its confluence with the Severn. The range of erratics located is astonishing, ranging from flints to granite (the latter in the Gavenny valley). To account for this he envisages massive invasion of the district by ice of a northern origin (which resulted in ice movement <u>up</u> the Wye to Clifford), and even invasion of the area by the Irish Sea Ice Sheet (to account for the flints and the marine clay described by Grindley at

Bredwardine (Grindley, 1923). The latter, Clarke suggests might have been transported in a frozen state, so that an incursion of the sea is not necessary to account for it). During the Newer Glaciation, he suggests that the eastward margin of the ice in the Wye is recorded by the Hereford moraine, and in the Usk valley by moraines at Tregare and "Bryngwenyn" (sic). At this stage the Black Mountain scarp was surmounted by the ice at the head of the Rhiangoll valley only, although the Golden Valley and Escley Brook show evidence of invasion by ice from the north/only during the Older glaciation. This is in contrast to Dwerryhouse and Miller who had suggested ice invasion of the Golden Valley during the Newer Drift glaciation. He was unable to find any evidence of glaciation in the valley of the Grwyne Fawr above Fforest Coalpit, although the neighbouring Grwyne Fawr valley was heavily glaciated.

A second thesis, presented for the M.A. degree of Manchester University by L.S. McCaw in 1936 is a quite remarkable piece of work.* It included careful work on the erosional history, soils and land use of the Black

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* The greater part of this most valuable work has, unfortunately, never been published, although the outline of the physical background for the section of the Black Mountains in the Land Use Survey report for Brecknock was extracted from it (White, 1943).

Mountains, as well as the most detailed account of the glaciation of the area. Of particular note was the production for the first time of a map showing the distribution of drift deposits in the Black Mountains (his geological map an extension of work initiated by Wickham King is also the first detailed geological map of the area). This is reproduced as part of fig. 9 . McCaw did not produce evidence of multiglaciation, and treated the glacial deposits of the area as contemporaneous. He estimated that the ice rose on the north flanks of the Black Mountains to a level of 1,800 feet allowing ice streams to enter the heads of the Rhiangoll, Honddu, Monnow, Escley and Dore valleys. This was aided by convergence of the ice upon the Talgarth area from both the Wye and the Upper Usk, due to the latter valley's restricted outlet below Talybont. Partly for this reason, the ice spread eastwards to a far greater extent from the Wye valley than from the Usk.

In the Usk valley, the glacier, blocking the mouths south flowing tributaries caused temporary lakes to form (in the lower Gavenny, Grwyne and Rhiangoll valleys), whilst glacial deepening of the Usk valley 100 feet or more is testified by the way the first two valleys hang above the main (the Rhiangoll received substantial amounts of ice over its watershed and thus was deepened to a depth comparable with that of the main valley).

Much of the earlier work on the glaciation of the area was incorporated in useful summaries published in the British Regional Geology Handbooks for the Welsh Border land and South Wales which appeared in 1935 and 1937 respectively (Pringle & George, 1937, Pocock & Whitehead, 1938). A second paper by Pocock also appeared in 1940, devoted to a detailed examination of the terrace and drift deposits of the Wye, which he had treated but briefly in his 1926 paper. As a result of the Second World War, however, the flow of papers ceased, and relatively little interest has been shown in the glacial history of the area in post war years.

The War had, in particular, held up completion of the mapping of the One-inch Geological Sheets 233 (Monmouth) and 250 (Chepstow), work on which had started in 1933. This was recommenced in 1945 and completed in 1947, the sheets appearing in 1960 and 1958, respectively.

The combined sheet memoir (Welch & Trotter, 1961) was not published until 1961, although useful notes had appeared previously in the annual 'Summary of Progress' of the Survey. It is interesting to note the discrepancies occurring along the junction between the new sheets and those of Abergavenny and Newport published almost sixty years earlier (fig. 5), although attention is not drawn to these in the memoir. In particular the drift deposits are shown extending much higher into the hills on the north side of the Abergavenny to Raglan road. The great majority of the deposits in this area are now mapped as 'morainic drift' where previously similar deposits had been mapped as sand and gravel. This is described in the memoir (p.126) as "rubbly, earthy gravel with more clayey patches and might equally well be described as a gravelly boulder clay". In addition various lake clays were mapped near the extremity of the ice lobe which pushed east up the valley of the Clawdd Brook, and the Troddi's present course east is ascribed to glacial diversion. River terraces mapped between Llanbadoc and Newbridge are described, but no correlations were suggested with the more extensive terrace remnants of the Severn mapped on the same sheet.

Two post-war theses might be noted. Rice, in a thesis submitted to the University of London in 1954 included a discussion of the drift deposits of that valley upstream of Hay (Rice, 1954). The most important recent contribution is, however, that of Trotman (1963). In a thesis submitted to the University of Wales she included a study of pollen from cores taken from the raised bog at Waen Ddu, a cirque on the Carboniferous Limestone scarp south of Crickhowell. She suggests (p. 109) that "the evidence from Waun Ddu indicates complete ice freedom since the last full glacial", although (p. 87) zone I deposits suggest periglacial activity, as do, to a lesser extent, those of zone III.

Other contributions include a summary of existing knowledge of the glaciation of Brecknock in an article by North (1955), a similar, but slightly more extended discussion being included in Thomas (1959). Papers by Crampton discuss glacial and postglacial events in the light of the heavy mineral and pollen content of the soils of the area (Crampton, 1960; 1966).

A great deal of the area under discussion lies outside that covered by 'recent' geological mapping, and thus our knowledge of glacial events largely stems from the work of amateur researchers who were mostly active at the turn of the century. The advent of the specialist, working through the Universities or research organisations, came in the interwar period, and with it, unfortunately, the disappearance of amateur effort in this field. This thesis is the first to consider the glaciation of part of the south-east borderland on the basis of detailed mapping of its morphology.

CHAPTER 6

GLACIAL CHRONOLOGY

This discussion of the major problems of glacial chronology in areas adjacent and relevant to the Usk (the Midlands and Wales), will be prefaced by a statement of the terminology which will be used, throughout the thesis. Palaeobotanical studies in England, especially since 1950, have enabled a relative chronology for the Quaternary of the British Isles to be established (West, 1963), which commands a fair degree of support. This has been based on pollen analytical studies of interglacial deposits, and their relationship with the various drift sheets. This British sequence will be used, wherever possible, and the sequence (for the Middle and Upper Pleistocene only, the Lower Pleistocene having little relevance for this area as yet), together with Continental correlatives, is given in Table 5 :

TABLE 5

[redacted] OF BRITISH AND CONT[redacted] [redacted]N SEQUENCES (BASED ON FL[redacted], 1957, 409–413)

	BRITAIN	CONTINENTAL	
		ALPS	N. EUROPE
UPPER PLEISTOCENE	Weichselian G. Ipswichian I.G. Gipping G.	Wurm R/W I.G. Riss G.	Weichsel G. Eem I. G. Saale G.
MIDDLE PLEISTOCENE	Hoxnian I. G. Lowestoft G. Cromerian I. G.	M/R I.G. Mindel G. G/M I.G.	Holstein I.G. Elster G.
L O W E R P L E I S T O C E N E			

An approach to the absolute dating of glacial and interglacial episodes has been made in recent years with the increasing use of precise dating techniques, especially radiocarbon dating. A dating for the European sequence during the Last (Weichselian) Glaciation (after Fairbridge, 1961, 144) is given in Table 6 :

TABLE 6

APPROXIMATE DATING OF EVENTS OF THE WURM GLACIATION Modified after FAIRBRIDGE 1961.

		Years B.P.
LAST INTERGLACIAL (Ipswichian)		100,000 - 75,000
EARLY WURM (EARLY WEICHSELIAN)		75,000 - 50,000
Main Interstadial (Upton Warren Interstadial)		50,000 - 30,000
MAIN WURM (LATE WEICHSELIAN)		
Younger Loess IIa		30,000 - 27,000
Paudarf Oscillation		27,000 - 25,000
Younger Loess IIb		25,000 - 21,000
Herning Oscillation		21,000 - 19,000
Daniglacial		19,000 - 17,000
LATE WURM (LATE GLACIAL)		
Masurian Interstadial		17,000 - 16,000
P.Z. Ia	Gotiglacial	16,000 - 13,300
Ib	Bölling	13,300 - 12,500
Ic	Older Dryas	12,500 - 12,000
II	Alleröd	12,000 - 10,800
III	Younger Dryas	10,800 - 10,300
POSTGLACIAL (Pollen Zones IV-X)		

In the south-east Borderland we may look to two adjacent areas for a chronological framework against which out own findings may be matched: West Wales and the Midlands. The Pleistocene sequence of these two areas has received considerable attention, whilst useful links have been established with the Severn/Avon terrace sequence in the case of the Midlands, and the raised beach deposits of Gower in West Wales (although the drift/beach relationship in Gower has never been satisfactorily demonstrated, and radio-carbon dating seems now to offer a more profitable lead).

(a) West Wales

The division of the drift of South Wales into an Older and a Newer Drift based mainly on morphological characteristics (Chapter 5) has long been accepted. The 'Older Drift of south Gower (which from its erratic content was considered to have been laid in part by Irish Sea Ice) was shown by T.N. George (1933) to overlie the main raised beach of the Peninsula, the *Patella* beach, which was therefore considered 'pre-glacial', despite the inclusion of erratic material within it This was ascribed to a period of "incipient glaciation" when icebergs calved from minor valley glaciers reaching the Channel coast, and elsewhere, foundered on the shores of Gower.

The pre-Older Drift age assigned to the Patella beach was accepted by Griffiths in his study of the drift deposits of South Wales (Griffiths, 1940). He identified a lower and an upper boulder clay with associated sands and gravels indicative of retreat stages throughout most of South Wales, and proposed the following chronological sequence:

TABLE 7

GLACIAL CHRONOLOGY OF SOUTH WALES

AFTER J. C. GRIFFITHS, 1940

7.	Sands and Gravels	Newer
6.	Boulder clay ('Head' outside glaciated area)	Drift
5.	Sands and Gravels	Older
4.	Boulder clay	Drift
3.	Blown sand and ossiferous breccia	Raised
2.	Raised beach	Beach
1.	Raised beach Platform	

Griffiths tentatively equated his Raised Beach, Older Drift and Newer Drift deposits with East Anglian deposits now assigned to the Lowestoft, Gipping and Weichselian Glacial episodes respectively.

The sequence exposed in Minchin Hole, Gower was critical to T.N. George's work. He recorded the following succession (George, 1933):

4. Wind blown sand
3. Marine sand: the Neritoides beach
2. Ossiferous cave breccia.
1. Patella Beach

The Neritoides Beach was correlated with a blown sand in Caswell Bay which could be seen to underlie, head, from which it was concluded that the Neritoides beach also probably antedated the local (Older Drift) glacial deposits.

The Minchin Hole section (the face of which has receded) was recently re-examined by D.Q. Bowen. Bowen whose interpretation differs significantly from that of T.N. George (Bowen, 1966). Bowen records:

6. Upper Head
5. Cemented sand
4. Loose sand (the Neritoides sand)
3. Stratified cave earth
2. Lower Head
1. Patella Beach

The main contrast is that Bowen notes a head deposit capping the section, and the cave breccia of George is interpreted as a lower head. Mammalian fauna discovered in the cave earth above the latter (3) is considered similar to that from the Upper Flood Plain (Ilford) Terrace of the lower Thames for which an Eemian age has been suggested. "This provides a horizon which can be dated, and to which the other members of the stratigraphy can be related" (Bowen, 1966, 475). Thus the underlying 'lower head' (2) is assigned to the Gipping, and the Upper Head to the Weichselian, placing the *Patella* Beach in the Hoxnian interglacial. Additional evidence for this hypothesis is found in the presence of a fossil soil reported by Ball (1965) at Worms Head, Gower. This appears to have formed under climatic conditions similar to the present but with warmer summers, and as it overlies what George considered to be glacio-fluvial deposit (but identified by Bowen as Lower Head) the palaeosol is correlated with the Minchin Hole cave earth, and placed in the last interglacial (Ipswichian). The Gower Drift is thus referred to the Gipping, the Weichselian being a period of only periglacial activity in Gower.

This chronology is at variance with a chronology suggested by him in his study of Central south Wales in the previous year (Bowen, 1965), in which he distinguished three ice advances in the area: an 'Early Glaciation' in which Irish Sea and local ice merged (erratics of this glacial advance were incorporated in the _Patella_ beach); a 'Main Welsh Glaciation' of exclusively local ice, which covered Gower; and a 'Welsh Readvance Glaciation', the margins of which are delimited by fresh topography. These glacial episodes were assigned to the Gipping, Older Weichselian and Main Weichselian respectively, the _Patella_ beach then being thought to be Ipswichian in age.

Bowen (1966) correlates his Gower sequence with West Wales exposures, contending that like Gower that area was last glaciated during the Gipping, the Weichselian being represented by periglacial deposits. Both Wirtz (1953) and Mitchell (1960) had previously suggested that the last glaciation to affect coastal West Wales was Gipping. Wirtz considered the Irish

Sea Ice to have reached its maximum during the early part of the Riss (Gipping), the Younger Riss being a period of local Welsh Glaciation. The Gower Raised Beach is thus put into the M/R (Hoxnian) Interglacial, whilst the Wurm was essentially a valley glaciation. Mitchell, whilst conceding an invasion of Irish Sea Ice into the Cheshire Plain in the 'Smestow Cold Period' (Weichselian), considers that at this time in West Wales the Irish Sea Ice sheet did not extend south of the Lleyn Peninsula. His suggested chronology in respect of Wales is given in Table: 8:

TABLE 8

PLEISTOCENE SEQUENCE IN WALES AFTER MITCHELL (1960)

	General Terminology	Wales
UPPER PLEISTOCENE	Smestow Cold Period	Corrie Glaciation Shrewsbury Re-advance Llandaff Mountain Gl. Main Irish Sea Gl. of Cheshire Plain.
	Ipswich Warm Period	Interglacial (Llansant-ffraid soil)
	Gipping Cold Period	Irish Sea Ice in South Wales (Pencoed, Newquay
MIDDLE PLEISTOCENE	Hoxne Warm Period	Interglacial (Gower Beach)
	Lowestoft Cold Period	Glaciation (Gower erratics)
	Cromer Warm Period	Interglacial (Gower Shore Platform).
L O W E R P L E I S T O C E N E (Evidence of 200 foot sea level)		

The original work of Watson (1966) in the Aberystwyth area is also in broad agreement with the conclusions of Wirtz, Mitchell and Bowen. Watson considerес many of the deposits previously identified as tills to be the result of massive periglacial activity inthe Weichselian, the only truly glacial deposits being Gipping or earlier in age. A similar suggestion has been put forward in respect of the Brecon Beacons by Lewis (1966), which he considers only to have nurtured cirque glaciers during the Weichselian.

An opposing view is held by another, smaller, group of investigators, who consider that West Wales was glaciated in the Weichselian, This was implied by Charlesworth in his 1929 paper, in which he outlined the development of a series of proglacial lakes in valleys draining into the south of Cardigan Bay during 'Newer Drift Times', as a result of Irish Sea Ice moving in from the coast. Zeuner goes farther than this (Zeuner, 1959, 146), suggesting that the Gower Raised Beach is Last Interglacial (Ipswichian) and thus the 'Older Drift' which overlies it is the equivalent of the Little

Eastern Glaciation of East Anglia (i.e. Weichselian). This Ipswichian dating for the Gower Raised Beach is supported by the unpublished work of Groom (1966)⁺, although she considers the beach to be overlain only by head deposits. More recently, strong support for a Weichselian Glaciation of West Wales has been provided by radio-carbon dating, and one recently published result (John, 1965) suggests that the extent of glaciation at this period was far more extensive than visualised even by Charlesworth. They also suggest a glacial episode much later within the Weichselian than previously considered.

Four radio-carbon dates for West Wales sites have been published (Table 9). Three lie within the area of Charlesworth's 'Newer Drift South Wales End-Moraine', but the fourth, from Mullock Bridge on the northern shore of the entrance to Milford Haven, lies far to the north of any former 'Newer Drift' identification.

⁺MS. kindly made available to me by the author.

TABLE 9

RADIO-CARBON DATING OF WEST WALES DEPOSITS

Location	Reference	Type of Deposit	Years B.P.
Mullock Bridge, Pembs. (SM 811080)	John, 1965	marine mollusca	37,960 +1700 -1400
Tre-llys, N. Pembs. (SM 898349)	John, 1965	marine mollusca	37,310 +1515 -1275
Banc-y-warren, Cards (SN 2023482)	Brown, et al, 1967	Peaty, organic mud	31,800 +1400 -1200
Cilmaenllwyd, Cards (SN 203482)	John, 1967	Wood fragments	33,750 +2500 -1900

On the basis of his 1965 datings, B.S. John proposed an extensive glaciation in Wester Britain later than 38,000 years B.P., which concurs with the suggestion of Penny (1964) that the maximum of the Last Glaciation throughout Britain was the approximat equivalent of the European Main Wurm (25,000 - 17,000 years B.P.). These datings are unexpectedly recent, and if they are to be accepted will require complete revision of established views on drift morphology and age relationships.

(b) The Midlands.

The pioneer work of L.J. Wills in the Severn Valley, and Miss Tomlinson in the Avon has been the basis for recent studies of various aspects of the Pleistocene in the Midlands by Shotton and his associates in recent years. Of particular value was the correlation suggested by Wills of the various glacial advances with episodes of aggradation and down cutting within the Severn basin, contained in two papers (Wills, 1937, 1938), and briefly summarised in a regional volume (Wills, 1948). Wills suggested two main periods of glaciation corresponding with the Older and Newer Drift, and separated by a lengthy interglacial. The glacial episodes are not simple, terrace deposits in particular pointing to a waning and readvance of the ice at least once in each major period. Four glacial advances are therefore suggested (Table 10):

TABLE 10

TERRACE AND GLACIAL SEQUENCES OF THE WEST MIDLANDS (AFTER WILLS, 1948)

	TERRACES		WESTERN ICE STAGES
	SEVERN	AVON	
NEWER DRIFT	Worcester	No. 1.	Welsh Readvance
			Interglaciation
	Main	No. 2 & 3	Main Irish Sea and third Welsh Gl.
GREAT INTER-GLACI-ATION	Kidderminster	No. 4	Interglacial
OLDER DRIFT	Bushley Green	No. 5	Second Welsh Gl.
			Interglaciation
	Woolridge	---	First Welsh Gl.

Wills emphasized the morphological distinction between the Older and Newer Drifts, the former being largely hill-top remanie deposits, the formation of which was followed by a prolonged period of more temperate conditions with extensive river erosion. He refers to four major ice advances into the lowlands from the Welsh massif. The Oldest, the First Welsh Glaciation, reached the Cotswold scarp, overriding it at the Moreton Gap, although its western flank seems to have lain against the Malverns (Wills, 1948, 112). The Second Welsh Glaciation covered similar ground, but on this occasion did not surmount the Cotswolds (Wills, 1948, 115). The Third Welsh (Newer Drift) was far less extensive, coalescing with the Irish Sea Ice in the north-east Borderland, and shown (Wills, 1948, fig. 29) to extend down the Wye to Hereford, and down the Usk to beyond Abergavenny. This is essentially the Newer Drift boundary of Charlesworth (1929), although the issue is confused because Wills considers the Welsh Readvance Glaciation to have occupied much the same territory.

The state of Midland Pleistocene chronology in the early nineteen sixties has been summarized by Tomlinson (1963). Her correlation of the Midland Drifts and the Severn/Avon Terrace sequence with the East Anglian Pleistocene are summarized in the following Table:

TABLE 11

CORRELATION OF THE MIDLAND AND EAST ANGLIAN PLEISTOCENE SEQUENCES, AFTER TOMLINSON (1963)

	MIDLANDS		EAST ANGLIA
	Glacial/Interglacial periods	Severn/Avon terrace sequence	
Newer Drift	Main Irish Sea Gl. Third Welsh Gl.	Main No. 2	Hunstanton Gl. (Weichselian)
	Interglacial	Kidderminster No. 3 & 4	Ipswichian I.G.
Older	Second Welsh Gl. Main Eastern Gl. Middle Pennine Gl.	Bushley Green No. 5 Woolridge	Gipping Gl.
	Interglacial	——	Hoxnian I.G.
Older Drift	First Welsh Gl. Northern & Plateau Drift Lower Boulder Clay	——	Lowestoft Gl.

It will be noted that the Woolridge Terrace is now assigned to the period of the Second Welsh Glaciation (Gipping), the conclusion of Hey, (1958, 166) who has investigated these gravels in the lower Severn. The Main Irish Sea Drift of the Midlands is placed by Tomlinson in the Early Weichselian, and the Main Terrace of the Severn and the No. 2 Terrace of the Avon at the beginning of the Main Interstadial. This suggestion is based in part on radio-carbon dating of deposits from Fladbury (Avon No. 2 Terrace: 38,000 years B.P.), and Upton Warren (associated with Main Terrace of Severn: 42,000 years B.P.) (Coope, 1962, and Coope, Shotton and Strachan, 1961). A further dating from the Tame Valley (Avon No. 2 Terrace) of approximately 32,000 years B.P. (Coope and Sands, 1966) has suggested that the name 'Upton Warren Interstadial' might
now be justified for this episode, which they show (1966, fig. 2) to extend from 50,000 to 23,000 years B.P.

The Welsh Readvance is omitted from the above table as its existence is now questioned, although the sequence of events in the Midlands following the withdrawal of the Main Irish Sea Ice is, paradoxically, "somewhat obscure" (Tomlinson, 1963, 198). Peake, however, working in the north-east Wales Borderland (Peake, 1961) suggests two advances of the ice there, a Little Welsh (the equivalent of Wills's 'Welsh Re-advance'), radio-carbon dated ca. 28,000 years B.P. and later a Llay Advance at about 20,000 years B.P. These have been correlated with the Worcester Terrace. and the lower 'Power Station Terrace' of the Severn (Beckinsale and Richardson, 1964), the gravels which are largely buried as a result of recent aggradation in the lower reaches of the river.* Boulton and Worsley (1967) have suggested, however, that Peake's Llay Advance is part of the marginal deposit of Irish Sea Ice invasion of the Cheshire Plain dated as Late Weichselian from included shell fragments (found at Sandiway, Northwich and radio-carbon dated at approximately 28,000 years B.P.). This is in line with John's findings in West Wales, but it has been contested by Poole (1966) who points out that the drift sheet to which Boulton and Worsley refer has been cut into by the lake stages of Lake Lapworth, which have been correlated with the Main Terrace of the Severn, for which a reliable dating of approximately 40,000 years B.P. has been given (Coope, Shotton and Strachan, 1961).

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*The relationship of the lower terraces and the buried channel of the Severn are discussed in detail in Chapter 12.

CONCLUSION

A great deal of divergent opinion still exists concerning the late Pleistocene glacial chronology of western England and Wales. Opinion is fundamentally divided as to whether the last major glaciation affecting the coastal tract of West Wales in particular occured in the Gipping or the Weichselian, and if the latter, whether it was an early or a late Weichselian Glaciation. Bowen is the latest proponent of the former view, whilst John's datings suggest that the major glaciation occured in the late Weichselian. Radio-carbon dating from the Midlands, however, in the main suggests that the Main Irish Sea Glaciation of that area occured in the Early Weichselian, which Wills (1948, fig. 32) tentatively correlates with the Irish Sea Ice invasion of west and south Wales. Many of these problems will probably be resolved when radio-carbon dates for a larger number of sites become available.

CHAPTER 7.

GLACIAL MORPHOLOGY OF THE MIDDLE AND PART OF THE UPPER USK.

In this, and the following chapter, the morphology of that part of the Usk drainage basin showing a marked development of depositional and erosional features of glacial origin will be considered. This area coincides with that considered by Charlesworth (1929) to have been glaciated during the 'Newer Drift' Glaciation.

The morphological description is for convenience divided into two chapters. In the area considered in this chapter ice movement was controlled by deeply cut valley lines, whereas in the Vale of Gwent, considered in Chapter 8, the valley of the Usk is shallower, and its influence on the direction of ice movement was not always dominant.

In this Chapter, the area delimited in fig. 4 as the 'Middle Usk' will be considered, along with part of the main valley (upstream as far as Brecon) forming part of the 'Upper Usk'. The area is considered in sections, each of which displays a degree of unity in its landforms. The sections are each illustrated by a detailed morphological map, and the location of these, in respect of each other, and within the Usk as a whole, is shown in fig. 10.

The area covered in Chapter 7 is predominantly one of transition, the river here cutting through the line of the Fforest Fawr - Black Mountains scarp in a narrow stretch extending from Llanddetti to Penmyarth (considered in section c). Above this the valley flanks the foot of the Fforest Fawr scarp, and lies marginal to the internal lowland area comprising the Llangorse-Llynfi Basin. At its downstream end (section f) the valley is widening out as the Vale of Gwent is approached, although the massive upland areas of the Coalfield Plateau and the Black Mountains still rise abruptly to the south and the north respectively. The rapid change in the character of the valley to be observed between Brecon and Abergavenny seem inconsonant with the widely accepted view of the Usk as a major river of long standing (Chapter 4), and the evidence on which this is based will be critically reviewed (Section a).

The morphological detail shown on the maps here to be described was mapped in the field at a scale of 1:10,560. The possibility of reducing the time required for this by using the available aerial photo coverage was explored. Comparison of air photographs at the Ministry of Housing and Local Government's Welsh Office at Cardiff with completed field mapping suggested that only the larger scale features could be mapped directly from air photographs,* and the quality of maps compiled in this way would therefore be considerably inferior to those made by direct observation. Consequently air photograph interpretation was not used to supplement field mapping.

The style of morphological mapping was a personal one, of an essentially geneticnature. The reasons for the choice of this style have been outlined in Chapter 1. A brief outline of the nature of the main landforms portrayed by the symbols is given below.

1. Concave or Convex Break of Slope. These lines indicate discontinuities of slope. The discontinuity, or break, should be "visibly angular" (Waters, 1958, 13) so that it is possible for its position to be plotted on maps (at a scale of 1:10,560) in the field without hesitation. Inflexions of slope are not included, although the distinction between a poorly developed break, and a marked

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* This is in part a reflection of the very poor quality photographs which were available at that time.

inflexion would be difficult to define, and such slope changes have normally been mapped as breaks. A concave break of slope is one in which the slope facet above it is steeper than that below, whereas when the break is convex, the angle of the slope facet below is greater than that above.

2. Morainic Ridge. The most common morphological feature of areas of glacial deposition is probably the ridge. These can sometimes be shown (from exposures) to be eskers, or where they occur en echelon, with apparently smoothed forms aligned with the probable direction of ice movement, they can reasonably be mapped as drumlins. The great majority of ridges in drift deposits cannot, however, be shown to belong to either of these classes, and they have been simply mapped as 'morainic ridges,' using a simple line symbol which highlights the significant trend. It should not be supposed that features mapped in this way are moraines (either lateral, medial or terminal) in the restricted sense of that term, although many undoubtedly are. The symbol simply shows ridge forms in drift, some of which are composed of till, but the majority of which are glacio-fluvial.

3. Kettle or Kettle hole. Any hollow within stratified drift which was considered most likely to have developed by the melting out of included ice masses was mapped as kettle. There is a great variety of form, ranging from shallow, pan-shaped depressions to deep, water-filled hollows.

4. Ice contact. Flint (1957, 147) describes ice contact, surfaces as "the sideslope or face of a mass of sediment that was built up against a steep supporting wall of glacier ice...... indentations remain where great protuberances in the ice once stood, and projections, mostly cuspate, remain where the ice was marked by crevasse-like re-entrants". Although well developed contacts occur which accord with this description, they are few, and faces of glacio-fluvial deposits have been mapped as ice contacts wherever their location suggests an ice-marginal position,and their detailed form does not show evidence of fluvial modification, but is of swelling character with cuspate tendencies. This form is not easily described, but fairly readily identified, with practice, in the field.

5. Kame terrace. A flat-topped, terrace-like accumulation of stratified drift usually found flanking the valley wall, but occasionally built against higher morainic accumulations.

Ideally their leading edge should preserve ice contacts, as they were laid down between the glacier and flanking high ground, but evidence of their former little-greater extent, combined with a slightly rolling surface form is considered sufficient grounds for mapping lateral terrace-like features as kame terraces. Kames are mound-like hills of stratified drift considered to have been deposited in crevasses or other openings in the ice (Flint, 1957, 150). Mounds of stratified drift without linear tendencies, and relatively flat-topped, have been mapped as kames, whether or not ice contacts are evident.

6. Meltwater channel. Any channel of fluvial origin, the major form of which was judged not to have been eroded by present-day drainage, was mapped as a meltwater channel. Some are totally unconnected with present stream lines, but others have been utilised by post-Glacial drainage. In form there is great variety, probably depending on their significance as meltwater distributaries, and the length of time that they were so used. The smallest were less than five feet deep, with gently sloping sides. The larger normally show trench-like form, with flat floors, especially if they have not been modified by post-Glacial drainage. By comparison

with meltwater channels mapped in other parts of Britain, meltwater channels show a very meagre development in the Usk.

7. Major river-cut bluff. Wherever, during the post-Glacial re-grading of the valley, the river has incised itself into the drift fill, or has eroded it as a result of lateral swinging of its trace, a steep, undercut slope facet results, forming a bluff. It was considered important that these should be mapped for they indicate that the former drift extent has been reduced as a result of post-Glacial fluvial action.

8. River terraces. Any level trace of land considered to have been developed by lateral movement of the river trace, and separated from the lowest such level (i.e. the flood plain) by a distinct morphological break, has been mapped as a river terrace. This includes terraces cut into outwash deposits during the incision of the river as well as terraces developed wholly in alluvial deposits. The lowest of these features may be flood plain terraces, subject to flooding during periods of exceptionally high over-bank discharge. The minor bluff separating them from the flood plain is evidence of recent, slight, incision by the river.

9. Gravel fan (Detritus or alluvial fan). Deposits of mainly larger-grade river-borne sediments which are found at the mouths of many tributary streams. If the space is available, these spread in fan-like form across the floor of the main valley, or wherever the stream shows an abrupt reduction of gradient. The arrows are drawn in the direction of steepest slope, which is often very gentle. These features are discussed in detail in Chapter 10 (pp. 360 ff).

The features discussed above were mapped widely throughout the valley. Other more localised features will be described at the appropriate place in the descriptive sections following.

(a) THE SUGGESTED PLEISTOCENE DEVELOPMENT OF THE UPPER AND MIDDLE USK.

Above Brecon the Usk flows in a generally easterly direction, gathering tributaries both from the Eppynt and the Fforest Fawr scarp. For the most part the valley is shallow and winding, with considerable drift accumulations on its floor. At Brecon there is a noticeable change in the character of the valley (fig. 11). It swings towards a south-easterly direction, becomes straighter in form, and generally reveals a wide, alluviated floor flanked by steeply-rising sides. East of the Honddu, which joins it at Brecon, it has no significant tributaries from the north until the confluence of several streams from the Black Mountains about Crickhowell. Llangorse Lake, a shallow tract of water filling a basin in the upper Llynfi valley, tributary to the Wye, is little over 1¼ miles distant from the Usk, separated from it by the narrow ridge of Allt yr Esgair. To the south of Talybont the Usk temporarily takes a more southerly direction before swinging abruptly eastwards through a gorge-like section of the valley at Llanddetti. The river retains its incised character, although the valley opens out in its upper levels at Llangynidr, until a further alluviated section is reached at Penmyarth, at the confluence of the Rhiangoll. The constricted section of the valley at Llanddetti (fig. 11) is found where the line of the Fforest Fawr - Black Mountains scarp, formed of the Brownstones division of the Lower Old Red Sandstone crosses the valley.

To the east of Brecon there is thus a strong suggestion that the valley is of recent origin:

(a) the river here gathers no left bank tributaries, the Usk-Wye watershed (fig. 15) here running very close to the Usk;

(b) right bank tributaries of the Usk (especially the Caerfanell) meet the main river at discordant angles;

(c) the Llanddetti gorge, and the form of that part of the valley immediately downstream (i.e. past Llangynidr) does not suggest that it has long formed part of the main valley of a major drainage basin;

(d) the form of the valley <u>above</u> Llanddetti suggests that it owes more to the gouging of ice than to valley development by normal fluvial erosion.

As a case for river capture along this line cannot be substantiated, it is suggested that the drainage pattern of this area has been considerably modified by the action of transfluent and diffluent ice streams during the Pleistocene.*

Examination of the drainage pattern (fig. 11) reveals that all the Usk tributaries which meet the main valley at sharp angles appear to be trending towards the lowland area about Llangorse Lake. In particular, the Caerfanell shows a distinct alignment with the Llynfi, the col at Pennorth at 620 feet (C on fig. 11) falling exactly on a line drawn between the two rivers. The Tarell is structurally guided along the Cribarth Disturbance)** and it is possible that this river and the Upper Usk (which appears to be strike-controlled above Brecon), as well as the Menascin and Cynrig, formerly flowed across the present Usk-Wye watershed via the Brynich col (B on fig. 11 ; 730 feet, O.D.) into the Dulas valley. This col seems also to have been eroded along the line of the Cribarth Disturbance. Fig. 12 shows the suggested pre-glacial drainage pattern of the area. It is one which shows a considerable degree of structural adjustment, the Tarrell and associated streams exploiting the Cribarth Disturbance, whilst the streams of the Llangorse area are developed in

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* This idea, based on Professor Linton's work on watershed breaching by ice action (Linton 1949(a); 1949(b); 1951) was developed in discussion with Miss G.E. Groom.

** See Chapter 3, p.

the marl division of the lower part of the Old Red Sandstone Series. The upper Usk, a strike stream, has eroded westwards capturing the south-flowing streams of the Eppynt. This pattern, it is suggested, replaced the early consequent pattern of the area discussed in Chapter 4, the Honddu then flowing across the present Middle Usk to join with one of the eastern streams of the Coalfield (probably the Ebbw Fawr). This ancient drainage must have been changed at an early stage by subsequent developments, as few cols remain on the Fforest Fawr - Coalfield watersheds to record the crossing points of the consequent streams.

The conditions which might give rise to such radical changes of the drainage pattern are visualised as follows: The drainage of the area, as the result of major subsequent developments is, at the onset of the glacial episode, directed towards the north-east and the Wye (itself probably of subsequent origin) flowing at the foot of the Black Mountains scarp. These streams cross a triangular-shaped lowland floored by the marls of the lower Old Red Sandstone Series. This is flanked by the Fforest Fawr-Black Mountains scarp on the south and east, and the rising land of the Eppynt in the north-west. The main exit is towards the Wye in the north-east, although a zone of relatively low-lying country runs westwards along the line of the present upper Usk, and so into the Towy valley at Llandovery. To the east, one of the Black Mountains streams, the Rhiangoll, has developed an important left bank tributary the Crawnon, partly exploiting the shattered strata along the line of the Vale of Neath Disturbance. This runs close to the former watershed, and the scarp is thus likely to be weak in this area, as in addition it shows a marked change of trend about here.* It is possible that the Caerfanell has also exploited a zone of faulting over part of its course, explaining its parallelism with the fault-controlled Crawnon to the south, and the considerable deepening of this valley in contrast to those of other streams draining the Fforest Fawr scarp. Its headwater stream (fig. 11) could well have formed part of a former south-easterly draining consequent before capture by the Caerfanell extending south-westwards along a line of faulting.

Into what we shall for convenience refer to as the 'Llangorse lowland' ice streams converged, both from the Fforest Fawr Scarp, and from the Eppynt and beyond as a

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* Miss G.E. Groom has pointed out the similarity with the stepped plan of parts of the Cotswold scarp demonstrated to her by Professor Wooldridge. He was inclined to suggest that this phenomenon might be related to ancient north-south axes, later affected by the regional tilting towards the south-east.

result of the overtopping of the scarp. Although some ice is known to have moved west into the Towy, the main avenue of movement of ice out of the area would have been to the middle Wye in the north east. This valley was carrying much of the eastern ice flow from the Central Wales Plateau, however, and it is possible that a restricted outlet (much narrower than at present) caused ice to build up in the Llangorse lowland. Thus what Linton (1951, 11) has termed a 'basin of impeded outflow' was present, causing the ice-surface within it to rise until cols in the high ground surrounding it were reached, thus offering an escape route for ice into neighbouring, relatively ice-free areas. This is most likely to have occurred in the east where the Black Mountains and the small streams draining off the present Carboniferous Limestone scarp east of the Crawnon would have nourished only small ice streams. There are, however, a number of places where ice seems likely to have overflowed the Fforest Fawr - Black Mountains scarp in a southerly or easterly direction: at the head of the Tarell valley where a deep col with its floor at 1440 feet O.D. leads into the head of the Taf Fawr (col not marked on fig. 11); at Torpantau where a col at 1430 feet O.D. (H in fig. 11) leads from the head of the Caerfanell into the Taf Fechan; at the head of Cwm Sorgwm on the Black Mountains scarp (Col I at 1,150 feet O.D.); and at Pen y genffordd at the head of the Rhiangoll (1,060 feet O.D. not marked on fig. 11). In view of these other examples it seems not unlikely that ice crossed and deepened a col on the scarp at Llanddetti, where the scarp is in any case generally much lower today. A further col (G in fig. 11) near the head of the Crawnon suggests that the narrow interfluve between the Crawnon and Caerfanell (rising barely above 1250 feet near Pen Rhiw-calch (103 176) was swamped by ice, ice moving across the upper Crawnon valley, crossing the Carboniferous Limestone scarp by means of col G at Ffos-y-Wern (1470 feet O.D.), thus entering the head of the Sirhowy valley at Trefil. It is noticeable that the Sirhowy is today the most deeply developed valley head along the north crop of the Coalfield to the east of Merthyr.

The Llanddetti col would have an advantage over the more southerly cols at least in that it gave access to a relatively ice-free area, and also that it was an area where the rocks had been shattered along the line of the

Vale of Neath Disturbance. Although the pre-glacial Crawnon is shown in fig. 12 following the line of the Disturbance (and the present Usk) east of Llangynidr, it now seems more likely that the river formerly flowed over the Pant y beili saddle (P in Fig. 11), to join the Rhiangoll at Tretower. Initial ice movement was therefore probably through the Llanddetti col, and then to the north of Myarth Hill (7 in fig. 11). This ice was probably augmented by ice spilling over to the north of Buckland Hill at Bwlch, although movement transverse to this (via. cols D and F, fig. 11) appears to have been considerably more significant. Erosion of this ice, confluent with ice from the upper Rhiangoll (some of which probably derived from beyond the Black Mountains scarp) may account for overdeepening of the lower Rhiangoll about Tretower, the site of considerable alluviation during deglaciation. A diffluent tongue from the main glacier in the lower Crawnon seems later to have initiated the present direct route east along the line of the Disturbance, which was later taken by the Usk. Erosion of these two subparallel ice streams has trimmed Myarth Hill into its present boat-like form. The late occupance of the more direct route east of Llangynidr probably explains its shallowness when compared with that of the Rhiangoll at Tretower.

At Llanddetti it is no longer possible to say at what height the original col lay as the scarp is no longer continuous in this area. To the south of the river there is a steep and almost continuous slope to the summit of Tor y Foel (1806 feet O.D.), although a slight lessening of the slope occurs at about 1300 feet. Evidence of high level movement of ice is, however, to be seen in the lower part of the Caerfanell, where col E (fig. 11) takes the form of a drift-floored trough at 940 feet O.D., which appears to have been formed by ice moving at a high level eastwards out of the Caerfanell into the trough at Llanddetti. North of the river Buckland Hill (1034 feet, O.D.) seems to have been completely overrun by ice, and gives no hint of its pre-glacial form. The ice movement which developed this route through the scarp at Llanddetti may be considered transfluent (see Linton, 1951, p. 11 ff.) as a new direction of ice movement was established near the source of ice accumulation which could not be considered as the result of erosion by the distributary of an existing glacier (i.e. diffluence) and indeed, at a later stage all ice movement from the northern scarp of the Brecon Beacons seems to have been channelled along this route.

Apart from the evidence of the Usk trough itself, there is considerable evidence of south-easterly movement of ice in the area. The form of Llangorse Lake, and the valley of the Llynfi above it suggest hollowing out by an ice stream pushing southwards into the Bwlch area, whilst the ridge of Allt yr Esgair on the Usk-Wye watershed shows an ice-smoothed form which could only result from ice moving in a direction parallel to the alignment of the ridge (4 in fig. 11). Myarth Hill (7) shows similar evidence of ice moulding. These two hills may be compared to features referred to by Linton (1963, 3) as 'rock drumlins'.

Ice erosion on the scale that has been suggested must have occurred during the glacial maximum for the area. The floor of the glacial trough at Talybont, for example, is now 250 feet below the level of the Pennorth col (C in fig. 11) which it is suggested, marks the line of the proto Caerfanell-Llynfi stream, and which itself has almost certainly been deepened by the passage of ice.

An unknown amount of superficial deposits fill the rock-cut basin of the Usk immediately adjacent (there are, however, 130 feet of superficial deposits covering the rock floor of the Caerfanell valley at the dam site of the Talybont Reservoir (North, 1956, 57) and a greater thickness is likely in the main valley). A valley perhaps 400 feet deeper has therefore been gouged out transverse to the pre-glacial valley pattern. Similarly at Brecon the clearly ice-gouged, trough-like valley of the Usk immediately east of the town has an alluviated floor at 425 feet O.D., which is 300 feet below the floor of the col at Brynich, considered to have formerly carried the drainage from this area. Ice erosion in this part of the Upper Usk has obviously occurred on a major scale, almost totally obliterating the landforms related to the pre-glacial drainage pattern. It is virtually only the anomalies which exist in the present day drainage, combined with clear evidence of significant ice modification, which suggests that a major redirection of drainage has occurred in the area.

Once the route across the scarp at Llanddetti had been established, further deepening and widening of the trough is likely to have occurred during a phase of less extensive glaciation - perhaps the last - when the ice was confined to the valleys. Ice coming from the Fforest Fawr cirques, and down the Eppynt valleys would then be channelled along this newly opened route to the east. Evidence will be presented later that the last glacial advance in the area was a valley glaciation, at which time the Usk and the Wye carried the main ice streams moving off the Welsh massif in this area, and the Llangorse Basin remained as a kind of unglaciated enclave between the two valleys.

Objections to the theory. The theory presented concerning drainage evolution is not entirely satisfactory, and some of the arguments that can be made against it are here considered. In particular glacial modification of landforms is proposed on a scale far greater than any previously suggested for this area, although M'Caw (1936) suggested that the former course of the Usk lay over the Bwlch col, and the present valley through Llanddetti was the result of glacial erosion. The argument hinges on the relative effectiveness of ice in the area as an erosive agent. Unfortunately, the effectiveness of former ice streams as erosive agents is not easily demonstrated, especially in soft rock areas, and the problem is complicated further when the major erosional phase is considered to antedate the last glacial episode, weathering rates being accelerated, and slopes smoothed by solifluxion activity during that period. Apart from hill streamlining, the main evidence of erosive action by the ice is to be seen in the trough-like valley of the Usk itself. This has been eroded to a level considerably below that of the present valley floor (Unfortunately no bores have been put down in this part of the valley). As the river is running over the rock floor of its valley in the Llanddetti gorge, a reverse gradient of the rock floor occurs above here, and it can only be attributed to glacial erosion. Indeed, the form of the valley past Talybont suggests that it has been gouged out by a very powerful glacier moving down-valley. If ice appears to have been so effective when the glaciers were probably not large enough to have overflowed from the main valleys, it seems entirely reasonable to ascribe very considerable erosional activity to the period when ice thicknesses were at a maximum. The exact thickness of ice during the maximum can only be guessed at, but Howard (1903,) has reported drift on the north scarp of the Black Mountains above Talgarth at 1,200 feet, and drift can very often be seen on hill slopes well above 1,000 feet contour. A thin till was noted, for example, at over 1,400 feet at the roadside near Blaen Onneu, above Llangynidr (158173). The attribution of considerable erosional competence to ice of thicknesses perhaps exceeding 1,000 feet is entirely reasonable.

Other, largely fluvial, objections may be made. It could be argued that the trend of the south-bank tributaries of the Usk is of little account as they are obsequents of no great age, the present length of which is the result of scarp retreat, which was in any case probably accelerated during the Pleistocene. This is a valid point, but the form and trend of the Caerfanell cannot be dismissed in this way. These factors suggest that it is a drainage feature of some age, which may best be explained by postulating that it once flowed northwards to join the streams now draining the Llangorse Basin.

A further argument against the sequence of drainage changes suggested is that it is unlikely that following the substitution of a subsequent stream pattern for the original consequent system, this would be disrupted and a drainage established having a trend not dissimilar to that of the original consequents. That this should happen is quite understandable if, as it appears, the movement of the diffluent ice streams across the watershed was determined by the presence of cols related to the old consequent drainage pattern.

It is relatively easy to find faults in a theory, and far more difficult to produce an alternative. In this case if glacial interference is discounted, how may the anomalous course of the Usk below Brecon be explained? River capture has already been ruled out, so the only alternative seems to consider the Middle Usk as of considerable antiquity, but modified by glaciation.* This suggestion is most unsatisfactory, leaving unexplained the considerable constriction of the valley at Llanddetti,

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*This is implicit in the work of Brown (1956) who identifies remnants of his Middle and Low Peneplains on the shoulders of the valley of the Middle Usk. Disruption after the Low Peneplain stage by subsequent growth from the Middle Wye, and re-establishment of the former route during the Pleistocene, would, however, explain its present constriction at lower levels.

the absence of left bank tributaries, the anomalous course of the major watershed, and the oblique junction of the Caerfanell valley with the main valley.

CONCLUSION.

It is thus considered that although considerable problems are raised, the most reasonable explanation of the present drainage pattern of the area is that the Usk below Brecon was developed as a transfluent ice trough during the glacial maximum for the area. The major landscape forms were shaped at that time, and the land-forms of the Llangorse Basin are probably a relic of this period. Succeeding glacial advances were confined to the main valleys, the Beacons ice stream being hence-forward diverted eastwards along the Usk. Further deepening and shaping of the valley occurred, and a significant rock basin was excavated at Talybont, although the resistant Brownstones crossing the valley between Llanddetti and Llangynidr retarded ice erosion there, the valley today being extremely narrow, without any thick-ness of superficial deposits on the rock floor.

(b) THE BRECON AREA.

1. MAJOR VALLEY FORMS.

Brecon lies at the head of the main valley of the Usk. Above it, although the Usk gathers tributaries off both the Eppynt and the Fforest Fawr scarp, it no longer has the appearance of a major valley, whilst to the east a trenched, alluviated form is evident. The reason for this is clearly associated with the development of the river between Brecon and Llangynidr as a transfluent ice route during the Pleistocene, as outlined in section (a) of this Chapter, whilst the valley above the town is of greater age, and owes less to ice erosion.

The detailed relief and drainage of the Brecon area is shown in fig. 13. It will be noted that although the Usk flows in a general E.S.E. direction past Brecon, the relief of the area has an important S.W. - N.E. trend. The Tarrell, flowing in this direction to join the Usk at Brecon, is aligned with the low saddle to the north of the Slwch Tump (the Ffynonau gap), and the col in the Wye-Usk watershed at Blaen-Brynich, whilst to the north of this there is a discontinuous zone of high ground formed by the spur of Mynydd Illtyd (to the south of the Usk), the hill north of the river at Llanspyddid, and Pen y Crug. Beyond this is a further zone of low lying ground following a similar trend, and extending from the Usk valley above Aberyscir through the low saddle to the east of the lower Yscir, the saddle at Penoyre (isolating Pen y Crug from the bulk of the Eppynt), and (off the map) a low col to the east of the Honddu, formed on the watershed with its neighbour, the Dulas, a tributary of the Wye.

As stated in Chapter 3 (page 24) there is good reason for thinking that the stream alignments and cols between the Tarell valley and Blaen Brynich are developed along the extension of the Cribarth Disturbance. The supposed line of this major shatter zone, and the regional setting of this small area is seen in fig. 11. It is not unlikely that the second alignment of cols through Penoyre marks a related line of faulting, in view of its sub-parallel alignment. It will be seen that the present drainage is now largely discordant with structure, although the Usk west of Aberyscir is broadly sympathetic to local strike. Both the Honddu and the Usk break through the intermediate alignment of high ground, the latter in a minor gorge between Aberyscir and Llanspyddid, whilst the broad through-route past Cradoc no longer carries a major stream.

(a) Former theories of local drainage development. To account for the anomalous relationship between relief and drainage in this small area, previous writers have suggested alteration of the pre-glacial river pattern due to glacial interference. Carter (1906) suggested morainic blocking of the pre-glacial Usk valley at Cradoc, and the Honddu north of the Slwch Tump, causing the Usk to cut the Llanspyddid gorge and the Honddu to cut its gorge-like valley past Brecon Cathedral to make its present confluence with the Usk at Brecon instead of a former confluence near Cefn Brynich (fig. 13). B.B. Clarke (1934) considered that blocking of the original valley at Cradoc by ice as Wills (1912) had proposed to account for the diversions of the Dee at Llangollen, more likely, and suggested that the former course of the Usk may have lain on the north side of the Slwch Tump. These theories assume that only fluvial erosion is capable of carving alternative routes of valley-like magnitude. The possibility that ice moving down the Usk was not all contained within the present valley does not seem to have been taken into account.

(b) Pre-glacial drainage. In section (a) the evidence was outlined upon which it is suggested a pre-Glacial, structurally-adjusted, drainage was broken up during the Pleistocene by the development of a transfluent ice route to the south-east, thus leading to the extension of a glacial trough across former drainage lines as far west as Brecon. A pre-Glacial upper Usk flowing over the Cradoc saddle, and then over the Ffynonau gap, and the Blaen Brynich col as a middle Wye tributary was suggested (fig. 12). The height and magnitude of these cols and saddles is today, however, of only indirect significance, as this early drainage pattern was at a high level, and they have clearly been deepened and modified by the passage of ice. They may be regarded as indicative only of early drainage trends.

(c) Glacial modification. Predominant movement of ice eastwards seems to have been early established, and glacial erosion and deposition in the area seems to have derived from ice moving in that direction. The Usk valley is relatively shallow above Brecon, and yet a number of ice streams were clearly confluent here, the more important coming from the Fforest Fawr scarp, others streaming south through the Eppynt valleys. The increasing thickness of ice in the main valley would lead eventually to the development of diffluent ice streams, which would utilise cols on minor ridges dividing tributaries from the main valley, in so doing considerably enlarging them. For example, the col at Pencyre, with drumlins within it aligned in a north-easterly direction, is considered to have been enlarged in this way by ice spilling from the main valley into the lower part of the Honddu, which probably carried less ice. As previously pointed out, the original col seems to have been developed along a line of structural weakness.

East of Aberyscir it is suggested that the Usk formerly flowed past Cradoc, the form of the present valley past Llanspyddid suggesting that it was not an important through-route for ice, but that it was developed at a late stage by diffluent ice crossing a low point on the interfluve between the main valley and a minor one previously entered and enlarged by ice crossing the spur immediately west of Llanspyddid.

The trench-like form of the Usk valley immediately east of Brecon was earlier ascribed to localized glacial gouging. On the north side of the Slwch Tump, however, the saddle between the Lower Honddu and the Brynich Brook (the Ffynonau gap) is considerably wider than the main valley, and floored with drift of unknown thickness, which shows drumlinoid forms with east-west alignments. The Lower Honddu is incised into this drift fill at the western end of the saddle, the saddle appearing to have been eroded, and drift deposited, by ice crossing the Lower Honddu transversely from the main valley immediately above Brecon. It is suggested that ice moving east initially utilised the line of the early Usk (fig. 12) up the valley of the latter for a short distance before entering the newly developed transfluent trough near Llanfrynach. At a later stage, ice crossing a pre-existing col on the spur formerly separating the two tributary valleys had enlarged it sufficiently for it to take the main eastward flow, which eventually deepened it below the level of the former route through the Ffynonau gap. This caused the Honddu to incise itself during deglaciation.

2. DEGLACIATION PHENOMENA.

Within the saddles at Cradoc, and to the north of the Slwch Tump the morainic surface left following ice melt seems to have been preserved almost intact (fig. 14) although the Honddu has been incised into the latter to the north of Brecon, whilst a small stream rising in the Cradoc saddle has cut a narrow valley which drains eastwards to the Usk near Fenni-fach (022 289). The drift in these areas normally shows an irregular surface, only locally developing ridges that could be mapped as drumlins, although the morphology tends to trend generally in a west-east direction. In the Yscir and Tarell valleys fairly extensive benches of drift, probably of basal moraine covered with a thin deposit of outwash, have been left following incision of the river into the former drift floor of the valley, in response to glacial deepening of the Usk valley.

In the main valley, morainic deposits are much less extensive, suggesting that alluviation following ice withdrawal has here been more significant, or that fluvial erosion has perhaps removed drift from the valley floor. There is little valley floor drift in the area immediately about Brecon, (except for gravel terraces built out from the Honddu, to be discussed later), or immediately upstream of Aberyscir. Low points in the drift surface flooring the valley in these areas appear to have been infilled by post-glacial alluviation. At Llanspyddid, however, the bed of the glacier appears to have been considerably higher than the present river bed, for the river has incised itself into the smoothed (? by meltwater) surface of till and also into the underlying bedrock. The till now forms a bench declining from 540 feet O.D. at the upstream end of the gorge to less than 500 feet at its eastern end. The fall of the glacial valley floor downstream about here is indicated by the rolling drift surface preserved in the re-entrant leading up into the Cradoc saddle east of Fenni-fach, which merges with alluvial deposits built up about it.

The till bench at the foot of the steeply eroded slope on the south side of the Usk at Dinas is about 60 feet above the flood plain of the river. It suggests a lateral deposit of the ice, perhaps smoothed by solifluxion. It may be paralleled on the north side of the valley by a narrow bench overlooking the railway track to the east of Brecon. Upstream of the confluence with the Usk of the small Brynich Brook a low undulating bench of till does not appear to be cleanly cut by the river, and may have formerly declined steeply towards the valley centre. An ice contact on the face of the gravel deposit above it suggests that this was a basal deposit formed when the ice abutted against the low hill athwart the valley immediately east of here, at which time drainage off the ice was depositing gravels in the north between Cefn Brynich and Llanhamlach. The deposit in the north is a type of kame terrace. The deposits of this area will be discussed in the next section.

Other deposits within the main valley appear to have been fluvially-formed during deglaciation, with the exception of the terraces at Brecon previously referred to. Brecon is sited upon a series of gravel terraces developed on either side of the Lower Honddu immediately above its confluence with the Usk. The most pronounced is that upon which the town centre (from the Struet to St. Mary's Square) is built. Its leading edge is marked by a distinct bluff on all sides except the east, where a faint channel is found close against the valley side. The terrace has a slight slope away from the Honddu valley (i.e. in a southerly direction). It is paralleled by a smaller one on the west bank of the Honddu occupied by the Castle Hotel. A second terrace, with a more pronounced cross-slope, forms the site of the Cathedral. It also has a parallel terrace developed on the east bank of the river. Between the two main terraces on the western bank of the river there appears to be a minor terrace development on which Brecon Castle has been sited. This is intermediate in height between the other two, but it is difficult to estimate the amount of human interference with the landforms here. It will be noted that:

(i) the terraces are all developed below the level of the drift fill of the saddle north of the Slwch Tump, into which the Honddu is incised, indicating that their formation post-dates that incision. The saddle has a drift surface at between 580 and 610 feet O.D., whereas the two main terraces are between 480 - 510 feet and 445 - 470 feet. The flood plain of the river is here at about 430 feet O.D.

(ii) they project into the main valley, indicating formation when the ice of the valley was no longer active. Any significant forward movement would have destroyed them.

(iii) they do not continue along the valley for any distance, although there is a possible downstream continuation of the upper one which may be confused with a till bench similar to that developed on the south side of the river.

No exposures were available that revealed the bedding. It is suggested that these features were formed during the final stages of ice melt, the upper terrace being formed first, and then the lower, following contraction of the glacier, which allowed a further extension into the valley. There is a reference to terraces formed in this way by Hoppe and Ekman (1964, 338).

Riverine Deposits. A river terrace can be traced downstream from the gorge-section at Llanspyddid to Dinas. The large proportion of poorly rounded stones observed in an exposure opposite the latter place suggests that it was formed largely of till, which was probably washed out of the gorge at Llanspyddid. The terrace has a steep down-valley gradient, declining from 472 feet at Llanspyddid to 432 feet immediately below Brecon, and 422 feet O.D. opposite Dinas. This is slightly steeper than present river gradient, the terrace being highest above the river at Llanspyddid. Exact relationships were not determined. The river is eroding the rock bed of the valley at Penni-fach, and also in the incised section at Cefn Brynich. Down-cutting of the floor of the latter has probably caused this minor incision of the river within this section.

Overlying the terrace are fans of gravel which have been built out into the main valley by the Tarell, the Cynrig (east of Dinas) and from the small valley incised into the eastern part of the Cradoc saddle (fig. 14). The Honddu and Brynich Brook show incised courses until their confluence with the main river, and so have not developed fans. The rivers which have developed fans are now incised into them, showing that their development is not continuing (see Chapter 9, pp. 360-69).

3. CONCLUSION.

Extensive fluvio-glacial deposits at Cefn Brynich suggest that the ice paused there during deglaciation.

Elsewhere, glacio-fluvial deposits are not extensive. The presumed sub-glacial drift surface appears to have lain below the present alluvial spread at Brecon, but rises upstream through the Llanspyddid gorge.

To the north of the river, wide drift-floored saddles show that ice movement was not confined to the present valley, and it is suggested that the former course lay through the Cradoc saddle and to the north of the Slwch Tump, the present valley being formed by diffluent ice streams. The matter is complicated by the disruption of a former north-easterly trending drainage pattern. Ice smoothed rock bosses north of Llanfrynach appear to be developed where ice following an essentially pre-glacially developed valley entered the trough developed headwards from the transfluent gap at Llanddetti.

(c) LLANFRYNACH - LLANDDETTI.

The formation of this part of the Usk valley by transfluent ice during the glacial maximum in the area is described in section a. The valley shows an extremely regular form with steep sides rising above an alluviated floor, although the valley widens at Llanfrynach, where the Cynrig and Menascin are confluent with the Usk, and a low streamlined hill of solid rock rises in the valley centre. The Usk passes this on the north, entrenched between high banks of drift, but there is a suggestion that the alluviated trough is continued on the south side, as is shown in fig. 11. The Caerfanell shows similar evidence of severe glacial erosion, continuing as a deep curving trough well into the heart of the western part of the Brecon Beacons.

GLACIAL RETREAT PHENOMENA WITHIN THE VALLEY.

The glacial morphology of this section of the Usk is shown in fig. 15. Morainic deposits are found in two main places: at Buckland and near Llanfrynach, the area between being occupied by the bedrock hollow filled by aggradational material, previously referred to. The impressive series of cross-valley ridges at Buckland+ is

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+ See Plate 3.

the lower of the two, and appears to be the result of a fairly prolonged period when the ice snout lay at the beginning of the gorge section past Llanddetti. Accumulation of morainic material at this point may be associated with the constriction of the valley, as a temporary re-advance of the ice front would be impeded by the narrowness of the valley below this point. It is possible that the morainic accumulation is a type of push moraine: no exposures are available. It comprises a series of ridges, most of which are transverse to the valley. The river has cut through these, and slumping due to undercutting is evident on the west side. Individual ridges appear to be linked with similarly trending ridges on the opposite side of the valley. Hollows between the ridges are in some cases undrained, and at Buckland one has been utilised for the construction of a large fishpond. Meltwater channels can be traced on both sides of the moraine close to the valley side, and the road on the west side of the valley uses one such channel in its climb over it.

The Buckland moraine rises approximately 65 feet above the alluvial deposits which flank the river in its course through it. No outwash deposits can be identified which are associated with this moraine. Immediately downstream the morainic deposits are undercut, and they sink below an alluvial deposit infilling a small basin in the valley floor, and a short distance below this sandstone flags are to be seen in the bed of the river. This indicates:

1. that the formation of this morainic dump largely post-dates the dissection of the Llangynidr valley train (to be discussed in the next section);

and 2. that the stream draining the ice front was able to transport most of the debris that it was carrying to well beyond the moraine. The narrowness of the gorge, and the high gradient of the rock floor may have assisted this.

The second pause in the last ice retreat in this short stretch of the valley is marked by outwash deposits, which also occur at a point where the valley is restricted, this time by the low hill athwart the valley at Llanfrynach. The Usk today cuts through a narrow, shallow valley to the north of the hill, whilst to the south there is a broad gap, about 50 feet higher than the floodplain of the Usk, which is floored by outwash. There are no exposures showing the nature of the deposits in the gap, but it seems unlikely that they can be anything else. Water passing through the gap has undercut the south side of the central hill mass (fig. 15), producing a minor cliffed zone. This cliffing cannot be recent, because there is a large water-filled kettle hole close to this side of the gap which must have been formed by the melting of an included ice mass <u>after</u> the gap had ceased to function as a major down-valley drainage route. The upstream end of the gap is marked by a series of low ridges rising above the surface of the outwash, and generally transverse to it. These are considered to be morainic ridges partly buried by the up-valley development of this small valley train.* Beyond this, the outwash deposit is terminated on the edge of the gravel fan at the mouth of the Cynrig, the surface of which is less broken than that of the valley train, and slopes northwards to the Usk, whereas the valley train has a slope south-eastwards through the Llanfrynach gap. The Menascin crosses the eastern end of this gap, where the ground becomes particularly marshy.

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* The term 'valley train' is used throughout this work to describe "a long narrow body of outwash confined within a valley". (Flint, 1957, 139).

In this area, two probable drumlins rise above the surface, showing evidence of water-trimming on their western ends. There is a general northerly slope across the gap in this area, partly due to the Menascin which has built out a low gravel fan upon its surface west of Llanfrynach.

On the north side of the valley morainic evidence is slight, although a sloping, hummocky terrace flanks the Usk on its south side near the road bridge (079271) and on its north bank, upstream of the confluence of the Brynich (067277), two eroded, arcuate ridges are found at a level similar to those on the south of the valley.

Above these, at a level of 450 - 480 feet, a deposit of gravel is built up around the series of low hills in the Groesffordd area. A good exposure of this was available during road works near Brynich Bridge (069277). This forms a fairly even surface, demarcated from the rock hills rising above it by a sharp break of slope, and sloping both riverwards and down valley. Although its face is predominantly river-cut, probable ice contact forms exist in two places where river under-cutting has not occurred (fig. 15). For these reasons, and also its association with meltwater channels, it is considered to be a kame terrace. Its height suggests formation at a stage prior to the deposition of outwash and morainic deposits in the Llanfrynach area, possibly when the ice front lay at Buckland. Shrinkage of the ice to uncover the central hill in the Llanfrynach area concentrated melt water into two channels, on either side of it. During this stage, removal of some pre-existing marginal gravel accumulation probably occurred, leaving the trimmed remnant of the present. The northern meltwater escape established itself as the most important, and thus was followed by the Usk upon withdrawal of the ice.

The origin of the hill rising from the centre of the valley is uncertain. It is probably the remnant of a larger mass for it shows evidence of streamlining by ice passing along the valley. Two ice streams might have merged here, before entering the narrow section of the valley past Talybont: a northern stream, probably of predominantly Eppynt and upper Usk origin, passing east through the Penoyre col (A in fig. 11), the Ffynonau gap, north of the Slwch Tump, and the small Brynich valley; and a southern stream, mainly of Beacons ice, passing along the present trough of the Usk below Brecon, and through the Llanfrynach gap. The Slwch Tump and the Llanfrynach hill would have formed part of the ridge of higher ground separating these two ice streams, whilst the complete isolation of the Llanfrynach hill would have been achieved at a later stage when the main ice flow was probably confined to the present valley of the Usk.

Between the two morainic deposits at Llanfrynach and Buckland the valley is now occupied by an extensive area of alluvial deposits. These stretch across the whole width of the valley floor, and near Pencelli are scarred by numerous old river channels.* At the mouth of the Caerfanell, the river has built a gravel fan across the flood plain of the Usk, upon which is sited the village of Talybont. In general, the alluvial deposits are flanked by a narrow bench of boulder clay, although on the north-west side of the Caerfanell fan, a flat-topped, steep sided finger of gravel projects into the valley. Its northern face appears to be an ice contact whilst its downstream side has been undercut by the Caerfanell. It is judged to be a kame. Two abandoned

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* This tendency towards exaggerated meandering, associated with a rapidly changing river trace, has been noted to be associated with extensively aggraded areas in other parts of the Usk.

pits indicate gravel working in the past, although they are now vegetated and there are no good exposures. It is separated from the valley side by a meltwater channel, whilst a flat bench leading into the Caerfanell at a higher level may be the product of meltwater erosion. At Pencelli, the flat-topped bluff overlooking the village on which stands the ruins of Pencelli Castle, is considered to be the remnant of an ice margin gravel deposit - a kame terrace (fig. 15). No clean exposure was available, although well rolled pebbles in a very silty matrix are to be seen in the cutting between the Castle and the canal.

About Pencelli, there are two well-marked terrace features. The outwash filling the Llanfrynach gap is terminated by a marked 7-8 foot bluff. This 'terrace' which is very flat and badly drained near the Menascin has a leading edge slightly above 400 feet. Below this a second, quite distinct terrace with its leading edge at about 390 feet rises above the flood plain which here is at about 380 feet O.D. It appears unlikely that these features are river terraces, the result of down cutting by the Usk, because the alluvial floor of the valley suggests that it is being aggraded, rather than degraded. Almost everywhere else the marshy alluvial floor meets the valley sides. The solution may, however, be founded in two less extensive, but similar features at Talybont and Buckland respectively. Both lie near the mouths of tributary streams, and that at Buckland is very clearly the remnant of a small delta (see Plate 1), although no exposure was available to reveal the bedding of the deposits. This was the case also at Talybont (Plate 2), where a similar, flat-topped feature flanks the valley side to the south-east of the village. This has been cut away by the Caerfanell during the formation of its fan, which thus post-dates it.

The height of these features was determined with a surveying aneroid. The leading edge of the Buckland feature was measured in two places, giving heights of 389 and 390 feet, whilst the alluvium here is at 366 feet (this may be the surface of a low level terrace due to downcutting of the Usk in the Llanddetti gorge). The eroded leading edge of the Talybont feature was measured in two places also, and gave heights of 394 and 396 feet, whilst the fan of the Caerfanell is at 378 feet. The slight variation in height does not detract from the suggestion that these are deltaic remains as it is considered that the Talybont feature is the remainder of a much larger structure which would have, of course, a slight cross slope. Instrumental error must be taken into consideration when using a surveying aneroid, and a variation of 2 or 3 feet may be put down to this. Upstream, at Pencelli, the lower terrace is at a similar height, and it is suggested that these three features are deltaic remnants related to a water level of approximately 390 feet O.D.

It is not difficult to account for the formation of such a lake. The Buckland moraine was quite obviously once continuous across the valley whilst upstream, the wide expanse of alluvium indicates an ice-eroded rock basin. The exact depth, as already noted, is a matter of surmise as no bores have been put down (North, 1956, 57). The form of the valley floor suggests, however, that riverine aggradation rather than lacustrine sedimentation accounts for the present form, suggesting that the morainic dam at Buckland was breached before the hollow was infilled, and that alluvial material has completed the infill. If the Buckland, Talybont and Pencelli features are deltaic however, it is likely that lacustrine sediments will be revealed by deep boring. The probable extent of moraine-dammed "Lake Talybont" and associated features, is shown in fig. 16.

The Bwlch Channel.

To the north-west of Bwlch, the col (D in fig. 11) in the watershed dividing Allt yr Esgair from Buckland Hill is cut into by a marked channel. This has an "up and down" profile, its southern end being drained by a stream descending into the Usk valley north of Buckland, whilst its northern part slopes into the head of the Llynfi valley. The channel is at about 625 feet, O.D., and is thus about 250 feet above the level of the main valley from near Buckland.

The col into which the channel is incised was clearly eroded by ice, probably passing southwards from the Llangorse Basin into the Usk (fig. 11). The channel, however, must have been formed by water crossing the col, and this is most likely to have occurred during the late stage of valley glaciation, when the Llangorse Basin was relatively ice free. It is suggested that drainage down valley, both of englacial and marginal meltwater, might have been hampered by the constriction of the valley at

Llanddetti, and for a short while drainage occurred northwards across the watershed at this point. It is possible that the "up and down" profile indicated that the water forming it was under hydrostatic pressure, but more likely that the slope down into the Usk is the result of headward erosion by the small stream draining that angle of the valley.

CONCLUSION.

The final retreat of the ice in the area is marked by two dumps of morainic material at Buckland and Llanfrynach, indicating halt-stages. The Buckland moraine was probably developed after dissection of the Llangynidr valley train. When the ice front lay at Llanfrynach, a temporary lake is likely to have been held up behind the Buckland moraine, as evidenced by deltaic remains at three places. Higher level glacio-fluvial deposits flanking the supposed site of 'Glacial Lake Talybont' are considered to date from the Buckland ice halt.

(d) LLANDDETTI - PENMYARTH.

1. GENERAL.

The section of the Usk valley between Llanddetti and Penmyarth (fig. 17) is in complete contrast to the stretches of the valley above and below it. The latter are both wide in section and flat floored, whilst in between, at Llangynidr, the river is confined by high terraced banks with an almost complete absence of flood plain. It is separated, however (see inset map, fig. 4) from the wide, flat floored lower Rhiangoll valley at Tretower by the smooth bulk of Myarth, whilst the line of the west-facing scarp of the Black Mountains is continued by Buckland Hill, and the related constriction of the valley at Llanddetti.

2. EROSIONAL FORM OF THE VALLEY.

At Llanddetti the river swings from the predominantly north-south course it has been following into an ESE course. The valley has narrowed, and steep sides fall to a valley floor encumbered with glacial debris.+ The outer (southern) side of this wide bend of the valley, in particular, shows the result of glacial erosion at its base, showing markedly oversteepened slopes. In this section

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+ See Plate 5.

the Usk reveals the solid rock, flowing over large tabular slabs of Old Red Sandstone. From here to below Glan Usk its bed is formed of the Brownstones division of the Sandstone, with numerous rapids and small waterfalls. South of Llangynidr Bridge the river is remarkable for the number of potholes which have been developed in the sandstone.

At Llangynidr+, the valley gains width, partly due to the several tributaries which join it from the south (there are none from the north). The valley here is assymetrical, the river hugging the north of the valley, under the steep slopes of Myarth, although the dip in the Old Red Sandstone is towards the south. Despite the incision of the river, the valley is generally wide, and the village of Llangynidr spreads over a gently sloping bench. Crossing this bench, the Crawnon and the Claisfer (particularly the former) have incised themselves deeply, partly in response to the downcutting of the Usk, in so doing revealing the limited depth of glacial infill of this section. East of Llangynidr, the valley narrows again before the confluence of the Rhiangoll, where conditions more nearly like those above Llanddetti are seen once more.

+ Plate 4.

3. DEPOSITIONAL FORMS.

Although we have noted the many solid rock exposures of this stretch, both along the Usk and in the tributary streams, the glacial deposits are, none the less, most important. There is a distinct variation in the nature of these deposits (see inset, fig. 17) those above the Crawnon confluence being almost wholly morainic in origin, whilst those to the east of the Crawnon are predominantly terrace forms of fluvial or glacio-fluvial origin.

(a) Morainic deposits.

Above the confluence of the Crawnon, morainic ridge and kettle is most common. This is in fact one of the major morainic dumps within this part of the Usk valley. Ridges are predominantly aligned along valley. The morainic surface appears to decline in height, relative to the river, as traced upstream, disappearing beneath alluvial deposits south of Llanddetti Hall. The pattern of ridge and kettle becomes more chaotic as traced eastwards, although the pronounced along-valley trend is maintained. In the Glawcoed area (141200) the extremely sandy nature of the surface deposits suggests a variable cover of probable ablation material.*

The relationship of the Glawcoed morainic deposits and those at Buckland, half a mile upstream (shown on fig.15 , not on fig. 17) which were discussed briefly in the proceding section, are interesting. The two morainic areas are separated by a stretch of alluvium filling the valley floor, the relationship of which with the valley sides suggests that it fills a hollow in the drift surface. The surface form of the Glawcoed deposits could indicate that the ice had there overridden a morainic plug in the Llanddetti gorge as it left the over-deepened section of the valley about Talybont. Formation of the Buckland moraine would seem to have post-dated the dissection of the Glawcoed morainic plug, and associated glacio-fluvial deposits, otherwise one would expect the valley immediately downstream of the Buckland moraine to be filled with outwash to a level above that of the recent alluvium.

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* At Glawcoed difficulty was experienced during the construction of the water pipeline to Newport from Talybont reservoir due to the rapid variation in the character of the deposits here, and in particular, sinking in pockets of fine sand. (Information from the local farmer, verified by inspection of log books of the pipe laying team made available by the Newport and South Monmouthshire Water Board. These include detailed notes on the nature of the material through which the trench was cut, although their usefulness is reduced by the absence of any locational guide other than distance measured in chains from the start of the pipeline).

(b) Terrace forms.

East of the Crawnon confluence, morainic ridge is almost totally absent from the valley floor, although a few are to be found in marginal locations rising above other deposits. Here the distinctive landform is the terrace, a series of these rising on both sides of the river, although best developed on the south side. These are not all river terraces, and for reasons to be outlined later, it is considered that these were formed very largely by the dissection of an extensive fluvio-glacial deposit, formed when the ice front lay in the Llanddetti gorge.

The terraces in the valley were investigated by

(1) mapping morphologically on a six-inch scale; and
(2) measuring the height of the main ones with a surveying aneroid.

The morphology of this part of the valley is shown in fig. 17, whilst terrace height relationships are expressed diagrammatically in fig. 18.

Fig. 18 is an abbreviated version of the usual diagram to show thalweg/terrace relationships. In view of the limited significance of these localised terraces in relation to the valley as a whole, the aneroid survey was relatively rapid, and the aim was:

(1) to obtain measurements representative of the cross section;

(2) in terraces of significant lateral extent such measurements were taken at intervals along the terrace, although where terrace remnants were small, one aneroid measurement was generally considered suitable.

The terraces have been numbered in fig. 17 independently on the north and south sides of the river, and these have been plotted in fig. 18, terraces from the south bank having the number prefixed by an 'S' and those from the north bank by an 'N'.

Height relationships and morphology convince that one is not dealing simply with a valley fill dissected by the river in post glacial time. In ascending order of height, the features identified are as follows:-

(1) Kame terraces. These are the best developed of all, and are distinguished by their height, the rolling form of their surface, and the presence of ice contact features at places along their outer edges.

The Kame terrace shown in figure17 declines in height from over 400 feet near Cilwych-fawr (144203) upstream of Llangynidr Bridge) to less than 290 feet in Glan Usk Park. It is the highest extensive terrace feature, although a number of more isolated benches, generally boulder-strewn and judged to be either the remnants of marginal moraines or meltwater erosion, are to be found in places on both sides of the valley. North of Llangynidr Bridge, the terrace can be seen to be two-tiered, suggesting an earlier and higher kame terrace left stranded by ice shrinkage. The upper terrace leads into the mouth of a well developed overflow channel cutting through the col between Buckland Hill and Myarth into the large amphitheatre east of Bwlch (F in fig. 11).

The surface of the kame terrace is rolling, but everywhere displays a marked break of slope at its rear. In a few places ridges rise above it. These are considered to be remnants of lateral moraine engulfed by fluvio-glacial deposits.

The diagnostic features are, however, the ice contact features to be found at places along its leading edge, which prove that it was not originally part of a continuous sheet of outwash filling the valley. These are to be found on the slope above Llangynidr Bridge, at Gliffaes, and at two places where the Usk enters the broader valley of the lower Rhiangoll-Usk (fig. 17). The latter suggests that a mass of dead ice persisted here, against which these fluvio-glacial deposits were built. Elsewhere, the kame terrace has been undercut by river erosion. The width of these terraces compared with the narrowness of this part of the valley suggests that the ice was very much decayed during their formation, and possibly completely overspread by glacio-fluvial detritus in places.

(ii) Valley train remnants. If the uppermost of the main terraces is accepted as a kame terrace, a major problem arises concerning the origin of the lower terraces. The presence of kame terraces is indicative of extensive glacio-fluvial accumulation in association with wasting ice masses. In more central positions within the valley, crevasse fillings might be expected, associated with masses of supra-glacial and englacial material let down on the uneven surface of basal deposits. In this instance, however, the terrace immediately flanking the leading edge of the kame terrace has a generally even surface which suggests fluvial deposition. The few poor exposures all reveal gravels, whilst there is some evidence of fluvial trimming of the high level kame terrace features. The evidence seems to suggest that we have remnants of a valley train, probably developed when the ice front lay in the Llanddetti Gorge. The surface of the valley train at Llangynidr is low relative to the Glawcoed moraine (the highest measured points on the valley train being 385 feet - on both sides of the river near Llangynidr - whereas the morainic ridges at Glawcoed exceed 400 feet). This could be explained by the suggestion, put forward in the discussion of the Glawcoed deposits, that they comprise an old morainic plug - perhaps a recessional moraine - overridden by the glacier.

(iii) <u>River Terraces.</u> The valley train is found at a height varying from 40 to 70 feet above the present flood plain of the Usk. Its gradient is greater than that of the flood plain, so that the height relative to the river declines as traced downstream. The valley train once filled the valley below the level of the kame terraces, and the present narrowly incised form of the valley past Llangynidr is largely the result of its dissection.

stages in the dissection of the valley train are recorded by river terraces.

Throughout most of this section the river has not migrated laterally to any great extent during incision, so that river terraces are generally narrow and discontinuous. The main exception to this is near Llangynidr Bridge where the river had tended to swing against the north bank, leaving two tiers of terraces on its south side, and in Glan Usk Park where the extent of terraces suggests a slow movement down the valley of the first meander formed by the Usk after leaving the constricted section above Penmyarth. (Plates 7 and 8)

It would be expected that a river dissecting a valley fill would carve it into a series of unpaired, meander terraces. In fact this does not appear to be the case. Fragments of one terrace, lying broadly within one plane, appear to dominate (terraces S 1, S 4, N 4, S 12, N 5, N 7 and S 14). Above this there is only one small terrace remnant (N 5) and terrace S 15 is possibly a terrace developed at a lower level, although this may be part of the flood plain, distinguished from its adjoining parts by a meander scar. The major terrace stage is best developed in Glan Usk Park, and for convenience we will refer to it as the Glan Usk stage. If it is accepted that the terrace fragments enumerated belong to one stage, the gradient at that stage appears to have been slightly greater than that of the present flood plain (fig. 18).

The reason for the extensive terrace development of the Glan Usk stage is not clear. There is no reason for suspecting a minor phase of rejuvenation affecting the whole river, although low terraces are developed elsewhere. It is more likely that such terraces are related to erosion of local base levels formed by upstanding areas of the rock floor of the valley left after ice withdrawal. Throughout the Llangynidr gorge the Usk is running over the rock floor of the valley, and there is evidence that the river has cut down considerably into this. This is best displayed below the small waterfall of Pwll yr hesg (158202), where lithological contrasts are being exploited by the river. Extensive pot-holing upstream of the fall, and rock outcrops above river level in this area further testify to the effectiveness of the river in eroding its bed. It

It is quite possible that the Glan Usk stage records the completion of the removal of the bulk of the superficial deposits, further down-cutting being into the rock floor of the valley and therefore slower, giving the river scope for more considerable lateral development.

4. CONCLUSION.

The extensive gravels partially filling the valley below Llangynidr are considered to be glacio-fluvial. The higher gravels form kame terraces, extensively developed on both sides of the valley, which were probably built up against the wasting remnant of the last ice mass to occupy this part of the Usk. Below them a valley train, probably developed from an ice front in the Llanddetti gorge, has been dissected by the river which now flows along the rock floor of the valley throughout this stretch. The terrace pattern is dominated by one series of terraces (the Glan Usk Stage) suggesting a major halt in down-cutting by the river. The reason for this is not clear, although it could reflect the re-exposure by the river of the rock floor of the valley. The relation of the Buckland moraine to the morainic deposits at Glawcoed indicate that it was formed after dissection of the morainic and glacio-fluvial deposits in the valley about Llangynidr.

(e) THE VALLEYS OF THE BLACK MOUNTAINS.

As will be shown in section (f), the Usk valley between Crickhowell and Abergavenny shows evidence of considerable enlargement by ice erosion, and its detailed topography is today one controlled primarily by the forms of ice and meltwater deposition left during the final retreat of the ice. It is therefore difficult to establish the nature of this part of the Usk prior to the Pleistocene Glaciation, although in view of the evidence produced in section (a) of this Chapter, for the Pleistocene initiation of the stretch of the Usk between Brecon and Llangynidr, it is important that this should be done. Reconnaissance revealed that the valleys of the Black Mountains to the north of the Usk appeared to be relatively lightly glaciated, and therefore likely to show evidence of their pre-glacial form. This in turn could be expected to throw light on the pre-glacial form of the present main valley to which they are tributary. Three of the valleys of the Black Mountains were studied in detail with this objective in mind (fig. 19): the Rhiangoll, the Grwyne Fechan - Lower Grwyne Fawr, and the Gavenny.

Previous workers (Clarke, 1936; M'Caw, 1936) have pointed out the considerable variation in the character of the Black Mountain valleys, due in part to their erosional history, some having lost or gained waters by piratical activity, others having been modified to a varying degree by glacial action. This is true of the rivers selected, the Grwyne Fechan showing less evidence of glacial activity than the other two, whilst the Gavenny is a misfit stream, its former headwaters now draining eastwards to the Wye <u>via</u> the Monnow.

1. THE RHIANGOLL.

This, the westernmost of the Black Mountains rivers has two important cols on its watershed. They are (i) at the head of Cwm Sorgwm (161 284 - see Fig. 11), where the col opens out into the Llangorse Basin; and (ii) at Pen-y-genffordd (173 301) at the head of the main valley, which leads into the Enig valley, tributary to the Llynfi at Talgarth. Howard (1903, 107) noted an abundance of "yellow fossiliferous sandstones" above Cwmdu, probably of Silurian origin, which would seem to be evidence of a movement of ice from the Wye. M'Caw (1936) also held that ice had entered the Rhiangoll valley by both of these cols. The term 'abundant' used by Howard would seem to be relative, as none of these erratics were discovered during the field mapping, the primary deposit above Cwmdu being a light till, with large angular blocks of Old Red Sandstone. There is, however, no reason to doubt that at least the Sorgwm col allowed the movement of 'Wye' ice into this valley. If ice accumulation in the angle of the Fforest Fawr - Black Mountains scarp was sufficiently great to overtop it south east of Talybont, thus establishing the present Middle Usk, there seems to be no reason for supposing that a subsidiary ice stream did not cross into the Sorgwm, the col at its head being at ca. 1140 feet O.D. This crossing, as with the initiation of the diffluent trough between Talybont and Llangynidr, must have occurred prior to the last ice advance in the Usk, for the glacial forms within the Sorgwm valley are subdued, and long smooth slopes, indicative of solifluxion activity are characteristic. The evidence for an ice crossing of the main scarp at Pen-y-genffordd (1,060 feet O.D.) is less convincing, as ice pressure would here be relieved by movement eastwards along the wide valley of the Middle Wye towards the Plain of Hereford and the col does not suggest enlargement by ice, but until evidence to the contrary is produced, it is reasonable to accept

Howard's erratics (found upstream of the Sorgwm confluence) as evidence of such a movement.

The upper Rhiangoll valley has an assymmetrical form, the most prominent feature being an extensive bench developed on the eastern side of the valley between Fforest and a short distance downstream of Cwmdu (fig. 19). A smaller development of the same feature is to be found on the western side of the valley at Cwm-Fforest. Below Cwmdu it declines in height and disappears with the widening of the valley as the basin about Tretower is approached. It attains a maximum width of almost quarter of a mile. Its leading edge declines from c. 880 feet O.D. at Fforest (which is approximately 60 feet above river level) to ca. 620 feet at Cwmrhos (184 248) above Cwmdu, where the river is at approximately 485 feet. Downstream of this it becomes narrower and ill defined, and a lower bench, clearly formed by glacial deposition, is developed between the remnants of the higher bench and the river.

The surface of the main bench shows wide variations in cross profile, with often no easily identifiable break of slope at the inner edge. In places a series of minor benches may be picked out which seem to merge laterally, usually downstream, into the main bench. The form of the leading edge of the bench also varies considerably in form (Plate 10). Although a few landslip scars and some evidence of stream undercutting is to be seen, the face does not suggest that it results from simple stream incision.

Possible modes of formation considered for this feature were:

(1) Structural. As there is a southerly component to the dip of the rock in this area, the possibility that the bench was determined by a resistant rock outcrop was considered. M'Caw's map of the geology of this area (M'Caw, 1936) shows, however, no resistant bed at this level. Further, its complexity in form does not accord with this suggestion.

(2) Solifluxion activity. The movement of surface deposits on slopes can result in a terrace-like feature at the base of the valley sides. The factors which encourage the development of these solifluxion terraces are not entirely clear, but lithology and aspect are two obviously significant factors. Although solifluxion has occurred to a limited degree over most hill slopes within the area, and is probably responsible for the poorly-

defined up-slope limit to the bench, it is not considered that solifluxion has been primarily responsible for this feature. Firstly, there would not seem to be any reason for such marked development of solifluxion terraces here, when their presence has not been obvious in other parts of the area studied. Frost processes are generally considered to be most effective in soils with high silt content, which might account for the development of these terraces in some of the Coalfield valleys. Here, where the terrace is so markedly developed, soils of relatively coarse grain size are dominant. Secondly, the development of solifluxion terraces could be expected to reflect both aspect and slope. Although most marked on westerly facing slopes where summer melt would be expected to be relatively great, there is a marked development on N.E. and E.N.E. facing slopes on the western side of the valley. The evidence on this point would seem to be contradictory. Finally, there seems to be no relationship between the height and slope of the 'backing' zone, and the degree of development of the terrace. In particular, the increasing height of the terrace as traced downstream is not capable of explanation if we postulate a solifluxional origin.

(3) Rejuvenation would explain the increasing height of the face as traced downstream, incision becoming progressively less marked up valley. However, it is necessary to explain the absence of any clear cut evidence of river incision, and the gradual disappearance of the main bench, below Cwmdu.

(4) A composite origin is thus suggested:

(i) massive ice erosion in the Lower Rhiangoll caused by ice entering the area from three sources: from the upper Usk _via_ the diffluent trough and the Pant-y-beili saddle (section (a)); from the Llangorse Basin _via_ the Sorgwm col; and from the upper Rhiangoll, and possibly also from the upper Wye _via_ the Pen-genffordd col. Erosion on a major scale in the Tretower basin, perhaps exploiting structural weaknesses, would account for the absence of any evidence there of a higher, older, valley level.

(ii) ice retreat and incision of the rivers into the former valley floors now 'hanging' above the deeply eroded lower Rhiangoll in the Tretower area.

(iii) re-glaciation, during which the Rhiangoll was not entered by ice from the Wye drainage basin. Ice action and associated meltwater, modified, to a minor extent, the newly incised 'valley in valley' form.

2. THE GRWYNE FECHAN/LOWER GRWYNE FAWR.

This stream (diagram B, fig. 19) trends in a north-south direction, and is confluent with the south-easterly trending Usk at Glangrwyney. Below Llanbedr, a tapering spur of high ground divides the wide valley of the Usk at Crickhowell from the gorge-like valley of the Grwyne Fawr at Llangenny. This spur is crossed by a wide saddle above Great Oak (B in fig. 20) which is aligned with the Middle Grwyne Fawr, itself a subsequent development along the supposed line of the extension of the Vale of Neath Disturbance (fig. 20).

Two major events are evident in the erosional history of this valley:

(i) Capture of the present upper Grwyne Fawr by subsequent development along the Vale of Neath Disturbance. This stream formerly drained over the col at Bettws (C in fig. 20) into the lower Gavenny valley, and was confluent with the Usk at Abergavenny (see, for example, Jones, 1951).

(ii) Glaciation. Ice from two sources appears to have been present in this valley: local ice, and ice from the

Usk which crossed the Great Oak saddle. Ice accumulation within this valley is generally considered to have been greater ~~in this valley~~ than in the Grwyne Fawr, which retains a relatively narrow cross-valley profile. Clarke (1936, 168) for example, considers the valley to have seen the passage of a "tremendous amount of ice," a view reiterated by Thomas (1959), although the evidence for this is extremely meagre. Clarke based this view on the presence of "great cwms above Llanbedr...(where) the whole east side is eaten away by one cwm after another," and Thomas also refers to these cwms, indicating in a diagram (fig. 21) the location of a considerable number in this and the Rhiangoll valley. It is not contended that the tributary valley-heads within the Black Mountains did not act as centres of ice accumulation, but a measure of their significance in this respect would surely be indicated by their form, and the amount of morainic deposits associated with them. Examination of several such valley heads mapped by Thomas as cirques revealed a general paucity of morainic debris, and very poorly developed cirque forms. Whilst local lithology might be responsible for the development of a typical incipient cirque form, it is surely quite misleading to refer to "this great stream (of ice) going down the Grwyne Fechan" (Clarke, 1936, 168). This view is reinforced by the contrast afforded by those areas which have been invaded by ice from the Usk. The whole of the Grwyne Fawr below Fforest Coalpit (284 208) has drift banked high on the lower slopes of both sides of the river. This was quite rightly attributed by M'Caw (1936) to an "ice lobe which was pared off the Usk glacier by the Wern" (i.e. above Great Oak). The saddle at this place is only 400 feet above the Usk valley floor at Crickhowell, and as drift is to be found well above this level on the slopes of the Usk valley, entry of a diffluent ice mass into the Lower Grwyne is quite feasible. There is evidence for this other than the contrasts in the amount of drift in the Grwyne Fechan and Lower and Middle Grwyne Fawr. In the Grwyne Fawr between the point where the river bends south (above Llangenny), and Fforest Coalpit, the drift forms an irregular bench developed on both sides of the valley. The height of this above the river becomes progressively less as traced upstream, which suggests deposition by an ice body moving in that direction. The maximum extent of ice up the Grwyne Fawr is difficult to determine, but the last major drift deposit appears to be an amalgam of ridges of well-rolled gravels and sands near Pwll-hwyaid, Fforest Coalpit (281 207), whilst to the east of that, a triangular alluvial flat near Pont yspig (286 209) appears to have formed in a body of water held up by the ice. The lobe of ice crossing the Great Oak saddle would probably also deflect south along the lower Grwyne Fawr to join the Usk glacier again at Glangrwyney. The thick drift in this section, with ice contact features near the bottom of the valley in a few places (e.g. at Golden Grove, near Llangenny - 241 176) shows that the valley was eroded to a depth comparable to that of the present prior to the last glaciation of the area. Finally, it will be observed that the marked bench extending down to Llanbedr in the Grwyne Fechan terminates abruptly south of the village, where it has attained its greatest width. Its place is taken by an ill-drained depression about Moor Park (238 199). It is suggested that the former southward continuation of this bench was removed by ice crossing it between the Great Oak saddle and the middle Grwyne Fawr.

As noted by M'Caw (1936), the rejuvenation of the Grwyne Fechan is the best example in the Black Mountains. 'Valley in valley' form is particularly well developed (fig. 19) in the area about Llanbedr, and contrasts with similar features discussed previously in the Rhiangoll in that here the benches are more regular in form, and maximum bench development is to be found on the western side of the valley. The main bench levels may be distinguished:

1. A high series which may be traced at over 1000 feet above the Hermitage (229 251), and declines to just over 700 feet O.D. half a mile above Llanbedr.
2. The main bench, flanking the mouth of Cwm Banw at just over 700 feet, falling to ca. 560 feet O.D. near Llanbedr. Its leading edge near the village is over 100 feet above the river, which is eroding the rock floor of the valley. Exposures of solid rock are evident at places on the leading edge of the bench. (Plate 11)

Below Llanbedr the valley retains its incised form, but benches of non-glacial origin are not here identifiable, with the possible exception of a well marked bench between 390 and 410 feet immediately south west of Llangenny (fig.19) where the Grwyne valley joins the Usk. A series of benches exist in this section of the valley, but they all show till exposures, and from their form and relationship to each other, are considered to be glacial features, possibly cut by marginal meltwater streams.

The Grwyne Fechan appears, therefore, to show two main phases of downcutting (as evidenced by benching) whilst the incised form of the lower Grwyne Fawr, despite removal of any benches which existed prior to the movement across it of a lobe of diffluent ice from the Usk Glacier, is also testimony to an early phase of rejuvenation. This phase is linked by M'Caw with the capture of the upper Grwyne Fawr, which he considered to follow partial planation at the 700-750 foot level, linked by him with Miller's "Forest of Dean Plateau stage" (Miller, 1935), although he also considered that lowering of the 'Usk floor' was shown by incision of the river 60-70 feet in the Llangenny gorge. If a major Pleistocene enlargement of the Usk drainage, as suggested in section (a) is accepted, it would seem unlikely that the most widespread polycyclic forms in the area would refer to a stage prior to this event. The benches so well developed in the Grwyne Fechan are therefore accepted as evidence of the depth of the valley system in this area before glacial enlargement of the Usk drainage, and in particular, the deepening of the valley downstream of the Penmyarth gorge.

3. THE GAVENNY VALLEY.

Before considering in detail the topography of the small Gavenny valley, the theories concerning its erosional history will be briefly reviewed. The Gavenny is a misfit stream, occupying a wide valley which is aligned with the headward portion of the Monnow and the Honddu, which now drain westwards to the Wye (fig. 19A). To the north of the headwater streams of the Gavenny a large dump of glacial drift, with ridges aligned predominantly transverse to the valley separates it from the Honddu, which approaches this and then swings sharply north-east to join the Monnow. Most workers (Howard, 1903; Wood, 1905; M'Caw, 1936) accordingly invoke glacial blockage at Llanvihangel Crucorney to account for the diversion of this former Usk tributary. Only Clarke, who does not appear to have noted the morainic ridges suggests simple river capture by the Monnow, possibly "associated with the uplift which incised the lower Wye" (Clarke, 1936, 162).

Neither theory is entirely satisfactory:

1. To allow for glacial diversion of such a large stream, a more effective glacial dam would be required than that afforded by the glacial ridges at Llanvihangel Crucorney. Standing on the flood plain of the Honddu to the north of it, the 'moraine' is admittedly a most impressive sight, an arcuate, smooth and steeply faced ridge rising almost 100 feet above the valley floor. However, detailed examination reveals that the supposed face of the moraine is only capped by drift, the lower part being cut in bedrock. We are looking, therefore, at a barrier, the large part of which may be attributed to the down-cutting of the present Honddu as it rounds the bend at Crucorney. Moreover, the morainic ridges do not, in fact, form a very effective blockage of the valley, being breached (fig. 19A) at the eastern, and to a lesser extent, the western end, by streams draining north to the Honddu.

2. It has not been adequately explained why this capture should take place so close to, but not along the line of, the supposed extension of the Vale of Neath Disturbance.

The probable line of the Vale of Neath Disturbance, as suggested by morphological evidence, is shown in fig. 19A, by means of an overlay. The straight, trench-like valley of the Monnow, downstream of the Honddu confluence is aligned exactly with the gorge of Cwm Coedycerrig, and the Middle Grwyne Fawr, west of Fforest Coalpit. A low col (760 feet O.D.) at Groes-lwyd (321 223) on the ridge west of Pandy is aligned with this, as is the western of the two streams cutting back here. Capture at Llanvihangel Crucorney can be explained as a result of subsequent development along the line of the Vale of Neath Disturbance only if it is assumed that the Monnow was tributary to the Honddu (and thence to the Usk) before capture occurred. Initial capture of the Monnow by a Wye tributary to the north of Pandy, where the former south-flowing Monnow crossed the line of the Disturbance would soon result in reversal of the flow of the remainder of the Monnow above its confluence with the Honddu, and eventual capture of the Honddu near Crucorney. That such changes could be ascribed to glacial interference, disregarding the presence nearby of a major shatter zone, seems most unlikely.

It is therefore concluded that the capture of the former headwaters of the Gavenny did not take place during the glacial episode, and possibly preceded it, and that in so far as river evolution is concerned, the moraine at Crucorney is not significant. The preservation of such extensive morainic deposits at this place can therefore be attributed to the river diversion, rather than the cause of it, the moraine today extending across almost the whole width of the valley because there is no major stream draining this part of the valley. Likewise, the fine arcuate up-valley face of the 'moraine' is largely due to lateral river erosion since deposition of the drift in the upper part of the Gavenny.

It has formerly been assumed that the Crucorney 'moraine' derived from a local glacier which descended the Honddu valley. No detailed examination of the deposits in the upper part of the Gavenny valley was made, with the object of determining their provenance, but in view of the observation (e.g. in respect of the Grwyne) that deposits of the Usk Glacier tend to be more abundant than those of local ice, it is suggested that the Crucorney moraine might mark the termination of an ice tongue pushing up this valley from the Usk Glacier. This seems most likely in view of the evidence (p. 291) that ice crossed the Wern Ddu saddle at 540 feet O.D. on the eastern side of the Gavenny valley just one mile south of the Ysgyryd Fawr (fig. 20), to leave fresh drift within the upper Troddi drainage basin. It is not unlikely that the mass of morainic ridge and kettle preserved in the re-entrant of Cwm Bryn Arw at Bettws (fig. 19A)[1] also derived from this source.

The flood plain of the Honddu, where it rounds the bend at Llanvihangel Crucorney is at ca. 420 feet O.D. Immediately south of this the morainic ridges reach a maximum height of 547 feet near the centre of the former valley, falling to approximately 450 feet in the marshy area at the head of the Gavenny. The Gavonny soon becomes entrenched, forming a minor gorge in the floor of the main valley, which ends abruptly at the summit of a low angled, 75-feet high bluff in the northern outskirts of Abergavenny (see diagram C in fig. 19). At the foot of this bluff, which forms part of the sides of the glaciated trough of the Usk, a low gravel fan extends over Bailey Park (p. 243). The Gavenny is also incised

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[1] Unidentified by the Geological Survey in their mapping of the Abergavenny Sheet.

into this, only to a lesser degree, and it is confined between high bluffs almost until it reaches the Usk floodplain at 155 feet.

The floor or the 'main' valley into which the Gavenny is incised is essentially solid, although the drift cover is more extensive than suggested by the mapping of the Geological Survey (fig. 19A) which distinguishes generally only those areas where the drift shows bold morphological expression, or where gravel digging has exposed thicknesses of glacio-fluvial deposits. Taking into account the effect of glaciation, which appears to have been more severe here than in the other two valleys studied in the Black Mountains, we have therefore a reasonable indication of the valley form prior to the glacial enlargement of the Usk. The valley form was shaped when the Honddu and upper Monnow were Usk tributaries. The relative shallowness of the Honddu valley suggests that diversion of these two streams may have occurred at a relatively late stage, and might be interglacial.

4. CONCLUSION.

In these three valleys of the Black Mountains there is distinct evidence of rejuvenation: at least two stages (but one main) exist in the Grwyne Fechan, and one distinct stage in both the Rhiangoll and Gavenny. Extrapolating these benches to suggest floor levels in the main valley is not easy, due to the unevenness of the bench surfaces, combined with considerable cross-valley slopes. For this reason, combined with the probably considerable amount of glacial modification, it was not considered that independent field measurement of bench height ranges would produce significantly more accurate estimates of former valley levels than could be made from the existing large scale topographic maps. Former valley levels indicated by these benches are:

a) The Rhiangoll. The most difficult to estimate, on account of the irregularity of its benches. The main bench is best defined above the Sorgwm confluence, where its forward edge lies at 650 feet. Its remnant at Cwmdu, a narrow strip restricted to the eastern side of the valley, is cut by the 600 foot contour. Assuming that the portion removed had a cross-valley profile of the same order as the wider benches upstream, this would give a level of about 500 feet at the head of the Tretower Basin.

b) The Grwyne Fechan - Lower Grwyne Fawr. The main bench in this valley declines in height (leading edge) from approximately 700 to 560 feet in the one and a half miles above Llanbedr. Just under two miles downstream, where the Llangenny gorge opens out into the Usk, a marked bench at approximately 400 feet is at the level to which the Llanbedr bench appears to extrapolate.

c) The Gavenny valley. This meets the Usk valley at 300 feet.

As the Usk floodplain declines from approximately 250 feet to 150 feet in the reach between the Rhiangoll confluence and Abergavenny, a pre-glacial valley depth of between 150 and 200 feet shallower than that of the present is indicated.

It has been established in the case of the Rhiangoll, and the Grwyne Fechan - Lower Grwyne Fawr that the incision into their upper, wider, valleys took place prior to the last glacial episode, and this is probably true also of the Gavenny, although the evidence is less clear in this case, the stream having developed a less marked inner valley. The following sequence of events is therefore suggested:

5. Post-glacial stream readjustment
4. Glaciation, marked in the Usk, leaving drift showing fresh forms

3. Incision of the tributary drainage in response to the deepening of the main valley.

2. Major glacial phase, leading to enlargement of the Usk drainage, and deepening of its valley, especially in the Penmyarth - Abergavenny section.

1. Development of the (?) Pre-glacial valley system.

(f) PENMYARTH - ABERGAVENNY.

Leaving the narrow, incised valley section past Llangynidr, at Penmyarth the Usk enters a wide-floored valley section (fig. 20), flanked by high and generally steeply rising sides. This continues until Abergavenny, where the northern valley side dies away, the Coalfield scarp swings south, and the Usk enters the internal lowland of the Vale of Gwent.

In this section the detailed glacial morphology of the valley between Penmyarth and Abergavenny will be examined, but problems concerning the major valley form and drainage pattern will first be considered.

1. VALLEY FORM.

In the preceding section (e), certain of the valleys of the Black Mountains were examined, with the object of determining the extent to which the features of rejuvenation which they display could be attributed to glacial deepening of the Usk valley, from which an estimate was made of the former depth of that valley. Bearing in mind the conclusions arrived at there, the anomalies of the present valley form and drainage pattern of this part of the Usk will be considered. The main problem is to determine the extent to which the valley form east of Penmyarth is due to glacial erosion.

East of Penmyarth the valley floor is flat and alluviated, increasing gradually in width downstream. The depth of the rock floor of the valley is not known, no borings having been put down in this area, although the angles with which the solid rock of the valley sides meets the superficial fill, suggests that it might be of the order of 100 feet or more, increasing in depth towards Abergavenny. The exact width of this infilled trough cannot be determined with certainty, for the lower parts of the valley sides are concealed over much of this section by drift thicknesses, but an estimate of the extent of this feature has been made in fig. 20.

It is difficult to ascribe a particular valley side slope to glacial erosion, as opposed to normal fluvial development, although if the suggestion made in section (a) that the Usk prior to the glacial episode was a far less significant stream is accepted, it follows that the major landforms in the Middle Usk must show the effect of significant glacial modification. Two classes of slope types have (fig. 20) however, been ascribed to glacial erosion:

(i) The steepest slopes where high ground locally approaches the valley. These areas of steep slope show no consistent relationship to local lithological contrasts, and suggest instead the truncation of spurs formerly extending farther into the valley. They usually comprise bold facets, easily demarcated by distinct convex breaks of slope. As a group they suggest formation by an eroding agency moving along the valley, rather than by normal valley side development.

(ii) Valley side slopes which show more moderate angles, but on which the drainage is immature. The slope tends towards straightness in plan, but often with minor, inconsistent surface irregularities. Streams draining the valley side in such areas are often numerous, but have entrenched themselves to only a limited extent, indicating their immaturity. In a few cases (e.g. the small Cwm-gu Brook, east of Tretower) the stream is incised markedly in its upper, headward reach, but loses its valley form as the main valley is approached, suggesting that glacial widening of the main valley has removed the valley form of its lower portion. This is a very mild form of a hanging valley.

The reason for the development of these two slope types, differentiated mainly by contrasts of slope angle, is not clear. Lithological factors are probably significant, as also the form of the pre-glacial valley relative to the present, glacially modified system.

If the location of the steeper slopes, considered to be evidence of ice erosion is examined on fig. 20, it will be seen that their alternating position on opposing valley sides suggests a pre-glacial valley pattern of more meandering form. The former valley seems, in particular, to have been more responsive in plan to tributary confluence than it is at present. For example, it is likely to have had a more southerly position immediately downstream of Crickhowell, being partly responsible for the formation of the large embayment opposite the town into which drain the Onneu and the Onneu fach.

One feature particularly difficult to explain in this context is the flat-crested rock spur upon which the town of Crickhowell has developed. Rising eighty feet above the level of the flood plain, it is possibly the relic of a rock step formerly crossing the valley at this point, although the reason for its survival is not clear.

In section (a) it was suggested that ice movement into the area from the Upper Usk following the development of the transfluent route at Llanddetti was initially _via_ the Crawnon valley which formerly flowed over the Pant y beili saddle (A in fig. 20) into the steep sided valley east of Bwlch today occupied by the small Ewyn Brook, and thence to the lower Rhiangoll. This would account for the severe erosion of the floor of the Rhiangoll about Tretower (although a structural weakness is also suspected) and the present continuation of the alluviated trough of the Usk into that valley instead of upstream along the main valley towards Llangynidr (fig. 20).* The shallowness of the latter valley was attributed to its late adoption as the major eastward route for ice passing through the gap at Llanddetti from the Upper Usk.

The northward flowing tributaries of the Usk do not show such distinct evidence of rejuvenation as those

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* Deposits flooring the lower Rhiangoll valley at Tretower were considered by M'Caw (1936) to indicate the former presence of a pro-glacial lake.

flowing from the Black Mountains, but this can be accounted for by their limited length (and therefore youthful valley forms) and in some cases, the degree of glacial modification that they have suffered. Two - the Crawnon valley, and Cwm Llanwenarth, opening out into the Usk at Govilon - have trough-like forms, ending abruptly in steep-sided corrie heads[1]. With the exception of the Clydach, others are of limited size, although most show evidence of ice accumulation (e.g. the deposits in Waun Ddu, a corrie at the head of the Onneu-fach were studied by Trotman (1963). Ice moving off the north scarp of the Coalfield <u>via</u> the Clydach valley would appear to be the main source of Carboniferous material found in the drift in the Vale of Gwent, but the valley shows remarkably little evidence of glacial modification, and retains a steep, gorge-like form over most of its length. This might be accounted for if capture of the Ebbw Fach by the Clydach (Strahan, 1902) occurred during the Pleistocene as a result of glacial erosion along the outcrop of the Lower Coal Measures. This, combined with high discharge rates from melting ice, would allow the formation

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1 The Crawnon is fault guided, which has probably assisted in the development of the trough-like form of the valley. No fault control has been proved in Cwm Llanwenarth, but this would be the most likely explanation of contrasts with adjoining valleys.

of the major part of the deep, gorge-like section of the Clydach (above the hamlet of Cheltenham - 225 129) to be placed in the late and post-Glacial, accounting for the lack of drift or other evidence of glacial occupance of that part of the valley. There is, even so, some evidence of rejuvenation in the lower part of the Clydach, the river becoming progressively more entrenched downstream of the village of Clydach into the bottom of its wider valley which meets the main valley at approximately 450 feet above Gilwern.

Conclusion. Glaciation appears to have changed a rather narrow valley, meandering in plan, and shallower (as suggested in previous section) by 150-200 feet[1] to the present straight, wide, and steep sided form. In the Llangynidr area ice movement is likely, following the opening of the Llanddetti gorge by diffluent ice, to have been initially over the Pant y beili saddle into the Ewyn and lower Rhiangoll, following the probable early course of the Crawnon, but the more direct route eastwards was later opened up.

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[1] 450-500 feet in the lower Rhiangoll, as against 300 at present; 400 feet + in the Gilwern area, as against the present 200 feet; and 273-300 feet at Abergavenny, as against 155-165 feet at present. These figures do not take into account significant glacial lowering of the benches in tributary valleys indicating rejuvenation.

2. DETAILED MORPHOLOGY.

Fig. 20A shows the morphology of this section of the valley. The features shown may, for convenience, be discussed under the heads: (i) glacial retreat phenomena; (ii) Riverine features; and (iii) Other.

(i) Glacial retreat phenomena. Glacial deposits are to be found lining the lower valley side everywhere except for the short stretch between Crickhowell and the mouth of the Grwyne valley. Only at Gilwern and Abergavenny is drift found in the centre of the valley floor, and the form of the drift fringing the floor elsewhere suggests that only locally did it formerly project significantly farther towards the valley centre at a level above that of the present flood plain, although the leading edge of the drift has been undercut by the river in many places. Thus the areas occupied by riverine deposits today are considered in the main to be areas where the drift deposits left by the retreating glacier formed hollows beneath the level of the present flood plain. Ice contacts observed to descent to flood plain level in several places (e.g. near Dan-y-graig, 233 159; and near Pysgodlyn, 263 158) confirm this.

Three main halts in the recession of the glacier during its final retreat from the main valley are identified: at Abergavenny, Gilwern, and Dan-y-Parc.

(a) Abergavenny. The form of the thick deposit of glacio-fluvial sands and gravels which almost completely block the valley in the Abergavenny and Llanfoist areas is discussed in section (a) of Chapter 8. The fact that glacio-fluvial deposits are almost completely absent immediately upstream of this is mentioned there. Instead, sloping benches of till[+] are present on both sides of the valley, with ice contacts well developed, suggesting that a considerable thickness of riverine deposits (and also outwash at lower levels) overlies basal drift in the valley centre.

(b) Gilwern. There are morainic deposits here on both valley sides, and in the centre of the valley upstream of Ty Mawr, the Usk clearly having broken through a formerly continuous cross-valley barrier of drift. The deposits on the northern valley side are in fact higher than the rest, and comprise ridges and small kettle with along-valley alignments plastered on the valley side at the foot of a spur apparently truncated by glacial erosion. The deposits

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[+] Plate 12.

lie mainly between 300 and 420 feet O.D., with an irregular slope below mapped as an ice-contact. It is suggested that these deposits are of lateral moraine formed at a stage prior to the retreat, and here extensive due to an abundant detritus supply due to weathering of the freshly quarried slope face above. On the south of the valley a smooth ridge swinging out from the valley side north of Gilwern seems to have been truncated by erosion by the Clydach. The flowing lines suggest moulding by lateral meltwater drainage. In the valley centre ridges, mainly aligned down-valley with kettle, are formed of gravels and sand, whilst between this and the south side of the valley to the east of the Clydach is a very bouldery deposit, which appears to have been washed out at an early stage from the Clydach valley to form a high-level gravel fan (not shown on fig. 20A). It is not certain what these deposits represent. Although they are tentatively considered to be a form of recessional deposit, a pause in the general retreat of the ice seeming necessary to explain the localized assumulation of drift, the along-valley alignment and absence of deposits at a comparable level on the north side of the valley remains unexplained. It is possible, though considered unlikely, that the deposits are sited where the sub-drift floor rises close to the surface. A third possibility considered, is that here lateral morainic deposits of the Usk were augmented and deflected away from the valley side by the confluence of ice coming from the Clydach valley. A form of recessional deposit is, however, judged to be the most probable. This has since been breached by the Usk, whilst the Clydach has broken its link with morainic deposits on the south side of the valley, laying down a tiered gravel deposit.

(c) Dan y Parc. Here, along the eastern flank of the Onneu re-entrant, a series of ridges trends obliquely towards the centre of the valley. They have been cut away at their northern extremity, but a small ridge rising above the surface of the gravel fan at Cwrt y gollen on the northern side of the valley has a similar alignment, and is probably a remnant of a once more extensive deposit. The Onneu Fach appears also to have trimmed the deposit, laying the extensive Llangattwg Park gravel fan (see pp.365-368) against its up-valley face, but a section at least of this appears to be an ice contact. The Nant Wenallt, a small tributary of the Usk, has been deflected by the formation of the moraine across its mouth, and its present lower course appears to have been initiated as a meltwater route leading away from the moraine. This stream has developed a small fan of gravel in the angle between the moraine and the valley side, the leading edge of which has been trimmed by the river. It seems likely that the major part of this recessional deposit was removed by meltwater soon after its formation, that part on the south side of the valley surviving due to its protected location in the Onneu re-entrant.

These three morainic deposits are considered to have derived from the Usk glacier as it finally retreated from this part of the valley. In a meeting of the Welsh Geomorphological Research Group held at Aberystwyth, in September 1966, Dr. C.B. Crampton put forward the suggestion that the last glacier to affect this area derived not from the upper Usk, but from the Clydach, this being responsible for the fresh drift forms (with fairly abundant Coalfield derived erratics) in the Vale of Gwent. This, he claimed, would also explain the relative paucity of fresh drift forms above Crickhowell, extensive morainic deposits not being encountered above there until Buckland is reached. His evidence for this unusual suggestion is that minerals of Coalfield derivation are present in the soils at Cwrt y

Gollen, upstream of the Clydach confluence, which indicated that ice from the Clydach was able to spread up-valley some distance, which would not have been possible had there been ice from the Upper Usk in the main valley. This suggestion is not supported:

(a) If ice from the Clydach were able to extend as a piedmont tongue well into the Vale of Gwent as Crampton suggested, a movement up valley far beyond Cwrt y gollen, which is only one mile upstream of the Clydach re-entrant, would be expected. Wind action on unvegetated, unconsolidated, deposits would be quite capable of moving finer material of Coalfield origin this short distance up-valley.

(b) the morphology of the area about the mouth of the Clydach does not suggest that the drift features were built up by ice emanating from that valley. In particular it is difficult to see how the moraine in the Onneu re-entrant could be formed other than by ice coming down the Usk.

(c) ice gathering grounds on the north crop of the Coalfield would not seem capable of nourishing so extensive an ice stream, when the well developed corries fretting the north face of the Fforest Fawr scarp were apparently unable to feed the Usk Glacier with sufficient ice to enable it to extend into the Middle Usk.

(ii) Riverine features. The extent of flood plain related to the present day river level is relatively limited, there having been slight recent incision of the river, and a low terrace covers the greater part of the valley floor. Great parts of this were, however, swept by flood waters in the exceptional flood of November 1961. The extent of building which has taken place on this indicates that flooding at this level is relatively infrequent, and this, combined with the break of slope which readily distinguishes it from the flood plain proper has led to its mapping as a terrace, although the term 'flood plain terrace' would perhaps be more appropriate. It appears to be the downstream continuation of the lowest of the flight identified in Glan Usk Park (fig. 17), and averages only ten feet or a little more above river bed level.

The Geological Survey have mapped (One Inch Sheet 232, (Abergavenny) an extensive river terrace occupying the Onneu re-entrant at Llangattwg, and upstream of the Grwyne confluence at Cwrt y gollen. There is little doubt, however, that these are not river terraces, but gravel fans developed at the mouths of these important streams, their leading edge having been trimmed by lateral erosion of the river to produce a low terrace-like bluff. If they were terraces, it is hardly explicable that they should survive in such an unprotected locality as Cwrt y gollen, whilst nothing remains immediately downstream of the spur at Crickhowell. There are also places where fresh drift features can be identified on the hill slope extending down to the inner edge of the low terrace, which would be inconceivable if there was also a higher terrace level.

Other gravel fans not identified by the Survey are present at the mouth of the Clydach, and at the mouth of Cwm Gwenffrwd, the stream from which is confluent with the Usk a short distance downstream from Glangrwyney. Both major streams, the Clydach and the Grwyne, are now incised into their fans, whilst the Clydach seems to have an earlier, higher, and coarser grade fan, into which the river, when it deposited the fan corresponding in height to that developed on the other rivers, was incised. These fans will be considered in Chapter 9.

(iii) Other Drift Features. Kame terraces have been identified in three places. The highest is located on either side of the Clydach re-entrant, above Gilwern. It commences above Glaslyn Cottage (237 152) and extends south-eastwards for half a mile. Half-way along a marked meltwater channel descends the valley slope from its surface, and the terrace shows well developed ice contact forms. The continuation on the eastern side of the Clydach is less certain, although benching occurs at a comparable height. Developed at between 350 and 420 feet O.D. (the valley floor is at approximately 200 feet at this point today), it appears to have been formed prior to the lower deposits at the middle and side of the valley at Gilwern, discussed previously. It is possible that the ice margin lay at this level here when the terminal glacio-fluvial deposits at Abergavenny were being laid down.

In the Llangynidr gorge (section d) the highest terrace was identified as a kame terrace, and this can be traced down valley into this area as far as Llangattwg.

Immediately east of Glan Usk Park lateral movement of the river trace against the southern side of the valley has exposed bedrock, removing all traces of terraces at this point. The kame terrace reappears once again, however, near Llan-Wysg, Dardy (203 189), and it gradually broadens as it swings around the hillside towards Llangattwg, where it ends, probably having been eroded away by the Nant Onneu, or overspread by the large gravel fan developed by that stream and its neighbour, the Onneu fach. Possible ice contact features were identified near Dardy. The terrace, which had declined to 280-290 feet at the eastern end of Glan Usk Park, is at ca. 260-270 feet O.D. at Llangattwg.

On the north side of the valley a bench extending from Llwyn-orwn (198 202) to Pont Cumbeth (217 190) near Crickhowell (a distance of 1¼ miles) was initially mapped as a kame terrace, although its transverse profile was unusually steep for such a feature. Its surface form was irregular, and the leading edge appeared to be more complex than the normal river-cut bluff, suggesting river trimming of an ice contact. In retrospect, it is now considered to be a solifluction terrace, the leading edge of which has been partially removed by the river. Other sloping benches of drift (e.g. east of Govilon and at Llanwenarth) with features simulating ice-contacts may also result from such solifluctional movement.

Although the drift is rarely thick, developing marked morphological expression, other than on the valley floor, and the lowest slopes of the valley side, a drift cover, much of it showing solifluction movement, was normally to be seen on all but the steepest slopes, although this was often difficult to distinguish from locally developed weathering products, the drift at the higher levels appearing to have travelled only limited distances. Morphological mapping was normally confined to the lower parts of the valley, for reasons outlined earlier. It had been noted in several places, however, that there was a tendency for such valley-side drift to form a series of sloping benches of varying size and length. These were usually too small to be easily picked out from across the other side of the valley, and it was not possible to get a broad picture without mapping, as their continuation was masked by hedgerows. To determine whether they were more than locally significant, they were mapped in a number of places: in particular, the flank of the Clydach valley between Gilwern and Llanelly Church, and the southern side of the Onneu fach valley, taking the Nant Wenllau as the eastern boundary (fig. 20A). This mapping showed a multitude of benches, the picture becoming more confused as the mapping progressed. In a few cases, they appeared to be associated (usually low on the valley side) with lateral morainic ridges, and there were other cases where formation by marginal drainage was not improbable. Again, although a structural foundation was evident with some, for the majority the mode of formation was not immediately obvious. The most likely solution is that these are the result of small scale soliflúctional movement, and they accord very closely with the description of "replats de cryturbation" in the Llanidloes area of Mid-Wales given by Pissart (1963), which he attributed to mass movement under periglacial conditions, aided by nivation due to the formation of transverse snow banks. The examples he gives are, however, on unenclosed land, whereas those of the Usk valley are within the enclosed area. It was noted that field boundaries tended to be sited along the leading edge of the tread in the Usk examples, and cultivation, hastening soil creep, would thus tend to accentuate their forms.

3. CONCLUSIONS.

The marked trough-like character of this part of the Usk is related to its development as part of a major valley only in the Pleistocene, ice from the Upper Usk, and to a limited extent from the north crop of the Coalfield, changing the shallow pre-glacial valley system into the present deep through-valley. Three recessional stages are identified, whilst post-glacial fluvial aggradation by the Usk was accompanied by the development of gravel fans built out across the floor of the main valley by the tributary streams.

ADDENDUM TO CHAPTER 7

Since the text of Chapter 7 was written and prepared for presentation, a paper has been published by C. A. Lewis concerned with the Weichselian Glaciation of the Upper Usk and Middle Wye (Lewis, 1966) which totally contradicts the conclusions arrived at in this section, and which thus requires consideration.

Lewis has studied the periglacial features of the Brecon Beacons, which he considers to be the product of cryopedological activity during the Weichselian, the Beacons developing only cirque glaciers at this time, the longest of which was that of Cwm Cerrig Gleisiad (4,900ft.). As drift deposits in more lowland sites in the Usk and Middle Wye are clearly related to ice activity at this time, he accounts for them by suggesting that the Usk, and the Llynfi-Llangorse Basin, was invaded by ice from the Upper Wye which, by implication, crossed the Eppynt scarp, as well as pressing down the Wye valley below Builth.. The margins of this ice sheet are marked by kame deposits which he claims are found "blocking the mouths" of valleys tributary to the Usk from the south in the Brecon-Llandetti section, whilst an eastward movement of ice "towards or past, Abergavenny" is suggested. This glacier, he considers, divided during melt into two sectors on either side of the Eppynt upland. The ice in the Usk and Llynfi lowlands was thereafter cut off from its former source, and became dead, melting in situ, whereas ice in the Wye valley continued as an active glacier, accounting for the successive morainic features and associated terrace deposits in the valley about and above Hereford. The meltwater channel 'at Ffordd Fawr' in the Glasbury area* he considers to have carried subglacial drainage into the Wye from the Llynfi lowlands, when that area was covered with stagnant ice.

This theory does not appear to be sound, and may be criticised both in respect of its basic premise, and in detail. It requires acceptance of the assumption that at a time when the Beacons were able to support only minor cirque glaciers, the longest of

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* Most probably the Heol y Gaer Channel (No. 6 in Fig. 56A.) No grid reference is given by Lewis. This area is described in detail in Appendix 1V.

which extended for less than a mile, ice from Mid-Wales sources was able to cross the Eppynt scarp and the Usk-Wye watershed south of the Llangorse area, and to extend down the Usk valley itself at least as far as the 'Newer Drift' margin as delimited by Charlesworth (1929), for these deposits cannot be considered to antedate the last Glaciation. The proposal that the ice was so much more effective as an ice source than the Beacons at this or any other stage cannot be accepted. Any suggestion that ice from an even more northerly source was involved must also be ruled out as the ice margin at this stage suggested to the east and west of the Welsh massif by Lewis (fig. 1) indicates that there would be little barrier to movement into ice free terrain in those areas. In the Wye itself, an easy escape of ice south-westwards into the Towy valley appears not to have deterred crossing of the Eppynt scarp. The advantage enjoyed by the Central Wales Plateau in the upper Wye area over the Beacons as an ice source would appear to be slight. It is, of course, slightly farther north of the accepted southern limit of Pleistocene ice cover in Britain, whilst it is a more massive upland than the Beacons. In terms of precipitation, however, there is little contrast between the two areas today, whilst contemporary observations of the persistence of snow cover (see fig. 29, after Manley, in Bowen, 1957), suggest again a little contrast. Moreover the northern aspect of the Beacons is particularly favourable for ice accumulation, and the bold cirque forms of the Beacons scarp are not to be matched in Central Wales. It is therefore highly unlikely that such massive contrasts in the extent of ice accumulation, as required by Lewis, ever occured.

Morphological evidence also does not support the suggestion of such a massive ice cover in Mid-Wales during the final glacial episode. The drift forms of the Llynfi-Llangorse Basin are almost non-existent, and for this reason it has been suggested that it formed a largely unglaciated enclave during the final glaciation, during which ice was confined to the major valleys and upland regions. A major movement of ice during the Weichselian across the Usk-Wye watershed would surely also have left erosional evidence.

Lewis lays great emphasis (e.g. fig. 2 of his paper) on kame deposits blocking the mouths of right bank Usk tributaries, and shows only these kame deposits on his map, although he earlier notes that "the Usk (sic) is largely floored with kame deposits on both sides of the river". Reference to the detailed morphological maps of that area (figs. 14 and 15) will show that the suggestion that the kame deposits block the mouths of the valleys in question gives a grossly exaggerated impression of the true extent of these deposits, and whilst such deposits are more abundant to the south of the river, they are certainly not absent in the north (especially in the Groesffordd area, fig. 15). The relative abundance in the south is to be expected as most of the present drainage, and thus ice and associated morainic debris in the past, enters the main valley from the south.

Finally, even if periglacial activity has been as important in moulding the present-day landscape of the Beacons as Lewis suggests, there would seem to be no reason why this activity should be related to the whole of the Weichselian. Absolute rates of operation of such processes are not known, and it is suggested that to assign the periglacial features of the Beacons to the Late Glacial is more realistic than to postulate minimal ice accumulation during the Weichselian.

CHAPTER 8.

THE 'NEWER DRIFT' LOBE IN THE VALE OF GWENT.

1. GENERAL.

At Abergavenny the Usk glacier left the deep trench of the Middle Usk, entering the lowland of the Vale of Gwent. Here it spread out as a piedmont lobe (fig. 9), shown by drift deposits to extend from White Castle in the north-east past Raglan and Kemeys Commander to Little Mill in the south-west, a distance of fifteen miles. The area covered by this spread of fresh morainic material will, for convenience, be considered as a whole.

2. RELIEF AND DRAINAGE.

Above Abergavenny the Middle Usk divided two major upland areas, the Black Mountains and the Coalfield Plateau, the river entering the more low-lying but indented area of the Vale of Gwent as it turns in a more southerly direction past the town. It retains for a while its distinct valley form, as its course is paralleled as far south as Llanover by the Coalfield escarpment in the west, whilst in the east the lower slopes of the Ysgyryd Fach and the spur running south from it form its valley side. The misfit Gavenny, confluent with the Usk at Abergavenny, drains a wide vale (Chapter 7 , Section e), separating the two Ysgyryds from the main mass of the Black Mountains. They are themselves separated by the wide Wern Ddu col at 540 feet, leading eastwards into the head of the Pant Brook valley, tributary to the Troddi. Apart from the Gavenny, the Usk receives few tributaries of importance in this section, the most important being the Ochram Brook and the Fyrwd, draining the Coalfield scarp to the south and north of Llanellen respectively.

At Llanover the Usk turns abruptly eastwards, before turning south again at Clytha, cutting past the adjacent hill masses of Bettws Newydd and Llandegfedd, east and west of the river respectively. The easterly swing of the Usk away from the Coalfield at Llanover allows the development of a foothill zone, separated from the Llandegfedd Hills to the south by the deeply-cut valley of the Berthin Brook. This area will here be referred to as the Goetre area. It is drained by three groups of streams: the Nant Rhyd y meirch, flowing eastwards past Llanover in the north; the Nant y Robwl in the Goetre area, also flowing east, and confluent with the Usk at Chain Bridge; and in the south, two southward flowing streams, tributary to the Berthin Brook, which is itself tributary to the Usk just north of Usk. Between these three stream systems, two ridges strike out towards the Usk. The northerly of these, the Pen-gross-oped to Cross Llanvair ridge runs due east, widening as the river is approached into the rounded mass of Llanvair Hill, standing 200 feet above the Usk flood plain which flanks it on north and east. The southern ridge, between Penpelleni and Monkswood, has a more south-easterly trend, and forms a wedge of high ground (rising to over 375 ft. O.D.) between the Usk at Kemeys Commander, and the lower Berthin valley.

The main valley between Llanover and Clytha is wide, and flanked by low hill country. The hills north of the river are drained by the Ffrwd Brook, confluent with the Usk near Clytha, whilst the Nant Rhyd y meirch follows a course parallel to the main river for a distance in the south. The Usk turns abruptly southwards at Clytha, but the line of the valley below Llanover is continued eastwards as a zone of low-lying country drained mainly by the Clawdd Brook. This stream flows west past Llanarth (376109) to join the Usk on the bend at Clytha. The lowland zone is flanked on the south by the Bettws Newydd Hills, and to the north by an easterly trending ridge which forms the watershed between the Clawdd and the easterly flowing Troddi, in the north. The watershed at the head of the Clawdd is indeterminate, and low cols lead north and east into the Troddi drainage, and south into the valley of the Olway Brook. This will be referred to as the Bryngwyn area, and includes the Clawdd valley and the low watershed zone extending east as far as Raglan, and north towards the Troddi at Llantilio Crossenny.

The Troddi gathers a number of east and south flowing streams draining the western part of the North Monmouthshire Uplands. About Llantilio Crossenny and Llanvapley the valley is wide, with gently rising sides, but eastwards it becomes narrow, having a gorge-like form where it breaks through the north-south ridge of high ground at Tal-y-coed (418151).

South of Clytha the Usk itself enters an extremely narrow section of its valley, from which it finally emerges at Usk. To the east of the river, there is a generally abrupt rise to the Bettws Newydd Hills. These form an assymetrical hill mass, the highest hills, Clytha (625 feet), Trostrey (654 feet) and Llancaeo Hill (450 feet), flanking the Usk, there being a general decrease in height eastwards towards the valley of the Olway Brook.

3. MAJOR LINES OF ICE MOVEMENT.

Although fig. 9 shows the piedmont lobe of the 'Newer Drift' extending well into the North Monmouthshire Uplands, suggesting that ice overspilled its valley after leaving its trench-like middle section at Abergavenny, it will be argued later that the major ice stream was deflected southwards along the main valley towards Llanover, and that the disposition of the hill areas and low-lying vales had an important influence on ice movement in this terminal area during the final glaciation. Ice emerging from the Middle Usk was mainly deflected south towards Llanover, although a minor ice stream passed over the Waen Ddu col, north of the Ysgyrd fach, into the valley of the Pant Brook. This was probably augmented by ice from the Black Mountains valleys coming over the Bettws col from the Fforest Coalpit area.

The lowering of the valley sides as the Usk swings east at Llanover enabled a considerable lateral spread of the ice sheet, accompanied by thinning. Movement south-eastwards was inhibited by the Bettws Newydd Hills, ice being deflected either southwards across the Goetre area towards Usk, or eastwards up the Clawdd valley and across the low watershed into the Olway valley at Raglan, and the Troddi south-east of Llantilio Crossenny.

This is reflected in the distribution of morainic features within the lobe (fig. 30). These are concentrated on the lower slopes of the Coalfield scarp, along the hill crests flanking the north slopes of the Berthin valley, on the western and northern slopes of the Bettws Newydd Hills, and in the Bryngwyn area. The Usk valley itself, downstream of Abergavenny, will be shown to largely display dead-ice features. One small, isolated area of morainic topography at the head of the Pant Brook records the crossing by ice of the Wern Ddu col.

4. ICE SOURCES.

Ice entering the Vale of Gwent was mainly derived from the Upper Usk, and the north crop of the Coalfield (via the Clydach valley), and this comprised a major ice stream passing down the valley towards Llanover. Lesser ice streams probably originated:

1. <u>in the Black Mountains.</u> This area has not been investigated in detail, but it seems probable that the main line of ice movement was eastwards along the Grwyne Fawr valley to Fforest Coalpit, and thence over the Bettws col into the Gavenny valley. A lateral (diffluent) ice stream from the Usk glacier at Crickhowell, and crossing into the Grwyne valley south of Llanbedr by the Belfountain col. This would account for the extent of drift deposits in the Grwyne Fawr between Llanbedr and Fforest Coalpit (the surface of which tends to decline in height relative to the river as traced upstream), and the narrowness of the Grwyne valley between Llanbedr and Glangrwyne, that part of the valley not having functioned as a major ice distributary.

2. <u>The Coalfield Scarp.</u> Valley heads on the Coalfield scarp to the east of the Clydach which show evidence of cirque glacier development are:

(i) <u>Cwm Llanwenarth.</u> A deep, trough-like valley with an abrupt headwall (not illustrated). Extensive morainic features, generally transverse to the valley suggest significant local ice accumulation. An unusual feature is the absence of a rise to the cirque, the glacier having developed at the level of the present valley floor (ca. 760 feet). It is similar in this respect to the Crawnon valley above Llangynidr. The Cwm Shenkin Brook, which drains the valley has incised itself into the drift strewn floor of the valley, which 'hangs' above the main valley at about 600 feet, suggesting that the local ice stream, if confluent with the main glacier, was deflected eastwards at this level.

(ii) The Fyrwd Valley. The Fyrwd is a small stream joining the Usk almost a mile north of Llanellen. It rises in a striking amphitheatre-like feature on the slopes of the Blorenge known as 'the Punchbowl'. As its name suggests it is of markedly cirque-like form, with morainic ridges arranged in festoons in the valley descending from it (fig. 21). These are not, however, to be traced below the 650 feet contour which suggests that the ice from this cirque was not confluent with the ice in the main valley. The floor of the cirque is marshy, and lies at 940 feet O.D. The markedly amphitheatre-like development leaves no doubt that we are dealing with a true cirque, and not with an example of snow patch erosion and protalus ridge accumulation. The Punchbowl has a due easterly aspect.

(iii) The Ochram Valley. The Ochram rises on the south-eastern flank of the Blorenge, and flows in a semi-circular course to join the Usk one mile to the south of Llanellen. A large part of the right hand side of this valley has therefore a north-eastern aspect, and along this there is evidence of the development of two cirques: at the Malps (277101), with a floor at 1,100 feet, and at Craig y Cwm (286092) with a floor at less than 800 feet. Both display marshy, aggraded floors, and from them festoons of morainic deposits descend into the valley below, in this case to link up with the marginal deposits of the main glacier along the scarp foot. It is noticeable that the drift deposits are confined to the floor and the southern slopes of the valley, and that the head of the valley, having a south-easterly aspect, shows no sign of cirque development.

(iv) Elsewhere. There are no other definite cirques although in the head of an unnamed tributary of the Nant yr Robwl west of Ty Cooke (300053), probably nivation and the persistence of a snow patch in the north-easterly facing valley head has given rise to local oversteepening. In view of the absence of any evidence of marked erosive action, the three moraine-like ridges in the valley between 900 and 1,000 feet are interpreted as protalus ramparts marking various stages of ice accumulation in the valley head.

Conclusion.

The contribution of Black Mountain ice streams cannot be reasonably estimated, although the main outlet is likely to have been into the Gavenny valley via the Bettws col.

East of the Clydach, the only significant addition of ice to that in the main valley appears to have been from Cwm Llanwenarth and the Ochram valley. Drift in the Rhyd y Meirch valley south of this appears to have been due to the expansion of the Usk glacier into the mouth of this tributary valley.

The Punchbowl is clearly ice-eroded, but it appears that its small ice stream was not tributary to that in the main valley. It is probable that there was ice in the cirques after the disappearance of ice from the main valley, although the Cohram glacier seems to have been at one stage confluent to ice in the main valley.

The contribution of Coalfield drift (mainly via the Clydach valley) partly accounts for the exceptionally extensive drift deposits of the western and southern extremities of the Newer Drift ice lobe (fig. 9), although frost shattering combined with mass movement on the scarp itself was no doubt of local significance.

5. DETAILED MORPHOLOGICAL DESCRIPTION.

For convenience, the area covered by the Newer Drift ice lobe will be divided into five regions, which will be considered separately:

(a) The Usk valley, Abergavenny to Clytha, (fig. 21).

(b) The Usk valley, Clytha to Chain Bridge, (fig. 21).

(c) The Goetre Area. (figs. 23 and 24).

(d) The Usk valley, Chain Bridge to Usk, (figs. 25 and 26).

(e) The Bryngwyn Area. (figs. 27 and 28).

That part of the Troddi valley overspread by ice from the Usk has not been investigated in detail, and will not be considered here. A quick reconnaissance survey of the northern extremity of the lobe was however made, and the extent of drift in that area mapped (fig. 29).

(a) THE USK VALLEY, ABERGAVENNY TO CLYTHA.

There are marked contrasts in the form of the valley upstream of the environs of Abergavenny, and the valley about and downstream of the town. Upstream the valley is wide, floored mainly be recent alluvial deposits, with glacial drift restricted to the valley sides, or a narrow lateral belt along the edge of the valley floor. About Abergavenny, however, glacial deposits almost completely block the valley, the river flood plain contracting to a narrow strip, whilst downstream, although the flood plain widens locally, valley floor drift deposits remain dominant until Llanvihangel nigh Usk.

The drift morphology may be considered under the following heads:

(a) Predominantly hummocky drift of the valley floor;
(b) Kame terraces;
(c) Gravel fans;
(d) Higher level drift features of the valley side.

(a) Predominantly hummocky drift of the valley floor.

The term 'hummocky drift' is used in a descriptive sense only at this stage, and is not intended to suggest any mode of origin. It refers to the lowest level drift of the valley floor which has fresh forms, and which has in part been buried by the deposition of recent alluvium. It is characterised by a juxtaposition of ridges, which may or may not show preferred trends, with closed hollows. Within this broad category there are considerable areal differences.

(i) <u>Llanfoist - Llanellen area.</u> The best developed hummocky drift is at Llanfoist, on the south side of the Usk from Abergavenny, where a chaotic series of ridges with intervening depressions rises to over 200 feet O.D., or over 60 feet above the flood plain. Although the general impression in the field is of lack of order, mapping revealed that the ridges tend to conform to one of two trends: either parallel to the valley (and ice flow), or transverse to it. This mass of drift reaches its highest point along its up-valley edges, and a salient near the river thrusts some distance upstream beyond the main mass. Its inner edges have been affected by erosion and gravel deposition by a small stream draining off the Blorenge. Downvalley, the surface, whilst retaining its form, loses height and disappears beneath the flood plain which has been built up within deep re-entrants of the drift. A cutting was made through the Llanfoist deposit during the construction of the 'Heads of the Valleys' Road, and this revealed predominantly gravels, with sand in pockets, showing slump features. Borings (fig. 22) showed that the deposit, whilst tending to become finer with depth, did not change radically in its make up.

The hummocky moraine continues south as a belt along the valley side as far as a tributary of the Usk, the Fyrwd Brook, with a slightly more extensive development about the North Monmouthshire Golf Club (297124). The Fyrwd has built up a small fan of gravel over the drift, and there is a slight development of hummocky moraine on the south side of this stream, but beyond this its place is taken by a sloping terrace-like feature identified as a kame terrace (p. 242).

(ii) Abergavenny area. As the drift deposits occupying a similar location on opposite sides of the valley can reasonably be expected to be of similar age, one would expect more similarities of form than are evident in this part of the Usk. In fact the contrasts are most noticeable.

The town of Abergavenny is built upon an elevated area between the Usk and the Gavenny. Exposures produced during the demolition of old houses in the Tudor Street area, and subsequent rebuilding operations, revealed that the deposits here were practically identical in composition to those about Llanfoist. Here, however, instead of ridges and hillocks, the gravels are built (fig. 21) into a series of relatively flat-topped structures flanked by steepened sides, which are especially evident towards the river and in the lower Gavenny valley. These rise to a similar height as the ridge topography south of the river. The surface is gently undulating, and is bounded by well-defined break of slope. This is least well-defined towards the north where the surrounding land is higher. There are four of these level-topped features, two being relatively limited in area. A shallow valley-like depression between the two larger trends towards the Usk, but ends abruptly in an undrained hollow (? kettle) mapped by the Survey as containing an alluvial deposit. One of the smaller features appears to have been partly buried by the Cibi gravel fan. West of these features, there is, in the grounds of the Neville Hall Hospital (289146), an area of ridge and knoll structures, similar to those at Llanfoist. Here, however, the ridges tend to show an alignment transverse to the valley, and they are bounded on their downstream side by a broad shallow valley, of curving plan, draining towards the Usk.

Morphological mapping within the built-up area of Abergavenny was complicated as only a very limited area could be observed from one spot, and the form of the land beneath blocks of buildings very often had to be guessed. As it had been expected that the landforms on the north side of the river would be similar to those in the Llanfoist area, the possibility that the differences which emerged - namely between the flat crested forms north of the river, and the more irregular shapes to the south - were illusory* was considered. This was discounted in view of (a) the extension of the tabular features beyond the built-up area upstream of the river bridge (fig. 21); and (b) the persistence of bounding breaks of slope which could be traced under blocks of buildings and roads for quite long distances. Clearly the features are different, suggesting that different controls were operative during formation.

(iii) Left bank, south of Abergavenny. Downstream of Abergavenny, on the eastern side of the valley, there is

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* An illusion which might have been heightened by levelling for building.

an extensive valley floor accumulation of sands and gravels commencing at the Heads of the Valleys Road, and extending south into the Llanellen area. The term 'hummocky drift' is not really suitable, as the ridges have an orderly, generally down-valley trend, and slopes are much less abrupt than those in the Llanfoist area. The main exception to this is the sinuous ridge which descends the slopes of the Ysgyryd Fach from a height of almost 300 feet (308128). This was described as an esker by the Geological Survey (Robertson, 1927, 104) and excavations for the Heads of the Valleys Road roundabout, which cut into the lower end of the ridge, showed fine-grained water-lain deposits, sand predominating, with slump structures, which tends to confirm this view. It would appear to have been formed by water entering the ice following an ice-marginal course. At its lower end, the esker passes onto the highest part of the valley-floor drift, suggesting that that deposit relates to the period when ice remaining in the valley was at least 100 feet thick.

The valley floor drift has been undercut by the Usk in its northern part (opposite the Fyrwd confluence), where the drift also appears to have been trimmed into two undulating terraces (crossed by the Heads of the Valleys Road), the higher between 169 and 174 feet O.D., and the lower between 157 and 160 feet. The stream cutting the higher might have drained south across the shoulder of drift north of Little Hardwick (304119) which has been cut by a south-flowing stream at that level. The river cliff of the Usk at this point is tree clothed and exposures are poor, although surface gravel is plentiful. South of this bend the drift has not been undercut, and it disappears with an almost imperceptible break of slope beneath the alluvium. This is because the slope of the drift becomes progressively gentler, and bold drift forms of a higher level are not continued down to flood plain level. The drift deposit reaches a maximum height of just over 200 feet near the Bryn Oer Roundabout (at the eastern end of the 'Heads of the Valleys' Road - 307128), from where there is a slight fall to the mass north of Little Hardwick, which reaches c. 180 feet O.D. above the river cliff.

A lower deposit of hummocky drift occupies the centre of the valley south of Llanellen. Here again, a tendency for an along-valley alignment of ridges is evident, although ridges are usually subdued in form. A gravel fan developed at the mouth of the Ochram Brook has partly buried the drift topography there. A small plateau of drift to the south of the brook is reminiscent of those at Abergavenny, although here the surface is less even, and it stands lower in relation to surrounding features. The drift was formerly more extensive, having been cut away by the Usk in the east.

Towards Llanover, the drift appears to be moulded into broad, rather indefinite down-valley ridges, but beyond the Church they disappear, presumably below the low-gradient gravel fan of the Nant Rhyd y meirch. Low ridged drift forms reappear briefly on the south side of the valley at Llangattock nigh Usk.

(iv) Origin. It is not possible to point to a simple origin for the valley floor deposit of generally hummocky drift so far discussed. A few general observations might be made:

1. the drift most frequently has this hummocky character in the lowest part of the valley, and these forms are not continued far up the valley sides. This points to formation by the last ice occupying the valley in this section, and at a time when its effect was limited

to a narrow valley floor zone.

2. throughout this stretch there are contrasts in the morphology of opposing sides of the valley. Nowhere is there conclusive evidence that the drift was once a continuous barrier across the valley, there being the suggestion that the drift surface reached its lowest point somewhere along the line of the present river.

3. available exposures (mainly in the Abergavenny area) suggest a dominant factor in the deposition of this hummocky drift has been meltwater. (Plate 13)

Charlesworth (1957, 416) describes kame moraine as "rapidly undulating and swelling like a choppy and billowy 'sea' of confused hills, they form complexes of tumultuous rises and hollows intertwined with parallel or tortuous ridges which unite and interlock in a most bewildering manner.....(They) are dappled with numerous closed hollows." These closed hollows are kettle holes. He goes on to say that kame moraines are made up mainly of bedded and assorted sands and gravels, whose pebbles are well rounded and rarely striated. Flint (1957, 151) refers to similar 'kame and kettle topography' which is "the product of the ablation of thin glacier ice detached from the main body of the glacier, and therefore stagnant." Deposition upon dead or stagnant ice was favoured by Charlesworth as an explanation of kame moraine. These descriptions would seem to fit the drift features of the Llanfoist area in particular, and it is suggested that in that area, the accumulation of masses of stratified drift upon a tongue of stagnant, crevassed ice accounts for the present day topography. The absence of such features immediately upstream suggests that ice upstream of this point was never stagnant, but that rapid melt and 'retreat' occurred during deglaciation. The tongue of stagnant ice was continuous as far downstream as the Fyrwd, although the superglacial cover appears to have been thinner here, and the collapsed deposits reflect to a larger extent the form of the underlying rock floor.

The features of the north and east side of the valley, namely the tabular drift features in Abergavenny, and the massive deposit south of Bryn Oer, are less easily accounted for.+

Plateau-like areas within masses of 'dead ice moraine' have been described by Hoppe (1952). He suggests, however, that drift masses referred to previously as dead

+ They are marked in fig. 20A as 'Kame', but the extent of these features is considered greater than normally associated with crevasse fillings and related deposits.

ice moraines should in future be called hummocky moraine regions on the grounds that the ice does not appear to have been dynamically completely dead during formation of the drift features. Within these areas are plateaux of morainic material, often with ridges along their edges or slopes which he calls 'rim ridges'. These hummocky moraine regions investigated by Hoppe are, however, predominantly of till, not stratified drift, and the rim ridges in particular, show evidence of the squeezing of saturated basal till from under dead ice masses. The association of these hummocky moraine areas with drumlins, suggest that the hummocky moraine was formed, like the drumlins, sub-glacially, whilst Hoppe considers his hypothesis to be 'proved conclusively' in one locality where drumlins are actually superimposed upon moraine plateaux (Hoppe, 1959, 205). Whilst the features about Abergavenny are clearly mainly of glacio-fluvial gravels, not till, the occurrence of these plateau-like features in former dead ice regions is of particular interest. Concerning the origin of the moraine plateaux, Hoppe (1952) states that they appear in certain instances to be secondary formations "arising from the disintegration of moraine ridges", but more usually they are considered to be primary formations, or original elevations of the morainic material beneath the ice. Their plateau-like form has been emphasized by the development of rim ridges.

Kame Moraine (Charlesworth), Kame and kettle topography (Flint) and Hummocky moraine regions (Hoppe) are all associated with stagnant ice, the main contrast being in the amount of associated stratified drift. In the regions described by Hoppe, glacio-fluvial accumulations are only locally important, whereas the other two writers are referring to areas where there are extensive stratified deposits. In the Abergavenny area, stratified drift is dominant, but there are features comparable in their morphology to those described by Hoppe and considered to be of mainly sub-glacial origin. The evidence is not contradictory but suggests that the form of the sub-glacial surface, and the squeezing up of masses of sub-glacial drift might have contributed more to the form of kame moraine, where stratified drift predominates, than had previously been thought.

Different factors would appear to have been operative in respect of the Bryn Oer drift (south of the 'Heads of the Valleys' road terminus), because here we do not have the disordered pattern of ridge and hollow characteristic of drift areas affected by the melting out of extensive stagnant ice. Moreover the thickness of drift here compared with thicknesses on the west side of the valley at this point suggest that glacio-fluvial accumulation was marginal to, rather than upon, the ice. A more rapid melt is suggested for this side of the valley, allowing the thick mass of glacio-fluvial deposits to be built up against the valley side. Ice contact features south of Little Hardwick (304119) suggest that the deposit might have been banked against ice here. Terracing of the upstream end of this deposit was perhaps accomplished by meltwater streams before the ice had melted away on its upstream side. On the opposite side of the valley, the ice contacts north of Llanellen suggest that a tongue of ice persisted along where the river flows today.

South of Llanellen hummocky moraine in the centre of the valley suggests the persistence of wasting ice here also, whilst the plateau-like feature of stratified drift upstream of Llanover Church suggests a similar origin to that proposed for the Abergavenny drift forms.

Ridges are more subdued at Llanvihangel nigh Usk, and show a distinct along-valley trend. This could reflect a dominant longitudinal crevasse pattern, although an alternative origin seems more likely. It is suggested that these low ridges, rising little above recent alluvium, are basal morainic features, exposed by the washing away of less compacted stratified drift forms which may have been let down on them.

(b) Kame Terraces. The late persistence of ice in this stretch, whilst extensive deposits of stratified drift were built up about it is also suggested by kame terraces which are especially well developed on the north bank above Llanvihangel nigh Usk.

The most extensive kame terrace commences near Llangattock Lodge (319106) at the confluence of a small stream with the Usk, and its leading edge, which has here been undercut by the Usk is at a height of 177 ft. It can be traced past Penpergwm[+] (158 feet - 330102) to well beyond Llangattock nigh Usk, where the leading edge has declined to 137 feet, approximately 25 feet above the flood plain of the river at that point. Excellent ice contact features are to be found on the face of this terrace, especially

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+ Plate 14.

near Castle Arnold near Penpergwm (319101), whilst at Llangattock, bulky crevasse fillings project into and along the valley from its face (fig. 21). An exposure in the terrace where the river is eroding it at Llangattock (336098) showed that it was made up of well-rolled gravels of predominantly Old Red Sandstone origin, although a few erratic Millstone Grit pebbles were also noted. The gravels were well sorted, and there were intercalations of sand. A number of pebbles, mainly those from the marl division of the Old Red Sandstone, and one of coal had weathered badly, crumbling in the hand. Others had been cleanly frost shattered along bedding planes, but the segments had not been moved apart (Plate 29). Although this was not evident in the exposure at Llangattock, exposures farther up river were marked by the amount of cementation that had taken place. Exposures near Penpergwm old railway station (328096) and near Llangattock Lodge (317108) both revealed a resistant conglomerate formed by the cementation of the gravels (Plate 16). The cause of this was not investigated, but it is suggested that solution of calcium carbonate from limestone pebbles, and redeposition at depth by percolating rainwater might be responsible.* The few pebbles of carboniferous Limestone in the drift generally is a most noticeable feature.

There is a possible further fragment of this major left bank terrace at Llanvihangel Gobion (349093), isolated from the main part by river erosion. Its leading edge is here at 123 feet, declining to 120 feet. The identification of this as a kame terrace is not entirely satisfactory as:

(i) the main kame terrace has a gradient much steeper than that of the present flood plain, and if extrapolated down-valley to this area, suggests that any remnant here would be little above flood plain level. This possible fragment is higher than that, although its leading edge is partially buried by terrace gravels.

(ii) the gradient of this possible kame terrace fragment is much less than that of the main kame terrace.

(iii) its surface, although rolling, is less undulating than that of a normal kame terrace.

There is, however, no river terrace developed at this level in the locality, and its areal shape suggests that it did

*Calcium carbonate would be most easily dissolved in cold meltwater. Subsequent deposition could be the result of a rise in temperature or a release of pressure. This sequence could have occurred during one of the post-glacial cold phases, possibly at the time that frost thaw processes were shattering pebbles within the gravel. Similarly cemented gravels were also noted near Estavarney (354039).

not have formerly any significant cross valley or down valley extent. The evidence favours identification as a kame terrace largely buried by a later aggradational phase, but it is far from conclusive.

The other examples of kame terraces are generally poor. Between the Fyrwd Brook and Llanellen there is a terrace feature at a similar level with its upstream end pocked by kettle. There are possible ice contacts on its face, which although not convincing, are clearly not river-cut bluffs. It is probably a kame terrace. South of Llanellen this surface continues, although the centre of the valley is blocked by hummocky moraine. Between the two a tapering area of flat, peaty ground suggests that a body of water was held up here for some time during a late stage of deglaciation (shown as a possible lake Flat in fig. 21).

(c) <u>Gravel Fans.</u> These are found in the lower parts of most tributaries of the Usk. The best developed is that of the Cibi, upon which the northern residential areas of Abergavenny have developed. Its head is at c. 325 feet O.D., and its base, about a mile wide, is traced in part by the 200 foot contour. It has partly been built up around valley floor drift structures, and has possibly buried others. It is tempting to suggest that the Cibi fan continues eastwards to the incision of the Gavenny, but its bounding break of slope can be traced with ease around Bailey Park, and westwards to the former Brecon Road Railway Station. The even, gently sloping surface between that and the Gavenny incision (occupied in part by Bailey Park) was not mapped in the field as a gravel fan, although upon consideration, this seems most probable. It is suggested that the Gavenny fan was of extremely low gradient (and therefore not easily identifiable), and that the river has been incised into it. A low gradient fan appears to be associated with low-gradient rivers (e.g. the Grwyne), and this would appear to account for the great contrast with the bold Cibi fan.

All the western tributaries draining directly from the Coalfield scarp have similar fans, that of the Ochram being the best developed. On the eastern side of the valley neither the Fyrwd or the Clawdd Brooks appear to have developed gravel fans of any importance, but they both drain relatively low hill country, and have low-gradient thalwegs.

(d) Higher Level drift features of the valley side.
Between Llanfoist and Llanover the Usk runs close to the foot of the Carboniferous scarp. There are two features of particular interest to us in this stretch of the valley side (fig.21): (i) oversteepening of the scarp face between re-entrants, and (ii) a marked though steeply sloping bench between 350 and 500 feet O.D.

(i) Oversteepening. The term 'oversteepened' has been used because when viewed from the eastern side of the valley[+] it would appear that the middle slopes of the escarpment had been trimmed by an agent moving laterally along its face. The scarp is thus faceted, and in particular, the steep facet is clearly divided from the more gently sloping surface above and below by distinct breaks of slope. The form of the steepened faces suggests that they have been quarried by ice passing down the Usk and there are comparable examples upstream. The base of the steepening generally lies, however, along the boundary between the Red Marl and Red Sandstone divisions of the Old Red Sandstone, the marl forming the bench feature to be discussed later. It might therefore be suggested that the contrasting slope angles were reflections of contrasting lithology. This seems improbable as the oversteepened

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[+] Plate 15.

facets do not follow the outcrop into the small tributary valleys, but are confined to the spurs between them. The retention of the steepened form could, however, be a reflection of the lithology, although glacial erosion seems the most probable cause of the steepening.

(ii) The bench. This is found at the foot of the over-steepened face, being best developed between the Fyrwd and Ochram Brooks. Back and frontal edge heights are 500 and 350 feet, and 470 and 350 feet at the northern and southern ends respectively (fig. 21). Heights for the leading edge might be misleading, however, for whilst the reality of the bench is not in doubt, the leading edge in places is not a single break of slope, but a composite inflexion. South of the Ochram the bench appears to continue for another third of a mile, terminating where a small but deeply cut stream descends the hillside. North of the Fyrwd there is no bench at this level, but a much narrower bench extends for a short distance with its leading edge at c. 325 feet (fig. 21).

The oversteepened face backs the bench over most of its distance, although the bench also enters the lower part of the Ochram valley. Between the steepened scarp face and the bench there is sometimes an intervening zone with an intermediate slope angle. Below the bench, the slope drops to the valley floor deposits, the margins of which can be easily mapped in the field.

The bench is covered by pebble gravel, the upper limit of which appears to coincide with the break of slope at the rear. It is probable that the drift is just a thin surface cover on an essentially rock-formed feature. The origin is obscure, but it is suggested that here we have perhaps evidence of an advance of the ice which pre-dated that which laid down the gravel deposits of the valley floor. If the bench is not largely constructional, and field impressions are that it is not, then the bench must have been developed when the scarp face above was being undercut. As the outcropping strata on the bench is less resistant than that above, it is difficult to envisage a lower-gradient slope forming, unless the present bench lay then at valley floor level. Formation during an earlier ice advance, when the Usk valley was shallower than at present is thus proposed. The last ice advance considerably deepened the valley, but erosion of the scarp foot must have been less severe than previously, although the face of the bench would be an erosional relic of that time. This does not suppose that the depth of ice in the valley during the last advance did not rise above the level of the bench, although it seems certain that there was a critical stage towards the end when the ice was very thin.

The relation of the continuation of the bench on the south side of the Cohram with the extensive morainic material emanating from the Ochram valley glacier (shown on fig. 21) is interesting. The morainic material is streamed along the scarp slope along the south side of the Ochram re-entrant only, suggesting that the Usk glacier forced the Ochram ice to move south along the scarp foot. This morainic material is confined to the slopes above the bench, except where the bench enters the Cohram valley. This suggests that the Ochram ice formed a lateral tongue, with its surface mainly above the 400 feet O.D., and further that the Ochram ice did not extend significantly down into the Usk valley after the Usk glacier had thinned. An arcuate morainic ridge in the mouth of the Cohram valley, to the south of the canal, seems to indicate the maximum down-valley extent of the Ochram ice.

Thus it is probable that during the last ice advance the bench was at one stage sub-marginal, although it did not, except perhaps near Rhyd-y-meirch, become covered by lateral morainic deposits. Nor was the ice extensively fissured at this depth for the few marginal (and perhaps sub-marginal) drainage channels are confined to the higher slopes. Modification of the form of the bench at this stage seems to have consisted solely of ice moulding.

The theory proposed is admittedly not entirely satisfactory, although it fits the available evidence better than any alternative. A solifluctional origin seems unlikely: the bench shows no consistent relationship with the slope and height of the scarp face above, and dies away completely towards Llanfoist, where slopes are equally steep. Moreover, the south-westerly aspect of the opposite side of the valley would be more favourable for solifluxion processes, but there is little evidence of bench or terrace development there. Later erosion could, however, have removed traces of the bench from that side of the valley and at Llanfoist, if it is considered to date from an earlier advance. Erosion by marginal meltwater drainage was considered, but ruled out on morphological grounds. The bench is also quite definitely not a kame terrace.

It is suggested therefore that in the undercutting and benching of the scarp foot in the Llanellen area we have a suggestion of at least a dual ice advance in the Usk, separated by an interval in which considerable erosional work was accomplished. This accords with the evidence from the Black Mountains valleys, which suggest a Last glaciation deepening of the middle section of the Usk of at least 200 feet on the northern side of Gilwern Hill, and in the Llanelly area, and the drift choked floor of Cwm Llanwenarth opens out into the Usk valley at about this level near Govilon.

Other features may be mentioned briefly. The importance of the small valley glacier of the Ochram has been discussed previously (pp. 222). Three varying stages of development are suggested: (i) a maximum stage when the ice from this valley was joining that in the Usk, and streaming south along the scarp foot; (ii) a phase when the Usk ice had thinned the Ochram ice descending at a maximum to just below the present canal crossing (300091); (iii) a cirque glacier phase. The extent of morainic ridges festooned about the cirques suggests that this phase was relatively long.*

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* These are three stages which could be related to one major glacial phase, or to three separate advances.

The Punchbowl at the head of the Fyrwd, although a perfectly formed cirque, is very small, suggesting that it began to function as a basin of ice accumulation at a relatively late stage, and the extent of associated morainic material suggests that it did not contribute significantly to the Usk glacier. Cwm Craf (277124) above Llanfoist, shows evidence of nivation, but there are no true morainic accumulations.

The remaining features of note are high level benches. These have a generally low cross-gradient, and formation by lateral meltwater during a maximum stage is possible. The two highest (fig. 21) on the north side of the Fyrwd valley, and cut across the neck of the spur flanking the eastern side of the Cohram valley (above Llanellen) are at just over 900 feet, whilst there is a lower, less extensive till-covered bench above Llanfoist at c. 600 feet.

(b) CLYTHA - CHAIN BRIDGE.

1. GENERAL.

This section of the valley trends in a SSW direction, being guided by a fault, here bounding the western side of the northern part of the Silurian inlier (Walmsley, 1959). To the right of the river, marls of the lower division of the Old Red Sandstone rise to a maximum of 310 feet near Croes Llanvair (338 081), but eastwards Ludlovian rocks reach over 600 feet in Clytha Hill and Trostrey Hill.

Valley-side slopes are steep, especially in the east, meeting the drift of the valley floor in a generally abrupt break of slope. It is possible that the steepness of the eastern valley-side is partly structural, as cols at Bettws Newydd (361 062: cut by a meltwater channel) and north of Trostrey (362 053) as well as the valley past Trostrey Court (366 044) are aligned with the fault-controlled section of the Usk mapped by Walmsley (1959). His 'solid' mapping of the Bettws Newydd area is very incomplete due to the thickness of the drift in the area. South of Clytha the Usk swings away from the valley side, and at Bettws Newydd a ridge of high ground extends westwards, dropping steeply to the river at Chain Bridge. The angle formed by this ridge and the north-south trending western slopes of Clytha Hill is occupied by a triangular shaped lowland area with a thick drift cover.

This section of the valley contrasts markedly with that immediately above it, in that the Usk is here incised between high banks of drift, with an extremely limited flood plain development (fig. 33). There is also a major contrast in the amount of drift on the valley sides, that on the east generally showing a thick cover, especially near its foot, whilst the western slopes are virtually drift-free. A short distance to the south of Chain Bridge there is a morainic ridge at Kemeys Commander (see section (d), which marks the up-valley limit of a thick valley train of outwash deposits. The relationship of this section of the valley to both the deeply eroded (and alluviated) section of the Usk immediately upstream, and the extensive outwash downstream of Kemeys thus requires investigation.

2. MORPHOLOGICAL DETAILS.

The morphology of this section is shown in fig.

(a) <u>Valley floor drift fill.</u> The character of this varies, and a distinction may be made between the drift confined mainly to the western side of the river, and that about Brynderwen to the east.

The drift to the west shows a smooth, rolling form, the ridges which have been mapped on its surface (fig. 21) being broad and not easily plotted in the field. Towards Chain Bridge, a tendency towards down-valley alignment is obvious. The drift surface has a marked down-valley gradient, being highest just south of Clytha, where the Usk enters its confined section, the drift surface reaching between 160 and 170 feet O.D. here, whilst the flood plain at this point is at almost exactly 100 feet O.D. The downstream gradient of the drift is such that at Chain Bridge the alluvial deposits of the Usk and its tributary the Nant Robwl are built over a large part of its surface.

At the western edge of the valley floor a major melt-water channel (the Orchard House Channel) has been mapped. Above St. Mary's Yard (349 070) it is best developed, although no longer carrying any surface drainage. The downcutting of this channel, combined with trimming of the base of the western valley side partly accounts for the decline in the level of the drift surface in this direction, the drift of the valley floor reaching a maximum height (west of the river) mainly along the bluff flanking the recent incision of the Usk. To the south of St. Mary's Yard the meltwater channel is occupied by a minor stream draining off Llanvair Hill, and it becomes less distinct, probably due to alluviation of its lower reaches. A further channel, which deflects to the south-west of the Usk into the lower Robwl just above Chain Bridge suggests that it was formed before the Usk had entrenched itself along its present course, and in this area showed slight development of braiding, a distributary occupying the low ground between adjacent ridges of the drift surface.

To the east of the river only a limited area about Trostrey Lodge (357 074) has a drift surface character similar to that in the west, the main feature here being an extensive, semi-circular development of hummocky drift with kettle. The drift west of the Usk and at Trostrey Lodge is characterised by low, long and rather indistinct ridges. Their form suggests fairly uniform deposition of probably mainly englacial and subglacial moraine on a smoothed sub-drift surface, the present form reflecting also later trimming by meltwater streams, especially in the west.

The hummocky drift with kettle about Brynderwen[+] is of a quite different character, ridges being short and steep sided, and forming a more chaotic pattern. The main development of this forms a semi-circular belt, cut by the Usk in the west, and at an altitude of between 150 and 250 feet O.D., although one isolated ridge runs up the flanks of Coed y Bwnydd (367 068) to almost 400 feet. The form of the main accumulation suggests fluvio-glacial deposition upon and within well-crevassed ice. If the ridge on Coed y Bwnydd is of the same origin, it suggests an ice thickness of at least 200 feet. Immediately south of this deposit, a very marked meltwater channel cuts through the crest of the ridge at Bettws Newydd. Its floor is at a height of 290 feet O.D. at its highest point, and it appears to have been cut by lateral drainage from ice filling the valley above the constriction formed by the Bettws Newydd ridge.

It is difficult to account for this extremely localized accumulation of hummocky drift at Brynderwen. This could be:

(a) the result of removal by meltwater streams or a subsequent ice advance, of a similar deposit once occupying the western sector of the valley;

[+]Plate 17.

or (b) due to conditions which favoured the local accumulation of meltwater deposits.

Although meltwater erosion was clearly far more significant at a late stage along the western side of the valley and along the line of the present river than in the east, the area directly affected by meltwater action appears to be relatively limited, as indicated by the extent of the more smoothly flowing drift forms. A late ice advance is improbable.

Localized glacio-fluvial accumulation is possible where suitable changes occur in the gradient and channel forms of meltwater streams, although extreme localization of deposition as in this case would appear unlikely. Here, the presence of a major channel across the ridge at Bettws Newydd immediately to the south seems significant, as too the absence of significant meltwater deposits in the small valley draining southwards from it towards the Usk beyond Kemeys Commander. Shrinkage of the ice due to melt upstream of the channel is unlikely to have been matched by downcutting of the channel (probably initiated by lateral meltwater streams utilizing a pre-existing col ~~[illegible]~~). The ice marginal water body that might have formed in this way would provide ideal conditions for sedimentation, later draining and collapse of the sediments into crevasses formed by melt of the underlying ice body giving rise to the present forms. No exposures were available to determine whether there was evidence of lacustrine deposition, and no evidence of pro-glacial lake formation was noted.

(b) Meltwater channels and later riverine features. Two meltwater channels have already been noted in discussion of the drift fill: the Orchard House Channel, under the western valley side, and the Bettws Newydd Channel.

The deep, stream-less valley known as Snouch's Dingle, descending to the valley floor at Great House (361 081), south of Clytha, may also owe its present form in part to meltwater erosion (i.e. descent of lateral drainage towards the valley floor at the ice margin), and it is mapped as such in fig. 28. Its width, however, and the height at which it commences on Clytha Hill (over 500 feet O.D.) suggest that other factors are involved. Walmsley (1959) shows that it is fault-controlled. It is suggested that its present abrupt form, incommensurate with its drainage, is the result of ice coming down the

Usk attempting to override Clytha Hill. Whilst most of the ice was clearly deflected either eastwards into the Clawdd, or southwards along the present Usk, a minor tongue of ice, most likely guided by a pre-existing, fault-controlled, minor valley, appears to have ascended the flank of Clytha Hill, eroding the valley as it did so. No significant crossing of the ridge at the valley head appears, however, to have been made.

The Orchard House Channel, and the present course of the Usk seem to have been fashioned by meltwater draining from ice persisting in the Clytha area and lower Clawdd after it had disappeared from the main Usk valley between Clytha and Kemeys Commander (see section e of this Chapter. Sedimentation in the Clytha area, following ice melt, was probably controlled by downcutting of the present Usk channel above Chain Bridge. Minor river terraces marking stages in the incision of the river are present on the inner side of the developing meander bends (at Pant on the western side (357 078) and near Bryndeŕwen (354 071) in the east). These have a comparable relation with the present flood plain as the minor terrace developed opposite Clytha at Llanfair Kilgeddin (p. 310), but appear to merge with the flood plain towards Chain Bridge.

3. CONCLUSION.

The ice advance which extended down valley to Kemeys Commander and discharged vast quantities of meltwater to form the major valley train filling the valley below there (section d) is likely to have been the last ice to occupy the Usk below Clytha, and thus largely responsible for the drift deposits of the part of the valley under discussion. At one stage lateral drainage was crossing the ridge constricting the valley west of Bettws Newydd, and sedimentation in a minor pro-glacial lake upstream of this channel may be responsible for the marked accumulation of hummocky drift at Brynderwen. Ice persisting about Clytha and in the lower Clawdd after clearance from the Usk about Chain Bridge discharged meltwater southwards, re-establishing the pre-glacial course of the Usk.

(c) GOETRE AREA.

At Llanover the Usk swings eastwards away from the Coalfield scarp, but extensive drift deposits in the area about Goetre, to the south of Llanover, show that the ice continued along the foot of the scarp at least as far as the Berthin valley. The morphology of this area is shown in fig. 23.

1. SOUTHWARD EXTENT OF THE ICE.

The exact extent of the ice in this area is not easily determined. Drift showing marked constructional features terminates at the head of the slopes leading down into the Berthin valley near Little Mill, although in the Monkswood area to the east, constructional drift topography is to be found descending almost to valley floor level. It is unlikely that ice would extend to the brink of this valley, and not descend into it, and the general absence of drift in the valley itself is attributed to removal by meltwater. In view of the valley size, and its position, marginal to the line of the probable ice front, it almost certainly functioned as a major meltwater distributary at this time.

The possibility that the anomalous course of the Berthin Brook might have been initiated by marginal meltwater drainage was considered. This seems unlikely in view of the number of low cols leading southward into the ice-free areas drained by the Sor and lower Afon Lwyd. Meltwater would only have used the Berthin route if it was already established as a valley prior to the phase of ice invasion under consideration. The Berthin is likely to be a late-developed, structurally-guided member of the drainage system, which probably extended at the expense of minor Sor headwater streams.

The presence of a relatively deeply cut valley transverse to the ice flow, and near the ice margin must have hindered further southward movement, and it is reasonable to suppose that the ice margin lay along the line of the valley. There is, however, some reason for suspecting that small lobes of ice crossed cols from the Berthin into the head of the Sor drainage, for the remains of a small moraine are to be found at the head of that valley near Maes-mawr (322004). This ice lobe appears to have crossed the Beech Tree Col (marked on fig. 23), a fairly narrow, flat-bottomed feature with a floor at ca. 360 feet, some 200 feet above the floor of the Berthin valley. At the head of the main headwater of the Sor at Cwm is a much wider feature, shown in fig. 23 as Cwm saddle. During the construction of the Llandegfedd Reservoir the removal of trees and hedgerows with bulldozers permitted examination of the subsoil in this area. Numerous erratic pebbles, many of Coalfield derivation, in a sandy matrix, suggested outwash into this valley head at a time when the outlet via the lower Berthin valley might have been blocked, or alternatively from an ice lobe crossing the Berthin valley into the Cwm saddle. There is no other evidence of this. East of Cwm access was not possible into the extensive area occupied by the Glascoed Royal Ordnance Factory. A final col in the Berthin watershed is to be seen at Pontypool Road (298002), where it is utilised by the railway in its crossing from the Afon Lwyd valley. In this case, however, it is most likely to have been used by meltwater from the glacier in the Afon Lwyd, as there is no drift evidence in the headwater of the Berthin upstream of Little Mill. It is therefore suggested that although the ice might have advanced for a limited period beyond the Berthin Brook, that that valley marked the limit of the main advance.

2. DRIFT MORPHOLOLY NORTH OF THE BERTHIN BROOK

This is illustrated by fig. 23, which shows especially:

(1) the concentration of drift features in a belt extending from the Ochram valley through Penpelleni to Monkswood; and

(2) the reduced significance of kames and similar water-lain features.

The drift features concentrated in this NW-SE trending belt are predominantly marginal features of the ice tongue. Their prolific development in this area may in part be due to the additional morainic material added from the Ochram cirque glaciers, and possibly also as a result of frost shattering and mass movement on the scarp face generally. The dominance of till and moraine features, and the limited development of fluvio-glacial deposits and related morphological features may in part be accounted for by the location of this area above the main valley floor, well-drained by tributary streams of the Usk. As the area is some 200 feet above the Usk valley, ice would only have crossed it when at least several hundreds of feet thick, and active. When melting, and thinning occurred, the ice in the Goetre area would quickly become detached from the main stream of ice movement, and rapid melt would occur.

The main marginal features are to be found in a belt extending across the head of the Nant y Robwl valley to Penpelleni. These take the form of ridges elongated in a NW-SE direction. They are composed in the main of till, with coalfield erratics in a predominating clay matrix. They are clearly moraines, recording slight fluctuations of the ice front during the final retreat. Their discontinuous form suggests partial washing away by meltwater, or removal by minor readvance. Kettle holes between the ridges suggest burial of ice in outwash deposits. On the whole, however, outwash is limited in this area, a reflection of the relatively steep slopes down to the Usk in the east, and the Berthin Brook in the south. The greatest concentration of ridges is in an area to the north-west of Penpelleni. Here, not only are the ridges closest together, but they are most abrupt in form. Beyond this (i.e. to the south and west) the ridges are broader and spaced at wider intervals, although they remain as distinct landscape features. The contrast in morphology may be a reflection of a different age, the outer series being older, and subject to modification by solifluction during the formation of the second series.

To the east of Penpelleni there is a break in the morainic ridge topography which cannot be satisfactorily explained. It may be due in part to the alignment of the hill mass in this area in a direction (NNW-SSE) which is at right angles to the moraine ridges, and presumably parallel to the direction of ice movement. As it rises about 75 feet above the ridge on either side of it, it would tend to divert ice flow along its flanks, accounting for the concentration of morainic deposits there. The hill is capped by an irregular cover of till, but the few ridges mapped on it are indistinct. The alignment of the morainic ridges to the east of this (in the Monkswood area) is less distinctly NW-SE, and there is a tendency for the ridges to swing round to a north-south direction in the east as the Usk is approached. This suggests interference by ice persisting in the Usk trench after melting at higher levels. This is supported by the number of meltwater channels mapped crossing the narrow ridge from the Usk valley south of Kemeys Commander into the lower Berthin valley. These conform in the main to the vales formed between adjacent morainic ridges, although their continuity of slope and cross-sectional form leave no doubt as to their use as meltwater distributaries. It is likely that they were used by meltwater formerly running marginal to the ice when it occupied only the Usk trench, although the braiding of one channel suggests sub-glacial initiation.

North of Penpelleni the inner group of moraine ridges swing towards the upper part of the Rhyd y meirch valley. Here a secondary alignment of these ridges becomes evident, this time in an east-west direction. This suggests that the ridges maintaining the NW-SE line along the foot of the scarp are lateral moraine, whilst those branching eastwards from them record actual positions of the ice front during retreat. Between the Nant rhyd y meirch and the Ochram, the lateral character of the ridges is re-emphasised. Most retain the NW-SE alignment, but the meltwater channels associated with them run, in some cases, directly down slope. These are probably sub-glacial shutes, formed by marginal drainage turning abruptly to enter the body of the ice. It is interesting to note that only where constructional features of the ice are prominent do we get convincing examples of marginal drainage forms.

When the ice front lay along the ridges about Penpelleni, drainage from it appears to have drained southwards easily via the small south-flowing tributaries of the Berthin Brook. However, withdrawal of the ice into the basin of the Nant y Robwl resulted in impeded meltwater disposal from the ice. Evidence of this is to be seen in the kame terrace developed near Capel Ed (320051) to the north of Penpelleni. An enlargement of the morphology of this area is to be seen in fig. 24. A flat shelf is built up against the main belt of moraine ridges at this point. Its surface declines in height southwards, narrowing as it does so, and fades away in the area of Penpelleni village. Its face is made up partly of till, but probable ice contact areas suggest that a fluvio-glacial deposit was built up, possibly over hummocky basal or lateral morainic deposits. No exposures were found in the terrace, but it is suggested that it is a kame terrace formed by marginal drainage which eventually found its way into the Berthin valley via the col at Penpelleni.

From this col, a channel can be traced descending the hillside on the south side of the ridge to join a tributary of the Berthin Brook. This channel crosses the ridge at just over 300 feet O.D. A second meltwater channel is to be seen in fig. 24, a little to the east on this same ridge, and the absence of associated fluvio-glacial features suggests formation sub-glacially.

At the foot of the kame terrace, a distinct concave break of slope bounds a very damp, partly wooded flat occupying the upper part of the Nant y Robwl valley. The break of slope limiting this can be mapped easily on the north, south and west, but to the east there is a slope towards the river which has partly incised itself into this 'surface' near Goetre Church. East of this the Nant y Robwl cuts quite a narrow valley, in contrast to its open headwaters, in its fall to meet the Usk at Chain Bridge. The flat is at a level of ca. 285 feet at its western margins, but declines to ca. 250-260 feet near Goetre. It is suggested that this flat is most likely to have formed by sedimentation in a body of water held up by the ice in the upper part of the Nant y Robwl valley, and accordingly has been marked on fig. 24 as a former lake floor.

North of the Goetre flat, a number of meltwater channels cross the Pen-groes-oped - Croes Llanvair ridge. The most important are (commencing in the east, fig. 24):

1. the Llanvair Channel (at Llanvair Grange - 333072). A marked channel with a sinuous course crossing the ridge at ca. 285 feet, and descending on the south side of the ridge into the mouth of the Nant y Robwl valley.
2. a channel (329071) probably originally at ca. 270 feet, but now utilised by the railway which crosses the ridge at this point in a cutting.
3. a channel west of Hendre Uchaf (323072) with an intake at over 300 feet which leads into the head of a tributary of the Nant y Robwl (shown at the top centre of fig. 24). A further channel leads from this across a minor watershed into the flat described above. It meets the flat accordantly, suggesting that aggradation of the flat was linked with the cutting of the channel.

It is probable that the channels were initially sub-glacial, for there is no evidence to suggest that they carried drainage from a body of water held up in the Nant Rhyd y meirch valley, whilst their altitude and position on the ridge do not suggest that they mark successive positions of the ice margin. With clearance of ice from the ridge, it is however, probable that the Hendre Uchaf channel at least carried meltwater draining into the temporary lake held up in the Goetre area.

Drainage of water from the lake must have been effected either across the surface of the ice filling the lower Nant y Robwl, or along the flank of the ridge to the south-east of Penpelleni, as the channel at Penpelleni would appear to be too high to have functioned as a spillway. There is, however, no evidence of marginal drainage along the ridge.

3. CONCLUSION.

Ice movement southwards was halted by the Berthin valley although minor lobes might have crossed cols into the head of the Sor drainage. Ice would only have crossed the low hills about Goetre when it was relatively thick in the main valley below Abergavenny, as they rise 150-200 feet above it. The ice in this area would thus be relatively thin, and a stage is envisaged when the Goetre area was relatively clear of ice, although ice persisted in the main valley of the Usk as far downstream as Kemeys Commander. Retreat stages of the ice from the area are marked, however, by morainic accumulations about Penpelleni and on the Pen-groesoped - Croes Llanvair ridge to the north. Lateral morainic deposits are most evident, testifying to nivation and mass movement on the scarp, and to the contribution of the Ochram cirque glaciers. Fluvioglacial deposits are relatively limited in this area, but marginal drainage seems to have formed a kame terrace north of Penpelleni before escaping over a col into the Berthin valley, and melting of the ice occupying the upper Nant y Robwl seems to have resulted in the formation of a small proglacial lake. Present day drainage is influenced by the series of meltwater channels, most of which were initiated sub-glacially.

(d) THE USK VALLEY, CHAIN BRIDGE TO USK.

1. GENERAL.

The valley between Chain Bridge and Usk is well defined, the floor being thickly covered with drift deposits which appear gently rolling, into which the river has incised itself, with only slight flood plain development, in almost every case on the inner side of the meander curves. The meanders are tight and fill the valley completely, undercut slopes and bare rock outcrops being present where the river swings against the valley side (e.g. at Trostrey Weir). Within the meander cores, in general no solid rock outcrops separate the drift covering the valley floor from that of the valley sides, but nevertheless they can be easily separated in the field, a distinctive concave break of slope being evident at the junction. It seems therefore, that the Usk flows in a flat steep sided trench cut into the solid rock, which has been choked with glacial drift and only partially re-excavated by the river. Rising above this the hills are drift covered, but this drift may, at least on morphological grounds, be differentiated from that of the valley floor.

2. THE KEMEYS COMMANDER 'MORAINE'.

There is no really distinctive moraine in the main valley in this area, although there is evidence which suggests the ice front lingered for some considerable time at Kemeys Commander. Here, the drift deposits of the valley floor, which have gained height progressively when followed upstream from Usk, reach their highest point. Upstream (see fig. 25) the ground falls away relatively steeply in a series of minor ridges, cusps and re-entrants, considered to be an ice contact face. The ridge at Kemeys Commander is a complex feature formed of a number of minor ridges having a cross valley orientation, and in one case a large hollow with no natural outlet, probably a kettle hole. This ridge reaches its highest point (170 feet) near its western extremity where it has been cut through by the river. Undercutting of Craig yr Harris by the river on the opposite side of the valley has removed all traces of morainic debris in that area. Downstream of this subdued morainic remnant the drift deposits lose height far less rapidly, forming a relatively gentle slope, interrupted here and there by minor swells and broad basins. Where the river swings across the valley to impinge on its eastern side however, the gentle slope gives way to a steepened river cut and terraced bluff.

3. THE VALLEY TRAIN.

Standing on the ridge at Kemeys Commander and looking down valley it is clear that the surface of the drift falling away before one is but part of a more extensive feature continued in the bend of the next meander, and farther south in the area about Llancayo. This surface is gently rolling and loses height progressively as followed downstream. Exposures exist, particularly good ones being seen where the river is undercutting it on the bend north of Estavarney. Here, well rolled gravel, mainly of Old Red Sandstone and Millstone Grit, has been cemented into a resistant conglomerate which has been undercut to form a steep cliffed face (see footnote, p. 241). This deposit is fairly clearly a valley train of outwash formed when the ice front was at Kemeys Commander.

Into this valley train the river has incised itself, meandering slightly as it did so, so that terrace remnants have been left at various heights above the river.+ As a result, the original surface of the valley train is limited

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+ See Plate 18.

to areas on the inner side of the three major meander cores, and on the south side of the Berthin Brook, where the East Monmouthshire Agricultural College (366019) is sited. The location of these is indicated in fig. 25 (A, B, C & D). A further possible minor remnant is to be found on the north side of a small valley on the narrow spur separating the Berthin Brook from the Usk. The average height of the four main remnants has been determined by survey aneroid, and is shown in fig. 26 (A, B, C and D). It will be seen that their surface falls progressively downstream from a maximum height of approximately 75 feet above river level at Kemeys to a height of approximately 25 feet above river level at Rhadyr, 2½ miles downstream. The slope steepens appreciably as the former ice front at Kemeys is approached, probably as a result of the deposition of the coarser gravel shortly after the meltwater streams emerged from the ice, progressively finer gravel being deposited downstream, a concave slope, steeper upstream, developing. Unfortunately there are no suitable exposures at Kemeys to allow comparison of gravel size with that of exposures farther downstream. In order to portray the relationships of the various terraces at all adequately, it was necessary to greatly enlarge the vertical scale of the profile (to approximately 44 times the true scale). This has resulted in an over-emphasis of slope angles, which should be borne in mind when the profile is examined. This has served to emphasise the relative steepness of the upper part of remnant A, although the downstream portion of this flattens out, and furthermore, is at a level slightly below that of the succeeding downstream remnant (B), the maximum height discrepancy being of the order of 7 feet. It is suggested that the steepening may be partly accounted for by trimming of the river at an early stage which would have reduced the level of a part of the remnant to below that of the succeeding surface B. Unfortunately, field evidence is inconclusive on this point, the only supporting evidence being a slight undercutting of the slope on its western flank (see fig. 25).

The various relics of the surface of the valley train may be distinguished from the terraces cut into it by the undulating nature of its surface, which is probably due to the unequal settling of the gravels, and the melting out of included ice masses. Flint (1957, 139) states that as valley filling with outwash takes place more rapidly in the centre of the valley than along the sides, the outwash attains its greatest height in the middle, sloping outwards. Certainly no reversed slopes were observed, nor, as one would expect, do any of the more important streams maintain a marked valley-side course before joining the main river. As Flint later states, however, compaction of the deposits, usually thickest in the centre, usually reverses this initial outward slope, and this appears to have been the case here. Nevertheless, such an original form would account for the relatively sharp concave break of slope which the deposits of the valley train make with the valley side. No blockage of the side valleys appears to have occurred, and in fact several of the smaller tributaries appear to have subdued fan forms where they debouch onto the fluvio-glacial deposits. This is a feature common to most tributaries of the Usk, and is considered to be the result of rapid re-excavation of valleys choked with drift under periglacial conditions near the close of the Pleistocene (see pp. 360-369). This appears to be the case in the broad valley in which Trostrey Court is situated. Today it is drained by a misfit stream, which may owe its wider form to excavation by marginal drainage from the Usk glacier at an earlier stage than that marked by the Kemeys moraine, possibly linked with the well marked overflow cutting through the ridge at Bettws Newydd.

South of the Rhadyr remnant (D) it is difficult to locate further remnants of the original valley train surface, partly because the valley narrows so that a greater part of the valley floor has been worked in post-glacial times by the Usk. At the town of Usk, however, the outwash deposits must merge with the outwash carried down the valley of the Olway Brook from the ice margin near Raglan. The valley of the Olway is of remarkable width (fig. 33), even bearing in mind the glacial diversion into the Wye drainage basin of certain of its former headwater streams. The Olway Brook, as its name implies, is a small stream, and yet the alluvial spread of the valley floor rivals that of the main river. The actual flood plain of the river does not, however, extend today over more than a small portion of the alluvial deposits, and there is little doubt that the extensive alluvial spread marked on the 1" Geological sheet (233), is largely of glacio-fluvial origin. The extent of these deposits indicates that the Olway valley rivalled in importance that of the Usk for the conduct of melt water from the ice front. In post-glacial times, the Olway Brook has, by virtue of its small size, been able to incise itself only slightly into the valley train. It seems that the town of Usk is built on a flat formed where the valley train of these two major melt-water distributaries coalesced, which, due to post-glacial incision, is slightly above the level of the present flood plain. The continuation of the valley train in the main valley may be responsible for the deferred confluence of the Olway Brook, which hugs the eastern side of the valley to make a deferred confluence at Llanlywell, three and a half miles downstream of the mouth of the tributary valley.

4. THE TERRACES.

In the course of dissecting the valley train following the retreat of the ice, the ice has formed a number of river terraces, the location of which is shown in fig. 25. The height relationships of the various terraces and the valley train were determined, and the profiles based on an aneroid survey, are shown in fig. 26. This is a composite diagram, the average height of each terrace or valley train remnant having been projected onto a central line (shown in the inset map). In this way the height and slope of the various features could be represented fairly clearly, despite their limited altitudinal distribution. As the terraces are not located relative to the river profile, the river is shown crossing the profile at several points. No indication of terrace extent or height range is possible in this diagram, although the former is shown in fig. 25.

Terraces formed as a result of the dissection of a former valley fill of relatively loosely consolidated material are typically non-paired: valley deepening is rapid so that the river has attained a lower level when its meander swings against the opposite side of the valley. Terraces thus formed tend to be randomly scattered through the height range of any profile, showing that terrace development was not related to successive phases of still-stand. In such instances the occurrence of terrace remnants on the same level on both sides of the valley is unusual. To some extent this is true of the terraces of this part of the Usk, except that in this case terrace remnants do not occur on immediately opposite sides of the valley, but in successive meander cores. Nevertheless it is difficult to show that any two successive terraces were formed at the same time, although the small height differences involved make it dangerous to be categorical either way.

Individual terraces are, in general, well defined, and the flight of terraces crossed by the main Usk - Pontypool road at Rhadyr (valley train remnant D, terraces 10 and 11) is particularly well preserved. As the height differences between successive terraces are usually not great, the existence of a well-marked bluff separating them is the most useful means of delimiting them. Where this bluff is indistinct, as it is near Llancayo (between terraces 5, 6 and 7) where the terraces are crossed by a small tributary of the Usk, the relationship of the various terraces becomes obscure.

Terrace 3 forms an exceptional case in having a marked slope both downstream and across valley (towards the river), the terrace reaching its highest point on the inner upstream area of the meander core where it is being undercut by the Usk at Craig Glaster (see fig. 25).

Nevertheless it can be distinguished from the surface of the valley train on the west side of the valley, due to the presence of a fairly distinct, though degraded, bluff. Two reasons may be suggested to account for this sloping form: firstly it may be the result of early modification of the surface form of the valley train by meltwater, and is in effect, an original deformation of the surface. Secondly, it may (and this seems more likely) be the result of a meander migrating slowly across the valley with little counter movement, whilst at the same time deepening its course. It becomes flatter near its edge, which may be the result of a 'hesitation' in the general process of meander enlargement and downstream migration.

5. DOWNSTREAM EXTENSION OF THE VALLEY TRAIN.

The relationship of the valley train and the flood plain beyond the Rhadyr area is not easy to ascertain, partly due to the constriction of the valley at Usk and the alteration and masking of landforms within the built-up area. As noted above, it seems likely that Usk town is built on the confluence of the valley trains of both the Olway and the Usk valleys. The spur of high ground (solid rock) on which Usk Castle is built has protected this from erosion by the river. It seems likely that the area under the cliffed western side of the valley is a low terrace above the general level of the floodplain although parts of it were under water during the exceptional flood of November 1961. South of Usk the meanders of the river are no longer incised between terraced glaciofluvial deposits, and they swing freely over a wide flood plain. In this area there is evidence in parish boundaries and the field pattern of numerous changes of river course in historic time. At Usk the river crosses from the Silurian once more onto the marls of the Old Red Sandstone and this, to some extent, accounts for the dramatic widening of the valley south of the town. The addition of melt water from the Raglan area would also have given the river increased erosive power in this section, enabling it to carve a wider valley.

Projection of the slope of the valley train suggests that it meets the flood plain to the south of Usk. In Chapter 11 a narrow terrace of gravel extending down the western side of the valley from Llanbadoc almost to Tredunnock is described. This becomes less distinct as traced downstream, and it is suggested that at about

Tredunnock it merges with recent alluvial deposits. It is very probably that this is the downvalley continuation of the Kemeys Commander valley train, the lower terrace stages being below present flood plain level in this area. If so, its gradient must have decreased slightly. This is reasonable, in view of the decreasing gradient of the valley train surface noted to occur downvalley elsewhere. The relationship of the Llanbadoc terrace and the Kemeys Commander valley train are considered further in Chapter 11.

Relative heights of the valley train, present flood plain, and the Llanbadoc terrace, together with the depth of the sand and gravel infill of the valley at points between Llangybi and Uskmouth are shown diagrammatically in fig. 26A. The present depth of the sand and gravel fill in the centre of the valley probably reflects phases of downcutting by the Usk in response to changing load/energy relationships, as well as to fluctuating sea levels, aggradation occurring during the post-glacial rise in sea level.

6. CONCLUSION.

Advance of the ice to Kemeys Commander was marked by the formation of a thick valley train of outwash gravels.

which have since been cut into a series of random terraces during the incision of the river. Incision of the river was marked by the exaggeration of its meandering form, a type of ingrown meander developing. The valley train may be continued downvalley in the form of a narrow gravel terrace between Llanbadoc and Tredunnock. Outwash from the glacier when halted at Kemeys Commander was possibly carried as far as the river mouth, contributing to the gravels presently filling the rock floor of the buried channel in the Newport area.

The relationship of the valley floor deposits to the drift of the surrounding hills suggests that the Kemeys Commander valley train was laid by an ice advance post-dating that responsible for the deposits of the Goetre and Monkswood areas.

(e) BRYNGWYN AREA.

1. GENERAL.

The area considered in this section straddles the watershed between the rivers Usk and Troddi, and the Olway Brook. It forms a zone of relatively low-lying land in line with that section of the Usk between Llanover and Clytha. Ice pressing down the Usk valley below Llanover was split by the shoulder of Clytha Hill into two main streams, one turning southwards towards Chain Bridge, and the other continuing eastwards towards Raglan. Evidence to be outlined later suggests that the latter stream was the more important.

2. RELIEF AND DRAINAGE.

The relief of the area is shown in fig. 27 (A), and the drainage in section (B) of the same figure.

The main relief features are (1) the northern part of the (Silurian) Bettws Newydd Hills, culminating in Clytha Hill (625 feet) which rises south of the lower Clawdd valley; (2) the narrow-crested west-east ridge dividing the Troddi valley from the Usk drainage (which rises to a maximum of about 300 feet). This is broken between Llanarth and Llantilio Crossenny by a feature we shall refer to as the Wernyrheolydd saddle; and (3) a zone of higher, more broken terrain to the east of Penrhos and Tregare. This is part of a major belt of high ground extending south-eastwards from Graig Syfyrddin, one of the major masses of the North Monmouthshire Uplands, situated five miles to the north. This appears to reflect extensive sandstone and cornstone and Psammosteus limestone developments in the outcrop of the St. Maugham's and Raglan Marl Groups of the Old Red Sandstone.

Between these areas of high ground, the width of the Clawdd valley at Llanarth contrasts markedly with the narrowness of that of the Olway above Raglan, whilst the area between the two rivers is formed by low hills (generally less than 250 feet O.D.), aligned north-south.

The drainage is marked by great diversity of trend. The Clawdd Brook is the only west-flowing stream, although the Wilcae in the extreme south, the Wechan in the east, and the Troddi in the north, all flow in a predominantly easterly direction. The Olway is the only major south-flowing stream, although one long (unnamed) tributary of the Wilcae, and most of the right bank tributaries of the

Clawdd Brook show predominant southerly trends. In the higher ground north of the Troddi, all the left bank tributaries (and headwater) of that river show marked southerly or south-south-easterly trends.

Contrasts in valley form have already been noted, and might be considered further. The Troddi has a broad valley above Llantilio Crossenny, but this contracts eastwards towards Talycoed, where the river cuts through the belt of high ground striking south-eastwards from Graig Syfyrddin.

The easterly-flowing Nant Wechan cuts a similar gorge east of Penrhos, when it commences the crossing of this ridge of high ground, although it rises in a fairly broad, south-trending valley (aligned with the Olway above Raglan). The Clawdd valley can be divided into three sections: (i) a lower section which is remarkably broad (although the actual area of alluvial deposits contracts considerably as the Usk is approached) which extends upstream as far as Millbrook (391 110); (ii) a gorge-like section, with a marked steepening of the valley floor; and (iii) a more open, alluviated, headward section. The abrupt turn made by both the south flowing headwater streams before joining to flow west through the Mill-brook gorge, combined with the presence of a marked col containing the present source of the Olway (upon which the eastern headwater of the Clawdd is aligned) all suggest that the Clawdd has enlarged its catchment area at the expense of the Olway. The valley of the latter stream is narrow above Raglan, but below there it has attained a considerable width, and as mentioned in the preceding section, has a heavily alluviated floor. Its tributary, the Nant Wilcae, is a longer stream, gathering several others draining the eastern slopes of the Bettws Newydd Hills, and a further tributary from the north which rises in an area of indeterminate drainage to the east of Bryngwyn.

It is probable that the easterly trend of the Wilcae shows structural guidance. In the Silurian outcrop to the west, where the drift cover is thin, Walmsley (1959) has shown that the existing valley pattern is very closely governed by fault lines, and there seems little reason for supposing that these faults do not affect the adjacent Raglan Marl terrain. The fact that they have not been identified there by the Geological Survey (Sheet 233) may be attributed to the severe problems attendant on mapping of this 'soft' formation. It is noticeable that where (in the Llanvihangel-Ystern-Llewern area, for example) outliers of overlying more resistant formations have been preserved within down-faulted areas, extensive faulting has been identified within the marl outcrop. Two (converging) faults affecting the Silurian strata are aligned with the Wilcae Valley, and it is therefore likely that its easterly course is structurally controlled.

Although the easterly course of the Wilcae can be explained in this way, that of the Troddi and Wechan cannot, whilst the Clawdd flows in a direction not paralleled by any other stream in the area. One of the major problems of this area is therefore to account for the anomalies of the present drainage pattern.

3. ICE MOVEMENT.

The importance of the Clawdd valley as a line of ice movement was recognised initially by the Geological Survey (Robertson, 1927) when the Coalfield One-inch sheets were being mapped, and recent mapping of the Monmouth sheet has indicated that the eastern margin of the drift deposited by this ice tongue extended eastwards as far as the Olway valley. Northwards the area west of a line drawn from the Olway into the upper part of the Troddi valley beyond Whitecastle is drift covered. Contrasts in the morphology of the drift in the upper Troddi suggest, however, that it was the product of a separate (probably older) ice advance, the ice having entered the area via the Bryn-y-gwenin saddle (between the Ysgyryd fach and Ysgyryd fawr). The drift deposits of the Troddi valley have not, however, been investigated in detail.

Within the Bryngwyn area, only one line of ice movement is likely to have been significant: eastwards along the Clawdd valley from the Usk at Clytha, and over the watershed into the drainage basin of the Olway (both to the east and in the south, where drift indicates that it entered the valley of the Nant Wilcae). Northwards, ice appears to have entered the Troddi valley between Llwyn deri Bridge (384 132) and the commencement of the restricted section of that valley at Tal y Coed. This is evidenced by (1) extensive fresh drift deposits found on the floor of the Wernyrheolydd Saddle (crossing the watershed between the Troddi and Clawdd, to the south-east of Llwyn deri Bridge); and (2) the lake flats mapped by the Geological Survey above Llwynderi Bridge in the Troddi, and in a tributary of the Troddi at Llantilio Crossenny (Eastwood, 1937, 31). These suggest that the Troddi drainage during the deposition of these flats was predominantly ice-free, the blockage of the valley being accompoished by a lobe of ice spilling over from the Clawdd valley.

The drift deposits of the Bryngwyn area are therefore regarded as being derived from an ice advance eastwards via the Clawdd valley at a time when neighbouring areas were ice free. The possible erosional consequences of movement along this line, and the probable form of the pre-glacial topography of the area will be considered in detail later.

4. DRIFT MORPHOLOGY.

The drift morphology of the Bryngwyn area is shown in fig. 28. It may be considered in terms of three zones:

(1) an outer zone where outwash or erosional features related to the activity of meltwater

streams are prominent;

(ii) a median zone normally characterised by the strong development of morainic topography showing marked linear trends;

(iii) an inner zone where extensive sedimentation has occurred in association with the establishment of the present drainage pattern, and which lacks constructional forms normally associated with the ice margin.

(i) The Outer Zone. A most noticeable feature is the great extent of the fluvio-glacial sands and gravels to be found in the headwater section of the Clawdd valley,+ and which extends eastwards into the basin drained by the headwaters of the Wechan before their escape northwards via the Great Beiliau Gorge (424 122).

This deposit is unusual in two respects:

(1) it is concentrated in a limited area, now forming the water parting between the Olway, Clawdd and Wechan; and

(2) its western part is dissected by a wide channel system which extends from the head of the Olway into the Clawdd.

+ Plate 19 shows a section of this deposit in the Tregare Pit, whilst Plate 20 indicates the source (Coalfield) of some of the material.

The extreme localization of this deposit has been highlighted by the terminology used by the Survey in its mapping of this area, which differs from that used on the Abergavenny sheet which covers the greater part of the Vale of Gwent drift lobe.[1] Although its distinctiveness is thus perhaps less real than the map might suggest, the localization of this deposit of clean sands and gravels requires explanation. It is clearly a glacio-fluvial deposit, and might be explained:

(a) as the result of a concentration of meltwater discharge from the ice in this area;

or (b) by the inability of meltwater to remove glacio-fluvial material readily from the immediate ice margin area. It seems likely that both factors were operative. Although there is ample evidence of abundant meltwater release into the Wilcae and the Troddi valleys, there is also good

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[1]See page 81 . The deposit mapped as 'Morainic Drift' "consists of rubbly, earthy gravel with more clayey patches and might equally well be described as gravelly Boulder Clay" (Welch and Trotter, 1961, 126). Had this area been mapped at the same time as the Abergavenny sheet, this would have probably all been mapped as 'Glacial Sand and Gravel.'

evidence[1] for supposing that the Millbrook gorge on the Clawdd acted as an important sub-glacial meltwater route, delivering meltwater to a point where getaway into the Olway was not easy due to drift blockage of the earlier valley system.

It is therefore necessary to consider the extent of alteration that occurred to the pre-existing drainage system as a result of the glacial invasion. As has been noted earlier, the headwaters of both the Wechan and Clawdd make abrupt turns to join the main streams, and show a trend (towards the south or south-east) which conforms to the dominant drainage trend of the North Monmouthshire Uplands. It has not been possible to determine drift thicknesses but it seems likely that the Olway was formerly a more extensive stream, and its former valley system lies partly buried by drift in those areas where the former ice margin is drained by the Wechan and Clawdd.

It was suggested by the Geological Survey Officers that the Wechan's original course "was southwards by way

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[1]See later.

of the now almost dry valley extending from near Tregare to Raglan, and that this was blocked by ice turning the water eastwards through the overflow channel near Penrhos[1]." (Welch and Trotter, 1961, 127). There seems to be no reason for challenging this view, although it might be noted that no evidence exists for the damming-up of a body of water in the area, other than the presence of the "overflow" at Great Beiliau. It is possible that the Great Beiliau gorge was initiated at a period of maximum ice advance in the locality, when meltwater was escaping directly from the ice over the ridge into the lower Nant Wechan valley. The form of the gravel deposit - hummocky to the north of Tregare (with ridges showing marked east-west alignments), and sloping north-eastwards towards the Wechan gorge - suggests that the gorge was already functioning as a meltwater route when the gravels were deposited.

There is little doubt that the former drainage of the upper Clawdd was south-eastwards into the Olway, the Millbrook gorge being a youthful feature of the landscape.

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1 i.e. The Great Beiliau Gorge.

It is the gravels of this area which are dissected by the channel system noted earlier. The establishment of the Clawdd as the major river in this area, and the formation of the water-cut channels dissecting the sands and gravels, and drained by its headwaters may thus be considered together.

The relationship of the channel system to the deposit suggests that cutting of the former postdates formation of the latter. This might explain the less marked hummocky surface form compared with the deposit near Tregare. The following sequence of events is suggested:

(1) Deposition of glacio-fluvial deposits in irregular hollows left in the former upper Olway valley due to irregular drift deposition by a meltwater stream running through the ice along the line of the present Millbrook Gorge. The ice front at this stage may have retreated from the Tregare area to lie along the western side of the ridge presently bisected by the Millbrook Gorge. The fact that drainage along this is today to the west, whereas one would expect drainage so initiated to be directed away from the former ice front, suggests that the melt-

water stream was emerging under hydrostatic pressure from ice filling the deeply eroded area of the middle Clawdd, thus enabling it to cut a channel showing an 'uphill' gradient.

(ii) Rediscovery by meltwater of the former drainage line of the upper Olway, led to rapid downcutting into its drift fill, and incision of drainage into the gravel deposit between the ice front and the present col at the head of the Olway.

(iii) Lowering of water levels within the ice, probably as a result of the opening of the present line of the Usk (below Clytha) as a major englacial or sub-glacial drainage channel, led to the reversal of drainage within the ice margin of this area, which, following ice melt, led to the establishment of the Clawdd as the major stream draining this section of the former ice front.

To summarise, it is suggested that the gravel deposits about Tregare are oldest, being formed when the ice covered the former upper Olway, meltwater at this stage escaping north via the Great Beiliau gorge into the Wechan. Retreat of the ice front allowed glacio-fluvial deposition on the irregular drift surface filling the upper Olway, the main source of this material being meltwater flowing under hydrostatic pressure along the line of the Millbrook gorge. The re-establishment of the Olway drainage by streams re-excavating the former valley was only partially completed when a reversal of the drainage within the ice margin took place, probably as a result of the opening of the Usk below Clytha as a major meltwater route.

The other features of significance in this Outer Zone are similarly associated with the activity of meltwater. They include:

(a) the extensively aggraded floors of the Olway and its tributaries. The Troddi shows similar signs of aggradation, but, by contrast, the Wechan has a relatively insignificant aggradational fill, and that only below its gorge, which is further evidence for the recent addition of its present headwater streams to the Wye drainage system.

Aggradation in the headwaters of the Olway system is clearly a reflection of the proximity of the ice front, deposition of glacio-fluvial material being at a maximum there. The increasing width of the fill downstream, particularly noticeable in the Olway below Raglan, suggests however, that the rock floor of the valley is becoming progressively deeper down valley. This probably reflects grading to a low glacial sea level, aggradation in the Olway being subsidiary to that taking place in the Usk in response to the post-glacial sea level rise.

(b) Meltwater channels. In most cases they tend to converge upon elements of the present drainage system, but are of a form and size which points to excavation by meltwater. No measurements were made, but they have been grouped in two broad size classes in fig. 28.

The channels of the Raglan area, are the only ones which merit comment. The village itself encircled by a wide, flat-floored channel (the floor of which is shown to scale in fig. 28, being indicated by a stipple of fine dots) which connects with the Wilcae tributary valley in the west, and the upper Olway in the east. Smaller, steeply graded channels enter this from the north-west. The plan of this could be taken to suggest initiation sub-glacially, but it is also possible to conceive formation by meltwater issuing from an ice tongue in the valley of the Wilcae tributary. Drainage of meltwater over the watershed to the south of the Wilcae possibly from this same ice tongue is also indicated by a deep but narrow channel crossing it at Broom House (403 068).

(ii) <u>The Median Zone.</u> This is characterised by extensive, but localized hummocky moraine deposits. As elsewhere within the drift-covered area of the Vale, the deposits are predominantly of gravels, but they contrast with those of the Tregare area, previously discussed, in being much dirtier. Included areas of kettle further stress the importance of localized wasting ice masses, and indicate that the deposits are likely to have accumulated upon and within ice at its wasting margin.

The distribution of ridge and kettle shown in fig. 28 is further evidence for this, as drift with this characteristic topographical expression is best developed in relatively low-lying areas, namely the Wernyrheolydd saddle, and the valley of the Wilcae tributary to the south of Bryngwyn. When ice was deep in the Clawdd basin, but wastage was taking place, the margin is likely to have persisted longest in these low-lying areas of its watershed, whilst drainage within the ice would also tend to be concentrated upon these, thus providing an abundant supply of glacio-fluvial material.[1]

The exact mode of origin of this type of drift deposit remains uncertain, but the abrupt and markedly linear form of a considerable number of the elevated members suggests that deposition of glacio-fluvial material along stream courses within or perhaps upon the ice was important. The absence of any extensive deposits of clean gravels in these areas is probably accounted for by the incorporation of a proportion of ill-sorted morainic material.

In the south, although the main development of this ridge and hollow topography is restricted to the gap drained by the Wilcae tributary, a series of broader ridges are to be traced on the interfluve between the Wilcae and Clawdd valleys, whilst at the head of the Wilcae itself, a number of fairly abrupt ridges similar

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[1]The Millbrook gorge, to judge from present-day height relationships, would appear to have formed an even lower easterly outlet for meltwater, but deposition in this case was not within the ice margin which must, banked against the broad, north-south trending ridge, have remained thick.

to those south of Bryngwyn, are found. These (at 375 079) have marked down-valley alignments, and are at approximately 400 feet O.D., or over 200 feet higher than those developed south of Bryngwyn. If they are both considered to be predominantly meltwater laid (and this would appear to be certainly the case with those at the head of the Wilcae, so situated that it is difficult to conceive of them developing as an ice-margin morainic feature), the higher ones must ante-date those at the lower level. Formation of the higher ones when ice was extensive in the lower Wilcae seems likely, the alignment of the ridges showing that the line of the valley was influencing the flow of meltwater within the ice mass. The lower group of features are likely to relate to the period when ice wastage had reduced the extent of the ice so that it was confined mainly to the Clawdd valley, with lobes extending into the Wilcae drainage south of Bryngwyn, and into the Troddi valley via the Wernyrheolydd saddle (perhaps damming temporary lakes at Llwyn deri and Llantilio Crossenny. The relationship of the drift in the Wernyrheolydd saddle to the lake flats above Llwyn deri Bridge (as mapped by the Survey) can be seen in fig. 28).

The other, generally single, ridges found on the elevated areas between the major concentrations so far discussed, are problematical. In the main they tend to be aligned parallel to the supposed line of the former ice front, but there are noteworthy exceptions. As a class they are generally broader and less distinct, and kettle is less frequently associated. It is thought that they are essentially ice-marginal accumulations of morainic material, but exposures are lacking to confirm this.

Two further points concerning this median zone might be considered. Firstly, the discontinuous form of the belt which we consider to be essentially ice-marginal might be noted. There is no drift topography of significance on the ridge separating the Troddi from the Clawdd west of the Wernyrheolydd saddle. Indeed, the north side of the Usk valley between Clytha and the Ysgyryd Fach is also generally devoid of constructional drift topography (see fig. 21). This could be taken to indicate that no significant ice margin ever lay along this line: that ice in the Usk was continuous with ice invading the upper Troddi basin. This is probable at an early stage, but not during the final major ice advance in the lower Usk. The Troddi drift generally shows no marked drift topography, which has earlier been stated to be an indication of its greater age. The north flank of the Usk valley cannot, however, be considered to have been ice-free during the advance which left the prominent drift features to be found high on the flanks of the Bettws Newydd Hills and in the Goetre area. The reason for this remains unclear, although lithological contrasts between the opposing valley sides, and aspect (encouraging solifluxion activity, thus smoothing out former drift features) might perhaps be significant.

Finally we might note the limited width of this belt, drift topography of this character being almost completely lacking in the central and lower parts of the Clawdd valley. This feature will be more conveniently discussed in the next section.

(iii) The Inner Zone. This comprises the middle and lower Clawdd vale, and shows a number of unusual features:

(a) the peculiar relationship between the 'valley' and the river. The latter wanders indeterminately across the northern part of the small vale of the lower Clawdd, and suggests that it has played little part in the formation of this part of its valley.

(b) Abrupt, small-scale drift forms, extensive in other parts of the Usk are here largely absent, and instead we have a valley floor comprised either of flat-lying fluvially-laid sediments, or broad, elongate ridges of drift.

The abundant evidence of glacio-fluvial deposition and erosion in the median and outer zones suggest a strong thrust of ice from the Usk along the Clawdd Vale, and features of the latter area appear to reflect to a large degree the erosional effects of the ice. Infill by alluvial deposits, especially about Clytha, and in the Llanarth area suggest that erosion of the valley floor along this east-west zone had reduced it to a level below that of the present Usk floor downstream of Clytha, so that when drainage along that line was re-established following ice withdrawal, extensive aggradation occurred. It is probable that the broad drift ridges with along-valley alignments are the higher elements of essentially basal morainic material showing the effects of moulding by the easterly moving ice stream.

The contrast between the wide and deeply ice-eroded vale leading eastwards from Clytha, and the present valley of the Usk to the south of that place suggests that the Clawdd vale, continuing the trend of the Usk below Llanover, was most significant as a line of ice movement.

It is interesting to speculate whether the Clawdd vale, although apparently predominantly ice moulded at present, was initiated originally by fluvial erosion, ice movement in that directing being influenced by a pre-existing valley. The evidence available suggests that this is unlikely to have been the case:

(a) the Clawdd shows a trend which is not paralleled by any other stream in the area;

(b) neither has it any tributaries, with well-developed independent valley forms, which are aligned in such a fashion as to suggest that they were formerly confluent with a west-flowing tributary of the Usk.

Indeed the evidence suggests the contrary: that the area was formerly drained by streams trending in a south-easterly direction towards the Olway, the valley form of which (below Raglan) suggests that it formerly drained a much larger area than it does today. The Clawdd has no significant left bank tributaries, whilst the major right bank tributary (west of Llanarth; fig. 28) is aligned upon the Croes-bychan col and the Wilcae tributary valley.

It is therefore suggested that prior to glaciation, the area drained by the upper and middle Clawdd formed part of the Olway drainage, the area about Llanarth being drained by the Wilcae tributary, whilst the present Clawdd headwater region, west of Tregare, drained into the present upper Olway. Farther north the Troddi course through the ridge to the east of Tal-y-coed also suggests later initiation, disrupting a former southward-trending drainage pattern in that area. A tentative reconstruction of this earlier drainage pattern is shown in fig. 27 (C). It is not unlikely that a stream was beginning to exploit the weakly resistant marls outcropping along the line of the Clawdd vale (and contrasting with the more resistant Silurian strata flooring the Usk valley south of Clytha) encouraging initial ice penetration of the zone lying north of the Silurian inlier.

Although the features of the Lower Clawdd may be ascribed mainly to the erosional activity of the ice, and a subsequent aggradational phase, they merit more detailed consideration.

The westernmost of the three broad ridges, in Clytha Park, appears to have been slightly eroded by the Usk as it swings around the Clytha bend. The relationship of the ridge to the river, and the deposits displayed at river level are discussed in Appendix II. Although doubt exists as to whether the ridge extremity is exposed in the river bank, and is therefore overlying the organic layer, this seems to be the most satisfactory interpretation of the profile, the ridge being composed at this point of bouldery material showing loose layering in a clayey matrix. There are no other exposures of the material making up the ridges, but the Survey maps those parts falling within the area of the Monmouth sheet as 'morainic drift', and the surface morphology suggests that ice moulding, most probably of basal deposits, has been operative. The thickness of drift is similarly undetermined, but in view of the rise of the land surface eastward, and exposures of the marl at Greatoak (387 099), it is considered likely that these ridges are founded on upstanding areas of the sub-drift surface.

Basins within this surface also show a tendency towards an east-west elongation, and these, plotted alongside the relief features of the area between Penpergwm and Bryngwyn which show evidence of ice moulding, suggest most forcibly a dominantly eastward movement of the ice in this area during the last advance movement down the Usk below Clytha being considered relatively insignificant. It should be noted that this streamlining of the relief east-west does not accord with the local strike, which is here predominantly NE-SW.

The infill of the downworn areas appears to have been governed by the height of the Usk outlet south of Clytha, recent downcutting of this being revealed by minor terrace formation about Llanvair Kilgeddin. ~~(see page [illegible])~~. One aggradational flat, marked by an 'X' on fig. 28, does present a problem. This is of fairly stone-free clayey loam, and rises 10-15 feet above the level of the aggradational belt followed by the main stream of the Clawdd. The flat meets rising ground to the south in a marked concave break of slope, whilst the minor tributary of the Clawdd in the north is incised below the level of its surface. It merges eastwards with an alluvial tract at the head of this tributary. The origin of this is not clear, but formation of a minor lake flat before the disappearance of all ice masses from the area is suggested.

A major problem of this zone is the virtual absence of constructional features of glacio-fluvial origin, which might be expected low on the valley floor. Elsewhere in the Usk valley in comparable locations, kames and kame terraces are normally present, their absence from the valley floor in certain areas being accounted for by later river erosion. Here there is no major river, and yet only two glacio-fluvial features exist: the esker at Twyn y Cregen, a short distance above the confluence of the Clawdd with the Usk (fig. 28. This esker was the site of the finds of cracked pebbles discussed in Appendix I), and two north-east trending ridges to the east of Greatoak. The westerly of these has been mapped by the Geological Survey (Monmouth sheet) as composed of sand and gravels, and is probably an esker, although it shows very subdued form compared with that at Twyn y Cregen. The parallel ridge to the east is considered to be of similar origin, although no exposures were seen. If eskers (in view of the element of doubt, they have been marked on fig. 28 as 'morainic ridges'), their alignment suggests that the Bryngwyn ridge was influencing meltwater movement within the ice, and drainage south-eastwards towards the Cwrt-bychan col is indicated. The adjacent meltwater channel (at Great Oak 384 100) indicates a similar trend.

Meltwater channels show a similarly limited development in the area, except for a few dipping steeply down-slope, especially in the south-east (fig. 28).

The presence of ice-smoothed topography indicative of an advance phase, and the slight development of glacio-fluvial features west of Bryngwyn requires explanation, as it is peculiar to this area. The most satisfactory explanation is that ice here became stagnant, but that due to the opening of the present Usk valley route below Clytha for meltwater, meltwater other than that deriving from the shrinking local ice masses, did not enter the area. Thus the supply of glacio-fluvial material from higher up-valley would be cut off, leading to the limited development of glacio-fluvial features (as at Twyn y Cregen) and the relatively rapid melt of the ice. Hence, the marked kame-terrace about Penpergwm dies away (and loses height) towards Clytha, probably as a result of drainage through the glacier at a low level as the south-draining sector of the Usk between Clytha and Chain Bridge is approached.

5. CONCLUSION.

Advance of a lobe of the Usk Glacier eastwards from Clytha over less resistant rocks flanking the northern margin of the Silurian inlier has greatly modified the pre-Glacial topography. The progressive lessening of the erosive capacity of the glacier towards its snout, combined with unusual conditions of meltwater drainage, probably gave rise to the present westerly flowing drainage along this route. At its maximum the ice lobe appears to have entered the upper Olway valley, deflecting part of its former drainage east to form the Wechan, a Troddi tributary, whilst ice entered the main valley of the Troddi via the Wernyrheolydd Saddle, giving rise to temporary lakes. The present form of the Clawdd valley reflects a complex origin, the open headward portion formerly draining south into the Olway, the middle

section - the Millbrook Gorge - being developed by meltwater draining east initially, and under hydrostatic pressure, whilst the lowest section of the valley underwent significant aggradation following deglaciation.
The thrust of ice eastwards along the line of the Clawdd Vale was clearly more significant during the final glacial advance than ice movement down the present Usk valley below Clytha.

(f) LOW LEVEL DRIFT BEYOND THE NEWER DRIFT MARGIN.

Whilst mapping in the Usk valley below the area covered by the Newer Drift lobe, a thin drift cover was noticed, mainly on the lower slopes of the valley side, but high enough for it not to be outwash derived from farther upstream. The extent of this drift was mapped using chance observations and by systematic examination of all recently ploughed fields. The area covered in this way included the lower Usk and the country between the Newer Drift margin and the Brownstones escarpment to the east of the river. Locations where exposures were available, and the presence or absence of any drift cover was determined, are shown on fig. 29, by use of a circular symbol, filled in with solid black where drift was discovered.

The drift formed a very thin cover, and was devoid of any constructional forms. Ploughed fields were found to be most useful in determining the extent of the drift, although excavations occasionally allowed the examination of profiles. The following features were looked for:

(1) erratic material;

(2) stones showing evidence of rounding or smoothing in areas where they were unlikely to have been water-deposited.

Although the drift is mainly derived from the Old Red Sandstone outcrop in the upper Usk, in the Vale of Gwent a considerable amount of Carboniferous material has been introduced from Coalfield sources. This drift could usually be identified readily in the Vale by its erratic content, and only on the southern slopes of the North Monmouthshire Uplands did the drift in places appear to be wholly derived from Old Red Sandstone sources. In these areas, the well rounded form of a significant proportion of the stones in situations well removed from present day watercourses was regarded as sufficient proof of a former drift cover. In such cases, very careful inspection is required, as it required (as noted by A.H. Cox in Charlesworth, 1929) most careful observation to distinguish drift from solid rock.

In mapping this drift the ploughed field is considered to be more useful than a single profile of limited lateral extent, as experience has shown the drift to be so thin in places that its presence could only be postulated from observations taken over a relatively wide surface area. Care had to be taken in making observations of this sort. Gateways should be avoided, as in one instance a spread of extremely well-rolled stones of varied sources identified near the gate of a field in Raglan Marl country on the Usk-Wye watershed had been carried there from the Tregare gravel pit, three miles away, only a few years before. On the other hand, farmers often carry the larger stones turned up by the plough to the gateways, which tend to become muddy during the winter, and in such instances could indicate whether examination of the field for drift would be worth while. Gateway exposures are frequent, but were never used when a crop cover prevented examination of the field surface.

The distribution of these drift finds indicated in fig. 29 suggests :

1. a former extension of ice down the Usk valley as far as the Llangybi area;

2. an easterly movement into the lower part of the Olway valley by ice coming down the Usk;
3. that in the Raglan area ice at this stage did not extend as far as the margin of the Newer Drift deposits mapped by the Survey.

The thinness of this drift cover, and its lack of morphological expression suggests that it is older than the drift deposits farther up-valley, although its position within the valleys suggests that the age difference cannot be great. The thinness of the drift suggested that it might have been soliflucted from higher levels, but the relationship of finds of this drift to the local relief indicate that this was not so.

The absence of any of this drift (except for one find 800 yards east of the Tregare glacio- fluvial sand and gravel deposit (431109), which could well be outwash) in the upper part of the Olway valley is especially interesting, as it suggests, that at the time of this early ice advance, ice did not cross the watershed between the Clawdd and the Olway valleys. As this watershed is particularly ill-defined at present, it is likely that substantial lowering took place during the major

Newer Drift ice advance, otherwise a major early ice advance down valley, unaccompanied by a similar advance to the east would be inexplicable.

In view of the sporadic nature of the observations it would seem idle to speculate about the exact extent of the drift cover, although a line has been drawn in fig. 29 which tentatively suggests the extent of this early ice advance. The relations of this drift with the terraces developed south of Llangybi, however, merit examination.+ Discounting drift finds in the Bettws Newydd Hills, the highest found was on the western side of the Usk valley at Llangybi, where thin drift with sub-angular cobbles was seen at an altitude of about 250 feet near Park Farm in a trench (367969). Elsewhere the drift was mainly below 200 feet O.D. It appeared to extend down to the alluvial fill of the valley floor, and at Llangeview (388010) was identified in a field at less than 75 feet.

Erosional forms, both of the ice and associated meltwater streams, could be expected to be more long lasting than its constructional features. The drift was, as noted, devoid of the latter, and unfortunately

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+ See Chapter 11.

the erosional evidence is inconclusive:

1. a number of dry stream channels exist east of the Usk between Llangwm and Llantrisant, and west of the Usk near Llangybi (crossing cols into the Sor drainage). None are convincing as meltwater channels and if such erosion has contributed to their form it was clearly of some antiquity. The best example is, however, incised between terrace fragment 26 and the gravel capped hill (marked by an 'X' on fig. 35), south of Llangybi (Tredunnock terrace), which suggests that the glacial advance post-dated the formation of that terrace. Such an advance cannot have extended much farther down valley than Llangybi as the terrace gravels below there are undisturbed.

2. between the Olway valley and Llantrisant on the east side of the Usk there is a belt of low hills developed in the Raglan Marl group, and rising mainly to just over 200 feet, the forms of which suggest moulding by ice moving down the valley. The streamlined form of the hills is transverse to the streams which drain them, which flow in a dominantly westerly

direction. This streamlining, however, accords with the structural trend of the area, and the suggestion of moulding by ice is incapable of proof.

CONCLUSION.

The low level drift thus appears to be 'Newer Drift' in the sense that it post-dates the excavation of the valley system, although its thinness and lack of morphological expression suggest that it is older than thicker 'Newer Drift' deposits farther up-valley. Its position so low in the valley suggests that the interval separating the two might be an interstadial rather than a full interglacial. The slender evidence on which it is considered to post-date the Tredunnock terrace has been stated. It cannot be definitely associated with any of the later terrace stages. The Tredunnock terrace is equated with the Bushley Green terrace of the Severn, which has been assigned a late Gipping age (Tomlinson, 1963), which suggests that the Llangybi drift might be the product of an early Last Glacial (Wurm) ice advance.

CHAPTER 19.

THE EVIDENCE FOR AN OLDER DRIFT GLACIATION.

In the east of England, a two-fold division of the drift into an 'Older' and 'Newer' Drift was proposed at an early stage, based on criteria of attitude and morphological expression. (Wright, 1936; Clayton, 1957). In South Wales the best evidence for the composite nature of the glaciation is found in the shore sections of Cardigan Bay where Jehu (1904) and Williams (1927) reported two boulder clays separated by the sands and gravels of a retreat phase. The tills both contain shelly material derived from the Irish Sea Basin, but the length of time represented by the glacio-fluvial deposits is uncertain. Ice from the Irish Sea Basin is known to have penetrated into the Bristol Channel during the 'Older Drift' Glaciation, but not during the 'Newer Drift' Glaciation, the deposits of which, from purely local ice sources form fresh morainic accumulations at the mouths of the main valleys. During the 'Older Drift' Glaciation, the local ice advance is generally considered to have been more extensive, but deposits laid by local ice during this period are to be found in any extent only in west Wales and Gower (George 1933). In that area, the 'Newer Drift' ice advance (Charlesworth, 1929: map) did not extent to the coastal tract crossed by the Irish Sea Ice, so that 'Older Drift' deposits of purely local origin are displayed. Between the Tawe and Taff, however, Griffiths (1940, 26-27) thinks that the 'Newer Drift' local ice development was comparable in intensity with that of the 'Older Drift', so that underlying 'Older Drift' deposits are completely masked. In this area, therefore, the erratic material of the Irish Sea ice sheet provides the best evidence of an 'Older Drift' glaciation of the region, although it has not been proved to have extended further east than Cardiff. Irish Sea drift was first identified in the Vale of Glamorgan at Pencoed, near Bridgend by the Geological Survey (Strahan & Cantrill, 1904, 100), whilst Griffiths (1940, 96) reported erratic material of probable Pembrokeshire origin at Maendy Pool in the western suburbs of Cardiff. Pringle and George (1948, 92) also report finds of felsite pebbles from North Wales in the Cardiff area.

Evidence of an 'Older Drift' Glaciation east of Cardiff is to be sought therefore in drift deposits of local origin.

1. EVIDENCE OF AN EXTENSIVE LOCAL 'OLDER DRIFT' GLACIATION.

The case for an 'Older Drift' extensive local glaciation in the eastern part of South Wales has perhaps been stated most confidently by Charlesworth (1929, 85):

> "During the period of maximum glaciation the ice in the South Wales Coalfield overwhelmed not only the minor ridges, but with one or two exceptions, the most prominent escarpments of the Millstone Grit and Carboniferous Limestone. The southern limit of the Welsh ice is difficult to determine, as the drifts in this direction become thin and discontinuous, and are replaced by isolated erratic boulders. There is clear evidence, however, that it reached the latitude of Bridgend, and in the neighbourhood of Cardiff and Newport, lay beyond the present coast."

By contrast, the Geological Survey Memoirs for these parts of eastern South Wales not directly affected by the Irish Sea ice (Newport: Strachan, 1899; Monmouth & Chepstow: Welch and Trotter, 1961) make no direct reference to an 'Older Drift' Glaciation of the area.

The Monmouth and Chepstow Memoir ascribes the only glacial deposits in that area "to the final phase of the Glacial period" (Welch & Trotter, 1961, 126). The Welsh Borderland Geological Guide (Pocock and Whitehead, 1948) treats the glacial deposits of the area as though they were the product of a single ice advance commenting (p. 75) that "only doubtful traces of an older drift have been found in the district."

Wills, however, from his investigations of the glaciology of the Midlands suggests three advances of Welsh ice (mainly from the northern Borderland) into that area (Wills, 1948), and correlates the Older Drift of South Wales with his third glacial episode. Mitchell (1960, fig. 2) also shows ice of the "Lowestoft Cold period" reaching the Cotswold scarp, and the south shore or the Channel.

The only direct evidence so far cited of a glacial advance in the south-east Borderland beyond the 'Newer Drift" margin has been produced by Clarke for the Wye valley. He postulated an Older Drift Glaciation extending down that valley "probably to a point below Ross-on-Wye (Clarke, 1934, 10). The evidence for this includes possible overflow channels and hill-top drift cappings. Finds of isolated erratic pebbles in that area he considered to be "not wholly reliable", due to the effect of 'wash' from the terminal moraine of the 'Newer Drift' ice. The only reference to finds of erratic material south of the 'Newer Drift' margin in the Vale of Gwent is to be found in a paper by F.J. North (1940), who states that the thirty-three boulders built into the edge of a Bronze Age Barrow at Crick, between Chepstow and Newport, proved to be "glacially transported erratics derived either from the Old Red Sandstone or the Carboniferous Series". He goes on to say that no boulder clay is found locally, and that "it is more than likely that floating ice (at a time when the general level of the land was lower than it is now) was the medium responsible for the last stage of their transport". This suggestion clearly follows that which George (1932) proposed to explain the presence of erratic material in the Gower "pre-glacial" raised beach.

What other evidence have we for an 'Older Drift' glaciation of the south-east Borderland? Despite the boldness of Charlesworth's statement, he does not give the location of any "isolated erratic boulders" to support his claim that in the Cardiff and Newport area the 'Older

Drift' ice lay beyond the present coast. Study of the glacial deposits mapped by the Survey does, however, suggest two phases of glacial advance in the area, one considerably older than the other. The critical sheet is the Newport One-inch sheet (No. 249), published in 1891. The glacial pebble gravel and sand shown on that sheet can be divided into two categories in terms of attitude:

(1) the pebble gravel and sands of the Ebbw and Rhymney valleys, and further west. These spread over the interfluves and valley sides, and clearly post-date the excavation of the valleys.

(2) similarly named deposits of the lower Afon Lwyd valley which are restricted to hill crests flanking it. They are clearly relict, and as stated by the Memoir (Strahan, 1899, 78) "their mode of occurrence shows that much of the valley has been excavated since their deposition." The Caerleon deposit at the mouth of that valley is now considered, for reasons to be given in Chapter 11 to be riverine and not glacial in origin. I would include the extreme eastern edge of the glacial deposit on the Ebbw/Henllys Brook watershed north of High Cross (277897) in this category, as its form and relation to the

Henllys Brook vale are comparable to the relation of the Afon Llwyd deposits to the Afon Llwyd valley, and contrast with the hummocky newer drift forms along the western side of the ridge (e.g. at 264895). The location of these hill top gravel deposits is shown in fig. 29.

In an attempt to produce more conclusive evidence of an earlier, more extensive glaciation of the lower Usk, the area beyond the 'Newer Drift' margin was examined in detail. Although this revealed the presence of a thin drift deposit within the Usk and lower Olway valley to the south and east of Usk, respectively (discussed in Chapter 8, section F), it failed to produce substantial evidence of an 'Older Drift' ice extension in this area comparable to that which had been reported in parts of west Wales (George, 1933).

Search was concentrated upon interfluve areas, where ancient drift deposits are most likely to have survived. Ploughed fields and excavations were looked for especially, whilst the possibility that large erratic blocks might have been built into hedgerows during initial field clearance was borne in mind.

Discounting the low level drift about Usk, only one find of erratic material was made, and the situation of that find cast doubt as to its origin. A small collection of erratic material, mainly of Coalfield origin was made on a stripped surface adjacent to the crossing of the interfluve south of the Usk by the Newport Bypass (M4) to the west of Christchurch (343 890) shown on fig. 29. The material showed little sign of rounding, but could conceivably have been of glacial origin. Considerable doubt exists, however, as to whether the deposit is _in situ_, or even only slightly disturbed because of the proximity of the motorway. Houses had been demolished nearby, and pieces of slate were picked up in the vicinity. It seems worthy of record, but in itself cannot be accepted as reliable evidence of a former drift cover. It is difficult, nevertheless, to understand how such material could have been brought to the area, supposing that it is not _in situ_. The motorway crosses, a few miles west (fig. 38) the lower Ebbw valley, but the movement of heavy vehicles along the route of the motorway was for long hindered, pending completion of the Usk bridge, whilst at the time of the find, the Bryngles tunnel, on the west of the Usk, remained uncompleted.

The pitfalls which open to the geomorphologist when major engineering works are being carried out in an area were however, well illustrated at a nearby site during this section of the enquiry. A surface spread of gravel, including much interesting erratic material found on the summit planation at Christchurch School (345 892) was later found to have been carried into the area, thus dashing hopes of having located a highly significant deposit.*

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* The circumstances surrounding this find indicate the care which must be taken in examining similar deposits of limited extent. The gravel was noted to form a thin capping to a minor (three feet high) road cutting, recently formed during road widening. The cutting had exposed bedrock, the gravel forming a thin surface deposit which had washed down the face of the solid rock exposure in places. Examination of pebbles recovered from the surface above the cutting (kindly carried out by Mr. T.R. Owen and Dr. G. Kelling) revealed a most interesting derivation ranging from the Forest of Dean through the Woolhope and Mayhill areas to the Malvern Hills. Many were shattered (? periglacially), although all were rounded and clearly of riverine origin. In view of the height of the deposit (about 100 feet above the level of the Woolridge Terrace deposits of the Chepstow area) it seemed possible that a very early terrace of the Severn had been discovered. A further visit to the site, and enquiries made with the farmer of the land adjacent to the road revealed, however, that a pit in the field had been filled by the County Council, prior to road improvements, using material derived from Motorway excavations in the Magor area. The combination of circumstance seemed at the time almost incredible, viz: (1) that the pit should be located on the summit planation; (2) that this should be filled by material brought from a locality over five miles distant, and further that this material should be a terrace gravel of the Severn; and (3) that the origin should be so neatly concealed, the surface having been levelled, the spread material having later been exposed by the construction of the road cutting.

There appears therefore to be scant evidence for a more extensive local glaciation of South-east Wales. The main evidence of this is to be found in the hill top gravels of the Afon Llwyd valley, which in themselves do not necessarily indicate an ice advance into the lower part of that valley, as they could be of outwash origin.

The erratic material identified by North (1940) in the Bronze Age barrow at Crick is clearly exceptional. This could represent: (1) material imported into the locality by man, perhaps from a very wide area. The size (two to six feet in diameter) and number (32) of the boulders suggests that this is unlikely for an apparently quite ordinary barrow. (2) a local accumulation of erratic material, the presence of which determined the site of the barrow. This origin is favoured by North. It is difficult to envisage, however, how the erratics could have been dropped at this spot, as the height of the barrow (55-60 feet O.D.) is at a similar height to gravels in this area of the Survey's Terrace No. 2 (equivalent to the Kidderminster Terrace of Wills), and below the level of terraces 3 and 4 (the latter being the equivalent of Wills's Bushley Green Terrace). Tomlinson (1963, Table II) places the latter terrace in the Gipping (Riss) glacial episode, and the Kidderminster Terrace in the Ipswichian (Last) Interglacial. It is unlikely that the 'Older Drift' of South Wales is younger than the Ipswichian, and the survival of erratic material in an area which has been worked over by the Severn at that stage thus poses a major problem. North's suggestion of floating ice is also difficult to support. There is no other evidence for a high sea level so late in the Pleistocene (i.e. after the formation of most details of the present Severn coastlands), and a high sea level at a time when there were glaciers calving ice bergs in the Bristol Channel is improbable.

The low level of these supposed erratics, and their incorporation into a man-made feature makes it most likely that they have been carried there by man. In themselves they are therefore not reliable indicators of a former ice cover, although they do suggest that erratic material was far less distant than the 'Newer Drift' ice margin.

The case for an extensive local 'Older Drift' glaciation of the lower Usk remains, therefore, unproven. In view of the extent of local ice shown in the Swansea area during the 'Older Drift' glaciation, and the gravels in the Afon Llwyd valley (which indicate greater ice accumulation there at that stage than during the 'Newer Drift', when ice accumulation in that valley appears to have been minimal) it is interesting to speculate on the reasons for this.

The absence of evidence of a more extensive glaciation at this time in the lower Usk could be taken to indicate that its catchment area was different from that which had been established by the time of the 'Newer Drift' Glaciation. In Chapter 7 (section B) the case for the formation of the present Middle Usk by a diffluent ice tongue was stated. The absence of 'Older Drift' evidence from the lower Usk might indicate that this diversion occurred relatively late in the earlier glacial episode, the route prior to the 'newer Drift' Glaciation being able to carry relatively limited amounts of ice. The lack of 'Older Drift' evidence in the lower Usk, associated with the (slight) evidence of more extensive ice advances at this stage in the Afon Llwyd and Wye (Clarke, 1934), might therefore be considered as additional evidence for the case put forward for the initiation of the Middle Usk by diffluent ice during an early glacial episode.

2. EVIDENCE OF AN UP-CHANNEL EXTENSION OF THE IRISH SEA ICE.

In the Vale of Glamorgan the association in drift deposits of flints with far travelled erratics of Irish Sea origin (Howard & Small, 1900; Griffiths, 1940) suggested that flints might be useful as an indicator of the former extent of the Irish Sea ice in the Bristol Channel area, flint being very readily distinguished from most other rocks, and apparently more numerous than other distant erratics in the south Glamorgan drifts. Finds of flint have been reported at the mouth of the Wye (Ramsay, 1846, 322); in the Ely valley (Edgworth David, 1883, 44); Heath cutting, Cardiff (Dutton, 1903; Griffiths, 1939) and Flatholm (Buckland and Conybeare, 1824, quoted in Strahan and Cantrill, 1912). Strahan and Cantrill (1912) discussed the provenance of these flints and pointed out that flint is not easy to distinguish from chert which occurs in the Lias of the Vale of Glamorgan although the association with drift of a clearly western origin favours the suggestion that the flint is derived from Cretaceous outcrops on the bed of the Irish Sea (Pringle and George, 1948, 92).

It would seem, therefore, that finds of sub-angular flints in the eastern part of south Wales could be considered as evidence of the extension of the Irish Sea Ice into that area. Unfortunately that is not the case, because the terrace gravels of the Severn all contain flint pebbles (Wills, 1938) and extensive terrace gravel deposits of the Severn sequence have been found, all containing flints, between Chepstow and Newport (Welsh and Trotter, 1961). These gravels may have been carried for a considerable distance westwards, and the flints in the shingle beach on Flatholm, for example, may well have derived from the erosion of terrace gravels in the lower Severn. The dating of the Irish Sea advance is also significant, for it would almost certainly have destroyed terrace gravels in its path.

In the Newport area, seven finds of sub-angular flints were made (fig. 29), but four of these were found at levels where they were likely to have been derived from Severn terrace gravels. Only three were found above the level of the Severn terrace gravels: two on Chepstow Hill (352 903) at over 300 ft. O.D., and one at the St. Woolos Cemetery (299,875) on the 'Stelvio surface' at ca. 245 feet. Although these flints lie above the Severn terrace gravels, they could still have derived from very early gravels of the Severn. Equally they could have been derived from Irish Sea Ice. The flint as an indicator of Irish Sea ice movement in the upper Bristol Channel area would thus seem to be limited in its usefulness.

Drift exposures containing erratics of western or northern derivation remain the best criteria for tracing the extent of up-Channel penetration of the Irish Sea Ice, and such exposures have not been found east of Cardiff. Crampton (1960, 18) has, however, examined the heavy mineral assemblage of a drift profile at Cross Carn Einion (258 858), a mile west of Bassaleg, detecting a number of minerals completely foreign to the area (e.g. amphibole, staurolite and sillimanite) and concludes that "the influence of this....(Irish Sea) ice flow does not terminate in the area of Cardiff, as suggested by the distribution of erratics, but continues to the full extent of the glacial deposits" (i.e. to the lower Ebbw valley). The word 'influence' used by Crampton is important, for the minerals may well have been carried east by strong winds, and a movement of actual ice into the area cannot be postulated on these grounds.

3. CONCLUSION.

In the lower Usk no clear evidence was found of a more extensive 'Older Drift' glaciation. It is not possible to say that the evidence is completely lacking, but if present, such drift deposits are much thinner than those identified in parts of West Wales. The absence of such an ice advance in the Usk valley at this stage could be accounted for by supposing that the catchment of the Usk was significantly smaller at that time. There is alternative evidence for this.

There is no clear evidence of an extension into the Newport area of Irish Sea Ice. The Severn terrace gravels as an alternative source of flint, used to indicate the extent of the Irish Sea Ice in the South Wales coastlands, has scarcely been considered in the past. The proximity of flint-bearing terrace gravel in the Newport area thus makes flint finds in that area of doubtful value.

CHAPTER 10.

GLACIAL ADVANCES AND DEGLACIATION STAGES.

In preceding chapters, the glacial morphology of the area lying within the 'Newer Drift' spread of the Vale of Gwent, and upstream to Brecon has been examined in detail, and the scanty evidence for an 'Older Drift' Glaciation in the lower Usk has been examined. It is intended here to review these detailed observations, and to suggest stages in the development and final retreat of the Usk Glacier.

1. GLACIAL ADVANCES.

The best evidence upon which one could postulate multiple glacial advances in an area is that of a proved interglacial deposit sandwiched between deposits of clearly glacial derivation. The nearest approach to this in the Usk is the Clytha deposit, discussed in Appendix II. The organic layer there is clearly temperate, but requires accurate dating, whilst its relationship to, and the exact nature of, the overlying deposits is not clear. Although it is not possible to prove in this fashion the relative ages of two ice advances, tills of proved varying age not having been found in juxta-position, other evidence exists which indicates that the ice advance within the Usk was multiple:

(a) Drift differentiation. It was pointed out in the last chapter that no clear evidence exists in the Usk of an 'Older Drift' deposit of the character identified in West Wales and parts of eastern England. All identified drift deposits, however thin, appear to post date the excavation of the present valley system. In that sense, they must be regarded as 'Newer Drift'. Even so, a differentiation of this 'Newer Drift' may be made in terms of drift thickness, and morphological expression. The greater part of the area contained within the piedmont lobe of the Usk Glacier as defined by Charlesworth (1929) shows well-defined drift forms, but peripheral to this, in the Usk area, and in the Troddi valley upstream of Llantilio Crossenny, large areas are drift-covered but lacking in distinctive drift morphology. This distinction, as noted earlier, is well brought out by the Geological Survey mapping of this area, the drift mapping (probably on a morphological basis) of the Abergavenny sheet failing to detect the extensive drift spread in the upper Troddi, indicated by the more recent mapping of the Monmouth sheet. Such sharp morphological contrasts must indicate a long intervening period of weathering, and a multiple advance can therefore be confidently proposed.

(b) Erosional evidence. As outlined in section (a) of Chapter 7, there are grounds for believing that the Upper Usk was once tributary to the Wye, and that the present anomalous course of the Middle Usk can best be explained by transfluent ice erosion during a phase of maximum glaciation. Erosional forms of the ice related to two major episodes can be detected: (i) forms related to a maximum stage when transfluent ice was overflowing in several places the Fforest Fawr - Black Mountains scarp and a radial movement was occurring from the centre of ice accumulation focused on what is today the Llangorse-Llynfi Basin; and (ii) erosional features clearly the product of later stages when ice movement was confined to the present valley lines. It is possible, but unlikely, that this could represent two phases of a single advance, but there is ample evidence that this is not so. In particular the morphology of the Llangorse-Llynfi Basin suggests that with the development of the Usk exit to the south-east it remained as a small essentially unglaciated enclave during the last glacial stage, and its basic relief forms relate from the previous stage when ice was moving north to the Wye, and south-eastwards to cross the main scarp in the Bwlch area.

Two major glacial episodes may thus be distinguished, differing from each other in terms of ice magnitude and direction of movement, whilst there is some evidence for believing that a glacial advance occurred differing little in extent from that of the last, its deposits thus being largely obliterated by the later advance. For convenience, these glacial stages have been termed:

1. Upper Usk Maximum.
2. Vale of Gwent Maximum.
3. Last Glacial.

Upper Usk Maximum Glaciation. Prior to this glacial phase, the Upper Usk drained north-eastwards to the Middle Wye, the cutting of the Middle Usk taking place at this period due to the over topping of the Fforest Fawr - Black Mountains scarp by transfluent ice lobes from ice accumulating in the angle of the scarp centred on the present Llangorse-Lyynfi Basin. Earlier ice movement out of the south-central Wales area appears to have been either eastwards along the Wye to the Hereford Plain, or south-eastwards to the Vale of Gwent. It is difficult to say whether this route was used extensively towards the end of this period. Probably this episode can be correlated with the 'Older Drift' elsewhere, where a phase of glaciation more extensive than the later 'Newer Drift' is usually recorded. The apparent absence of Older Drift in the Vale of Gwent could be attributed to the fact that at this stage a major ice stream did not enter it. However it is necessary to postulate that the route was sufficiently well developed by the end of this glacial stage for ice of succeeding stage to be channelled along the new route. The streamlining of Allt yr Esgair, and the form of the upper Llynfi valley both suggest significant ice movement south-eastwards towards the Bwlch area; this movement must have occurred prior to the Last Glacial stage which was essentially a valley glaciation. In fig. 29A the earliest ice movement is shown by dotted arrows (1) trending north-eastwards, ice accumulating on the north-facing section of the main scarp moving along the Middle Wye into the ice-free terrain along the Welsh border. The movement of transfluent ice lobes is shown by the broad arrows (2) these crossing the scarp southwards into the heads of the Coalfield valleys as well as eastwards into the western valleys of the Black Mountains, whilst ice at this stage is also likely to have topped the Black Mountains' scarp at the head of Honddu valley. Although ice movement, especially during stages of expansion and retreat, is likely to have been influenced by existing valley lines, at its maximum the ice had assumed certain characteristics of an ice cap, with access to lower, ice-free areas to the south and east hindered by the barrier of a major scarp.

Vale of Gwent Maximum.

Only depositional evidence of this stage exists, there being a thin drift lacking any morphological expression which extends beyond the 'Newer Drift' margin as defined by Charlesworth (1929). As it is not a remanie deposit, but is found at lower levels within the valley, it is not considered to be comparable to the 'Older Drift' described elsewhere, although its lack of morphological form clearly distinguishes it from the more recent drift deposits.

It is probable that ice movement, as in the Last Glacial stage, was controlled by present day valley lines, although there is no evidence of this stage within the area covered by later drift deposits. The main ice thrust at its extremity appears to have been southwards, crossing the Berthin Brook and entering the head of the Sor drainage, whilst pushing down the main valley to beyond Llangybi and overflowing eastwards into the lower part of the Olway. It is probable that at the same time ice entered the head of the present Troddi, which might then have formed part of the Olway system. Initiation of the Troddi course through the belt of high ground east of Tal-y-coed is thus likely to have occurred at this stage; it certainly antedates the Last Glacial advance. The deposits of the Troddi appear to be thicker than the drift identified beyond the 'Newer Drift' margin in the Usk area, and advance into these two areas may thus not have been synchronous.

Last Glacial Stage.

Lines of ice movement during the last major glacial episode in the Usk are shown by unbroken black arrows in fig. 29A. Most of the constructional drift forms found within the valleys appears to belong to the retreat phase of this stage.

Ice accumulation during this stage appears to have been considerably less. With the route to the south-east now available, it might be argued that ice accumulation in the upper Usk might in any case be lessened, whilst in the lower Usk there is little evidence of an earlier, significantly more extensive glaciation. This is true, but the survival of the Llangorse-Llynfi Basin as an essentially unglaciated internal lowland, lying between two major ice streams, is evidence of a considerably less severe ice development. In the north the southward movement of a diffluent ice tongue into the lower Dulas valley above Bronllys can be mapped with ease (Appendix V), whilst the relatively low divide between the Usk and the Llangorse lowland in the south does not seem to have been crossed by significant quantities of ice at this period. This was therefore a period of valley glaciation, at which time ice accumulating within the catchment of the present Upper Usk was able to utilise the route through the scarp developed during the preceding period, spreading as it reached the lower-lying terrain of the Vale of Gwent into a minor piedmont glacier.

At this stage considerable deepening of the valley downstream of Brecon would have occurred, and the rejuvenation features of the Black Mountains discussed in section (e) of Chapter 7 may give an idea of the amount of glacial erosion involved. In two places at least (Brecon and Llangynidr), tortuous sections of the earlier route were replaced by the more direct line subsequently taken by the Usk.

The apparent failure of Usk ice to cross the low watershed into the Llangorse Basin - at least in appreciable quantities - whilst it emphasizes the fact that the last major glacial episode was essentially a valley glaciation, is difficult to explain in view of the activity of diffluent ice streams evident elsewhere in the Usk at this stage. There are two low cols leading into the Llangorse Basin at heights of between 600 and 650 feet O.D. (at Bwlch and Pennorth) whilst a third crosses the watershed just below 800 feet O.D. to the west of Talyllyn Junction (103 275). Upstream, north of Pen y Crug (025 310), diffluent ice seems to have entered the lower Honddu valley, the col exceeding 700 feet O.D. in height, whilst at Crickhowell diffluent ice is considered to have entered the Grwyne by crossing the Great Oak saddle at over 600 feet O.D. It would seem entirely reasonable to expect diffluent ice also to enter the Llangorse Basin, and it is not easy to explain its apparent failure to do so. That it did not is suggested by:

(a) the lack of drift topography in the area. Although only a reconnaissance survey was carried out, no drift forms were observed, although previous writers had suggested drift-damming to explain the formation of Llangorse Lake.

(b) the form of the two lower cols which does not suggest that they ever carried an ice stream crossing into the Llangorse area, but rather that they were eroded by ice moving <u>into</u> the Usk as two streams divided by Allt yr Esgair.

The apparent failure of Usk ice to cross the watershed into the Llangorse-Llynfi Basin during the Last Glacial Stage becomes even more inexplicable when the constriction of the valley at Llanddetti is considered. The effect of this would surely be to cause ice accumulation above it, thus giving rise to conditions most favourable for the development of diffluence.

A partial explanation of the diffluent ice movement across the Great Oak saddle may be seen in the addition of Coalfield-derived ice, especially from the Clydach, contributing to the size of the glacier, and probably reducing the ice surface gradient above the confluence. The present gradient of the Usk through the Llangynidr gorge is such, however, that although the cols crossing the Usk-Wye watershed above it are of a similar absolute height as the Great Oak saddle, the latter is almost twice as high above the floor of the main valley. It is thus concluded that any glacier in the Usk capable of developing a diffluent stream across the Great Oak saddle <u>must</u> have been capable of entry into the Llangorse Basin, although field evidence of this was not obtained. This enigma may be resolved if:

(a) the evidence upon which the absence of such a movement was suggested was inadequate. The erosional form of the cols would seem sufficient evidence that no major movement across the watershed occurred - but not evidence of a complete absence of such movement. Similarly, too much stress may have been laid on the absence of a drift morphology. There are elsewhere in the Usk extensive areas lacking significant drift forms if glacio-fluvial deposits of the deglaciation phase are discounted. The absence of such forms on the north side of the valley between Clytha and the Ysgyryd Fach has previously been commented upon. The majority of the drift forms of the main valley are deglaciation phenomena, the forms of which are related to the abundance of meltwater during the final withdrawal of the Usk glacier. Diffluent ice tongues would early become detached from the main glacier at this stage, and the development of glacio-fluvial forms would be limited by the essentially local source of meltwater. This would be especially marked if the diffluent ice had entered a minor drainage basin, as would be the case for ice crossing into the Llangorse area.

(b) the suggestion that ice crossed the Great Oak saddle is incorrect. A much shallower glacier in the Usk might then be suggested. It would then, however, be extremely difficult to account for the extent of drift in the Llanbedr - Fforest Coalpit reach of the Grwyne Fawr, whilst drift forms in the Vale of Gwent suggest that ice at this stage there reached heights of between 400 and 500 feet O.D. It is hardly likely that ten miles upstream ice would not be sufficiently thick to allow diffluent entry into the Grwyne via the Great Oak saddle.

It would thus seem necessary to postulate the crossing of the watershed, but by only minor ice tongues, the paucity of drift evidence being ascribed to purely local factors. The inadequacy of this suggestion is obvious, especially when the clear evidence of a diff-luent ice movement from the Wye Glacier into the Lower Dulas/Llynfi at Bronllys is noted (Appendix V). The problem remains, and requires further investigation. It does not, however, detract from the thesis that the Last Glacial Stage in the Usk was much more limited than the earlier Upper Usk Maximum, and was essentially a valley glaciation.

The main lines of ice movement at the later stage are shown in fig. 29A, and require little additional comment. It should be noted that these lines probably indicate ice movement during the maximum ice extent, and that at other times the Usk Glacier would be largely restricted to its valley. Certain detail is speculative: it is not clear that ice moved up the Gavenny valley, but ice development in the Usk is likely to have greatly exceeded that in the eastern valleys of the Black Mountains, and movement towards the ice-free Middle Monnow is considered probable, especially in view of evidence for ice crossing the Wern Ddu col into the head of the Troddi. In the Vale of Gwent ice movement was controlled by the deeply-cut line of the main valley above Llanover, but beyond there the low ridges of the Goytre area were overwhelmed, whilst the main ice thrust appears to have been eastward along what is now the Clawdd Vale.

2. DEGLACIATION STAGES.

Fig. 30 is a distribution map on which is plotted all the 'morainic ridge' features mapped in the Vale of

Gwent. Alignments are correct, and lengths shown are true to scale. Using this and other evidence, fig. 31 was constructed, it being a tentative attempt to show the main retreat phases of the Last Glacial Stage in the Vale of Gwent. Basic to this is the assumption that the majority of the morainic features shown in fig. 30 were developed at, or close to, the ice margin. The alignment of large numbers of these in belts transverse to the probable line of ice movement supports this. An associated problem has been referred to earlier - there are large gaps where constructional drift topography is completely lacking. Two factors seem significant: (a) the general association of drift development with areas of low ground (especially noticeable in the Bryngwyn area); and (b) the marked development of drift forms along the western margin of the Vale, where the morainic content of the ice was augmented by ice descending tributary valleys cut into the scarp, and probably also by frost action and slope movements on the scarp itself.

On the basis that morainic features developed at one stage would be over-ridden and destroyed if succeeded by an ice advance of greater magnitude, the belts of morainic features are considered to record terminal positions of successively younger age. The lack of continuity of these belts makes correspondence between, for example, the Goytre and Bryngwyn areas, particularly liable to error. The equivalence has been suggested by examination of the heights at which morainic features are located, the assumption being that ice marginal features of the same stage will not be significantly different in height over relatively short distances.

The maximum extent of the Last Glacial Stage appears to be marked in the south by subdued ridges on the northern flank and floor of the Berthin valley between Penperlleni and Monkswood, and similar features on the ridge south-west of Bryngwyn, and east of the Olway above Raglan. In lower-lying areas a later ice advance seems to have been equally or more extensive: no remnant of this stage is preserved in the trough of the Usk, probably being eroded or buried by outwash from the ice front which lingered at Kemeys Commander. Ice advance later into the Wernyrheolydd saddle and into the head of the Wilcae also seems to have obliterated structures of this earlier stage.

On the crest of the ridge between Penperlleni and the Usk there is a marked morainic belt which cannot be easily linked with moraines developed elsewhere. It is possible that a similar belt in the Bryngwyn area was overridden by the next ice advance, the main thrust of which appears to have been in the Bryngwyn area, overriding the Wernyrheolydd saddle and damming lakes in the Troddi east of Llanvapley and at Llantilio Crossenny. This later advance was retarded by the Pen-groesoped/Croes Llanvair ridge, which attains approximately 300 feet O.D., although it was able to enter the Troddi and Wilcae by saddles today little over 200 feet O.D. In the main valley the ice extended to Kemeys Commander, meltwater from it building up the extensive valley train preserved above flood plain level at least as far south as Usk. A short-lived lake may have been held up in the Nant y Robwl at Goetre, fed by meltwater spilling over the ridge east of Pen-groes-oped. Meltwater at this stage was thus discharging from the ice front along three major routes (fig. 31): southwards along the Usk valley, and from the Clawdd Vale lobe into the Wilcae (and Olway), and north-eastwards into the Troddi.

Following the 'Kemeys Commander Stage', a final ice thrust seems to have extended up the Clawdd Vale, probably entering again the Wernyrheolydd saddle, but not the Usk valley below Clytha, where the surface overridden by ice during the previous stage occupies the valley floor above Chain Bridge. The deepened floor of the main valley, continuing eastwards into the Clawdd, is evidence of this, whilst extensive kame terraces and other glacio-fluvial structures upstream of Clytha (particularly in the Abergavenny area) suggest that a mass of dead and wasting ice persisted long in the valley there. Meltwater from this seems to have discharged down the Usk south of Clytha, accounting for the paucity of glacio-fluvial deposits in the Clawdd Vale, melt from that area flowing westwards through the ice to escape down the Usk. Above Abergavenny the ice appears to have remained active, probably delivering morainic material onto the decaying mass downstream, and then melting back rapidly.

Further retreat of the Usk Glacier once it had cleared the Vale of Gwent was also marked by minor halt stages. At Gilwern and Dan y Parc morainic structures suggest temporary halts, whilst the extensive gravel fill in the Llangynidr gorge indicates that the retarding of a temporary advance by the constriction of the valley at Llanddetti caused the ice front to be located in that area for some time. The Buckland moraine seems to have caused a temporary blockage of the valley, and a body of water was held up between this and the ice front which appears to have next halted its retreat at Cefn Brynich.

At least seven - probably more- main halt stages in the general retreat of the Usk Glacier from its maximum during the Last Glacial Phase appear to be recorded in the Usk below Brecon:

Maximum - Berthin Brook/Olway Valley.

Retreat Stages:
1. Penperlleni.
2. Kemeys Commander/Llantilio Crossenny.
3. Clytha/Clawdd Vale.
4. Abergavenny.
5. Gilwern/Dan y Parc.
6. Buckland/Llangynidr.
7. Cefn Brynich.

It is likely that retreat of the main glacier was matched by the retreat of its tributary ice streams, none of which had so comparable or effective an ice-catchment area. The south-draining valleys of the Black Mountains are likely to have been largely ice-free before the Usk Glacier vacated the main valley to the south. Minor ice advances are recorded of the small corrie glaciers on the north-eastern corner of the Coalfield scarp. It is not certain that these are synchronous with subsidiary advance phases during the general retreat of the Usk Glacier, or record temporary regrowth of ice at an even later date. Trotman (1963) suggests possible ice growth in pollen zone la. in the small cirque basin at Waun Ddu (south of Llangattwg) but ice freedom thereafter, which suggests that the smaller cirques were probably active during the Last Glacial episode but not since, although the higher, massive cirques of the Brecon Beacons were also probably ice-filled during Pollen Zone lc.

3. FLUVIAL REGRADING OF THE VALLEY.

The Usk today shows a mainly graded course between Brecon and the river mouth. In only two places: between

Cefn Brynich and Llanhamlach, and in the Llangynidr gorge, does the gradient show a marked steepening, with extensive rock exposures on the river bed. The surface of the drift (exclusive of outwash) on the valley floor is, by contrast, remarkably irregular, rising in some places high above the river, whilst in others it may be presumed to be buried at depth. Where the drift floor of the valley lies below the present flood plain, aggradation by meltwater streams during final retreat is likely to have dominated, whilst the paucity of terrace forms suggests that removal of drift obstructions in the valley was probably quickly effected by the same agency. The areas where aggradation and degradation have respectively dominated are shown in fig. 32. It will be observed that aggradation has been most prevalent, although incision of the river into the glacial infill has been significant between Cefn Brynich and Llanhamlach, Llanddetti and Penmyarth, and between Clytha and Usk.

The alluvial deposits of the Usk (fig. 33[1]) thus show today a highly variable width, reflecting development

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[1] Compiled from the Geological Survey One-inch sheets (below Crickhowell), and field mapping.

above Usk between alternating areas of upstanding drift ridge and hollow. Downstream of Usk, and in the Olway, downcutting to a base level lower than the present, followed by aggradation, is evident from the interfingering of the alluvial deposits into minor tributary valleys. As the valley train extending downstream from Kemeys Commander appears to be close to flood plain level at the mouth of the Olway valley (i.e. at Usk), this suggests that downcutting of the Usk and Olway to the lower base level preceded the formation of the valley train, and that outwash both in the Usk and the Olway assisted in aggrading these valleys. The present exceptional extent of the alluvial fill in the Olway is probably related to the increased erosive power of the stream as a result of meltwater addition during the maximum of the last glacial episode. This would have enabled rapid deepening in response to the lowered base level, whilst aggradation would later have been accelerated by the development of the valley train below Kemeys, and the Late and Post Glacial sea level rise. The effect of this fluctuating sea level on the morphology of the valley below Usk will be discussed in a later chapter.

GRAVEL FANS.

Morphological mapping in both the Usk and the Wye (Appendix V) has revealed low fan structures developed usually about the lower parts of tributaries where they reach the floor of the main valley. The distribution of these fans in both valleys is shown in fig. 34. Time did not permit detailed examination of these features, and the comments made here are therefore of a general nature.

Location and form. Fig. 34 shows that the size of the fans varies considerably, and further that not all rivers appear to have developed fans at their mouths. Most of the fans mapped were found up-valley of the drift margin of the last Glacial Stage, but this is considered to be due to the fact that only here do swift-running tributaries rising in high mountain areas join the main stream. A few small fans were mapped debouching onto the alluvial fill of the Usk valley between Newbridge-on-Usk and Caerleon, for example.

The size of the fan, or its absence, seems to be largely dependent on the form of the main valley and the lowest reach of the tributary valley. If the rivers locally have incised forms, fan development is not possible. Thus the Crawnon, incised itself, and joining the Usk where it also is incised, has not been able to develop a fan, although fan forms are marked on neighbouring streams. Even if the tributary is incised up until its confluence with the main valley, fan growth is usually possible out into the main valley, although this may restrict lateral movement of the main stream, as the Caerfanell fan seems to have done at Talybont, and the Grwyne fan has done upstream of Gilwern. At Brecon (see fig. 14: these fans are not shown in fig. 34) two streams, the Tarell and the Honddu, draining from opposite sides of the valley, are confluent with the Usk within a short distance. Growth of the Tarell fan appears to have deflected the river to the north side of the valley here, thus preventing the development of a similar fan by the Honddu, although high terrace deposits here may have been built out in a similar fashion by the river prior to complete melt of the ice in the main valley.

Low gradients in the tributaries would also seem to discourage fan growth, as the general paucity of fan development in the Vale of Gwent suggests. Both the

Ffrwd and Clawdd Brooks at Clytha, for example, show no sign of fan development, aggradation probably affecting a greater length of the valley floor.

Gradients of the fan surfaces were not measured, but they seemed to be least on those developed by streams showing low gradient thalwegs (e.g. the Tarell and Grwyne), and steepest on short streams draining steeply off mountain slopes (e.g. the streams draining off the Sugar Loaf between Glangrwyney and Abergavenny).

<u>Origin.</u> Alluvial fans develop when heavily laden and swiftly flowing streams suffer a sudden velocity check. Normally this is also associated with braiding of the stream, or the development of distributaries, the stream in its steep section normally following a confined course through a ravine or canyon (Holmes, 1965, 551). Beaty (1963) has suggested, however, that the fans examined by him in California and Nevada were developed largely by debris flows occurring as a result of cloudbursts. Most discussion of alluvial fans is in respect of arid areas, where the juxtaposition of upstanding mountain masses and plain areas, combined with episodic heavy rainfall and stream discharge, and a weathering mantle only loosely

bound with vegetation, seems to provide ideal conditions for their development. Fans have, however, been reported from recently deglaciated terrain by Hoppe and Ekman (1963), and Cruickshank and Colhoun (1965, 228, fig. 6). The Swedish examples cited by Hoppe and Ekman were developed by meltwater streams spilling over into an ice-free valley. Gresswell (1967, 170) shows examples of two developing fans in Norway on streams fed by meltwater from nearby glaciers. High discharge concentrated in only part of the year, combined with an abundant debris load in the streams seems to be common to all these examples.

Fans in the Usk and Wye are clearly fossil, the rivers that formed them being today incised into their surface. Fossil gravel fans were described in the Cotswold Sub-Edge Plain by Tomlinson (1940), but these examples were of angular gravel and the stratification displays folding, overfolding, and festooning, which is attributed to solifluxion movement. They differ from the fans discussed here in that they are essentially slope deposits, merging upwards into hillwash. They show local thickening where gullies dissect the scarp face, but they are not manifestly fluvially-laid as in the case of the Usk examples.

Period of formation. Wills (1950, 129) placed the formation of the Cotswold taele gravels in his Third Glaciation, when periglacial activity was modifying landforms outside the area overrun by ice. The evidence for this includes their connection with the No. 2 terrace of the Avon, and the inclusion of cold fauna (Tomlinson, 1963, 197). At this time, ice still occupied the Usk, so the Usk fans must post-date these, and in any case, evidence of periglacial processes affecting these deposits has not been seen. As indicated by Charlesworth (1957, 504) late glacial conditions would seem to favour the development of these fans. Hillsides were swathed in loosely consolidated, thinly vegetated drift, and river discharges were probably greater than the present, showing a pronounced spring and summer maximum, when they would be swollen with melt from snow and glacier ice. The climate as a whole was cooler and moister than today. Formation of the gravel fans in the Usk and the Wye during the Late Glacial, following the melt of ice in the main valley, is therefore suggested. It is possible that accumulation was at a maximum during pollen zones I and III, at which time Trotman (1963) has shown that periglacial activity was pronounced in the Usk, and conditions were likewise favourable for the development of fans.

An alternative dating has, however, been suggested by Crampton in an unpublished paper[1]. He examines the combined fan of the Onneu Fawr and Onneu Fach in Llangattwg Park, which he describes as a "terraced alluvial fan" composed of a bouldery layer overlying an earlier deposited sandy subsoil, and in places overlain by a more recently deposited sandy loam topsoil. The bouldery layer is shallow and of variable depth, and Crampton suggests that this reflects moulding by powerful river currents into low ridges, elongated downstream. This, he considers, occurred during a period of increased river discharge which he dates by reference to the burial cairn of Garn Goch (212 177), located on the fan near to the village of Llangattwg. This has not been professionally excavated, but has been variously described as a long barrow of Neolithic age, and a Bronze Age round

[1] I am grateful to Dr. Crampton for permission to cite this unpublished MS (Crampton, 1965).

barrow, on account of its somewhat indeterminate form. Crampton suggests that it is a round barrow, its weakly developed 'tail' which led some to describe it as a long barrow being an accumulation of boulders against the side of the cairn facing upstream. He suggests that the decline of *Quercus* forest of the Bronze Age under the wet and cool sub-Atlantic climate of the succeeding Iron Age resulted in deforestation and soil erosion. He cites evidence produced by Higgins (1933) which suggests that the mid-Iron Age was one of the peak periods of storm activity in South Wales. Charcoal horizons in soils of the region also suggest deforestation by burning:

> "So it would appear that forest destruction by burning and precipitous erosion encouraged by particularly violent storm activity occurred .... In Brecknock ample quantities of debris would have been available for river transportation and subsequent deposition, to form alluvial fans and terraces". (Crampton, 1965, 47-48).

This is a most ingenious theory, but it seems to be founded on a basic misunderstanding of the nature of the Llangattwg fan. The fan (fig. 20A) is over three-quarters of a mile wide at its riverward extremity, and it has a height of approximately 225 feet O.D. along this edge, increasing to 338 feet O.D. near Llangattwg Park House, half a mile to the south-west. This is the surface of what is clearly a very substantial aggradational deposit. To suggest that a cairn could have been constructed in this valley prior to its formation, and survived, implies that it is a thin surface veneer of very limited thickness, an assumption that morphologically would appear to be unjustified. Unfortunately there is no direct indication of the thickness of the Llangattwg deposits, although erosion of its extremity by the Usk has formed a ten-foot high bluff. Hoppe and Ekman commented on the "surprisingly thin" deposits of the slightly larger fan they examined by means of seismic refraction surveys in the Kebnekaise district of Sweden (Hoppe and Ekman, 1964, 341), although this was between 20 and 25 metres thick in its central portion, decreasing to 10-15 metres near its lowest edge. No burial mound could possibly survive aggradation of this order. It is possible that Garn Goch has been modified by fluvial activity, but there is little doubt that the cairn is built on the fan and post-dates its formation.

A late Glacial formation is therefore suggested. The best evidence for this is at Gilwern, where a deep kettle is found at the foot of a bluff trimmed in a morainic deposit by the River Clydach during the formation of the fan. This suggests that ice buried at depth (and overlain by fan deposits) did not melt out until aggradation on the fan had ceased (otherwise the kettle hole would have been filled). As a group, the fans between Penmyarth and Abergavenny all suggest formation shortly after final ice melt. For example, the small fans between Llanwenarth and Abergavenny and at Govilon (fig. 20A) have been built out over marginal morainic deposits, and with them have been trimmed by the river during aggradation within this section of the valley. Similarly the Llangattwg fan shows a terraced face, suggesting that it at least ante-dates incision below the level of the low terrace developed in this area.

CONCLUSION. The gravel fans are clearly fossil, and a Late-Glacial origin is suggested. At this period stream discharge is likely to have been more concentrated into the warmer months of the year than at present, and load supplied to the streams from drift moved by periglacial processes in their upper reaches would be beyond the capacity of the streams to transport when gradients slackened as the main valley was approached. The suggestion of Crampton of a mid-Iron Age formation is not endorsed, although further slight aggradation may possibly have taken place at this time.

CHAPTER 11.

MORPHOLOGY OF THE USK VALLEY BELOW THE MAIN 'NEWER DRIFT' MARGIN (USK - NEWPORT).

1. VALLEY FORM AND GEOLOGY.

This part of the valley may be divided into three sections:

(a) Usk - Newbridge. The valley floor here attains its maximum width ($\frac{3}{4}$ mile), the valley having been widened out in the weakly-resistant Raglan Marl Group of the Old Red Sandstone series (fig. 5). The edge of the valley floor between Usk and Llantrisant is closely coincident with the outcrop of the overlying St. Maughams Group, made up of more resistant interbedded marls and sandstones. The Brownstones escarpment is here running in a NE-SW direction and is approaching the river near Newbridge, the Usk in this section running almost due south. To the east of the river there is therefore a widening wedge of rising hill country between the valley and the main Brownstones scarp. In the west, the Marl gives way to the Silurian strata of the Usk inlier (mainly limestones, shales and grits), the outcrop of which closely follows the western side of the valley and approaches close to the river at Llanbadoc, south of Usk. The Raglan Marl outcrop may be traced in a south-westerly direction from Llangybi across the Cwrt Bleddyn saddle (360949) into the Lower Sor valley.

The river shows a marked meandering form, but the meander belt occupies the eastern portion only of the wide flood plain.

(b) Newbridge to Malpas. At Newbridge the Usk crosses onto the outcrop of the St. Maugham's Group, and for the next three miles follows a course at the foot of the main Brownstones escarpment of the Wentwood Ridge. Within this section, the river leaves the area recently mapped by the Geological Survey (Sheet 250), and enters the area covered by the older mapping of the Newport Sheet. As the latter does not subdivide the Red Marl as is customary with the more recent mapping, it is impossible to do more than guess the extent of the outcrop of the St. Maugham's Group in the lowest part of the valley. It seems likely, however, that the outcrop crosses to the south of the river near Bulmore, and that the wide-crested Chepstow Hill is made up of this formation. The pronounced NE-SW alignment of ridges in the Newport, Malpas and Caerleon areas, as well as the long ridge north-east of Llanhennock, are probably all associated with the development of Psammosteus Limestone bands within the Marls. The contrasting lithology of these limestones with the surrounding marls has been noted to give rise to narrow ridge and valley topography elsewhere (Welch & Trotter, 1961, 32). Thus to the west of Bulmore the Usk has probably entered the Raglan Marl tract again, although here there is a considerable development of limestones giving rise to more indented terrain.

In this section the Usk receives two important right bank tributaries, the Sor and Afon Lwyd, which break through a belt of high ground (Lodge Farm Ridge - Llanhennock ridge) to join the Usk above Caerleon. There are no left bank tributaries of any importance, as the river is here running close to its watershed. The valley sides drop steeply to the valley floor, and aggradation has clearly been a dominant feature of recent evolution. The river is tidal to above Newbridge, and the whole stretch is susceptible to flooding. At some unrecorded period in the past embankments were built along the river side to prevent flooding, but the valley floor has been avoided by settlement. The embankments reveal that the meanders of the river are fairly stable, there being little evidence of significant lateral movement, although a motte and bailey fortification near Old Kemeys (389939) has been partially destroyed by the undercutting of the river.

(c) <u>Malpas to the mouth.</u> At Malpas the river turns abruptly southwards through the western extension (? St. Maughan's Group) of the Wentwood Ridge to cross the 'Levels' of Caldicot and Wentloog, before entering the Severn. Newport is built at a place where the river impinges on the solid rock of the western side of the valley, upon which the castle was built, and where a river crossing was relatively easy. The valley is quite narrow (five-eighths of a mile) and the hills rise steeply east and west of the river.

2. EVOLUTION.

This part of the Usk lay beyond the spread of fresh morainic deposits referred to as the 'Newer Drift': the lowest point where these can be positively identified on the floor of the valley is at Kemeys Commander. Outwash deposits from this ice stand almost certainly lie at depth within this section for some distance below Usk. During the Newer Drift Glaciation this part of the Usk was therefore free of ice and subject largely to modification by fluvial agencies. We can expect, therefore, to find erosional evidence of the evolution of the valley in this section going back to at least the end of the Gipping glaciation, whereas upstream such evidence appears to have been largely destroyed by the last major ice advance.

Morphological mapping revealed a variety of slope facets, and in some cases near-level surfaces cut along the valley sides, mainly along the crests of spurs. Some were gravel covered. Their distribution is shown in fig. 35. Drift was also noted in a few places, and it was discussed in chapter 8 (Section F).

Two major phases in the evolution of the valley are evident from its present day form :

(a) downcutting to a base level lower than that of the present, so that the valley sides now drop steeply to a rock floor buried some depth below that of the present valley.

(b) aggradation, presumably consequent upon a rising sea level.

Evidence is presented later (Chapter 12) that the phase of valley excavation to below the present sea level probably occurred fairly late during the Last (Wurm) Glaciation. The relation to the Newer Drift deposits at Kemeys to the valley fill below there suggest that features which pre-date the fill (i.e. terraces cut into the rock side above the fill) also pre-date the maximum ice advance during the last glaciation of the area. On a basis of relation to fill, a two-fold division of the valley bench and terrace features may be made:

(i) those features which post-date the fill, being developed on its surface. These are terraces of largely aggradational form, although associated trimming of parts of the adjacent valley side is possible. These are restricted to that part of the valley between Usk and Newbridge.

(ii) features, basically erosional, which record stages in valley deepening, and which thus pre-date the valley fill. These may be divided into (a) valley side benches or bevels; and (b) rock-based terraces.

The rock-based terraces often display a considerable degree of planation, and in many cases retain a capping of terrace gravels. Valley-side benches are usually smaller in area, and steeper and more irregular in cross-profile. They are evidence of pauses in the erosion of the valley, but are unlikely to have lain at the level of the former valley floor.

1. <u>Post-aggradational river terraces.</u> These are found in a belt along the western side of the valley between Llanbadoc and Tredunnock. They fall within the area of the Chepstow sheet, and the Memoir (Welch & Trotter, 1961, 134) refers to them as "a narrow belt of pebbly clay from Llanbadoc to a point ¾ mile south of Llangybi. This gravel slopes down from about 80 ft. O.D. to the flood plain at 50 ft. O.D. South of the point mentioned above, the terrace of pebbly gravel merges with the First Terrace (Loam)." My mapping of this area was carried out before the publication of the Chepstow Sheet in 1958, and whilst the basis of my mapping was morphological, that of the Survey was lithological, so that there appears a slight discrepancy between the maps as regards the extent of the terraces mentioned above. In general, the morphological form suggests a far less extensive terrace area than is actually covered by gravels. Moreover, the transverse slope is less than is suggested by the Memoir, and the tread of the terrace can be quite easily defined in the field. The break of slope at the rear of the terrace declines from about 60 feet near Llanbadoc to less than

50 feet south of Llangybi, whilst the leading edge declines in the same distance from 56 feet to 41 feet. In the same areas, the flood plain slopes from 48 feet to 34 feet.

Streams crossing the terrace have dissected it, although the continuity of the deposits is apparently maintained. Thus the equivalent of the Survey's single terrace are terraces 1 to 3 on fig. 35, whilst terrace 4 is an additional flat at this level not noted by the Survey. Although the streams crossing the terrace belt have been incised into it, small fans of gravel have been built out over it at places, into which the streams are now also incised.

There are two possible modes of origin for this terrace:

(1) that it results from a recent phase of downcutting (post-dating the main aggradational episode) by the Usk. This seems unlikely in view of the absence of terraces at this level on the eastern side of the Usk and down-stream of Newbridge. Fairly extensive terrace evidence might be expected to survive from such a recent phase of rejuvenation, however minor. Moreover, the terraces would

be likely to have a down-valley gradient very similar to that of the present flood plain, and the complete absence of terraces as evidence of such a recent stage from the whole of the lower part of the valley would be inexplicable.

(2) that the terrace, although post-dating the excavation of the buried valley, pre-dates the present fill, and may therefore be buried beneath the alluvium in the lower part of the Usk. Although the figures given above suggest that this is unlikely, in fact there is a considerable decrease in the gradient of the flood plain in the tidal portion of the valley south of Newbridge (the flood plain declines only five feet in height in the seven miles below Newbridge, but had declined 23 feet in less than four miles above). Thus, if the terrace maintains its present gradient, which it could be expected to do if it was developed in relation to a sea level somewhat lower than the present, it would certainly have been buried south of Newbridge.

The evidence generally suggests a terrace of considerable age, and the latter suggestion is preferred. The probability that this terrace is a down-valley relict of the valley train developed in relation to the Kemeys Commander terminal moraine has been discussed in Chapter 8 (section C), and the height relationship of the terrace to the flood plain, and valley train is shown diagrammatically in fig. 26A.

Below Newbridge there are no terrace features which post-date the cutting of the buried channel, although the Caerleon terrace (13) was considered at one stage to fall within this category. The Geological Survey (Sheet 249) shows a narrow marl exposure along its up-valley face, and origin as a rock terrace pre-dating the cutting of the buried channel accords with the other evidence. The glacial origin of the surface deposits at Caerleon suggested by the Survey will be challenged in the following section.

2. Rock-based terraces and valley side benching. The distribution of these features should be noted:

1. They are almost wholly restricted to the valley below Newbridge;

2. They are mainly confined to the western side of the valley above Caerleon, but none are developed on that side between Caerleon and Malpas;

3. At Newport, they are developed on spurs both to the east and west of the river.

This suggests that there has been a general down-dip movement of the river above Caerleon, although also an intensification of the bend in the river between Caerleon and Newport.

a) Above Caerleon. The best-developed rock-cut terraces (fig. 35) are about Tredunnock (numbers 5, 6 (Plate 21) and 7). The Survey mapped five gravel terraces here "varying in height from 125 to 172 feet above O.D." (Welch & Trotter, 1961, 134), which it included in its 2nd Terrace (of the Usk) category. Four of these are well-defined morphologically, but the fifth (marked by an 'X' on fig. 35) has no terrace form, being a summit capping of terrace gravels on a round-crested hill to the east of Cefn-llechi (373957). Terrace 10 lies a little below the level of terraces 5 - 7, but is similarly well-developed, but terrace 11 is a somewhat uneven crest flattening. The only other terrace of note above Caerleon is at Pencreeg fawr, Llanhennock (No. 12).*

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* After the above account had been written, two further terrace fragments at approximately the same level as the Tredunnock terraces were discovered on the valley side south and south-east of Llangybi. They are shown in fig. 35 as terraces 26 and 27. Their height was not measured, but the lower one (26) was estimated at 165 feet O.D., the higher one at about 210 feet, its leading edge being defined by the 200-foot contour. They were not shown on fig. 36. There was a scatter of pebble gravel on terrace 26, although one or two large poorly rounded boulders suggested a possible glacial origin.

b) The Caerleon Terrace. The marked terrace upon which Caerleon stands presents a particular problem, as its surface has been mapped by the Survey to be covered by a deposit of glacial pebble gravel and sand. In the Memoir (Strahan, 1899, 78) it is noted that "the patch (of glacial gravels) at Caerleon is of doubtful origin and extent. Red clay, with bands of gravel containing large grit-pebbles, is exposed to a depth of 10 feet in the railway-cutting; it has neither the form, appearance, nor position of a river terrace, and by inference is glacial." Excavations within the Roman fort at Caerleon usually refer to the deposit underlying the lowest level of human occupation as "natural clay" (Threipland, Arch. Camb., 1965) or "natural clay (leached)" (Boon, Arch. Camb., 1964).

In view of the description of the deposit in the Memoir one is tempted, reluctantly, to agree with the inference. I do not believe, however, that in its position it can be glacial.

(1) no other drift deposits are to be found so low in the valley in the lower reaches of the Usk and Afon Llywd;

(2) if glacial, at this level, it must post-date the Tredunnock Terraces, and it is inconceivable that they could have survived a glacial advance of this magnitude.

Strahan's identification of the deposit as glacial appears to be based on an examination of an exposure within the railway cutting, which in fact crosses the hill slope <u>above</u> the concave break of slope considered to define the rear of the terrace. It seems unlikely that this slope deposit is exactly similar to that covering the terrace, and it is tentatively suggested that part of a head deposit might have been exposed in the cutting, which might have included grit pebbles of glacial origin, derived from further up-slope. The cutting is now grassed over and there is no suitable exposure within the vicinity.

Only one poor exposure could be found in the surface of the terrace when this problem was being considered (in the autumn of 1966). Fresh spoil from the foundations of a grandstand being built at the football field (335907) consisted of well-rounded pebbles (all Old Red Sandstone) up to three inches in diameter, in a loamy matrix. Mixed with them were a few larger, more angular pieces of sandstone, and small pieces of pottery and clinker. Surface deposits will obviously have been considerably disturbed during the construction of the Roman settlement. It is suggested that the pebbles were derived from river gravel, which forms a thin cover to the rock-cut terrace. The angular pieces of sandstone could derive from the underlying rock surface, or could have been introduced by the Roman builders. The latter seems most likely in view of the frequent references to 'natural clay' in archaeological reports. If the deposit were of glacial origin, the presence of such angular fragments amongst well-rounded gravels would be unusual, and yet if the angular material is regarded as a later introduction, there is no reason for supposing that the deposit is any other than riverine in origin. Morphologically there is nothing to distinguish it from other well-developed terraces in the area, although it is exceptionally well-developed at a level where there are otherwise few terrace fragments. It is thus suggested that the exposure examined by the Survey Officers in the railway cutting was not of terrace deposits, and their observations are not therefore relevant to the problem of the origin of this feature. The terrace is considered to be riverine in origin.

A point of interest is the great width of the valley at this point, the present flood plain (and probable upstream extension of the buried channel) sweeping round close to the south side of the valley. There is no obvious explanation for this.

c) <u>The Newport area.</u> In the Newport area, the terrace flats of significance are:

(i) <u>East of the river.</u>

No. 16. Hummocky surface. Extends from Gaer Wood Camp through Beechwood Park. Slope to east and south. 255-264 feet, O.D.

17. Long crest flattening within new housing estate. Slight slope down spur, and also towards small valley bounding it to the south. 176-185 feet.

18. Summer Hill. Extends along two ridge crests, with height range 196-202 feet (northern) and 196-207 feet (southern). Well-marked, flattened crest. Allotment on southern spur showed well rolled gravel including one flint (? chert) pebble.

19. St. Julian's. Well marked surface on which the playing fields of St. Julian's School are sited. 100-108 feet.

(ii) West of the river.

No. 20. Barrack Hill. Uneven surface, but defined by a marked break of slope. Slope to south-east. 200-231 feet.

21. Queen's Hill. Narrow crest flattening. 144-157 feet.

22. Stow Hill. Crest flattening: rather uneven surface, but well defined. Slight rise west. 198-217 feet.

23. Small but well-defined flat at the 'Handpost'. ca. 234 feet.

24. Stelvio summit. Flat-topped area with height range 259-265 feet. Flint find in cemetery.

25. Similar, but separated from No. 24 by a slight bluff, and from the higher ground of the Ridgeway to the north by a shallow col, in which rises the Nant Coch.

Apart from these terraces, there are a number of benches of varying degree of development, especially in the Llanhennock area. They are considered to represent fragments of former, shallower, valley profiles, a suggestion which is supported by their concentration on the western side of the valley. Their location is shown in fig. 35. They will not be discussed in detail.

The height of the back and leading edge of the terraces and benches was measured, and those in the area between Newbridge and Newport have been plotted on a height range diagram (fig. 36). The position of the terrace and bench features on the diagram was determined by projecting them onto a line drawn centrally down the valley. The lateral extent of the terrace was considered to be of lesser importance, and because of the varying alignment of the terrace fragments, especially in the Newport area, with the centre line of the valley, would be frequently misrepresented. No allowance has therefore been made for this: the lateral extent of the terrace fragments can be seen in fig. 35. Only those bevels on the western side of the river, considered to be most likely to be of value, were measured and plotted on the height range diagram. In fact they gave little support to the stages suggested by the terrace evidence.

The terraces in fig.36 can be grouped into four classes in terms of height:

1. The Stelvio Stage. A summit level in the Newport area: three surfaces (16, 24 and 25) between c. 250 and 265 feet O.D.

2. The Summerhill Stage. Three surfaces at about 200 feet O.D., of which the best developed is that at Summerhill (gravel cover). No. 20 has a considerable slope, and could record the rise towards a former valley side.

3. The Tredunnock Stage. Best developed but represented by only one terrace in the Newport area (21). Nos. 11, 12 and 17 appear to be slightly too high to fit comfortably into this class, but they do not exhibit the same degree of planation as the three main terraces at Tredunnock[+] (5-7), nor do they have a gravel cover, and here again it is suggested that they were perhaps marginal to the former valley floor.

4. The Caerleon Stage: The extensive terrace at Caerleon seems to link up on height grounds with the more sloping but gravel-covered lower terraces at Tredunnock (8 and 9), although the gradient revealed is steeper than that of the present flood plain.

[+] Terrace 6 is shown in Plate 21.

Three terraces do not fit into this scheme: Nos. 10 and 19, which might be grouped together to form a stage intermediate between the Tredunnock and Caerleon stages. We shall see later that there is evidence for a stage at this level in the Severn lowlands. This too would have a steep gradient. Terrace flat 23 does not fall into any stage, and may record a short lived phase of planation during the deepening of the valley.

Four probable and one tentative stage in the evolution of the lower Usk may therefore be suggested:

1. Stelvio Stage: base level c. 250 feet.
2. Summerhill Stage: .... 190 feet.
3. Tredunnock Stage: .... 140 feet.
4. ? St. Julian's Stage: ...... 90 feet.
5. Caerleon Stage: .... 40 feet.

A further terrace level, perhaps buried in the lower Usk is exposed between Llanbadoc and Tredunnock (the Llanbadoc stage?).

In fig. 37 the terraces have been coloured to indicate the stages to which they are considered to belong.

It is interesting to note that Bucknell (1955), who carried out a study of the neighbouring Sor valley for his B.Sc. dissertation arrives at former base levels for that valley of 50, 100, 135, 175, 200 and 260 feet. These are all paralleled in the Usk, with the exception of the 175 foot level.

It will be noted that the proposed grouping of these terraces differs from that of the Survey: their second terrace group includes No. 10, which on height grounds is here left out to form a lower St. Julian's stage. This would seem reasonable in view of its flatness, and the 20 foot difference in height between it and the closely adjacent terrace 7. In fact the extreme height range of terraces 5-7 is only 21 feet, whereas the highest part of terrace 10 is 17 feet below the lowest measured point on these. The Survey also includes the Llanbadoc group of terraces (1-3) in its first terrace category, which includes terraces 8 and 9 in the Newbridge area. Height considerations would again seem to rule out this correlation: terraces 8 and 9 have height ranges of 94-63 and 93-73 feet, respectively, whereas the other terraces decline (leading edge) from 41 feet (No. 3) to 39 feet (No. 4), immediately upstream of Newbridge.

The relation of the Llanbadoc group of terraces to the solid rock form of the valley is different, the terrace being not cut into the valley side above the fill, appearing to represent an aggradational stage post-dating the excavation of the buried valley, but separated from the present fill by a phase of incision (accounting for its terraced form). The contrasting relationships of the low terraces above and below Newbridge to the rock valley form has been noted by the Survey (Welch and Trotter, 1961, 134), but they are placed in the same category on height grounds, the extent of gravel revealed by their mapping on the valley margin between Llanbadoc and Llangybi being greater than the height range of the terrace flat revealed by (my) morphological mapping.

3. RELATION TO THE SEVERN SEQUENCE.

The Usk is a tributary of the Severn and a correlation of the terrace stages of the Usk with the detailed terrace sequence worked out for the Severn by Wills must be considered. Terraces of the Severn sequence have been noted by Wills as far downstream as the Chepstow area, and the terrace deposits of the north bank of the Severn between the Wye and Llanwern have been mapped by the Geological Survey (One inch map sheet 250, Chepstow). Although the Survey mapped the terrace gravels of the Usk and the Wye within the bounds of the Chepstow and Monmouth sheets, a correlation between the gravels in those valleys and those of the Severn was not attempted, the numbering given to them (1st Terrace, etc.) not implying any linkage, but simply expressing the relative position of the terrace to the alluvium in the valleys concerned (Welch & Trotter, 1961, 131). The reason given for this is that the recent aggradation has caused the burial of the earlier formed terraces, so that the height of the unburied terraces above the alluvium in the lower reaches cannot be necessarily taken as a criteria of age. Burial of terrace gravels has almost certainly occurred in these valleys, and the relationships of the buried gravels will be obscure. It does not follow, however, that correlations on relative height grounds of the unburied terraces in confluent valleys are invalidated, for the base level changes governing terrace development have been uniform in effect. An attempt will therefore be made to correlate the terraces of the Usk and the Severn on a basis of height. Contrasts in the gradient of the former thalwegs of the valleys will result in varying absolute heights upstream, but the relative height relationships of the terraces should remain comparable.

The Survey has mapped terrace gravels at five levels along that part of the north bank of the Severn covered by the Monmouth and Chepstow sheets, four of which can be referred to the succession established by Wills (1938):

TABLE 12.

CORRELATION OF GEOLOGICAL SURVEY (CHEPSTOW SHEET) TERRACE TERMINOLOGY WITH THAT OF L.J. WILLS (1938).

Geological Survey	Wills
Terrace 5	Woolridge Terrace
" 4	Bushley Green Terrace
" 3	-----
" 2	Kidderminster Terrace
" 1	Main Terrace

A further level between Terraces 2 and 3 has been identified in places, but the independence of this is questioned, and it may be redistributed wash of the third terrace (Welch & Trotter, 1961, 133). The gradient of the second terrace has been estimated at one foot per mile, and of the terraces generally, Welch & Trotter remark (p. 132) that the "small downstream fall is so slight that it is possible to refer to the terraces within the area here described as of a specific height, e.g. the Second Terrace as the '50-foot Terrace' and the Third Terrace as the '100-foot Terrace'. Gradients, as would be expected, are greater on the Usk, and the terraces of the Newport/Caerleon area will therefore be used for correlative purposes.

Table 13 shows the proposed correlation between the Usk and the Severn sequence. Despite the comments of Welch and Trotter, the height of the two upper terraces is somewhat variable, and that of the lowest is ill-defined. No height is given for the latter in the Memoir, other than the comment that it "lies just above the level of the floodplain" at Wollaston Grange (p. 133), and the height for that terrace in Table No. 13 is taken from Wills (1938, 187). The farthest downstream record for each terrace is given in columns 2 and 3, and the height of this in column 4. The height of the comparable Usk terraces at the mouth of the valley is given in column 7, and it can be seen that on these grounds there is a very close correlation. There appears, however, to be no equivalent of the Stelvio stage in the Severn sequence. One contrast between the two valleys is the diminishing number and extent of terraces at lower levels in the Usk, whereas in the Severn these are the most widely developed. The absence of Main Terrace deposits to the west of the Wye confluence suggests that these are here buried, and a correlation with the Llanbadoc stage, likewise probably buried at the river mouth, is suggested. The close correlation of the higher terraces with the Severn sequence adds weight to the argument for the independence of the Llanbadoc stage, and to its correlation with the Severn No. 1 (Main) Terrace.

The implications of these correlations will be considered in a later chapter.

TABLE 13.

CORRELATION OF THE TERRACE STAGES OF THE SEVERN AND THE LOWER USK.

SEVERN [1]						USK			
TERRACE No.	LOCALITY [2] S. Monmouth	LOCALITY [2] Above Chepstow	HEIGHT [3]	WILLS'S TERMINOLOGY	REMARKS	HEIGHT (Newport/Caerleon) [5]	STAGE NAME [6]	GRAVEL EVI-DENCE	REMARKS
						290-320 ft.			
						255-265 ft.	Stelvie		
5	-----	Alvington	ca. 200 ft.	Woolridge		195-230 ft.	Summerhill	*	
4	Llanvaches		140-180 ft.	Bushley Green		145-185 ft.	Tredunnock	*	
3	Caerwent		ca. 100 ft.	-----		100-110 ft.	St. Julien's		Evidence thin.
2 - 3	Caerwent		Intermediate	-----	Head ?	-----			
2	Caerwent		ca. 50 ft.	Kidderminster	Most widely developed	45 - 60 ft.	Caerleon	*	? Steep Gradient
1	(? Buried)	Woolaston	20-35 ft. [4] (Just above flood plain)	Main		----	(?Llanbedoc)		

1. Based on details in Welch & Trotter (1961), pp. 131-133.
2. Only the furthest downstream locality for each terrace is given, as being the nearest to the Usk confluence.
3. The range of height at which the terrace is developed in the Chepstow/Newport area; or at the single locality upstream of Chepstow. Does not refer to the single locality noted in column two. Based on height measurements given in Welch and Trotter (1961, 132-135).
4. Height range from Wills (1938, 187-188); height not given in Memoir.
5. Author's height ranges.
6. Stage names adopted by author (p. 387).

CHAPTER 12.

THE BURIED CHANNEL AND SUPERFICIAL DEPOSITS OF THE LOWER USK.

1. INTRODUCTION.

It has long been known that the Usk, like all the major rivers of South Wales, has its rock-cut valley buried at depth at the mouth (Codrington 1898; Strahan 1899, 85; Anderson 1960, 40). In recent years a number of major engineering projects have been carried out in the Newport area, all requiring extensive site exploration. The opportunity has arisen, therefore, to examine the nature of the rock surface beneath the superficial deposits, and to note some of the characteristics of the deposits themselves. Recent boreholes have been examined from the sites of the Spencer Works, (Llanwern); Uskmouth A and B Power Stations; the Newport By-Pass Road; the George Street Bridge; and the Newport Main Drainage Scheme; as well as borehole logs of varying age relating to improvement schemes for Newport Docks. Upstream of Newport shallow borehole data is available for sites at Great

Bulmore, near Caerleon, and Llantrisant (fig.38), whilst in the Ebbw Valley, confluent with the Usk at Newport, borehole information has been obtained from the site of the Rogerstone Power Station.*

2. THE FORM OF THE SUB-DRIFT SURFACE.

Fig.39 shows the form of the solid rock surface in the Newport area, with rock head contours drawn at intervals of ten feet below Ordnance Datum. These have been interpolated from an uneven scatter of borehole records, and are most accurate in the vicinity of the engineering sites listed above. Absence of deep borehole data for the western part of Newport prevented the extension of this map to include the lower reaches of the Ebbw Valley.

The narrowest part of the present valley is at the confluence of the Malpas Brook with the Usk, the valley widening southwards until the alluvial flats of the levels are reached. Fig.39 indicates that the buried channel is narrowest in the same area, widening as the Severn is approached, but that a distinct valley form is continued south under the levels, where the Usk today meanders in an area of limited relief.

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* For details of sources of borehole information, see Appendix III.

In three places a line of closely spaced boreholes had been put down crossing the valley, and sections drawn along these lines are reproduced in fig.40. The location of these sections, and the boreholes used in the study, are shown in fig.41. Some of the bores used in the construction of section C, and one in section A, did not reach bedrock. In the latter case, it is probable that the deepest part of the buried valley is proved by bores on the west side of the river. In section C, the marl is reached at less than -40 ft.O.D. in two bores west of the river, but only one bore reaches the marl to the east of the river, at a depth of just over -65 ft.O.D. As the bores east of the river were driven to greater depths than those in the Docks area to the west, it seems certain that the buried channel lay to the east of the present river mouth.

The deepest proved points of the buried channel are therefore -31 ft.O.D. near Malpas, -40 ft. at the George Street Bridge, and -65 ft. near the present river mouth. Due to the spacing of the boresfrom which these sections have been constructed, an exact statement of the gradient of the buried valley is not possible, it being conceivable that the rock floor dips a further ten feet or more between certain bores. This is least likely in the case of section B, where the borehole spacing is closest, and the buried valley is not likely to be much deeper than -40 ft.O.D. at this point. In the case of section C, a minimum depth of -65 feet is proved, and the gradient of the channel between these two sections can be estimated as at least 10 feet per mile, and may possibly be more. This is considerably greater than the present gradient of the Usk in its lowest reach.

The upstream extension of the buried channel beyond the Newport area is difficult to determine, owing to lack of borehole data, although a series of shallow bores carried out for the Newport and South Monmouthshire Water Board provides some information. Bores at Great Bulmore (fig.36) were stopped at -16 ft. O.D. before they had penetrated the marl, showing a thickness of superficial deposits in excess of 36 feet. At Llantrisant, eleven miles from the river mouth, two of four bores reached marl (at approximately 11 and 19 ft. above O.D.), and a superficial thickness varying between 17 and 25 ft. was proved. The buried channel of the river rises to Ordnance Datum somewhere in the reach between these places. It is difficult to say where the buried channel merges with the valley floor associated with the present flood plain, due to glacial modification beyond Usk (Charlesworth, 1929). One mile south of Abergavenny, for example, on the site of the crossing of the Usk of the new "Heads of the Valleys Road," bores probed 50 ft. of superficial deposits beneath the flood plain at one place without reaching bedrock. It is certain that this local overdeepening and subsequent infilling is due to localised glacial scour, and is not related to the overdeepening proved by the buried valley at the river mouth.

At Rogerstone in the Ebbw Valley, site investigations showed that the flood plain (between 100 and 112 ft.O.D.) is underlain by superficial deposits varying from 20 to 56 feet in thickness. The present thalweg of the Ebbw shows a much steeper gradient than that of the Usk, and it is likely that the buried valley rises above Ordnance Datum in the Bassaleg area (fig.38).

East of the Usk the detailed form of the rock floor is known for a part of the Caldicot Level as a result of site investigations for the Spencer Works at Llanwern. The surface of the alluvium over the works' site varies between 15 and 19 feet above O.D. Below this, over almost the whole of the area (in places along its northern boundary the surface is beginning to rise towards the hills) the superficial deposits are underlain by an undulating platform between approximately 8 and 21 feet below O.D.

Comparison with other rivers of the area.

A map showing the form of the sub-drift surface in the Cardiff area has been produced by Anderson and Blundell (1965, fig.2). The three rivers entering the Channel there, the Rhymney, Taff and Ely, have maximum proved buried channel depths of 28, 42 and 38 feet below O.D. respectively, and it is deduced that the rock floors reach -50 ft.O.D. under the existing river mouths. Maximum proved depths for the buried channels of other South Wales rivers are -56ft.O.D. for the Wye at Chepstow (Anderson, 1960) and at least -200 ft. for the Tawe at Swansea (O.T.Jones quoted in Godwin, 1943, 221). In the latter case, however, glacial erosion has almost certainly been a contributory factor. On the south side of the Channel a depth of -65ft.O.D. has been proved in the mouth of the Bristol Avon (Hawkins, 1962, 370), whilst in the combined Torridge and Taw estuary, the bedrock lies at approximately -100 ft.O.D. (McFarlane, 1955, 426). The buried channel of the Severn itself descends from -19 ft. at Gloucester to -47 ft.O.D. at Severn (railway) Bridge, and -73 ft. at the Severn Tunnel. Although Hawkins (1962, 372) refers to the buried channel of the Severn descending to -110 ft. at the Shoots, it has elsewhere been pointed out (Beckinsale and Richardson, 1964, 103) that this depth occurs in a hollow in the river bed, probably due to tidal pot holing, and is not necessarily related to a low sea level. Proved depths for the Usk are thus consistent with those for the other rivers in the area. North (1955, 91) has shown how the present day rivers are continued off their mouths by depressions in the sea bed, and from examination of the submarine topography, Anderson and Blundell (1965, 373) suggest a former confluence of the Taff and Severn, five and a half miles south of Penarth at a depth of about 100 feet below the present sea level. On this basis, it seems likely that the Usk joined the Severn six miles south south west of its present mouth, probably at a depth approaching -100 ft.O.D.

A point of interest is the relatively steep gradient of the buried channel of the Usk. Beckinsale and Richardson (1964, 96) estimate the gradient of the Severn buried channel at Severn Tunnel at 1.8 feet per mile, referring to the "remarkable" gradient of the Bristol Avon (4ft. per mile). A similar gradient to that of the Usk can, however, be calculated for the Taff, from the sketch map of the sub-drift surface produced by Anderson and Blundell (1965) whilst that of the Rhymney can be seen to have a considerably steeper gradient.

Beckinsale and Richardson (1964, 97) suggest that the sub-drift surface in the Severn Tunnel area is an "aggraded trough.......about seven miles wide and has an undulating, or channel-seamed rock floor covered with patches of gravels and deep deposits of silt". The deeper channel of the buried valley is cut below this. Part of this was cut by the Severn prior to the deposition of the gravels of the Worcester terrace, and its level is reported to vary between -20 and -40 feet O.D. at the eastern end of the Tunnel (Leese and Vernon, 1960; Morgan, 1887). Downstream, at Avonmouth (Welsh and Trotter, 1961, 136), three bores put down by the N.C.B. encountered bedrock surfaces at 30, 35, and 51 feet (the last is probably in the buried channel of the Avon and may be discounted). In the Newport area, there is an indication of a surface at a similar depth in the Docks area, but a surface at less than 20 feet below O.D. to the east of the river, and continuing eastwards through the Llanwern site, seems more significant. This has been identified in the Cardiff area by Anderson and Blundell (1965, 372-373) who refer to it as "a gently undulating sub-sea level rock platform which extends north-eastwards under thick superficial deposits to the eastern edge of the District (and onwards to beyond Newport)". The height of this surface does not seem to fit in with the Severn terrace sequence (p.395), as the Main Terrace rock base is at about 10 feet above O.D. at the Severn Tunnel (Wills, 1938, 227), while the next lower, Worcester Terrace, has a rock platform at "-25 feet or possibly lower" at the Tunnel (Wills, 1938, 228). Further, the location of the platform in the Llanwern area to the north of the Keuper inlier at Goldcliff would also seem to strengthen the conclusion that this is not part of the basal rock surface of the Worcester terrace, as it is difficult to understand how the inlier, an isolated hill of weakly resistant rock, could maintain itself in the centre of the flood plain of a vigorously eroding river.

An alternative solution is to consider this feature a platform of marine erosion. When examined in relation to the solid rock form of the estuary (fig.42), the section between Portskewett and the Usk is unusual in several respects. It shows an unusual swing in an east-west direction, and in outline is remarkably straight, compared with the solid rock margin on the south side of the estuary, which is particularly ragged. This regularity of form can be seen to be an erosional feature, for if examined in detail, the spurs overlooking Caldicot Level are seen to have blunted ends. The suggestion that this is an old cliff line has been made by Steers (1948, 198). Fig.42 shows that this stretch of the north shore of the estuary faces the longest possible stretch of open water in the Channel - between Lavernock Point and

Brean Down - and thus waves reaching it when the levels were under tidal water would have the greatest possible fetch, and thus be strongest in an otherwise confined estuary. If we accept this suggestion, the channel of the Severn during the Worcester terrace phase is likely to have been on the south side of the Goldcliff inlier, which formed an island at a later stage as a result of rising sea level.

Conclusion.

The buried channel of the Usk descends from O.D. in the stretch between Llantrisant and Bulmore to at least 65 feet below O.D. near the present river mouth. This compares with buried channel depths proved for other rivers of the area, and suggests a confluence with the Severn towards the south side of the present estuary at a depth of nearly 100 feet below O.D. The undulating, sub-drift surface of the Llanwern area appears to be the continuation of a similar surface proved in the Cardiff area (Anderson and Blundell, 1965), and does not accord with rock surface levels suggested for the Severn terrace sequence, although erosion at the Worcester terrace stage may account for a surface in the Docks area. It is suggested that the Llanwern planation may be the result of a relatively late phase of marine erosion.

3. THE SUPERFICIAL DEPOSITS.

The three sections reproduced in fig.38 outline the major changes which occur in the character of the superficial deposits overlying the rock floor. The detail of the deposits shown in these sections has been considerably simplified from that contained in the borehole logs, which usually contain details of the changing composition and strength of the strata through which the bore passes, not all of which is of significance when an overall picture is required. In the sections, the indication of the limits of the deposits between the bores is conjectural, and although the spacing of the bores is on average only 200-300 feet apart, where the spacing is much wider (especially between bores 62 and 40 in Section C), there is considerable scope for variation. Some reassurance of the general validity of the sections is given by the concurrence of the main types of deposits at similar or expected levels in the majority of bores.

Examination of these sections, and other borehole logs, reveals the presence of two main types of deposits: a thick and extensive layer of clay, which tends to be silty in composition, overlying a variable thickness of sands and gravels. The latter deposit is generally found resting on the local rock of the buried valley floor. In addition there are small lenses of other deposits, of which part is of sufficient interest to be considered separately.

a) The sand and gravel layer.

The sand and gravel layer is persistent over the whole area. In general, it is seen to thicken as traced downstream, and to thin towards the valley sides. The three sections (fig.40) are fairly representative, and the thickness of the sand and gravel layer increases from a maximum of 20 feet in section A, to 26 feet in section B, and 40 feet in section C. In the latter, it is likely that even greater thicknesses underlie the two deep bores which did not reach bedrock. The continuation of this layer can be seen by reference to other bores. Borehole 48 on the east side of the river (near the Odeon Cinema, Grid.ref.ST/316,887) between sections A and B, can be taken as representative:

Ground level : 26.8 ft.O.D.

Made ground	19.8
Soft to firm brown and grey mottled, fissured, clay	8.8
Soft grey fissured clay	4.3
Grey brown clayey silt	-2.2
Grey brown sandy silt	-11.2
Grey brown clay with traces of peat and occasional pockets of sand	-19.8
Grey silty sand and gravel with occasional boulders	-25.7
Red brown silty sand and gravel with occasional boulders	-38.7
Firm to stiff red and grey fissured marl (penetrated)	-40.2

(Figures give the height of the base of the deposit and are related to Ordnance Datum).

A noticeable feature of many of the logs is the progressively sandier nature of the deposits above the main sand and gravel layer as that layer is approached. In addition, many of the logs record boulders and other large grade material near the base of the sand and gravel layer (as in the log detailed above). Borehole 10 (section A) records "firm grey silty boulder clay" resting on the rock floor.

The presence of this gravel bed has been noted previously. Strahan (1898, 86) referred to "a similar gravel, perhaps continuous and contemporaneous with that of the terrace (at Coedkernew), underlies the alluvial and at a lower level by about 50 to 70 feet". Engineers working on various improvement schemes at Newport Docks were also aware of this gravel bed and its properties, and it is apparently for this reason that the majority of bores put down in the Docks were not driven as far as the marl.

Upstream at Great Bulmore, beneath clays and silt, a bed of well graded gravel with traces of sandy silt was reached at 21 feet (-1 ft.O.D.), whilst at Llantrisant an extensive bed of sand and "ballast" underlies the flood plain (C.36 ft.O.D.) at depths ranging from three to sixteen feet. The gravels at Llantrisant reach a depth of 25 feet below the surface at one place, indicating that aggradation due to positive movement of base level, and not merely flood plain aggradation, has been operative here. A similar picture emerges from an examination of the Rogerstone borehole data in the Ebbw Valley. Here gravel, generally of a coarser grade than in the Usk and with many boulders, underlies the alluvium. Surface layers tend to be sandy. The deposit varies between 19 and 54 feet in thickness.

East of the Usk, although a sand and gravel bed is present under the Spencer works site, it is noticeably thinner than at the mouth of the river. It appears to feather out as traced eastwards, with a slight thickening of the deposit at the mouth of the small valley opening onto the levels at Llanwern village. In general, the bed rarely exceeds ten feet in thickness, and gravels are subordinate to peat beds which are extensive and persistent near the surface.

As the borehole data became increasingly familiar it became evident that the surface of the sand and gravel bed was at its lowest point near the valley centre, and it seemed possible that this might also show a buried valley form. In order to determine this, the level of the top of the sand and gravel layer was plotted for all those bores where details of the deposits had been noted, and the result is shown in fig.43. This reveals that the layer is trenched by a valley form, although this is much narrower than that shown by the rock head contours (fig.39). It lies along approximately the same line as the deeper valley, but it is displaced slightly westwards in the Docks area, where the unexpected bend in the rock-cut valley is reflected, in a more exaggerated form, in the shallow valley of the gravel surface. The latter is clearly indicative of renewed downcutting after deposition of the gravels.

Comparison with other rivers of the area.

Similar gravels have been reported in the Cardiff area by Strahan and Cantrill, 1912, 74), and in the Bristol Avon by Donovan (1960, 60), where a deposit of sand and gravel resting on bedrock reaches a maximum proved thickness of 16 feet (at Keynsham). At Avonmouth, thicknesses of up to 30 feet of gravel have been recorded (Welch & Trotter, 1961, 136), and similar gravels are present at the eastern end of the Severn Tunnel (Morgan 1887). The Severn Tunnel gravels were tentatively identified by Mills (1938, 228) as part of the Worcester Terrace, which sinks below the flood plain between Tewkesbury and Gloucester. This correlation is endorsed by Beckinsale and Richardson, who further suggest that gravels filling the lowest part of the buried valley belong to the Power Station Terrace, buried south of Worcester. Power Station Terrace gravels appear to have been removed in the lower reaches of the Severn by a later phase of downcutting. This is not the case with the Usk, where the gravel fill in the buried channel remains at the river mouth, and the gravel deposit appears to form a fairly continuous sheet over a wide area. It is tempting to correlate the lowest gravels in the Usk with the Power Station Terrace gravels of the Severn, as they occupy a comparable position, and their surface is trenched by a subsequent phase of down-cutting. If so, they appear to merge laterally with higher gravels (in the Docks area) which, on height considerations, could be tentatively correlated with the Worcester Terrace gravels of the Severn.

A similar basal sand and gravel in the Tawe valley at Swansea has shelly detritus mixed with it, suggesting a marine or brackish water origin, although much of the gravel could be shown to be derived from glacial drift (George and Griffiths, 1938, 67).

The failure of the most recent phase of downcutting in the area to remove these gravels from the buried channel at the river mouth, as in the Severn, could be related to the proximity of the ice front in the Usk (leading to the accumulation of a relatively greater thickness of gravels), or to more effective tidal scour within the Severn in past periods of low sea level, as at the present time.

A tentative correlation with the Severn gravels has been suggested, although the origin remains uncertain. In the Bristol Avon, which did not have significant ice accumulation within its basin during the Pleistocene, Donovan (1960, 64) has suggested that similar gravels might be the product of increased river volume due to an incomplete soil cover (leading to greater run-off) and periodic concentrations of discharge such as would be the case with a spring melt during a cold period. In the Usk, the gravels could be part of a valley train of outwash deposits buried by the subsequent rise of sea level. Even so, a correlation with the Severn is not ruled out for the dominating factors influencing the development of both valleys would be the variation in the amount of meltwater (and load supplied to the rivers), and the fluctuation of sea level. The main contrast could be expected in the nature of the gravels. In the Severn, a high degree of rounding and generally smaller grade material can be expected, the ice during the Last Glaciation only entering the upper part of the drainage basin. Detailed examination of the Usk gravels might reveal contrasts in this respect.

b) Other Superficial Deposits.

The most important constituent of the superficial deposits is clay, usually of a silty nature, and with frequent organic inclusions. The clays were shown by Sollas (1883) to be of partly marine and partly riverside origin, although the abundance of marine diatoms found in the clays at Llanwern (Godwin and Willis, 1964, 128) was considered to prove marine origin. These are to be found near the surface almost everywhere, although they are broken up in the levels by an extensive peat bed. Generally, however, the peat is found in pockets, and apart from in the Llanwern area, no extensive deposits were encountered. These peat inclusions indicate an intermittently rising sea level. Due to the large tidal range of the Bristol Channel, peat is considered to require an elevation of at least 20 feet above mean sea level before accumulation would take place (North, 1955, 69), and it may have accumulated at a level considerably in excess of this.

In the Llanwern area, the deepest occurrence of peat is, as noted by Anderson (1960, 41), 14 feet below O.D., although it is not extensive at this level. The main accumulation of peat is not far below the surface, separated from the sand and gravel layer by clays and silts. It reaches 14 feet thick in places, although the average is about 9 feet, with its base varying from three feet below O.D. to ten feet above. A four foot thickness of peat was discovered in borehole 40 in the Nash area at approximately this level.

In the Docks area a considerable number of peat beds and organic inclusions were recorded in bores. These were plotted on a height dispersion diagram (fig. 44). This reveals that organic deposits are to be found at practically all levels above the sand and gravel layer, although the immediate surface layers are usually free of such inclusions. If records of peat are considered separately, an above-average occurrence at between five and ten feet above O.D. becomes apparent. Godwin (1940, 320) has commented on the tendency for peat beds in the Bristol Channel area to occur at +8 feet or +10 feet, and just below O.D., whilst Beckinsale and Richardson (1964, 98) note three main levels of peat accumulation in the lower Severn (-47 to -40 feet, -8 to +8 feet, and 10 to 15 feet O.D.). Thus the upper level of Godwin, corresponding to the middle level of Beckinsale and Richardson, is clearly represented, but there is no equivalent in the Uskmouth area of the 10 to 15 feet level of the lower Severn.

In the Docks, bores put down in close proximity to those recording peat often did not encounter any, suggesting that the spasmodic occurrence of peat near the river mouth may be due to partial removal of the beds by river erosion, and it is noticeable that, when peat beds are not recorded, an 'organic content' is often noted in the clays and silts.

The deepest record of peat for the Newport area previously published is 31 feet below O.D. (Anderson, 1960, 41).

A recent site investigation in connection with the proposed dredging of the Dock entrance channel has revealed a peat bed considerably below this. Bores were put down in five places from a vessel in the Channel near the river mouth (fig. 41 , boreholes 89-93). Two encountered organic deposits. One (91) brought up fragments of roots from -47 feet O.D., whilst the other (90) encountered a six-inch bed of "soft peat" with its base at -50.6 feet O.D. None of these bores located bedrock. This is the deepest record of peat in the Channel east of Port Talbot (Godwin and Willis, 1964, 124), although peat between 40 and 47 feet below O.D. was recorded at the Severn (railway) Bridge, just north of Sharpness (Beckinsale and Richardson, 1964, 98). This is the lowest level of peat accumulation recognised in the lower Severn. It suggests accumulation when the sea level was at least 70 feet lower than the present.

Dating of the peats.

Dating of peat deposits, either by pollen analysis, or by radiocarbon methods, has been carried out on some of the Bristol Channel deposits, and may, for comparison, be considered here.

Pollen analysis of the Swansea peat deposits (Godwin, 1940) has revealed that the lowest may be ascribed to pollen zones IV - VIb, those above O.D. being placed in zones VII - VIII. The depths of the Swansea beds, and the pollen zones to which each has been ascribed by Godwin, are shown to the right of fig. 44. The lowest published record of peat for the Channel area comes from Baglan, near Port Talbot (5 foot bed resting on dense rounded gravel at -64.6 feet O.D.) and that and a peat from a similar level (20 cm. thick resting on similar gravels at -63.1 feet O.D.) has been pollen-analysed and radiocarbon dated at Cambridge (Godwin and Willis, 1964, 123-125). Radiocarbon dating of two samples of the former gave 11,260 years B.P., ± 170 and 11,980, ± 180, which suggested formation during the Allerod, a conclusion that was supported by the pollen analysis. Dates for samples taken at various levels within the other peat bed ranged from 10,350 (± 170) to 8,970 (± 160) years B.P., which supports pollen analysis findings (opening of zone IV into zone VI).

Nearer, the Usk, a peat deposit between +12.5 and -0.5 feet O.D. at the East Moors, Cardiff, was analysed by Hyde (1936), and Godwin (1940, 319) suggests that this may be placed in the latter part of zone VII, and early VIII. A sample of the Llanwern peats was recently radiocarbon dated at Cambridge (Godwin and Willis, 1964, 128) giving a date of 2,660 years B.P. (± 110), which places it late in zone VIII (Flint, 1957, Table 230, p.397). The position of this peat deposit is shown in fig. 44.

More extensive work on the peats of the Somerset Levels (Godwin, 1960, and Kidson, 1964) suggests that the Flandrian transgression commenced about 8,000 B.P. (zone VI) and ceased late in zone VIIa (ca. 6,000 years B.P.), the upper peats accumulating during the Neolithic and Bronze Ages, there being a further marine transgression in Romano-British times. The Llanwern dating agrees with this conclusion.

It is likely, therefore, that the peats found above Ordnance Datum in the Newport and Llanwern areas are of zones late VII and VIII. The deeper peats may range from zone II to zone VI.

Conclusion.

An extensive gravel sheet forms the base of the superficial deposits in the Newport area. Plotting of the surface levels revealed trenching broadly along the line of the buried channel, indicative of renewed downcutting following a major phase of aggradation. A similar episode is evident in the lower Severn. Direct correlation with the Severn terrace gravels is, however, not possible, although attitude and relationship to the late phase of downcutting suggests that the lowest may be the equivalent of the Power Station Gravels of the Severn, the higher gravels of the Docks then being equated with the Worcester Terrace. The proximity of the 'Newer Drift' ice maximum in the Usk is almost certainly responsible for contrasts revealed between the Usk and Severn. The silty clays overlying the gravel bed have frequent organic inclusions, although the marked zonation noted in the lower Severn peats was not evident. Peats noted above O.D. can be taken to post-date the Flandrian transgression, and in the Llanwern area these clearly separate an upper and lower marine clay (Godwin and Willis, 1964, 128), the latter probably dating from the Flandrian transgression, the former being Romano-British in age. In the Uskmouth area this distinction is not obvious, which it is suggested is due to erosional phases of the river having disturbed the sedimentary record.

4. FORMATION OF THE BURIED CHANNEL AND SUPERFICIAL DEPOSITS: GENERAL CORRELATION WITH THE SEVERN SEQUENCE.

a) The Severn Sequence.

Comparisons have already been drawn with the rock base and superficial deposits of the lower Severn. An attempt will be made to sketch the general sequence of events based on findings in the Usk, but with reference to the sequence worked out for the Severn valley by Wills (1938). Wills's findings have been confirmed by later workers, and a review of present knowledge of Pleistocene events in the Midlands has been given by Tomlinson (1963). The summary and analysis of recent work on the deposits and sub-drift form of the lower Severn by Beckinsale and Richardson (1964) is of particular value.

The special circumstances which have governed the development of the lower Severn might first be outlined.

The Severn catchment was considerably enlarged by the cutting of the Ironbridge overflow of Glacial Lake Lapworth, and the diversion into it of a major part of the former Dee drainage. Vigorous downcutting took place in the new middle reach, so that terraces are steeply inclined northwards as traced towards the Ironbridge Gorge, whereas downstream the lower ones sink beneath the alluvium of the present flood plain. The three lowest, already mentioned, are of most interest to us. The Main terrace, the first to be formed after the cutting of the Ironbridge overflow appears to be related to an early stage of the retreat of the Main Irish Sea Glaciation of the Cheshire Basin, and a C 14 dating has given it an age of between 38,000 and 42,000 years B.P. (Early Wurm), (Coope, Shotton & Strahan, 1961). This terrace, 105 feet above the flood plain at Bridgnorth, has declined to only ten feet above it at Woolaston, near Chepstow. The succeeding Worcester Terrace sinks beneath the flood plain between Tewkesbury and Gloucester, whilst the lowest, Power Station Terrace, merges with the alluvium south of Worcester. Both have been tentatively associated with ice advances in the upper Severn: the

Elleemore (Little Welsh) and Llay re-advances, respectively. Where these terraces lie below the present alluvium, their relations can only be determined from borehole evidence, and the picture is somewhat obscure. The tentative relationship suggested by Beckinsale and Richardson is, however, shown in fig. 45. The rock platform at the base of the Worcester terrace aggradation is of considerable width, and the deepest part of the buried channel, showing a narrow cross-profile, is incised below it. The cutting of this is considered to post-date the Worcester Terrace aggradation (Beckinsale and Richardson, 1964, 96). A final phase of downcutting has removed the Power Station Terrace gravels from the river mouth, and trenched their surface upstream as far as Worcester.

b) The buried channel.

The cutting of the buried channel is therefore considered to considerably post-date the last glacial maximum in southern Britain. In the Cardiff area, Anderson and Blundell envisage a similar sequence, the rivers eroding wide valleys in rock to at least -25 feet O.D. during the glacial epoch (or perhaps before), and a post glacial excavation of the deepest channel down to about -50 feet.

This dating of the cutting of the deepest part of the buried channel is supported by the work of Fairbridge (1961), who finds evidence for a Main Wurm sea level fall of 100 metres between 30,000 and 17,000 years B.P. Moreover, this low sea level appears to be lower than any that preceded it, the evidence suggesting a progressive fall in sea level during the Pleistocene independent of oscillations resulting from the expansion and waning of masses. A sea level of -55 metres is suggested for the Riss, and a level intermediate between this and the Main Wurm level for the Early Wurm.

There are conflicting views. Donovan (1962) produces evidence, based on a marine cut bench and overlying head deposits near Weston-super-Mare for a Last Glaciation (Wurm) sea level not much more than a few metres above or below present level. In the Teifi valley, the fill of the buried valley at its mouth is predominantly boulder clay (Allen, 1960, 280), which suggests formation during or before the last glaciation of the area: Allen refers to this as the "pre-glacial valley". Seismic refraction surveys show that it descends from -30 feet O.D. at Cenarth to -107 at its mouth (Allen, 1960, Francis, 1964).

It seems probable that a two-phase cutting of the buried channels is an oversimplification, and that their present form is composite, and related to a series of low sea levels (although the Main Wurm lowering might have been the most significant). The youth of the Severn as a major river might account for the strong evidence for a unitary cutting of its lowest channel at a late stage in the Wurm.

c. Terrace Gravel correlations.

Although the actuality of the Ellesmere and Llay readvance phases in the Cheshire Basin has been challenged (Poole and Whiteman, 1960), a correlation of the lower terraces in the Severn with these has been suggested. In the Usk, re-advance stages of the Last glaciation have not been positively identified. Further, it is impossible to identify terrace stages to the south of the 'Newer Drift' ice margin which post-date it. This is because the ice penetrated so far down valley that it entered the zone in which post-glacial aggradation has been dominant. Thus, its own outwash deposits can be traced disappearing beneath flood plain deposits only a few miles downstream of the former ice front at Kemeys

Commander (fig. 38). This problem was not encountered in the lower Severn because in the Last Glaciation ice did not penetrate into the lower valley, and also because the downcutting of its middle reach has enabled clear altitudinal differentiation of the terraces. Even if more adequate borehole evidence were available for the Usk above Newport, it is suggested that clear stages in the evolution of the valley would not be apparent. Thus, sub-alluvial aggradation stages, as in the Severn, cannot be positively identified for the Usk, although on grounds of location and surface form, those gravels occupying the lowest part of the buried channel have been tentatively correlated with the Power Station Terrace gravels of the Severn, and those higher lying, but co-terminous, gravels flanking them with the older Worcester Terrace.

d) The clay and peat infill.

Deposits overlying the basal sand and gravel layers are broadly similar to those described from other parts of the Bristol Channel and lower Severn, although peat beds are found at a much greater range of depth than elsewhere, and the three levels of maximum peat accumulation noted in other parts of the area were not evident.

This is attributed in part to erosional activity by the Usk, perhaps indicating the intermittent nature of the sea level rise.

The majority of the peat deposits lying above Ordnace Datum are considered to post-date the Flandrian transgression and may probably, by comparison with findings elsewhere, be ascribed mainly to pollen zones VII - VIII (Atlantic/Sub-Boreal). The deepest peats are likely to be earlier than zone VI. Peats at a slightly greater depth at Port Talbot have been shown to have begun accumulating in zone II. The lowest peat in the Uskmouth area (-50.6 feet O.D.) suggests accumulation when sea level was at least 70 feet below that of the present.

(e) Correlations.

The following tentative correlation may be suggested between the lower Usk and Severn (Table 14):

TABLE 14

CORRELATION OF EVENTS IN THE LOWER SEVERN AND USK

USK	SEVERN (After Beckinsale & Richardson, 1964)	
Aggradation with intermittently rising sea level. Periods of still-stand marked by peat accumulation; accelerated sea level rise by clay deposition, with perhaps marine planation & cliffing (Llanwern area)	Aggradation. Three main halt phases in the rise of sea level are indicated by peat horizons.	FLANDRIAN
Trenching of gravels.	Post Power Station Terrace incision	WEICHSELIAN
Aggradation (lowest gravels)	Power Station Terrace aggradation.	
(re-?) excavation of the deepest channel.	Post-Worcester Terrace incision	
Docks gravels?	Worcester Terrace aggradation	
Incision	Pre-Worcester Terrace incision	
Gravel aggradation (Buried)	Main Terrace aggradation.	

CHAPTER 13

CONCLUSION AND PROPOSED CHRONOLOGY

In this final Chapter it is proposed first to discuss the major environmental changes in the Usk suggested by the morphological evidence with which this work has been largely concerned, and then to consider this sequence in the light of chronologies worked out for adjacent areas, as outlined in Chapter 6.

(a) SEQUENCE OF ENVIRONMENTAL CHANGES.

The oldest for which evidence exists will be considered first: 1. Oldest glacial episode. In Chapter 7, it was shown that the present relief and drainage pattern of the Upper and Middle Usk could be most effectively explained by invoking erosion by transfluent ice from a basin impeded ice outflow in the region now occupied by the Llangorse Basin and part of the Upper Usk. The antiquity of this episode is proved by the absence of associated drift topography, although ice eroded forms relating to such transfluent ice movement can be demonstrated. The character of the landscape modification effected by this glacial episode suggests that evidence of it would either be lacking or this in the area downstream of the newly developed ice-breached watershed, and this is largely true. Examination of the triburaries of the middle Usk suggest, however, evidence of a former stage when the main valley was considerably shallower than today, and it is possible that this was developed initially during this early glacial episode. Moreover, at Llanellen, where the valley is about to loose its identity amongst the low hill masses of the Vale of Gwent, a marked benching of the valley side was mapped (Chapter 8 a) which could be most satisfactorily explained by glacial erosion of the upper segment (i.e. above the bench), resulting in spur truncation followed later by deepening, but not commensurate widening, of the valley. These features of the Middle Usk can be most satisfactorily linked with an ancient period of glacial activity which has earlier been referred to as the 'Upper Usk Maximum Glaciation'. They suggest that the valley system at that time was considerably shallower than at present - by at least 150-200 feet - at the end of this period. The landscape modification postulated is quite considerable, and it is quite likely that more than one glacial episode is invloved, but the evidence for this is lacking.

The interfluve cappings of glacial gravels in the lower Afon Lwyd, and between the Henllys Brook and the lower Ebbw valley near Rogerstone (fig. 29) must also be assigned to this glacial phase, on account of their location relative to present valley form, and in the case of the latter deposit, to the more recent drift spread in the Ebbw valley. They survive here, whereas similar deposits have not been identified in the lower Usk, because they lie beyond the territory invaded by later ice advances. Evidence of a similar, more extensive advance down the Usk has not been observed, presumably on account of the late development of the Middle Usk transfluent ice route, which might have occured after the maximum of the early glacial stage.

2. <u>Fluvial activity: the terrace of the lower Usk.</u>

The relationship between river terrace formation and glacial and interglacial stages has never been satisfactorily demonstrated. It is clearly complex, and especially confused in regions such as the lower Usk, where outwash was being released at one time from ice in relative proximity to the river mouth. Zeuner (1957, 49) has suggested that terrace gravel accumulation would be at a maximum at the beginning and end of the glacial episode, when refrigeration would be sufficient to produce large quantities of waste frost weathering, whilst fluvial activity during the warmer part of the year would be adequate to distribute this material along the valley. During the interglacial episodes, erosion, and thus terrace formation, would dominate. Whilst restating this idea, Charlesworth (1957, 1026) refers more specifically to rivers, the upper reaches of which formerly drained extra-glacial areas, whilst the lower reaches were affected by eustatic sea level movements. He suggests that these rivers would develop climatic river terraces above the nick-point, below which thalassostatic terraces would dominate. The interplay of these factors has complicated the interpretation of the terrace sequence of the lower Thames. There, Zeuner (1977, 356-62) plotted the heights of the erosional benches as revealed in boreholes, which he considered to record low sea levels, terrace deposits being related to aggradational phases and thus high sea levels. He pointed out that if the nickpoint migrating headwards as a result of negative sea level movement was not submerged by the following (interglacial) high sea level, it would continue during the interglacial to migrate headwards, continuing downcutting along the river. In the Severn drainage basin factors of this sort must be taken into consideration when discussing the terraces, which have been shown by Wills and Tomlinson to be successively lower in height in both glacial and interglacial phases.

In the Usk, the terraces cut into the valley side above the aggradational fill between Llangybi and Newport record halt stages in a major phase of erosional activity which can be seen to antedate the deposition of both low-level drift deposits in the Vale of Gwent (this can easily be demonstrated from the position of these drifts relative to the present valley floor). If it is accepted that the Upper Usk Maximum Glaciation and the glaciations represented by the Vale of Gwent drifts were seperated by at least an interglacial (and the alternative would would not seem to be tenable), the major incision of the lower Usk could be assigned to this interglacial. In the Severn, the Bushley Green Terrace, to which we have equated (Table 13) the most extensive and best preserved terrace in the lower Usk, the Tredunnock Terrace, is considered to have formed during the retreat stages of the Penultimate (Gipping) Glaciation (Tomlinson, 1963, 194), the incision between this and the succeeding Kidderminster Terrace being attributed to massive erosion during the "Great Interglacial" which has "almost given the appearance of an unglaciated area to the greater part of the Middle Severn Basin" (Wills, 1938). It is worth noting that the most significant phase of incision recorded in the lower Usk succeeds the Tredunnock Stage. It is suggested that this terrace was laid down at the close of the Upper Usk Maximum Glaciation, the major erosional phase following being ascribed to the interglacial preceding the Vale of Gwent Maximum Glaciation. The poorly preserved St Julian's stage and the more extensive Caerleon Stage probably record changing conditions during this interglacial, the Caerleon Stage being correlated with the Kidddrminster Terrace of the Severn (Table 13), which is considered (Tomlinson, 1963) to have formed during the Last (Ipswichian) Interglacial.

In the Middle Usk, fluvial deepening of the valleys is likely to have occured also at this time. Thus the valleys which were not heavily ice scoured during the later glacial advances show polycyclic valley forms, whilst deep scouring of the main valley (e.g. in the Abergavenny area, as recorded by borehole logs) was probably assisted by fluvial deepening during this interglacial.

3. The Vale of Gwent Maximum Glaciation. The evidence for this phase is found at present wholly within the Vale of Gwent beyond the limit of the succeeding ice advance. The evidence so far produced is not considerable, but the writer has no doubt as to the reality of this drift, and further work in the area will probably justify this statement. The position of these

drift finds so low in the valley suggests that their deposition cannot have been separated from the present by an interglacial episode, whilst their lack of morphological expression distinguishes them from thick, more recent drift deposits spread in a piedmont lobe in the northern half of the Vale. It is suggested, therefore, that they are separated from this later glacial advance by an interstadial, and not by a full interglacial.

During the Vale of Gwent Maximum, the main thrust of the ice appears to have been down the Usk, evidence of this advance being lacking from the upper Olway valley, which was invaded by ice during the final glacial episode. The low clayey terrace developed on the west bank of the Usk between Llanbadoc and Llangybi was probably developed during the wasting stages of this ice advance, as it rises above the level of the present flood plain and the buried outwash deposits which have been associated with the final stand of the succeeding ice advance at Kemeys Commander.

4. <u>The Last Glacial Advance</u>. The deposits related to this ice advance have been described by several writers,

and the extent of the terrain covered at this period can generally be easily demonstrated. Most of the drift features of the Vale of Gwent and the Usk valley above Abergavenny are deglaciation phenomena related to the wasting of this final glacial advance. These have been discussed in detail in Chapters 7 and 8, and the character of the ice withdrawal has been outlined in Chapter 10. In magnitude this advance was only slightly less than the preceding one, although the direction of the advance in the Vale was more variable, and invasion of the upper Olway valley, with associated drainage modification, was significant. Evidence from the upper and middle Usk suggests that this was essentially a valley glaciation, although Lewis (1966) has published an opposing view.

The farthest downvalley halt stage of the ice that has been identified is at Kemeys Commander (al though valley side drift spreads suggest that the ice must at one stage have penetrated farther than that: evidence in the valley itself is lacking), and the outwash gravels built up from this can be traced downvalley to merge with the extensive gravels plugging the 'buried channel' of the river at its mouth. The exact relationship of the gravel beds and buried rock surfaces at the river mouth to upstream features in the Usk can only be surmised at present. Rock head contours suggest at least two phases of incision, the deepest of these developing a channel at least - 65 feet O. D. at the river mouth, and probably extending down to almost - 100 feet O. D. at its former confluence with the Severn, six miles to the south west. Altitudinal relationships of gravels overlying the bedrock surfaces suggest correlation with the buried Worcester Terrace and Power Station Terrace gravels of the Severn. If we accept the views of Fairbridge (1961), the cutting of this deepest channel can be associated with the Last (Weichselian) Glaciation, the thick gravels which fill it being associated with the Post Glacial sea level rise.

5. Post Glacial Events. Following deglaciation, further landscape modification in the Usk was almost wholly by fluvial agencies. The erosion of upstanding masses of valley floor drift, and sedimentation in basins in the drift surface left by the melting of the Usk Glacier was probably largely acheived by meltwaters released during the final deglaciation

stages. No really significant modification of valley form appears to have occured since then, the few minor terraces probably resulting from slow incision of the river into resistant rock outcrops exposed by stripping of the drift cover.

In the lowest reach (below Usk) this period is marked by extensive aggradation, linked with the Post Glacial rise in sea level, which is likely to have continued into prehistoric time, as development of the lowest part of the Usk cannot be disassociated from development of the Caldicot and Wentloog Levels which flank it, and radio-carbon dating of deposits from Llanwern indicates that sedimentation there continued after 2,660 B.P. That the Post Glacial rise in sea level was not uniform, but was marked by phases of regression and accelerated transgression is shown by trenching of the surface of the supposed equivalent of the Power Station Terrace gravels (filling the lowest channel) and organic inclusions within the estuarine clays overlying the main sand and gravel deposit. It is suggested that marine planation during a major transgressive phase might account for the platform underlying the inner margins of the Caldicot Level.

Following the retreat of the Usk Glacier, Trotman (1963) finds no definite evidence of further ice accumulation in the low corrie at Waun Ddu, south of Llangattwg, although she suggests that it is not unlikely that the higher altitude north-facing corries in the Brecon Beacons were occupied during Zone 1 time. There is, evidence of at least periglacial activity at this time at Waun Ddu. It is suggested that the formation of the gravel fans discussed in Chapter 8 may be related to the Late Glacial, when accelerated slope movements supplied large quantities of waste to streams showing a markedly seasonal regime as a result of melt. With the advent of milder climatic conditions, and the reduction of the amount of waste entering the streams, largely as a result of vegetational stabilisation of slopes, these gravel fans have ceased to develop, and many now show incised forms, related to downcutting of the main valley.

Crampton (1966, 50), from upland soil pollen analysis suggests the spread of open forest high ground in South Wales which reached a maximum development in the Bronze Age. This was followed by peat growth which was most significant in post-Roman and Pre-Medievil times. Thomas (1956, 106) however, suggests that the deep profiles observed over much of the higher areas of the Brecon Beacons suggests peat development over a much longer period - 5,000 to 7,000 years - with erosion of this peat cover taking place within the past 500 years. He sees evidence for earlier gulleying of glacial tills in the Beacons, which he relates to a "a post-glacial fall of base level". Specialised climatic considerations have clearly controlled the growth and later erosion of the upland peat beds, but there is little doubt that gulleying of hill-slope drift spreads, as mapped by Thomas, was linked with fan development where tributaries joined major valleys. There seems little necessity for linking this episode with base level change.

(b) CHRONOLOGICAL CORRELATIONS.

The evidence outlined in the first section of this chapter suggests the following sequence:

6. Deglaciation
5. Glacial Advance (Vale of Gwent 'Newer Drift')
4. Interval (?Interstadial)
3. Glacial Advance (Vale of Gwent Maximum)
2. Interglacial
1. Ancient Glacial (Upper Usk Maximum - ? Composite)

If it is accepted that only one interglacial episode is represented in the sequence, then the glacial advances succeeding it must be referred to the Weichselian, and more precise correlation can be attemted by reference to the previously proposed correlation of terraces, buried gravels, and buried valley form in the lower Usk with similar features of the Severn, as suggested in chapter 11 and 12 (tables 13 and 14).

The contrasts noted in the character of the deposits in the Vale of Gwent relating to two ice advances suggest that these two advances were separated by an interstadial. If so, the two advances must be assigned to the Early and Main Weichselian, respectively. This places the last glaciation of the area much later than has hithertoo been suggested, but it is in line with recent radio-carbon datings from West Wales, whilst the two-fold glacial advance during the Weichselian is well established in northern Eurpoe. This sugges- tion is to some extent supported by correlations earlier proposed between the lower Usk and the Severn. On an altitudinal basis, the extensive Tredunnock Stage of the Usk isCorrelated (Table 13) with the Bushley Green Terrace of the Severn, now considered (Tomlinson, 1963, 194) to have been developed during the retreat of the Gipping ice from the Midlands. This was followed in the Midlands, as in the Usk, by a major period of fluvial erosion, which culmin- ated in the formation of the Kidderminster Terrace, assigned to the Last Interglacial, and correlated with the Caerleon Stage in the lower Usk. The drift deposits laid by the two ice advances identified in the Vale of Gwent are too low to be identified with these terrace stages. It is suggested, moreover, that it is more realistic to equate the low Llanbadoc terrace with a retreat stage of the 'Vale of Gwent Maximum Glaciation'. In the midlands the terrace developed following the retreat of the Early Weichselian glaciation, the Main Terrace of the Severn, has been given a radio-carbon dating of 42,000 - 38,000 years B.P. (Coope, Shotton and Strachan, 1961). This terrace has merged with the flood plain deposits of the Severn upstream of the Usk confluence. Its relationship in this respect is thus similar to that of the Llanbadoc terrace. It is clear, however, that positive identification of the buried terrace gravel stages will not be possible until a more intensive spread of borehole records is available for the whole of the aggraded section of the lower Usk. The only positive identification which can be made seems to be in respect of the buried channel cutting, which was probably synchronous in both Severn and Usk, and also the trenched filling of this deep channel, which seems to be almost certainly a correlative of the similarly trenched Power Station Terrace gravels of the Severn.

The valley train associated with the final halt stage of the last ice advance in the Vale of Gwent (the Kemeys Commander Halt stage) sinks beneath flood plain deposits in the vicinity of Usk, and, as fig 26A shows, there is a suggestion that a major gravel bed is continued down valley to the mouth of the river, where considerable thicknesses of gravels have been proved in bores (fig. 40). If a major ice advance is postulated for the Main Weichselian outwash from it contributed largely to the gravel beds which have been tentatively correlated with the Worcester and Power Station Terrace gravels of the Severn (Table 14). The observation of Beckinsale and Richardson (1964, 90) that the depth of incision between the Worcester Terrace and the preceding Main Terrace, and the large amount of debris within the Worcester Terrace trench "would be satisfactorily explained by an appreciable ice-advance and retreat", is relevant. The Worcester Terrace has been associated by Peake (1961) with the 'Welsh Readvance Glaciation' in the north-eastern Borderland, although this conclusion has been denied by Poole and Whiteman (1961). Boulton and Worsley (1967) have also suggested a major Main Weichselian Irish Sea Glaciation of the Cheshire Basin, although this too has been contested by Poole (1967).

A Weichselian advance of the Usk Glacier, combined with cutting and later aggradation of the deepest channel accords with Fairbridge's views concerning Pleistocene sea level fluctuation (Fairbridge, 1961). The lowest sea level he suggests occured in the Main Weichselian (Fig. 10, p. 133). If we accept the correlation of deep channel cutting (or even re-excavation) on the Usk with this low sea level, a Main Weichselian advance of the Usk Glacier would also account for the large quantities of coarse gravels filling this deepest channel, which it would otherwise be difficult to account for.

On these grounds a chronology is proposed which recognises a two-fold advance of the Usk Glacier in the Weichselian , as outlined in Table 15.

These conclusions also find support in the unpublished work of Groom (Groom, 1966) on the raised beaches of the Gower Peninsula. Groom, like Bowen, identifies two head deposits, which she relates to two major cold episodes within the Weichselian, considering that the Peninsula was not glaciated at this period. Glaciation of the Peninsula, both by 'local' and Irish Sea Ice she considers to have occured in the Gipping, assigning an Ipswichian age to the main raised beach. This enables the beach to be correlated with the Kidderminster Terrace of the Severn sequence,* whereas a correlation with the

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* And thus the Caerleon stage on the Usk. This is at 45 - 60 feet O. D., or approximately 20 - 35 feet above present flood plain level.

TABLE 15

PROPOSED LATE QUATERNARY CHRONOLOGY FOR THE USK VALLEY, AND CORRELATIONS WITH ADJACENT AREAS.

GENERAL TERMINOLOGY	USK VALLEY		MIDLANDS		WEST WALES AND GOWER.
	Glacial/Interglacial Stages	Fluvial Activity	Severn/Avon Terrace Stages	Glacial/Interglacial Stages	
LATE GLACIAL	Periglacial activity (P.Z. III) Ice in higher cirques of Beacons (P.Z. I)	Progressive 'grading' of profile; minor terracing. Gullying and gravel fan development. Aggradation in lowest reach.	Aggradation in Severn with rising sea level.		
LATE WEICHSELIAN	Last Glacial Advance in the Vale of Gwent	Aggradation (from Kemeys Fold Stage) Incision at river mouth - cutting of buried channel. Cocks gravels	Power Station Terrace. Excavation (or re-excavation) of deepest channel. Worcester Terrace	? Irish Sea Ice & Local Ice re-invasion of Wales.	Irish Sea Ice in West Wales. Periglacial activity in Gower - Upper Head.
MAIN (UPTON WARREN) INTERSTADIAL	? Interstadial	Weathering of drift Llancayo Terrace	Main Terrace Avon No. 2 Terrace	Upton Warren Interstadial Complex	Weathering
EARLY WEICHSELIAN	Vale of Gwent Maximum Glaciation.	Incision in response to lowered sea level		Main Irish Sea Glaciation. Third Welsh Glaciation.	Local Glaciation with (?) Irish Sea Ice in West Wales. Periglacial activity in Gower - Lower Head
IPSWICHIAN INTERGLACIAL	? Interglacial	Caerleon Stage St. Julian's Stage Major incision; esp. marked in Middle Usk	Kidderminster T., Avon No. 3 and 4 Terraces.	Interglacial	Gower Raised Beach
GIPPING GLACIATION	Upper Usk Maximum Glaciation (probably composite). Trans-fluent ice activity	Tredunnock and higher terrace stages	Bushley Green, Avon No. 5, and higher terraces	Second Welsh Gl. Main Eastern Gl.	Irish Sea Ice maximum - in Gower and Vale of Glamorgan.

Severn sequence is not possible with the earlier ages assigned to the beach by other writers (e.g. Cromerian by Mitchell (1960), and Hoxnian by Wirtz (1953) and Bowen (1966)). A correlation can thus also be proposed with the Late Monastirian shoreline of the Mediterranean (+7.5 m.), which Zeuner (1957, 305) places in the Last Interglacial (Ipswichian), all earlier Pleistocene beach terrace levels of the Mediterranean being higher. West (1963, 171) notes that evidence from the south of England in general suggests a sea level of 25ft. O.D. for the warmer part of the Ipswichian. Interglacial, although qualifies this, stating that "as yet, the evidence for the true maximum Ipswichian Interglacial sea-level is inconclusive". In so far as the south Wales successio, is concerned, an Ipswichian dating for the Gower Raised Beach would overcome a number of thorny problems.

The evidence for two major ice advances in Britain in the Weichselian is as yet not strong. In the Midlands, however, there are good grounds for placing the Main Irish Sea Glaciation in the early Weichselian, whilst a later (? Main Weichselian) advance of disputed extent is suggesed by the work of Peake (1961) and Boulton and Worsley (1967), although the conclusions of both papers have been contested. The four published radio-carbon datings for West Wales (John, 1965 and 1967, Brown et al, 1967) suggest a Main Weichselian Glaciation in that area of considerable extent, whilst there is the probability, by reference to other parts of Britain, of an Early Weichselian Glaciation of the area also, although John has cited evidence which suggests that non-glacial conditions persisted in certain other parts of Britain at this time.

For the Usk the time is not yet ripe for categorical chronological statements, but the interpretation outlined here of the evidence suggests a sequence of events which is in line with statements made recently on the basis of absolute dating techniques. It is to be hoped that an absolute dating will be made possible for the Usk area in view of its critical position between the Severn and western seaboard areas.

APPENDIX I.

A NOTE ON FROST-CRACKED PEBBLES FOUND AT CLYTHA.*

At the mouth of the Clawdd valley at Clytha (Grid ref. SO363,097) there is a ridge of sands and gravels elongated along the valley which was considered by the Geological Survey (Robertson, 1927, 103) to be an esker. Excavations in the mid-thirties (O'Neil and Foster-Smith, 1936) revealed that the natural ridge had been utilised in the Medieval period as the basis for a motte@type fortification to which the name Twyn y Cregen applies.

The esker is today sporadically dug for gravel, and a twenty-foot face is exposed, showing stratified gravels with small lenses of sand.+ The pebbles in the gravel are mainly of Old Red Sandstone origin, but Millstone Grit, Coal Measure and Pennant Sandstone pebbles are also incorporated. Examination of the face of the digging in 1960 revealed a number of pebbles wholly or

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* The substance of this note appeared in the Transactions of the Cardiff Naturalists' Society for 1958-9 (1961) under the title "A note on frost-cracked pebbles found at Llanarth, Monmouthshire". Although lying within the parish of Llanarth, the village of Llanarth is located several miles away, and the name of the nearby Clytha (Park) is thus used through this thesis to denote this important locality.

\+ Plate 28.

partly covered by a spider web of surface cracks which so far as the writer is aware, have not previously been reported in Great Britain.

All the pebbles which bore the cracking were composed of Old Red Sandstone. They vary in size from 1½ inches to 3¾ inches in diameter, and all are well rounded, presumably by fluvio-glacial action. The rounding of the pebbles obviously pre-dates the cracking. There appear to be no distinct foci to the cracking, the intensity and arrangement of the cracks being generally irregular. In the pebbles in which the bedding planes are pronounced, such as specimen B, Plate 27, the cracking tends to follow the bedding planes. Even so, the cracking on this and similar examples is not confined solely to the bedding planes. In most cases, however, the cracking, as in specimen A, Plate 27, follows no logical pattern. The cracking varies from extremely fine cracks on some pebbles to cracks of up to 2 mm. in width and 5 mm. in depth on others. There seems to be no relationship between pebble size and intensity of cracking. In a few cases, as with specimen A, Plate 27, the cracking has caused particles to become detached.

Since the initial discovery at Llanarth, the writer has noticed another instance of this cracking, this time in the Wye valley at Clyro in Radnorshire. In this case the pebbles were found in situ about three feet below ground surface in an exposure of gravelly drift (Grid ref. SO214435). This time, however, the cracking was developed in a more fissile rock, again of Old Red Sandstone origin, which tended to disintegrate at touch. Miss G.E. Groom of the Department of Geography of the University College of Swansea has also noticed examples of this cracking in the drift of South-West Wales, but in this case also, the pebbles tended to disintegrate when removed for examination. It is thought that lithological differences, and not a greater intensity of shattering, were responsible for the rapid disintegration of the latter pebbles.

The Clytha pebbles were examined by Dr. F.J. North and Mr. Emlyn Evans of the Geology Department of the National Museum of Wales, Cardiff, neither of whom had seen pebbles cracked in this fashion before. The possibility that the cracking might have been caused by repeated heating in the proximity of the hearth mentioned in the report of O'Neil and Foster-Smith was considered, and simple experiments were carried out in the Museum with a pebble of similar size and lithology as the cracked examples. This was subjected to heating, which resulted in cracking, but the cracking was of a much simpler form, and tended to detach fragments from the pebble. It seems likely, that had pebbles bearing this highly distinctive form of cracking been associated with the hearth, they would have been noted during excavation, and there is no mention of this in the report of O'Neil and Foster-Smith.

A more likely suggestion is that the cracking is periglacial in origin, and caused by freeze/thaw processes in immediate post or late glacial times. The Clawdd valley is only a few miles from the 'Newer Drift' ice margin, as delineated by Charlesworth (1929), and this area would have been vacated by the ice relatively early in the final retreat.

Only one reference to similar cracking has been discovered (Bout, 1957). Bout reports occurrences of somewhat similar cracking from three localities in France, attributing its formation to the dessication consequent upon the initial freezing of the moisture in the rock under periglacial conditions.* The mechanism by which

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* "Nous attribuons celle-ci a une déssication par le gel extrayant, pour alimenter la ségrégation de la glace ayant pris place dans le dépôt au temps de sa formation, l'humidité présente dans les nodules." - (P. Bout, 1957. French abstract, p.168.)

this occurs is still far from clear, however. In particular, it is surprising that the opening up of a network of cracks of a width such as those displayed in Plate 27(a) did not result in the complete disintegration of the pebble. The main question seems to be whether such cracks could have developed as a result of changes in the surface area of the pebble, or whether the cracks developed due to the disintegration of the grain structure along the lines of the present cracks. The first of these two possibilities seems least likely, as the degree of expansion which would be required to produce cracking of the intensity and extent noted would surely have produced stresses sufficient to cause the complete break-up of the pebble. It is conceivable, however, that removal of grains from the area of the cracks could have occurred without the setting up of such critical stresses within the pebbles, so enabling their unitary survival.
Disintegration of the rock structure within the cracks could have occurred by the growth of microscopic ice lenticles within bedding planes and other zones of weakness. The growth of ice lenses has been noted, on a larger scale, to attract moisture from the intervening areas, so causing the "dessication" or dehydration referred to by Bout

(although he does not seem to have considered the possibility of ice growth within the pebbles themselves). The drastic reduction in the moisture content of parts of the pebble, combined with the presence of fine but expanding ice lenticles might, given suitable lithology, result in cracking, the dehydrated areas of the pebble tending to contract, thus assisting in the expansion of the cracks and the growth of the ice lenticles within them. The width of the cracks indicates that material has been removed from within them, otherwise the end of dehydration following ice melt would surely have resulted in the closure of the cracks. The growth of ice lenticles could itself have caused the disintegration of the grain structure of the pebble in the vicinity of the cracks, for there stresses would be at a maximum, and a small-scale form of 'plucking' is conceivable. The sub-sequent survival of the pebble would depend in part on its resistance to weathering, and on its position within the superficial deposits. The more weakly-cemented sandstones would tend to disintegrate completely, although retaining pebble form (unless the deposit was affected by solifluxion movement) until disturbed.

The cracking is therefore tentatively referred to a combination of dehydration (as suggested by Bout) and the growth of fine ice lenticles within pre-existing zones of weakness in the surface skin of the pebble. A satisfactory explanation of this phenomena will require extensive laboratory experiment, combined with the microscopic examination of the relationship of the cracking pattern and rock micro-structures, as revealed in thin section.

It might be noted that pebbles in glacial sands and gravels, as well as in tills, were frequently observed cleanly cracked across, sometimes in several places, as shown in Plate 29. The association of this type of cracking with the type observed at Twyn y Cregen was not noted, and the contrasting nature of the fractures suggests that different controlling factors were operative.

APPENDIX II.

THE CLYTHA SECTION

1. GENERAL.

At Clytha (fig. 21), examination of the bank of the Usk near the confluence of the Clawdd Brook (359092) revealed a layer of peat with included roots and large pieces of timber outcropping at river level. This was of particular interest, because examination of the overlying deposits suggested that they might be in part of glacial origin, and there appeared, therefore, the possibility of dating these deposits.

2. LOCATION AND MORPHOLOGICAL SETTING OF THE SECTION.

At Clytha the Usk makes an abrupt turn from an easterly to a southerly direction, and the section of the river bank in which the peat deposits were found lies on the outer side of this bend, immediately south of the confluence of the Clawdd Brook. The detailed morphology of this area is shown in figs. 21 and 28. At this point a broad ridge of drift approaches the river, flanked on the south by a wide re-entrant filled by alluvium, and on the north by the Clawdd Brook. The relation of the drift ridge to the alluvium at its western end are confused because the ridge was formerly worked at this point and a large pit here opens out onto the river bank (Plate 23). The Geological Survey mapped the drift ridge as terminating a short distance before the river bank, with a narrow strip of alluvium between it and the river, and in this they were followed by Walmsley (1959), although his drift mapping was only incidental to mapping the solid geology. However, rapid erosion of the bank is occurring, and a public house which formerly existed about 150 yards upstream was abandoned for this reason; its remains have now practically disappeared. It is certain that there was once a bank of river alluvium at this point, although erosion may now have exposed the end of the drift ridge. The flat surface at the top of the bank extends back into the former working, and it has probably been flattened artificially. The form of those parts of the ridge extremity not disturbed by working certainly suggest that the former termination of the ridge was very close to the Usk at this point.

The origin of the ridge is not clear, although its alignment west-east and its broad drumlinoid form suggests moulding by ice pushing eastwards from the Usk along the Clawdd valley. The Twyn y Cregen esker, a few hundred yards away (fig. 28), on the north bank of the Clawdd, has a similar alignment.

The nature of the working which had disturbed the western end of the ridge could not be determined. Examination of the six-inch maps of the area, produced in the 1880's showed the pit in existence then, with a well in it serving a small cottage, which has now disappeared, near the river on the south-facing slope of the ridge. Similar pits in the area are mainly the result of old gravel working, although abundant surface gravels betray their origin. In this case there are no surface deposits.

3. DETAILS OF THE PROFILE (1958).

The exposure was first discovered in the summer of 1958, interest being aroused by a wide bench of peat extending riverwards from the base of the river bank just above the low-water level of the river. Embedded in its surface was the trunk of a young tree, laid horizontally, the end of which appeared to be buried beneath the deposits forming the river bank (plate 24). The river at this period was exceptionally low, and would normally have covered the peat bench. This had clearly been more resistant to the erosion of the river as it rounded the bend, its width being increased as overlying sediments were cut back. On September 29th, 1958, samples were taken from the peat and overlying deposits, and details were recorded from a cleaned, vertical face cut into the bank at one point. The profile was extended downwards by cutting a pit through the peat layer, thus exposing clays and gravels which were seen to be underlying it. These could not be seen elsewhere, as they too had receded farther due to river erosion on the bend than the peat bed, which thus projected into the water as a ledge. The exact spot chosen to cut the profile was at a point where the continuation of the tree trunk beneath the bank could be proved (or disproved). As can be seen in plate 25, the tree trunk was seen to continue well beneath the superficial deposits of the bank. Its end was not proved.

Details of the measured profile are given in fig. 49. (1) The lowest deposit recorded is the gravel, which lay at low water level. This appeared to be sorted with finer material, including much sand, in the upper layers, the base being formed by large fluvially-rounded pebbles. The base of the deposit was not proved, although probing below water level beyond the face of the bench revealed an extensive rock surface, taken to be bedrock, 27 inches below water level (i.e. 39 ins. below the top of the log as shown in fig. 49.

(2) Above the gravel, a clayey deposit immediately underlay the log of wood. This had a high sand content, and contained fragments of wood.

(3) The log of wood was part of the tree trunk exposed on the surface of the organic bench beyond the face of the bank, elsewhere a black organic layer containing abundant fragments of wood being found at this level. The log was four inches in diameter., and in a good state of preservation, although on the bench it had broken across in places and would not have survived in one piece, had it not been for the protection afforded by the peat bed in which it was embedded.

(4) A reddish clay, but with a grey hue, which forms the matrix of fragments of wood which are numerous near the base, and which shows a concretion.

(5) A similar clay, but without organic content, and showing a progressively more ocherous appearance towards the top.

(6) Separated from (5) by a concretion developed at the base, but otherwise a clay of similar colour, although distinguished by an unusual crumby-columnar structure. This may have been induced by root growth, as holes running through it suggest old root casts. Mottled black in places.

(7) At 50 inches from the base, a layer of scattered, sub-round pebbles, averaging 1¼ ins. in diameter.

(8) A loamy material, which is less cohesive than the clays of the lower part of the profile, and thus has retreated further, the boulder layer (9) forming a minor ledge near its base. The silt content appears to be considerably greater. This loam forms the matrix of the boulder layer (9), whilst scattered pebbles are to be found throughout it. Many of these pebbles, and those in the boulder layer below, were erratic. Mill-stone grit pieces could easily be picked out, but the variation in lithology, even of Old Red Sandstone pebbles, showed that they had originated over a wide area.

(9) Boulder layer. Large sub-angular boulders averaging 7-8 ins. in diameter, and forming a distinct layer which can be traced laterally with ease on the face of the bank. In places, it becomes more pebbly, and reaches thicknesses of up to 20 inches. At the place where the profile was measured the boulder layer is at its highest point, tending to decline in height as traced upstream or downstream.

The top of the bank varies in height, but is about 10 feet from the base of the pit. The crest of the bank might at some time have been levelled, for it lies in the mouth of the working developed in the end of the drift ridge.

4. POLLEN ANALYSIS.

A sample of peat from the bed was submitted to Dr. Isles Strachan of the Department of Geology, University of Birmingham for pollen analysis. Only one slide was made, and this gave the following pollen count:

Betula	2	Pinus	nil.	Ulnus	nil.	Quercus	6
Alnus	40	Tillia	2	Corylus	19	Pteridophyte	3

Dr. Strachan comments (personal communication, 10.1.61) that he had assumed that the sample was Late or Post-glacial, and that the high percentage of <u>Alnus</u> indicated an age not earlier than Zone VII (Neolithic). The analysis revealed "that the surrounding vegetation at the time of the peat formation was a mixed-oak forest with abundant alder. The virtual absence of herb pollen (3 found in addition to the ferns) indicates complete tree cover. Consequently, if the sample is not of post-Wurm age it must be of inter-glacial age since we know of no mixed oak forest cover during any phase of the Wurm glaciation in Britain. One would, of course, require quite strong evidence to suggest an interglacial age for the peat and preferably some distinctive faunal or floral criteria."

5. RE-EXAMINATION (1966).

The river bank at this point was examined again in the autumn of 1966. Erosion in the intervening period appeared to have been considerable, and the greater part of the face had fresh masses of slumped material below it, resting on the peat bench. There was, in addition, a mass of large boulders, many erratic, resting on the bench at the northern end of the exposure. These were not noticed in 1958, and it seems probable that they had been thrown over the bank at this point to retard erosion. The presence of a partly shaped millstone is proof of the extraneous origin of this material. A few large boulders farther downstream, partly buried in slumped loam masses, may also have arrived there in this way, although there is a possibility that they have been uncovered by the washing away of the loam. In view of the doubt as to their origin, they will be discounted from further consideration.

Fresh slumping enabled examination of the upper part of the bank over all except the extreme southern part of the eroded ridge. An upper loam with few stones overlying a bouldery or pebbly layer usually with a loam matrix was everywhere obvious, except at the extreme northern end of the exposure, where the loam (with occasional rounded pebbles up to 4 ins. diameter) was seen resting on a clayey bench (with organic inclusions) at river level. A few yards downstream, behind the mass of dumped boulders, smaller, usually well-rounded boulders, roughly sorted, could be seen in a matrix of loam, outcropping on a near-vertical face. This appeared to be the beginning of the lower stony zone. In the centre of the exposure, the bed of boulders noted in 1958 was still evident, below which was a poorly sorted bed of gravel. This was the area in which the face had been cleaned back and measured in 1958, although there was no evidence of this, due to the erosion which had occurred in the intervening period. To the south of this, little of the material which had slumped from the face had been removed by the river, so that exposures were poor. The loam appeared to be extremely stony in its lower layers, and poorly rounded stones, many of erratic origin were especially noticeable, although a high proportion of well-rolled pebbles remained.

The lowest section of the face was concealed by the material slumped from the top, except, as previously noted, in the extreme north of the exposure. The peat layer, which changed laterally into a clayey organic layer, or into timber in a clay bed, could, however, be traced almost everywhere at water level, as the slumped load had generally been washed away from its leading edge.[+] Erosion had, however, considerably reduced the width of the bench, although recession of the bank behind had been retarded by the dump of boulders.

[+] Plate 26.

6. ORIGIN.

The limitations of the quick examination and pollen count of the peat carried out by Strahan are admitted. It is quite impossible to assign the peat to a definite zone on the basis of such evidence, and it is unfortunate that it has not proved possible to get a detailed analysis of the deposit carried out since. Strahan's observations concerning the general character of the vegetation at the time of formation may, however, be accepted, and the peat would seem to relate either to the last Interglacial (Ipswichian) or to the post-glacial. The character of the overlying deposits is therefore significant.

The deposits above the organic layer cannot with certainty be described as alluvium or glacial drift. Possible origins are considered below:

1. Riverine aggradation (alluvium). Whilst the loamy material at the top of the profile is comparable with that exposed in river bank sections elsewhere, the inclusion of such large grade material so high in the profile is unusual, as too is the dominantly sub-angular shape. This could be explained by supposing that they were derived from the erosion of nearby drift deposits. The clays in the lower part of the profile are also unusual, though it

is conceivable that they might have accumulated as the result of silt deposition from relatively still water, perhaps in a hollow well removed from the river.

2. Glacial deposition. The relationship of the end of the drift ridge with the river bank is not clear due to the workings which have disturbed the end of the ridge. There is no doubt that when mapped by Officers of the Geological Survey towards the end of the last century, there was a narrow strip of alluvium between the end of the ridge and the river bank. In the time that has elapsed it is possible that erosion by the river on the bend, proved by the undermining of the former hotel, 150 yards upstream, has removed most of the alluvial material, exposing the end of the ridge. If so, the clayey zone capped by the boulder layer might be the buried end of the ridge, whilst the loamy deposit near the surface is the remnant of the alluvial deposit. The way in which the boulder layer declines in height up and downstream away from the profile supports this suggestion, as it seems to parallel the supposed surface form of the buried ridge. Further, if there were no riverward continuation of the ridge it must either have terminated very abruptly, or have been trimmed by the river. There is

certainly no evidence of the latter.

3. Solifluction was considered as a possible mechanism by which a deposit of possibly glacial origin could overlie a post-glacial peat. This would seem to be ruled out by the low-lying nature of the surrounding area.

4. Human interference. It is possible, though unlikely, that the overlying deposits were dumped there during the working of the pit. This pre-supposes that there was nothing there previously, and it is then necessary to explain the survival of the organic layer. Further, dumping would probably have produced bedding inclined riverwards, whilst in fact the bedding, where apparent is near horizontal.

The writer is inclined to the view that the toe of the ridge is being uncovered, the surface loam being the remnant of a riverine deposit, the organic layer predating the formation of the ridge. If so, the ice which formed the ridge seems to have advanced across an area of damp woodland, toppling the trees as it did so. Against this one must weigh the relatively fresh condition of the organic layer - especially the wood - which would be unusual in an interglacial deposit. If, however, the overlying material is of entirely riverine origin, the trees must have been growing in a marshy hollow well below the contemporary flood plain level (for terrace remnants in the Brynderwn area to the south suggest that the river level in this section of the valley has been progressively falling in post-glacial times).

Although no clear conclusion may be drawn, it was felt that it was necessary to record the presence of an organic deposit, and to consider some of the possible implications. The matter should be resolved, and this can only be done by dating the organic deposit, either by detailed pollen analysis, or by radiocarbon techniques. This should be done soon, as there is a danger that river erosion might remove the deposit completely in the future.

APPENDIX III.

Till Composition.

In order to determine whether there was any significant variation in the composition of the till throughout the area under study, a number of till samples were subjected to grain size analysis in the laboratory. The samples were taken from the following localities shown in fig. 46) :

1. Llansantffraed Church: road cutting (123234).
2. Fforest Coalpit. Morainic deposit being undercut by river (281207).
3. Gilwern. New housing site at Kennel Wood (248154).
4. Saleyard (Clydach Valley): roadside cutting (231137).
5. Capel Rd, Penpelleni. New housing site (324050).
6. Tregare: active gravel pit (409104).
7. Glasbury: roadside cutting on south side of river (179388).

No. 6 is not from a till, but from a fluvio-glacial deposit sampled for comparison, whilst No. 7 is a till sample from the Wye Valley. This was taken to compare the till composition of the two glaciers, in view of the fact that the Wye glacier originated in an area of predominantly Silurian and Ordovician rock, whereas little ice from these areas joined the Usk glacier, and probably for relatively short periods.

The samples so collected were subjected to grain-size analysis, a technique noted in Flint (1957, p.112 and 116) and discussed in detail in Krumbein and Pettijohn (1938). Samples were collected in 1 cwt. plastic bags. Care was taken in the collection of the samples to obtain unweathered material which had not been subjected to significant wash. Recent excavations were therefore found to be most suitable for this purpose, and the distribution of samples shown in fig. 46 is not ideal, but reflects availability of suitable exposures. Nevertheless, the sites were chosen with the object of revealing whether tributary ice tongues from varying sources were significantly different in their grain-size distribution. Sample 1 (Llansantffraed) was considered representative of the upper Usk tills before it had received any ice from the Coalfield. Sample 2 (Fforest Coalpit) should reveal the nature of the southern part of the Black Mountains, although this has probably been mixed with till carried from the main Usk valley over the low divide at Bellfountain by a diffluent ice tongue. Sample 3 (Gilwern) is of a till in the main Usk valley after the confluence of ice from Coalfield sources (via the Crawnon and Clydach valleys), whilst Sample 4 from the Clydach Valley was judged to be typical of a till deposit from one of the ice tongues descending into the Usk valley from the Coalfield rim. Finally, Sample 5 was taken to be representative of the till near the margin of the 'Newer Drift' ice sheet, as delimited on the Geological Survey One-inch maps.

In the laboratory, with the aid of an automatic shaking machine, the samples were passed through a standard bank of sieves which sorted them into the various grain sizes. These amounts were weighed and expressed as percentages of the whole. Any organic inclusions were removed. The sieves used were of the British Standard pattern (see Table 16). Material which did not pass through the sieve with the largest opening (No. 8, 2.057 mm. mesh) - granules and larger material) was not subjected to further treatment.

The following Table shows the size relationships of the sieves used to the standard Wentworth grade scale of sedimentary analyses.

TABLE 16.

DRIFT ANALYSIS:

Sieves used and size classification.

B.S. Sieve No.	Size mesh (mm.)	$\sqrt[4]{2}$ scale	Phi scale	Size Category
8	2.057	2.00	-1.00	Granule & larger
10	1.676	1.68	-0.75	Very Coarse Sand
12	1.405	1.41	-0.50	
14	1.204	1.19	-0.25	
16	1.003	1.00	-0.00	
18	0.853	0.841	+0.25	Coarse Sand
22	0.669	0.707	+0.50	
25	0.599	0.595	+0.75	
30	0.500	0.500	+1.00	
36	0.422	0.420	+1.25	Medium Sand
44	0.353	0.354	+1.50	
52	0.295	0.297	+1.75	
60	0.251	0.250	+2.00	
72	0.211	0.210	+2.25	Fine Sand
85	0.178	0.177	+2.50	
100	0.152	0.149	+2.75	
120	0.124	0.125	+3.00	
150	0.109	0.105	+3.25	Very fine Sand
170	0.089	0.088	+3.50	
200	0.076	0.074	+3.75	
240	0.064	0.062	+4.00	
240				Silt & clay

The proportion of granules and larger material to the rest is shown in Table 17.

TABLE 17.

PROPORTION OF GRANULE & LARGER SIZE MATERIAL WITHIN EACH SAMPLE.

Sample No.	Wt. of sample.	No. 8 Sieve (Wt.)	Proportion %
1	57.34 Kg.	12.98 Kg.	18.45
2	56.83	16.48	22.47
3	56.71	11.72	20.92
4	53.74	15.64	29.48
5	80.60	6.19	7.77
6	62.25	4.53	7.34
7	69.73	14.34	20.84

It will be noted that the lowest proportions of such large grade material occur in the two samples taken near the margin of the 'Newer Drift' ice lobe in the Vale of Gwent (Nos. 5 and 6).

Relative proportions of material of less than granule size is shown by means of cumulative percentage curves (figs. 47 - 48). Curves for all the Usk valley samples are plotted in fig. 47. This indicates a fairly even distribution of grain size within the till samples, and no great variation between the individual samples. By contrast the Tregare sample (6) shows markedly the effect of sorting, being composed predominantly of medium and fine sand, with a minimum admixture of silts, clays and coarse sands.

The broad similarity between the Usk till samples was expected in view of the extent of the outcrop of relatively uniform divisions of the Old Red Sandstone in the Middle and Upper Usk. Certain contrasts are, however, evident: the Llansantffraed sample (1) shows the highest proportion of silts and clays, which is possibly a reflection of the extent of the Lower Old Red Sandstone outcrop (predominantly marls) in the upper Usk. In contrast, sample 4 (Saleyard, Clydach Valley) shows the highest proportion of coarse and very coarse sands which accords with the proximity of this sample to outcrops of resistant Carboniferous rocks - the Millstone Grit in particular - in the north-eastern corner of the Coalfield. Sample 3, reflecting addition of this coarser, Coalfield-derived material, shows a high proportion of coarse and a low proportion of the finer grade material. The Fforest Coalpit sample (2) has a lower coarse proportion, but it similarly has a low fraction of fine sands. Finally, in sample 5 we note that the proportion of very fine material is once again rising, although the fabric has not achieved the fineness of grain so noticeable in sample 1. It would appear, therefore, although the sample is too small and the variation between samples too slight to be any more positive, that the till fabric in the Usk valley, which is particularly fine at Llansantffraed, becomes less so when traced down valley, due to the addition of coarser grained till, some from the Black Mountains, but especially from the Coalfield. The Clydach appears to have been the main ice-corridor from the Coalfield into the Usk valley, and increasing distance from this confluence is marked by the increasing proportion of fine grained elements in the till.

This conclusion is also supported, to some extent, by the figures shown in Table 17. As expected, the Saleyard sample (4) shows the highest content of very coarse material, whilst samples 2 and 3 show similarly high amounts. Sample 5 shows, as would be expected, a low content of coarse grained material, but this is relatively high in the case of sample 1, which is thus the most contrasted of all samples, showing a high proportion of the coarsest and finest material with minimum quantities of the intervening grades.

The curve for the Wye valley till sample taken at Glasbury is shown in fig. 48. This reveals a coarse and medium sand proportion higher than the average for the Usk tills taken as a whole, but of great interest is the fact that the curve is almost identical with that constructed for the Gilwern sample (No. 3). The Gilwern curve is shown as an overlay, facilitating comparison. The form of these two curves would appear too closely similar to be coincidental, and this strongly suggests that the till in these two widely differing localities was derived from the same source, notwithstanding the comment made on the Gilwern till sample above in relation to the Usk tills only. In Chapter 7 the case for a diffluent ice tongue initiating the present course of the Middle Usk was stated. Pressure of ice from the Upper Wye could have resulted in Wye ice crossing the Llangorse Basin, and passing into the Lower Usk via the Llanddetti Gorge (or less probably via the Bwlch pass or down the Sorgwm valley). Sample 1 (Llansantffraed) would then be considered to be 'pure' upper Usk ice, uncontaminated by Wye material, it being found on the south side of Allt yr Esgair, which is markedly ice-smoothed, possibly as a result of its location between two ice streams, one moving from the upper Usk, and the other from the Llangorse Basin.

Further support for this suggestion may be obtained if the cumulative results for the Wye till (No. 7) and the Llansantffraed (Upper Usk, 1) tills are averaged, and plotted (fig. 48A). This derived curve is remarkably similar to the Capel Ed. cumulative curve (5), shown here as an overlay. Capel Ed lies within the 'Newer Drift' lobe of the Vale of Gwent, and if Wye ice contributed substantially to the Usk Glacier, could be expected to reveal till characteristics reflecting these two diverse sources. The correspondence of these two curves would again appear to be too close to be coincidental, and adds weight to the case for a significant Wye ice contribution to the glacier in the Middle Usk.

This interpretation does not, unfortunately, find support from the other lines of inquiry set out in the main body of this thesis:

1. Although the Llanddetti gorge section of the Usk valley is regarded as largely the product of a transfluent ice tongue passing across the former watershed due to the build-up of ice in the Llangorse lowland (Chapter 7, pp. 112-27), the upper Usk ice is considered to be by far the more significant, in view of the deeply eroded form of the Usk valley between Brecon and Llanddetti. There is no clear erosional evidence of a persistent movement of ice across the Llangorse Lowland, and into the Usk, the only col which might have functioned in this way (at Bwlch) being shallow compared with the depth of the main trench.

2. The Llangorse Lowland in general shows no significant drift topography, although drift forms resulting from an overspill of ice from the main Wye glacier at Llyswen are easily traced in the Dulas valley east of Llanfilo, and in the Llynfi valley downstream of Talgarth (Appendix V). For this reason, it is considered that the glacial episode which is marked by the abundant drift forms of the Wye and Usk was essentially a valley glaciation, at which time the

Llangorse Lowland formed an unglaciated enclave. The cutting of the diffluent route is considered to pre-date this episode, and is likely to have been separated from it by an interglacial. It is therefore highly unlikely, even if the Wye ice did make a significant contribution to the diffluent tongue, that extensive drift related to this early episode would remain within the Usk valley.

This is a problem requiring further investigation. The form of curves 7 and 3, and of averaged curve 7 and 1 with 5 are too similar to be coincidental, and yet a direct relationship would seem to be denied by other lines of investigation. The number of samples taken for analysis clearly needs to be increased, whilst the Llangorse Lowland itself, a critical area in this respect, merits detailed examination of its landforms.

APPENDIX IV.

SOURCES OF INFORMATION: SUB-DRIFT SURFACE AND SUPERFICIAL DEPOSITS IN THE LOWER USK VALLEY.

1. LLANWERN AREA.

<u>Site investigations for the proposed Spencer Works, Llanwern, near Newport.</u> The Cementation Co. Ltd., Soil Mechanics Section. n.d. Report made available by courtesy of Messrs. Richard Thomas and Baldwin, Ltd., Spencer Works, Llanwern, Newport.

2. USKMOUTH.

<u>Report on site investigation for the Uskmouth Generating Station, Newport, Mon.</u> Messrs. L.G. Mouchel & Partners and Soil Mechanics Ltd., Dec. 1947.

<u>Report on site investigation at the Uskmouth Power Station.</u> <u>Generating Station B.</u> Le Grand-Sutcliffe & Gell Ltd., for L.G. Mouchel & Partners Ltd., August, 1957.

Reports made available by the Central Electricity Generating Board (Midlands Project Group).

3. NEWPORT BY-PASS ROUTE.

Site Investigation at Newport By-Pass - Preliminary Report. Soil Mechanics Ltd., for Sir Owen Williams & Partners. July, 1946. Also second report, 1947.

Soil Survey for the proposed Newport By-Pass, Monmouthshire. G.K.N. Reinforcements Ltd., Soil Mechanics Dept., for Sir Owen Williams & Partners. August, 1961 (Includes a geophysical Survey by Messrs. Le Grand Adeco Ltd.) Reports made available by courtesy of Sir Owen Williams & Partners (Consulting Engineers).

4. GEORGE STREET BRIDGE.

Reports on site investigations for proposed bridge over the River Usk at Newport, Mon. George Wimpey & Co. Ltd., February and November, 1961. Reports made available by Mott, Hay and Anderson, Consulting Engineers.

5. DOCKS AREA.

Borehole data of varying age made available by the British Transport Docks Board, South Wales Docks.

Recent reports used include:

Site investigation for the reconstruction of the west side of Docks Passage between North and South Docks, Newport, Monmouthshire. Soil Mechanics Ltd. Jan. 1953. Report on site investigation for a proposed dry dock at the Alexandra Docks, Newport. George Wimpey & Co. Ltd., for C.H. Bailey, Ltd., Oct. 1955.

6. OTHER AREAS WITHIN THE BOROUGH (MAINLY EAST BANK OF USK.)

Report on an investigation of ground conditions for the new Main Drainage Scheme, Newport, for the County Borough of Newport. The Cementation Co. Ltd., Soil Mechanics Section, February, 1963. Report made available by the County Borough of Newport's Engineering Dept.

7. CHANNEL OFF USKMOUTH.

Proposed dredging of the entrance channel to the Docks at Newport, Monmouth. Report on site investigation. George Wimpey & Co. Ltd., for the British Transport Commission. August, 1962.

8. USK VALLEY AT BULMORE AND LLANGIBBY, AFON LWYD VALLEY AT PONTHIR.

Results of borings carried out by Cementation Company Ltd., for the Newport and South Monmouthshire Water Board.

9. USK VALLEY SOUTH OF ABERGAVENNY

Soil Survey for the Heads of the Valleys Road. Section 1, Brynmawr to Abergavenny. Borehole 19. Information by courtesy of Messrs. Rendel, Palmer and Tritton, Consulting Engineers.

10. EBBW VALLEY, NORTH-WEST OF ROGERSTONE.

Report on site investigation for the proposed power station at Rogerstone, Monmouth. George Wimpey & Co. Ltd., Sept. 1955. Report made available by the Central Electricity Generating Board (Midlands Project Group).

APPENDIX V.

GLACIAL MORPHOLOGY OF THE WYE VALLEY BETWEEN LLYSWEN AND HAY-ON-WYE.

1. GENERAL.

For part of the time that the field work for this thesis was being carried out, the writer lived at Glasbury in the valley of the Wye, which is adjacent to that of the Usk. The small part of the Wye valley between Llyswen and Hay-on-Wye (fig. 50) was mapped using the same techniques as were employed in the Usk, to compare the efficiency of the two valleys as outlets for the Welsh ice pushing eastward the lowlands of the borderland.

Between Llyswen and Hay-on-Wye, the Wye turns from its former south-easterly course through the narrow valley below Builth to flow in a north-easterly direction. After being tightly confined within a narrow-floored valley, and having a relatively steep gradient, the river now enters a much broader section of its valley. Meanders are well developed (see fig. 50) and numerous mort lakes provide evidence of recent changes in the river trace. The decrease in the river gradient is the probable cause of the extensive gravel spreads about Glasbury. With this is associated (Leopold, Wolman & Miller, 1964, 437) a tendency towards braiding by the Wye.[+] Valley sides remain steep, rising in the south to the fine north-facing scarp of the Black Mountains, and in the north to the moorlands of south Radnorshire. As pointed out long ago by Mackinder (1902), this reach of the Wye appears to be strike controlled and of subsequent origin. It is joined from the south by six obsequents, rising on the Black Mountain scarp, and following sub-parallel courses to the river. Tributaries from the north are relatively insignificant, the most important being those tributary to the Wye at Glasbury and Maesyronen (Cilkeney Dingle), and the Clyro Brook.

2. GEOLOGY.

The only published large scale geological map of this area is the Old Series, One-Inch sheet (Talgarth 42 NE) of 1845, which is of limited value. Fortunately in 1936, the Rev. L.S. M'Caw included in an unpublished M.A. thesis on the Black Mountains (M'Caw, 1936), a brief

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[+] See Plate 34.

sketch of the geology. This remains today the most detailed account (it includes a sketch map) of the geology of the Black Mountains.

The area lies wholly within the Devonian outcrop of the Welsh borderland which, along the northern scarp of the Black Mountains maintains a fairly constant dip in a south-easterly direction. The hills to the north of the Wye are made up of the marl division of the Old Red Sandstone, but to the south of the river tough sandstones predominate, and the scenery is consequently more striking. In addition, the Old Red Sandstone to the south of the river is reinforced by Psammosteus Limestone bands, whilst the Black Mountains themselves are capped by the resistant Brownstones division. The Black Mountain scarp is a compound feature rising in three stages or steps from this Wye-valley, the treads of the steps lying at approximately 500, 1,200 and 2,200 feet above O.D. (fig. 50). These are probably structural in origin, being formed by the differential erosion of the various members of the Old Red Sandstone Series. Some authorities claim, however, to have recognised erosion surfaces coincident with them (Brown, 1960; Thomas, 1959).

The lowest step is made up of fine sandstones with calcareous bands (Ischnacanthus zone, 1, 6, Table 1). This is not such a well marked and persistent feature as the two higher steps of the scarp, particularly when traced westward (see fig. 50) where it loses its identity near the mouth of the Llynfi valley. This may be due to the greater efficiency of glacial erosion at this level. The second step is coincident with the Psammosteous Limestone outcrop (I 8, Table 18) which is reinforced by the Cephalaspis sandstones of the Lower Dittonian (II 1), whilst the third step or scarp, the crest of the Black Mountains, is made up of the massive conglomerates and sandstones of the Brownstone group (III).

TABLE 18.

THE GEOLOGICAL SUCCESSION OF THE BLACK MOUNTAINS.

(AFTER M'CAW, 1936).

III BROWNSTONES (5-600 feet)		False bedded, terrigenous flags and conglomerates.
II DITTONIAN (c. 1,000 feet)	4.	Marls with green and purple Sandstones.
	3.	Cornstones with sandstones and marls.
	2.	Marls with interbedded thin sandstones.
	1.	_Cephalaspis_ cornstone and sandstones. Usually in two bands c. 10 feet thick and separated by marls.
I DOWNTONIAN	10.	Marls with purple sandstones.
	9.	_Eurypterid_ grits amidst marls.
	8.	Psammosteous limestones. Fine grained and in solid or nodular bands varying from 1" to 12 ft. thick and embedded in calcareous sandstones and marls.
	7.	Thin calcareous sandstones and few thin marly limestones in marls.
	6.	_Ischnacanthus_ zone of fine sandstones with calcareous bands in red marls.
	5.	Deep-purple compact marls, almost devoid of sandstones.

Zones 4 - 1 are unrepresented in this area.

3. PREVIOUS WORK.

The effects of glaciation in this area have been discussed in papers by Howard (1903(b).), Dwerryhouse and Miller (1930), and Pocock (1926; 1948), whilst a useful summary of its effects within the County of Brecon is to be found in Thomas (1959), and for the borderland in Pocock and Whitehead (1948).

The section of the Wye valley at present under consideration appears, at least at one stage to have been at the confluence of two important ice streams: that coming down the Wye gorge from the Builth area, and the other from the south west, fed by ice from the Beacons, Carmarthen Fans and Mynydd Eppynt. Some of the latter ice found an exit via the Middle Usk into the Vale of Gwent, but the constriction of this valley at Llangynidr probably forced much of it to cross the Llangorse basin and so into the Wye via the lower Llynfi. One would suppose that the Llangorse basin would show abundant evidence of the passage of large quantities of ice, but this is not the case. Llangorse Lake is invariably ascribed to glacial damming, and Howard (1903(b), 105) has reported the discovery of W-E striation in a quarry exposure at Talyllyn. Nevertheless it must be admitted that the glacial deposits of this area are exceedingly thin, and not very extensive, and it is difficult to demonstrate conclusively in the field the ice-dammed origin of the Lake, although alternative explanations of its origin are similarly unconvincing. In contrast, extensive glacio-fluvial deposits in the Llynfi valley north of Llanfillo (119333), apparently originating from the Wye glacier via a col above Llyswen, are testimony to the size and importance of that glacier.

Overriding by ice of the scarp of the Black Mountains at the head of the Golden valley (Bach col, 570 feet) and even at the head of the Honddu (1,780 feet) at Cnapiau, as described by Dwerryhouse and Miller (1930), and M'Caw (1936) respectively, are indicative of the extent of ice in the Wye, whilst even the west scarp of the Black Mountains, overlooking the Llangorse Basin was overridden at the head of Cwm Sorgwm (1,140 feet) (Howard, 1903). Howard (1903) has shown that till covers the second step of the scarp from the Golden valley col at Bach to Pengenffordd and at 950 feet on the flanks of Mynydd Troed (plate, 7p.104-5). Using this evidence, and that of marginal drainage channels to be found about Bryngwyn Hill on the north side of the Wye, Dwerryhouse and Miller (1930), postulate that at its maximum the Wye valley was occupied by a glacier which must have been almost nine miles wide. The floor of the valley shows thick deposits of glacio-fluvial material, and many fresh glacial forms, which is in direct contrast with the Llangorse Basin. This suggests that the glacial maximum in this area considerably pre-dated the glacial advance which left fresh drift topography in the Wye valley. At the earlier time the Llangorse Basin was ice-filled and probably acted as a through route for ice from the upper Usk. In the later glacial episode however, it suggests that the Llangorse Basin was largely ice free, giving opportunity for solifluxion processes to modify many of the early glacial forms.

Cirque development.

One feature worthy of note is the absence of convincing cirques on the Black Mountain scarp, particularly when this is compared with the very well developed cirques notching the Beacons' scarp 15 miles to the south-west, which is made up of the same geological formation.

The following reasons might be put forward to account for this:

(1) Reduced precipitation. The Black Mountains stand on the eastern border of the Welsh massif in an area of declining rainfall totals. The scarp today receives an annual rainfall mean of between 40 and 60 inches, whereas that of the Beacons is considerably higher: 70 to 90 inches (Ordnance Survey National Atlas: 1:625,000 Sheet, Rainfall Annual Average, 1881-1915). There is no reason for assuming that the relative difference was substantially different during the Pleistocene.

(2) Aspect. The Black Mountain scarp has a north-westerly aspect, whereas that of the Beacons faces north-north-east. It is generally accepted that north or north-easterly facing slopes are the most favourable for cirque development, receiving minimum insolation totals.

(3) Glacial erosion. The location of the two scarps relative to the main lines of ice movement is highly significant. The Beacons were major source areas for ice, and as far as we are aware, there was no significant movement along the scarp face, movement being predominantly outwards. By contrast, the Middle Wye formed an important

corridor for ice moving eastwards. The till deposits of the second 'tread' prove that Wye ice once surmounted the second scarp, and thus is likely to have eroded the foot of the third scarp in moving down valley. It is thus suggested that incipient cirque forms developed early in the Pleistocene might have been obliterated by lateral erosion of the glacier at its maximum stage.

(4) Differing degree of valley development. The streams flowing off the Beacons today flow in far more significant valleys than those running off the north scarp of the Black Mountains. This in itself could be a reflection of the greater degree of cirque and valley glacier development, but it is suggested that the difference is probably longstanding. A case can be made out, as noted in Chapter 7 , for considering the Beacons' streams as relatively old members of the drainage pattern. The more deeply incised valley heads would therefore have provided the basis for marked cirque development by encouraging massive ice accumulation at an early stage.

It is not suggested, however, that ice accumulation did not occur on the Black Mountains scarp. Thomas (1959, 108, fig.) indicates the position of two 'cirques or cirques-like valley heads' on the scarp at the source of the Ennig and the Digedi Brook. These do approach the conventional cirque form. There is, however, a distinctive valley head form along this scarp. Most streams begin in deep gullies notching the face of the third step (Plate 30). They are wide at the top, narrowing downslope. These are similar in form to hollows observed to be holding small glaciers by Groom (1959) in Spitzbergen which she terms 'niche glaciers'. These appear to be developed in locations which would not favour the development of more conventional cirque forms, in particular, when there is an absence of deep valley heads. Even so, it is quite clear that the contribution of local ice to the Wye glacier was exceedingly limited.

In addition to what has been said about ice movement generally in the area, Pocock has written about (but not mapped) terraces in the Wye valley (Pocock 1926, 1940), recognising three main terraces at heights of 60+, 35 and 15-20 feet above the river, which could be traced upstream to a recessional moraine at Erwood. The anomalous mass of high ground athwart the valley between Clyro and Hay has been commented on by most writers, some like Grindley (1954), and Dwerryhouse and Miller (1930), seeing it as a recessional moraine which has diverted the Wye from its former course at Clyro to its present cutting at Hay.

4. ANALYSIS OF THE MORPHOLOGICAL MAP.

The area between Hay and Llyswen, including the first step of the Black Mountain scarp in the south, but not the hills to the north of the valley was mapped morphologically, and the results are shown in fig. 51. It will be described in the text, and ideas previously put forward will be re-examined in the light of this. Too often in the past glacial features have been the subject of extensive written work, inadequately supported by maps based on field evidence.

(a) <u>The Clyro-Hay Barrier.</u>

The morphology of this area will be seen in fig. 51, whilst fig. 52 portrays the main features of the relief and drainage. The 300 foot contour swings across the valley at this point to enclose a block of high land reaching over 400 feet in the centre of the valley. It rises abruptly from the valley floor on its upstream side, and the river flood plain is almost completely eliminated due to its presence. South of the river this ridge is continued by the knoll on which Hay Castle stands.+ This is not apparent in fig.52 as it falls within the 50 foot contour interval employed, but is shown rising above superficial deposits in fig. 51. The Wye breaks through this ridge in the form of an ingrown meander, being overlooked by cliffs on the convex sides of the meander bends at Wyecliff and to the south of the river at Hay), with terrace remnants contained within the meander loops. On the north side of the valley the centre block of high ground is continued as a hummocky neck of land barely 60 feet above river level, which is quite obviously composed of superficial deposits.

Dwerryhouse and Miller (1930), and also Pocock (1940), have suggested that the Wye in this section is epigenetic, the river formerly flowing north of the present valley at Clyro. At first this idea was discounted, the main reason being that although the glacial blocking of the deep through valley could be proved at Clyro, the central hill seemed to have but a thin veneer of drift, and as it is quite obviously a solid rock structure, would in any

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+ Hay Castle, standing above the gap formed by the river, can be seen in Plate 31.

case have resulted in a remarkable restriction of the valley at this point. If too, one examines the relief map (fig.50) the 350 foot contour appears to be most significant. Not until this level is reached does the sharp rise of the valley sides begin. If the 350 foot contour is thus accepted as defining the extent of the valley floor, it will be seen that there is a considerable widening at Hay, giving ample room for the pre-glacial valley, along the line of the present river. That being so, it could well be that the moraine blocked gap at Clyro was of purely glacial origin, and that the river has returned to its former coursee but has incised itself into the rock floor of its pre-glacial valley.

Upon further consideration this theory is abandoned. The Wye in this stretch is generally accepted as of subsequent origin, M'Caw showing the river exploiting the marls at the base of the Ischnacanthus scarp, whilst more recently the probability that this stretch is controlled by the Cribarth Disturbance has been expressed (p. 24). The trend of the supposed former valley through Clyro conforms with the local strike pattern, whereas the present course past Hay does not. Moreover the steep and straight northern valley side east of Glasbury may be fault controlled. What then, is the origin of this anomalous block of high ground? M'Caw unfortunately maps the whole of the valley floor on the north side of the Wye at Hay as of glacio-fluvial deposits, which examination of the fine exposure at Wyecliff +(223426), for example, immediately shows to be mistaken. The hill at its riverward end shows none of the hummocky topography normally associated with depositional forms of glacial origin, although ice moulding may have contributed to its present streamlined shape. Field examination revealed the mass of the hill to be of solid rock, whilst at Clyro the bulk of the ridge is made up of morainic mound and hollow. The precise junction of the two is not clear. The relief map (fig. 52) shows, however, that the main axis of the hill is NE-SW and that this lies along the line of the broken scarp of the Ischnacanthus zone, well developed in the Glasbury area to the south-west, and in the Clifford area to the north-east. If this is so, the river is seen to be superimposed across the Ischnacanthus scarp, the reason for which could be the diversion of drainage across it during the final wasting stages of the ice in the area. This suggestion is illustrated

+ Plate 32.

in a diagrammatic form in fig. 53. The degraded cliff north-east of Wyecliff probably marks the continuation of the scarp face (and south side of the pre-glacial valley) of the *Ischnacanthus* zone, which is buried farther north by the dump of superficial deposits filling the south side of the Clyro gap.

It is suggested therefore, that, as is shown in fig. 53, the pre-glacial valley of the Wye lay through the Clyro area. Although the Dulas Brook today swings northwards before joining the main river below Hay it may in pre-glacial times have continued the more north-westerly course of its upper section to join the Wye near Wyecliff, as is shown in fig. 53. The present course past Hay may have been initiated subglacially, the channel so formed being used by marginal drainage when the ice had wasted to uncover the Clyro-Hay ridge. Meltwater drainage probably utilised part of the former lower course of the Dulas Brook, and other small tributaries which may have been exploiting the strike of the strata, as appears to be the case in a number of places on this scarp farther west (discussed later). At present the Wye cuts sharply across the strike at the Warren (opposite Wyecliff), is strike controlled (and eroding down-strike to produce a markedly assymetrical valley) at Hay, and cuts across the structural grain again about a mile north of the town.

To conclude, the present river course past Hay is seen as a glacial drainage diversion used by meltwater during a stage of deglaciation when wasting had uncovered the Clyro-Hay ridge. The new river course is superimposed partly across the <u>Ischnacanthus</u> scarp, the former valley course being plugged by extensive morainic deposits at Clyro. It will be shown later that meltwater escaped briefly across the northern end of the ridge into the valley of the Clyro Brook, but that the main kame terrace developed between Llyswen and Hay has a surface level which indicates that the meltwater forming it drained through the Hay gap.

(b) <u>Terraces and associated features.</u>

On both sides of the valley, and particularly well developed in the Llyswen area, are terrace-like features of depositional origin. Not all of these are river terraces. Some are of glacio-fluvial origin. They have been distinguished in fig. 51 and will be discussed here, commencing with the highest in the Llyswen area.

(i) Kame Terraces. At Llyswen (fig. 51) on both sides of the valley there is a bench-like feature about 60 feet above river level that is interpreted as a kame terrace. It has an undulating surface, and to the east of Dderw there are a number of shallow kettle holes (see fig. 57), two of which contain water. The riverward face of the feature is irregular, and appears to be of depositional rather than erosional origin. This seems to be predominantly an ice contact, the best example being found WNW of Dderw. The kame terrace falls from about 350 feet near Llyswen Rectory (130382) to about 303 feet at Boxbush (157378) where it has been almost completely cut away by the river. It continues as a thin, river trimmed bench, eventually terminating at Pipton (168381) as a spur between the Wye and the Llynfi, where its surface reaches a minimum level of 296 feet. On the north bank of the river in this area a similar feature is to be found, although the gradient is much less, falling from 341 feet opposite Llyswen to 320 feet near Boughrood Brest (142387).

On the south side of the valley at Aberllynfi (fig. 51) the combined flood plain of the Wye and Llynfi is flanked by a steep water-cut bluff rising to over 300 feet O.D. It may well be that this is the remnant of the kame terrace, but it is overlain by a composite fan of gravel laid down by two small tributary streams of the Llynfi. At Glasbury there is no similar feature on the south side of the valley, and road widening operations revealed there a thick till deposit containing rounded boulders of up to three feet in diameter, covering the base of the hillside. Where the Hay road crosses the track of the former railway (188397), however, there begins a feature which persists to Hay (fig. 51).+ It has a bench-like form, above which rise low hills marking the continuation of the lower scarp. The latter are basically solid, with a thin cover of boulder clay, and some evidence of ice smoothing. Some of the streams which cross it have at one time built out fans on its surface, but the streams are now entrenched into the surface. Its leading edge is just below 300 feet, so that its surface is delineated well by the 300 foot contour. Its riverward face has been undercut by the river in places, but at others there is evidence of ice contact. It is suggested that this too is basically a kame terrace, which has been overlain by fans of alluvial

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+ Shown in Plate 34.

material in places. At the Warren (opposite Wyecliff - 221426), near Hay, this surface passes laterally into a small morainic ridge which may be the relic of a more extensive feature now removed by river erosion.

The kame terrace in the Llyswen-Aberllynfi section has a fairly steep gradient, but in contrast, from Glasbury to Hay it retains a fairly uniform level despite its undulating surface. It is suggested that this may be a reflection of a local base level formed by resistant rock in the floor of the marginal channel carrying drainage across the "ridge" at Hay (i.e. along the present river course). If marginal water was escaping down valley that way instead of continuing along the ice margin, the level of fluvio-glacial deposits laid by such streams would be controlled by the height of the outlet. The change in gradient could however be simply a reflection of the changing gradient of the ice surface at this point.

On the north side of the valley there is a kettle-holed bench at Glasbury at about the same level (175399), and another, showing a good exposure of bedded gravels, on the roadside south-west of Llowes (189411). At Clyro

Court (208428) there is a further fragment at this level (fig. 51) with evidence of ice contact, along its face. This is, however, replaced near Clyro village by a higher surface at 330 feet, also with an ice contact face.+ The surface of this can be traced north-eastwards into the mouth of a channel which today carries the main road across the end of the Clyro ridge, and which opens out into the lower part of the valley of the Clyro Brook. It is suggested, therefore, that the marginal drainage which laid down the upper of the two terraces escaped across the mass of superficial deposits blocking the former valley forming a col. at Clyro. The lower bench is probably a later feature formed after the Clyro channel (due to ice wastage) had been abandoned. At this stage drainage may have been re-entering the ice to escape from the ice front via the major overflow developed (along the line of the present river) at Hay. This must have occurred at a late stage in the withdrawal of ice from the area.

An early phase in the cutting of the Hay overflow may be marked by a sloping bench near Wyecliff falling from over 300 feet to 275 feet where it has been undercut

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+ See Plate 33.

by the river. The persistent undulating bench at 300 feet found on both sides of the valley between Llyswen and Hay is thus interpreted as a kame terrace formed when ice wastage had uncovered the morainic barrier at Clyro. At first marginal drainage on the north side of the ice escaped via a channel across the ridge at Clyro, but further shrinkage allowed meltwater to cross the ice to the lower outlet developed on the south side of the barrier at Hay.

(ii) The Valley Train. The pronounced meander of the Wye at Llyswen is incised into an undulating surface some 25 to 30 feet above river level. There is a sharp drop from this surface to the river, and in the Llyswen area only a small fragment (not shown in fig. 51) of a lower terrace exists below this level (near Boughrood). Near Glan Gwy (151382), however, the river has been able to swing more freely about the valley floor, and this surface has been removed completely by river erosion on the south side, tapering to disappear a mile above Glasbury on the north side. It is considered that this is the remnant of a valley train, possibly connected with the recessional moraine at Erwood. It appears to have a more broken surface (especially near Llyswen) than one would expect were it a river terrace. The face of the higher bench (kame terrace) flanking it on both sides of the valley in places shows clear ice contact forms.

(iii) The River Terraces. Below the level of the valley train surface there are at least two series of terrace remnants. The higher one (fig. 51) has important remnants at Glan Gwy (where it has a maximum height of 298 feet), Glasbury (north bank), Llowes and Clyro (260 feet). It will be noticed that it is separated from the valley train remnant above Glan Gwy by a height of only three or four feet, although, as can be seen in fig. 51, it is demarcated by a distinct bluff. It continues the gradient of the valley train which suggests that it may be the river trimmed remnant of that deposit.

This is, of course, part of the former valley floor, the continuation of which is moraine blocked (see fig. 53). The irregular margin of the terrace appears to indicate that upon the withdrawal of the ice a hollow was left in this area which has since been filled, probably by silting during periods of flood, as it is improbable that the river ever flowed over this tight corner of the valley floor.

Even today there is a slight fall towards this corner, which contains marsh.

The lower terrace is not so well defined, and its surface is broken by former river channels. Important remnants are found (fig. 51) above Glasbury (very uneven with old river channels, some containing mort lakes); on the north bank of the river at Glasbury Bridge; and south of the river downstream of the Bridge. This lower terrace rises only a few feet above the flood plain, and it is not now subject to flooding, although during the exceptional flood of November 1961, parts of this terrace were covered by flood water (including parts of Glasbury village).

The flood plain of the river is quite extensive here, and this is the first major broadening of the valley floor after a 15 mile gorge section, where the river, with a high gradient is tightly confined between stepped benches. Prolonged rainfall in the upper part of the catchment basin is usually accompanied by a rapid rise of river level and flooding, particularly between Glasbury and Hay. This tendency towards flooding is assisted by the virtual termination of the flood plain and the constricted outlet at Hay.

Having concluded the description of the terrace features shown in fig. 51 , the views of Pocock on the terraces of this part of the Wye valley might be considered. He reported three gravel terraces "best seen west of Glasbury on the road to Boughrood" (1940, 110). These were at levels of 60+, 35 and 15-20 feet above river level, and quite obviously correspond respectively to the kame terraces, valley train and upper river terrace, described above. Pocock distinguished these from three minor terracing stages at an even lower level which were composed of alluvium. It must be admitted that this distinction was not obvious in the field in so far as the two river terraces described above were concerned, the higher one, according to Pocock being gravel, and the lower alluvium, although it accords well with the interpretation given: namely that the upper one is the river trimmed surface of the valley train, which would be expected to have a greater proportion of gravel than a normal riverine deposit. Nevertheless, it should be noted that the river is currently moving large quantities of gravel, and the distinction between gravel and alluvial terraces whilst seemingly straight-forward would probably be difficult to justify.

The three gravel terraces are linked by Pocock with the recessional moraine at Erwood: our conclusions are thus broadly in agreement. With respect to the uppermost terrace however, he states that "a bed of loam over the drift of the third terrace is common in the country round Hay and indicates the formation of a lake....", describing an exposure showing this at Glasbury. Unfortunately Pocock's paper was not available until after the field work was completed, and there has not been an opportunity to locate and examine this exposure. He states that the loam is found "60 feet or more above the river" which at Glasbury is at approximately 265 feet O.D., so that the lake surface in which this loam formed must have stood at a level of at least 330 feet. Although he refers to this lake as being "blocked..... perhaps due to a barrier of ice not yet melted" (Pocock, 1940, 110), it is difficult to conceive of this circumstance, and blockage by morainic deposits at Clyro seems more likely, where the overflow channel is at approximately the right height to function as a spillway.

Nevertheless, on the evidence which has been produced so far it is difficult to accept its existence.

There are no strand lines or deltaic deposits at this level, and the 'third terrace' has declined in height to almost 300 feet in the Hay area. Further, if we are to accept the third terrace as a kame terrace, it is difficult to reconcile this with lake deposits at a higher level: the presence of kame deposits presupposes that glacio-fluvial drainage was able to escape at at least that level down valley. Further, it is unlikely that lake deposits so low in the valley would have survived a re-advance of the ice, if the loam referred to by Pocock is considered to pre-date the kame terrace.

A more tenable theory is that a lake was temporarily held up behind the Hay-Clyro ridge, because immediately upstream of this the level of the valley floor following ice withdrawal must have been lower than it is today: the face of the kame terrace is not river trimmed; it meets the valley floor at a sharp angle, and aggradation has clearly been operative in this area. It is quite probable that when the ice withdrew the valley above Hay was considerably below the level of the outlet, which formed a temporary lake, being filled by gravels washed downstream during the dissection of the valley train by the Wye. Completion of the filling of the lake may be indicated by the terrace developed at Llowes and Clyro, and subsequent downcutting of the outlet at Hay has resulted in the incision of the river into this surface. The terrace certainly continues through the Hay outlet as a terrace on the north bank upstream of Hay bridge. The evidence for the existence of a lake behind the Hay barrier is not therefore conclusive.*

(c) Meltwater Channels.

One of the most interesting features of the first step of the scarp is the number of channels which are to be found on it, generally unconnected with the present drainage pattern, and running in a north-easterly direction. These are to be found also on the second step of the scarp and one of the finest examples seen was at a height of almost 1,300 feet crossing the crest of the ridge between the Digedi and Cilonw Brooks above Pen-y-werlod-serth, Llanigon (230373). The mapping,

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* It is interesting to note that several farmers met in the course of the field work spoke of the valley floor in the Glasbury area as being the bed of a former lake.

however, was confined to the summit and face of the first step between Talgarth and Hay. The distribution of channels on it is shown in fig. 54.

The channels are generally dry, except in very wet weather although a few lead down into the valleys of streams crossing the scarp. They vary in form from broad, shallow, elongated depressions, to deep trench-like channels, and the majority of them are to be found crossing the crests and eastern slopes of the stream interfluves. In general, the shallow open form is most common, and many of these appear not to have cut through the till which thickly covers the step. The major channels have, however, been cut into solid rock.

Apart from a classification in terms of size, the channels may be placed in three groups:

1. Those crossing the crests of minor watersheds (there are numerous examples of these, the best crossing the watershed west of the Nant Ysgallen, which will be discussed in detail later.)

2. Channels which score the face of the scarp. These often begin as hillside benches, sometimes turning into more conventional channels when traced downvalley. The most noticeable group of these (fig. 54) are to be found on the hillside to the east of Gwernfed Park (179378).

3. Channels running down steep slopes, only some of which are connected with channels in group 1. They do not generally contain streams, but even so could be interpreted as gulleys, were it not for the fact that they fade away rapidly downslope, and seem in general to be unconnected with the present drainage system.

Channels such as those in group one have for many years been interpreted as 'overflow channels', and the situation of these channels crossing the interfluves of small valleys tributary to the Wye would immediately suggest this origin. Ice in the main valley, it would be suggested, would persist, fed as it was from the Central Wales Plateau, for a considerable time after the ice in the tributary valleys had melted. Pro-glacial lakes would thus form in some of these where the natural outlet into the main valley was ice-blocked, the lakes spilling over the lowest col, or perhaps along the ice margin, into the next valley. One of the most noted studies of such pro-glacial lake systems was that of Kendall in the Cleveland Hills (1902), and many subsequent workers have invoked pro-glacial lake systems evidenced by overflow channels. Recent work has shown, however, that many features of them are inconsistent with this origin. Certain of them have been noted to have an 'up and down' form (Peel, 1956): that is, they do not have a constant downstream gradient. Whilst many ingenious explanations have been put forward (Peel, 1956; Twidale, 1956) to account for this, and to retain their supposed origin as overflows, other workers, notably Sissons (1958) have, after investigating numerous examples in the field, arrived at the conclusion that those previously noted were often part of a more extensive system of channels the existence of which was not compatible with the pro-glacial lake theory. An alternative hypothesis has therefore been put forward by Sissons (1958) based on evidence of the effectiveness sub-glacial, en-glacial and supra-glacial stream erosion from existing glaciers in Scandinavia, which considers them to have been formed by meltwater streams flowing on, in, marginal to, and under the ice. The up and down profile of some has been explained as meltwater erosion under hydrostatic pressure within the ice. This theory has been examined in the field by other workers (Price, 1960 and 1963) and Sissons has suggested that many of the areas in which earlier workers have indicated the presence of pro-glacial lake systems might profitably be re-examined (Sissons, 1963). In particular, he points out that in view of an alternative origin for so-called overflows, as outlined above, before the presence of former pro-glacial lakes is postulated, more satisfactory evidence such as strand lines, lacustrine, and deltaic deposits should be produced.

In the light of this recent work the channels found on the first step of the scarp are examined. It seems fairly certain that they were all cut by meltwater. Those in group two seem to be channels cut by meltwater streams running along the margin of the ice when it had wasted to a fairly low level, whilst those in group three are interpreted as sub-glacial chutes. These latter were first noticed developing on active glaciers by Mannerfelt (1945), where meltwater streams running on or marginal to the ice disappeared into it, between the ice and the valley side, cutting a steep channel into the rock as it did so.

It is not proposed to examine all the meltwater channels shown on fig. 54 in detail, but instead to examine the well developed series about the valley of the Nant Ysgallen (fig. 55).

The Nant Ysgallen rises at an altitude of about 1,200 feet on the flank of the 'Tumpa' (fig. 50), and breaches the second step of the scarp in a deep V-shaped valley to emerge onto the shelf of the lowest step near Llwyn-barried Farm (fig. 54). At this point the slackening of gradient appears to have caused the formation of a low cone of detritus. Crossing the first shelf it becomes progressively more entrenched until near Heol-y-gaer it makes an abrupt turn east into a deeply cut gorge+ which finally opens out at Pont yr Angel onto the surface of the fluvio-glacial deposits fringing the flat floor of the Wye valley at this point.

+ The Pen-y-gengl Gorge: shown in Plate 35.

The abrupt bend of the Ysgallen at Heol-y-gaer is the only major departure from the N.W. trend of the obsequent streams of the scarp, and in view of the fact that the north-easterly course below the bend is approximately along the strike of the strata, subsequent adjustment - river diversion - might be expected. Moreover, the continuation of the N.W. trend of the upper section of the stream is marked beyond Heol-y-gaer by a drift encumbered valley which hangs above the main Wye valley at Glasbury Bridge. The quantity of drift in it masks the former gradient of the valley floor, and although it is drained today by only a small stream near its mouth, there seems little doubt that this was the former course of the Nant Ysgallen before it adopted the north-eastward course through the Pen-y-gengl gorge.

River capture is a possible cause of the diversion of the Nant Ysgallen, although as the new course is longer than the old, there is no gradient advantage. Although this new course coincides with the strike, a factor of greater importance is its coincidence with the general trend of the meltwater channels (fig. 54). As those mapped as 'major meltwater channels' have the dimensions of small valleys, the possibility arises that the diversion was initiated along the line of a major meltwater channel, which retained this drainage after the withdrawal of the ice from the area. It seems that this is the most likely reason for the diversion and this hypothesis is adopted here. This does not imply that the new course of the Ysgallen is not structurally controlled, there being good evidence that it is, especially in view of the fact that (fig. 55) the ridge immediately south of the bend in the Ysgallen shows re-entrants, drained on the north side by small tributary on the Ysgallen, all of which are in line with the new course of the river. There is every reason to suppose that meltwater would drain wherever possible over existing cols, the location of which might be governed by structural weaknesses.

Examination of fig. 55 reveals that there are three other major meltwater channels in the area, one crossing the ridge north of the abandoned lower Ysgallen valley, one near the foot of the second scarp step and one to the south. In addition there are two minor meltwater channels (not including those scoring the face of the second scarp), and a number of 'marginal benches' on the face of the scarp overlooking the Wye. For convenience, the plan of these meltwater channels is shown diagrammatically in fig. 56 (A). The key to the numbering is as follows:

1. Llwyn-barried channel
2. Tynllyne
3. Llwyn-y-brain
4. Little Lodge
5. Heol-y-gaer channel
6. Tiruched
7. Glasbury Station
8. Pen-y-gengl

The most striking is No. 6, the Tiruched Channel (see Plates 36 and 37), which takes the form of a flat floored trench about 50 feet deep, and sloping steeply down to the bench on the south side of the Wye at Llwynaubach. The anomalous form of this feature was sufficient for an historian describing the remains of the Roman marching camp on the adjacent hill to comment on it (Jones, 1958), erroneously ascribing it to faulting. On the other side of the abandoned lower Ysgallen valley another channel, similarly deeply cut (the Little Lodge Channel: No.4) appears to continue its line. The gradient of these two channels suggest that they once functioned as one meltwater route, although the lower part of the Little Lodge Channel is now at a level of 15-20 feet below the floor of the upper end of the Tiruched channel. The Llwyn-barried channel (No. 1) also appears to be continued by channel 3 (Llyn-y-brain), and this alignment of individual channels upon each other is a characteristic of the whole series (see fig. 54), there being a marked series of alignments at the foot of the second step of the scarp. Closer examination reveals however that some individual channels of this series are better developed than others, and that there is not a continuous decline in channel height from S.W. to N.E., suggesting that if they were initiated as one system, as their alignment suggests, certain elements have been occupied by meltwater longer than others. If the new course of the Nant Ysgallen is considered to be initiated as a meltwater channel, the ridge crest opposite this forms an important exception, with no channel across it in line with the Pen-y-gengl gorge (No. 8, fig.7), although a number of shallow channels cross the next ridge to the S.W. The reason for this is unclear, although it is probably of limited significance.

The third of the major channels is the Llwyn-y-brain (No. 3) which drops as a steep sided narrow channel from a broad, flat-lying area in the Ysgallen valley into the valley of the Digedi Brook near Llanigon. The two minor channels are the Tynllyne (No.2), which commences at the same flat as channel 3, before cutting the crest of the interfluve and running obliquely across the contours into the Digedi valley, and the Llwyn-barried channel (No.1), which is broad and shallow, possibly partly due to infilling by the growth of a detritus fan (fig. 55).

On the scarp face overlooking the Wye three benches have been mapped which are considered to have been cut by meltwater streams running along the ice margin, the ice in effect forming the one side of the channel. Similar benches have been described by Mannerfelt (1949). All three benches have a marked downstream slope. Only one of these (No.7) was examined in detail, and is included in fig. 56(A), although the position of all three is shown in fig. 55. The Glasbury Station Bench (No.7) curves around the hillside from the face overlooking the Wye into the lower part of the former Ysgallen valley. There is a tendency for its outer edge to be higher than the inner part, except where, in two places, minor channels notch the outer edge, descending the hillside for a short distance. It slopes from 409 feet at its southern end to approximately 345 feet where it loses its identity in the abandoned section of the Yagallen valley.

The highest point of the floors of the channels discussed above was determined with a surveying aneroid, and the results are listed below, the estimated height* of the col before glacial modification being given in brackets :

TABLE 19.

MELTWATER CHANNEL HEIGHT : IN THE DIGEDI VALLEY.

1. Llwyn-barried	508	(520)
2. Tynllyne	496	(515)
3. Llwyn-y-brain	493	(520)
4. Little Lodge	468	(495)
5. Heol-y-gaer	435	(440)
6. Tiruched	371	(620)
7. Glasbury Sta.	407	(-)
8. Pen-y-gengl	---	(Post-glacial deepening (510)

* This estimate was made by examining the form of the ridge on either side of the channel, noting in particular the position of the break of slope bounding the head of the steep side slope of the channel, where this existed.

No. 5 was not discussed above, as it forms part of the abandoned lower Ysgallen valley, but there is some evidence that this was at one stage utilised by meltwater entering the Pen-y-gengl channel (i.e. flowing in a reverse direction along the former valley floor).

Some of the reasons why the linking of such channels with pro-glacial lake systems has been questioned in recent years are given above. Strong independent evidence for the existence of such lakes must be produced, and in the case of the Digedi Valley, the evidence for this is thin. No deltaic deposits or strand lines were observed, and the only possible area where such a lake might have existed is below Ffordd Las (fig. 55) where there is an area of flat and marshy ground, frequently flooded in winter. The Llwyn-y-brain channel leads out of this, commencing at approximately the same level as the flat, whilst the Tynllyne Channel (No.2) also commences at its edge, although there is a perceptible rise from the flat to its mouth, which is three feet higher than Channel 3. To the south the flat has been partly overspread by the Ysgallen gravel fan. This is the possible site of a former lake, although final judgement should be reserved until more objective evidence (i.e. analysis of the deposits flooring the flat) is available. It is however, difficult to see how sedimentation could have occurred in this area other than within a body of water, and this could only have existed if the lower Digedi was ice-dammed.

The majority of these channels are therefore interpreted as meltwater channels, some cut marginal to the ice and others beneath it by sub-glacial or englacial meltwater streams. Sissons (1958) has stressed that wasting ice would thin and disappear first on ridge tops, the ice in the valley being thickest, so that the ice margin would waste in a line approximately parallel to the contours. It is difficult to say, however, whether all the ridge crest channels were cut sub-glacially. The fact that the channels commence at successively lower levels as the Wye is approached suggests that they may have been marginal in origin, but the course of channels 4 and 6, for example, cutting across the line of the Ysgallen valley with complete disregard for it would support a sub-glacial origin. It may well be, however, that they are of complex origin, being initiated by sub-glacial drainage, and later adopted by ice margin streams as the ice wasted. This hypothesis is adopted here, as a sequence of events accompanying the wasting of the ice is illustrated in fig. 56(B).

It is suggested that wasting of the ice gave rise to a marginal stream running at the foot of the second step of the scarp. Drainage down the present Ysgallen valley was prevented by the ice, and a short-lived lake was formed, spilling at various times into the Digedi valley via channels 2 and 3 (Stage I). The presence of two outlets is not easy to explain, although the differing form of channel 2 suggests that it may have been formed by lake water entering a temporary opening in the ice when the lip of channel 3 was at a higher level, and the ice margin was higher on the north-facing slope at Tynllyne. The lake seems to have disappeared due to infilling and erosion of the outlet. It is possible that before a lower outlet opened for marginal drainage, meltwater was draining from the ice in a reverse direction along the Ysgallen valley into the lake area (probably drained at this stage) and eastwards via channel 3, for near Llwynfilly+ (fig. 50) a fan of gravelly material can be seen sloping in an easterly

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+ Grid Ref. 199 389.

direction. Further wastage of the ice resulted in the uncovering of a lower col on the site of the Pen-y-gengl channel, and initiation of Stage II (fig.56 (B). The absence of a channel on the ridge between Nos. 1 and 4 may indicate that marginal drainage had temporarily entered the ice. It would seem, however, from estimated heights of the pre-existing cols given in Table 19that relatively slight wastage of the ice would have allowed the opening of channel 4 which perhaps fed channel 8 via the abandoned Ysgallen valley (5), before a more direct route opened (Channel 6, Stage III). With the opening of route IV along the face of the scarp, channel 4 was abandoned, and in the absence of benching on the hill face immediately north of channel 7, drainage appears to have continued via channel 6 or re-entered the ice. The small channels notching the bench of channel 7 are evidence that the latter did occur at one stage. The cutting of channel 4 below the level of the entrance to channel 6 does suggest however that meltwater from the former had abandoned the channel 6 route before channel 8 opened, possibly entering the wasting ice tongue in the Ysgallen valley.

It will be observed that the three major meltwater channels crossing the north ridge (channels 3, 5 and 6) all lead down eventually to the terrace of fluvio-glacial deposits, channel 3 being continued by major meltwater channels at Tylau (214407) and Waun-derwen (218413), north of Llanigon. The low level of these latter channels - between 300 and 400 feet - suggests that they may have been utilised by meltwater at stage II (fig.56(B). As stage IV requires an ice level of over 400 feet at Glasbury, it seems unlikely that the formation of the kame terrace between Glasbury and Hay (290-315 feet) was contemporaneous with this.

(d) The Glas Waen Overflow.

South of Llyswen (fig.50) there is a wide col 175 feet above the floor of the Wye valley which leads into the small valley of the Triffrwd, a tributary of the Dulas which is itself confluent with the Llynfi near Talgarth.

This col. appears to have been a through route for a diffluent tongue of the Wye ice, here beginning to move east, because:

1. the width of the valley far exceeds the erosional competence of the small stream which at present drains it;
2. the col and the lower part of the Triffrwd valley is thickly drift encumbered. This drift can only have been derived from the Wye, as it stands in contrast to the terrain to the south and west which is remarkable for its absence of recent glacial forms.

This through route from the Wye to the Llynfi at Talgarth was mapped morphologically, and the result is shown in fig. 57.

The significant morphological features may be summarised as follows:

South of Llyswen the small stream rising in the col and tributary to the Wye runs in a deep V-shaped valley below the level of two sloping benches. South of these is a marshy flat, flanked on the south and west by an area of ridge and kettle. This flat is at present drained through these deposits <u>via</u> a narrow gap into the Triffrwd, whilst the watershed between the Wye and

Llynfi drainage has an indeterminate course along the northern edge of the flat. The Triffrwd valley is flanked by a bench of gravel to the east, pocked here and there by kettle holes, whilst the valley floor is occupied by a low terrace. Near the confluence with the Dulas the valley is relatively wide, its southern side being spread with morainic material, but eastwards it narrows, where the Dulas breaks through a mass of gravel almost blocking the valley at Tregunter (136340). There was a fine exposure of these stratified gravels in 1960 during road improvements half a mile west of Bronllys. The gravel dies away at Bronllys to be replaced by a till-covered bench flanking the flood plain of the Llynfi, whilst the flood plain is restricted in extent by the presence of a large detritus (gravel) fan at the mouth of the Ennig valley. Meltwater channels are particularly numerous on the flank of the hill east of the lower Triffrwd, whilst others are to be found crossing the spur dividing the Dulas from the Llynfi (fig. 57). In contrast to this, the Dulas valley above the confluence, as too the Llangorse Basin, shows no clear evidence of glaciation.

The Glas Wen col probably follows a zone of structural weakness, for its alignment is matched by that of a series of stream segments and cols to the south-west, whilst in the other direction a line drawn through it coincides with the remarkably straight north side of the Wye valley between Glasbury and Rhydspence. The probability that the Wye below Glasbury is exploiting an extension of the Cribarth Disturbance has been stated by T.R. Owen (personal communication), and has been discussed in an earlier section. The exact line of the Disturbance north-east of Brecon is, however, unclear, although stream alignments suggest the presence of two major sub-parallel faults, the one followed by the Dulas valley below Felinfach, and the other by the Glas Wen col and various small aligned valleys between there and Talachddu. Ice moving across the site of the Glas Wen col from the Wye would thus almost certainly have utilised a pre-existing valley and col.

The sequence of events responsible for this assembly of morphological features appears to have been first, glacial breaching of the Triffrwd-Wye watershed by a tongue of ice from the Wye glacier. Breaching of watersheds on a major scale was first demonstrated in the British Isles by Linton (1949), and it seems entirely reasonable to postulate movement of ice across an existing low col, so deepening it to its present form. This ice tongue must have been at a height of 6-700 feet O.D., and it appears to have pushed eastwards on entering the Dulas valley to rejoin the main body of ice at Aberllynfi on a bench to the south of the river. Certainly recent glacial forms between Talgarth and Aberllynfi suggest a ground moraine. At this stage too the ice appears to have overwhelmed the spur east of Llanfillo, leaving hummocky terrain seamed in places by meltwater channels. This early stage is also testified by the numerous meltwater channels cutting obliquely down the hill slope near Talgarth Sanatorium (137354) the highest of these commencing at over 600 feet, and probably of sub-glacial origin. There are, however, gravel deposits above Bronllys at 600 feet, and the marginal drainage responsible for these appears to have escaped eastwards to Coldbrook (154360).

The considerable gravel deposits both in the Triffrwd and Dulas valleys suggests that much of the marginal drainage of the Wye glacier crossed the col when only dead ice remained in the Triffrwd valley. North of Tregunter there is reason to believe that the valley was formerly completely filled by outwash, but in the Triffrwd valley gravel appears to have accumulated extensively only on the east side, probably as a kame terrace (fig. 57) marginal to stagnating ice. On the opposite side of the Triffrwd a pronounced meltwater channel swings in a half circle downslope, almost to the level of the valley floor. This suggests that the lack of kame deposits on this side may be due to the disappearance of marginal drainage beneath the ice. A route was probably maintained through the wasting ice for en-glacial drainage into the basin about Talgarth. If this were not the case water would have been dammed up in the Dulas valley, and there is no evidence of this. It would be expected too that outwash gravels would have accumulated in the Dulas valley (above Llanfillo), but there is no evidence of this either. This is in marked contrast to the extensive gravels on the east side of the valley which suggest an important meltwater system laying gravels on and marginal to blocks of stagnant ice almost as far east as Bronllys.

Farther up the Triffrwd valley ridges of drift crossing the valley transversely suggest an ice halt, possibly after thinning had detached stagnant masses further down valley. If this is a recessional moraine it seems to be partly covered by outwash. A further retreat of the ice resulted in ponding of water behind this, and the market flat of marshy ground suggests that there was a temporary lake which was eventually drained by the cutting of its spillway into the Triffrwd valley to lake floor level.

(e) The Lower Llynfi Valley.

This area, between Talgarth and Aberllynfi requires separate treatment as the main features of its morphology are not the same as those discussed in the Wye valley.

It is basically simple in form with a till covered bench on both sides of the valley, but best developed on the south side, where it declines in height from just over 400 feet near Talgarth to approximately 350 feet west of Aberllynfi. This bench is shown on figs. 51 and 57., being mapped as a 'flat of indeterminate origin'. Its surface shows a number of elongated mounds (showing till exposures in places), probably drumlins, which are generally aligned in a SW-NE direction. In the centre of the valley the flood plain of the Llynfi is widest near Talgarth, tapering to disappear near Three Cocks Junction, where the Llynfi cuts a minor gorge before descending to the level of the Wye floodplain. The Llynfi floodplain appears to grade to the level of the kame terrace in the main valley.

The relationship of the till bench and the kame terrace can best be seen south of Aberllynfi where they are separated by a distinct bluff. Examination of the upper Llynfi valley shows that the bench is not developed there, and it is suggested (as previously indicated) that the bench surface is the ground moraine of the glacier which over-rode the Glas Waen col. Outwash from that source at a later stage possibly resulted in the excavation of the valley floor to its present level, the irregular form of the face of the boulder clay bench being accounted for by slumping and solifluxion.

(f) Gravel Fans.

As in the Usk, gravel fans are a persistent feature of the morphology of this part of the Wye valley. They are to be found almost everywhere where streams descend from hill areas to the aggraded floor of the Wye valley or its major tributary, the Llynfi. Their location is shown in figs. 51 and 57, and the distribution of gravel fans in the Usk and Wye is separately shown in fig. 34. The origin of these features has been discussed in relation to those in the Usk, and as there is no reason to think that those of the Wye are significantly different from those of the Usk, they will not be considered in detail.

5. CONCLUSIONS.

The contrast is evident between the Llangorse Basin and the Wye valley, the one showing little evidence of glacial activity, and the other an abundance of fresh glacial forms. It is quite clear that the last advance of the ice within this area was essentially a valley glaciation, and lowland areas amidst the hills which did not form outlets from areas of ice accumulation were subject largely to the operation of periglacial processes. In the case of the Llangorse Basin, no important valley enters it from the surrounding upland areas of the Eppynt, Beacons or the Black Mountains, and thus during a valley glaciation it would remain as an unglaciated enclave.

There is also the contrast between the Usk and the Wye valleys. Despite the fact that the former has important areas of ice accumulation much lower within its drainage basin than the Wye - for example, the important corries of the Beacons and the north-eastern scarp of the Coalfield - the latter valley shows far more abundant evidence of glacial activity. In particular, meltwater channels and fluvio-glacial forms are much more extensive than in the Usk, whilst in the lowlands to the east the much larger spread of morainic deposits in the Plain of Hereford compared with that of the Vale of Gwent is evidence in itself of the size of the respective glaciers. Factors which have contributed to this contrast include the larger catchment area of the upper Wye, and its more westerly location within the Welsh massif (resulting in higher precipitation values).

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