# Late Pleistocene and Holocene Geology of the Upper Afon Teifi Valley

## Parts of 1:10 000 sheets SN54NE, 55SE, 64NW, 65NW, 65NE & 65SW

Integrated Geoscience Surveys South Programme

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# Late Pleistocene and Holocene Geology of the Upper Afon Teifi Valley

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T. Huw Sheppard



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# Foreword

This report is the published product of a survey made by the British Geological Survey (BGS) of the late Pleistocene and Holocene geology of the upper Afon Teifi valley between the towns of Lampeter and Tregaron, as a component of 1:50 000 scale series sheet 195 (Lampeter). The survey of sheet 195 is co-funded by the Wales Assembly Government.

The survey was conducted at 1:10 000 scale from May to October 2002 by T. H. Sheppard. Additional small areas of the central Afon Teifi valley were partly surveyed at 1:10 000 scale in the south around Lampeter by J. R. Davies in 1996 as part of the Afon Teifi catchment survey project, and in the north around Tregaron by D. G. Woodhall in 1989 as part of 1:50 000 series sheet 178 (Llanilar).

All localities cited fall within the SN National Grid square, which prefixes the given grid references.

The majority of localities cited in the text are within private ownership and visiting permissions must be sought from the relevant landowner.

*Frontispiece: DTM-based digital reconstruction of Llyn Garthenor at the close of the Devensian. View looking eastwards towards Llandewi Brefi and the Cambrian mountains.*

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# Summary

This report describes the late Pleistocene and Holocene geology of the upper Afon Teifi valley. The morphology of the Teifi and tributary Dulais valleys suggests that the latter represents a pre-Devensian meander loop of the Tertiary Afon Teifi, with interconnects to the modern Teifi valley seen at Cockshead and Olmarch. The modern Teifi valley south of Olmarch may be glacially-excavated. A number of Devensian valley glacier and Holocene fluvial depositional environments are recognised as landform assemblages. These include glacial till, glaciofluvial gravel deposits (kamiform benches, moraines, outwash plains), glaciolacustrine deposits, and Holocene alluvial deposits.

# 1 Introduction

The Afon Teifi headwaters rise in the uplands of Central Wales at Teifi Pools [78100 67600] and flow south-westward along the flanks of the Cambrian Mountains through the towns of Pontrhydfendigaid, Tregaron [68600 58500] and Lampeter [57100 48000], before turning westward and flowing seaward through Llanybydder, Llandysul and Newcastle Emlyn, eventually entering Cardigan Bay via a wide estuary at Cardigan (Aberteifi) [18300 46700] (Figure 1). Within this study, that part of the river valley which lies between Teifi Pools and Lampeter is termed the Upper Teifi, and that part which lies between Lampeter and Cardigan the Lower Teifi. This report concerns that part of the Upper Teifi which lies between Lampeter and the southward terminus of Cors Caron (Tregaron Bog), thus comprising some 19km of the Teifi's course; some 40km$^2$ of the Teifi valley was mapped during the present survey.

The area surveyed embraces the principal Teifi valley and the Afon Dulais valley, the latter being a tributary stream which flows within its own valley parallel to and north-west of the Teifi for some 8 km (Figure 1), before reaching a confluence on the alluvial flats near Lampeter. Other tributary valleys partly examined within the survey include the Afon Denys at Pont Silian [58100 50900], the Nant Clywedog at Llanfair Clydogau [62400 51100], the Afon Brefi at Llandewi Brefi [66300 55300], and the Afon Brenig at Tregaron [68000 59700]. With the exception of the Afon Brenig, all of these lesser streams exhibit a rapid increase in thalweg gradient as they approach their respective confluences, and as a consequence are largely entrenched.

The upper Teifi valley system contains significant deposits of late Pleistocene glacial, glaciofluvial, glaciolacustrine, periglacial and fluvial sediment together with later Holocene accumulations. These pre-, syn- and post-glacial processes are largely responsible for fashioning the terrain of the valley, and thus the link between sedimentary process and resultant geomorphology is demonstrated in the modern landscape.

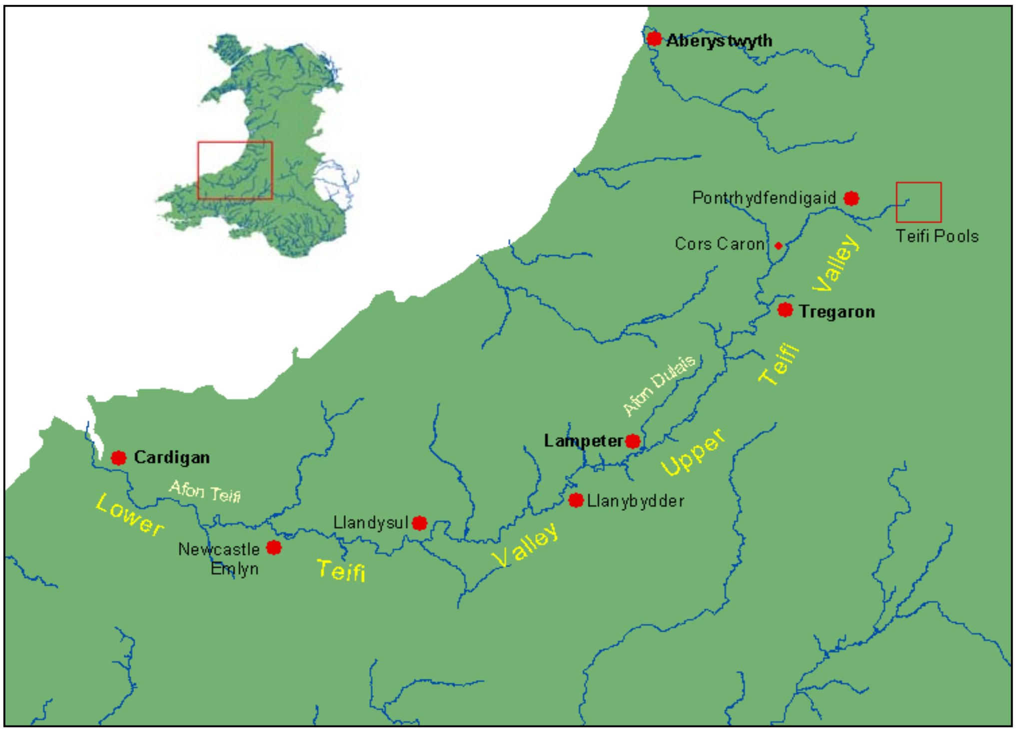


**Figure 1.** Sketch map of the course and principal towns of the Afon Teifi valley.

# 2 Quaternary chronostratigraphy

The extensive Pleistocene deposits of both the upper (Davies *et. al*, 1997) and lower (Waters *et al*., 1997; Hambrey *et. al*, 2001) Teifi valley have largely been assigned to the Late Devensian substage, which represents the uppermost Pleistocene.

The onset of the Late Devensian is considered to be 26 000 years before present (BP) (Mitchell *et al*., 1973; Campbell & Bowen, 1989) (Table 1). Campbell and Bowen (1989) estimate that maximum cooling and glaciation during the Late Devensian was achieved between 20 000 and 18 000 BP, and suggest a date of 17 000 BP for the completion of deglaciation in south-west Wales and a date of 14 468 BP in the north. Glaciation and deglaciation are thus assigned in their entirety to the Late Devensian substage known as the Older Dryas (Table 1). Gradual climatic warming, during and after deglaciation, was interrupted by a brief cooling event between 11 000 and 10 000 BP, known as the Late Devensian late-glacial or Loch Lomond stadial event, during the substage known as the Younger Dryas. The conclusion of this cooling event marks the resumption of warming and the onset of the Holocene at 10 000 BP.

<table>
<tr><th>Timing (Ka BP)</th><th colspan="2">Stage</th><th>Environment and processes</th></tr>
<tr><td>10Ka - Present</td><td colspan="2">Holocene</td><td>Interstadial warming; modern fluvial and solifluction processes</td></tr>
<tr><td>11Ka – 10Ka</td><td>Younger Dryas</td><td rowspan="7">Late (Upper) Devensian</td><td>Climatic cooling, periglacial conditions return</td></tr>
<tr><td>12Ka – 11Ka</td><td>Allerød</td><td>maximum interstadial warming</td></tr>
<tr><td>17Ka – 12Ka</td><td rowspan="4">Older Dryas</td><td>Continued warming; Post-glacial fluvial processes, solifluction</td></tr>
<tr><td>18Ka – 17Ka</td><td>Climatic warming. Principal deglaciation; formation of moraines, outwash plains and glaciolacustrine basins</td></tr>
<tr><td>20Ka – 18Ka</td><td>Maximum cooling and glacial advance, deposition of tills and glacial advance deposits</td></tr>
<tr><td>26Ka – 20Ka</td><td>Onset of late Devensian, cooling and glacial advance; sediment processes unknown in upper Teifi</td></tr>
</table>

**Table 1.** Late Devensian chronology

# 3 The pre-glacial Teifi valley

The Teifi valley was initiated by uplift and erosion during the mid-Tertiary (Brown, 1960; Dobson & Whittington, 1987; Waters *et al*, 1997), when the original headwaters rose in the north at Plynlimon and the Teifi was likely a much larger river (Waters et al, 1997). The development of the early valley was characterised by at least two periods when significant downcutting was initiated (Jones, 1965), probably related to local relative sea-level falls associated with glaciations in the early Pleistocene (Hambrey *et al*., 2001). During such episodes the river was prone to re-grade its thalweg via avulsive diversion; as a consequence, Jones (1965) was able to identify numerous loops and other abandoned courses of the pre-glacial Teifi. Several such structures in the lower Teifi valley have been studied by geophysical methods (Allen, 1960;

Francis, 1964; Nunn & Boztas, 1977) and recently drilled by BGS (Waters *et al*, 1997; Wilby, 1998). All are now largely infilled with Late Devensian glacigenic sediment. No pre-glacial deposits have been found within the present study, but it is likely that some fill material persists at depth.

## 3.1 BEDROCK STRUCTURE & PLEISTOCENE GEOMORPHOLOGY

The situation of the modern Teifi valley broadly marks the contact between the relatively hard, resistant sandstones and siltstones of the Cwmystwyth Grits Group, which make up the high ground to the south-east, and the relatively weak, thin sandstones and silty mudstones of the Blaen Myherin Mudstones Formation and Devil's Bridge Formation making up the floors of the Teifi and Dulais valleys, together with the low interfluve ridge between. Drainage is thus deflected by the resistant Cwmystwyth Grits Group along trend of the contact, which reflects the regional orientation of the rocks with the southwest-northeast axial trend of the Tywi lineament (Davies *et al*, 1997). As the juxtaposition between the two units is sharp, it is likely that the Teifi and Dulais valleys are also partly controlled by fault or fracture zone trends coincident with regional structure (Figure 2).

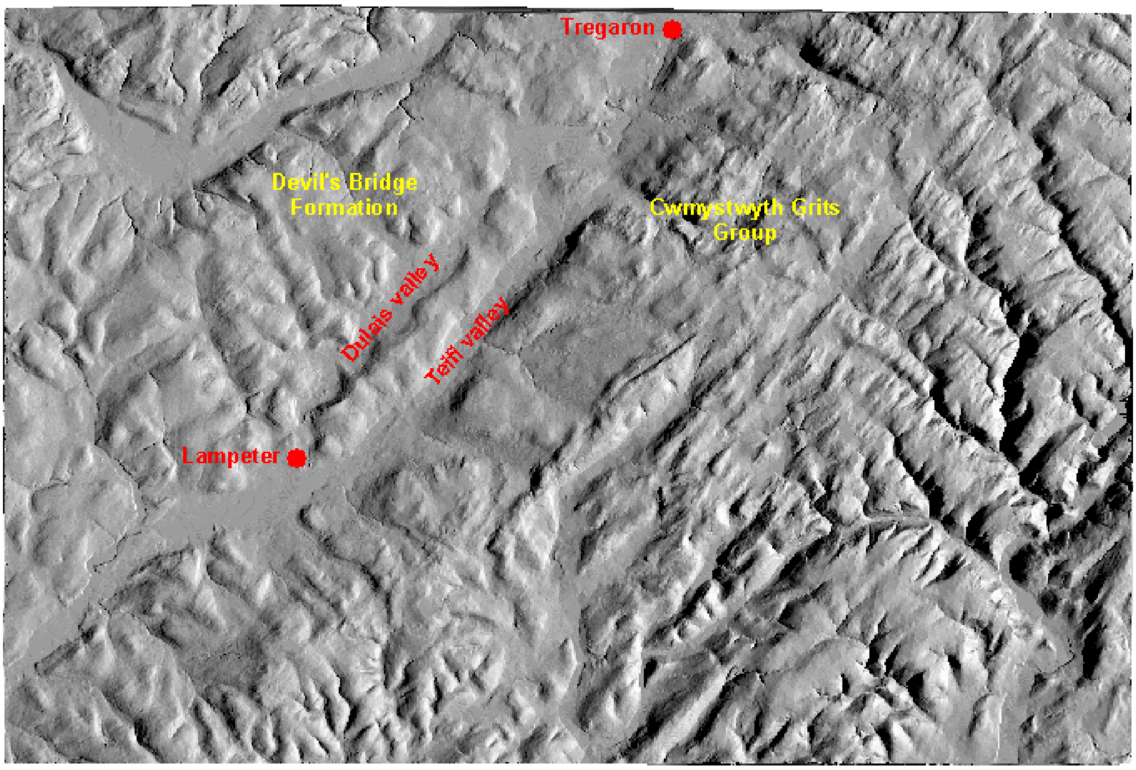


**Figure 2.** Hillshade view of sheet 195 derived from DTM data. The Cwmystwyth Grits Group form rough terrain east of the Teifi, whilst the Devil's Bridge Formation forms rolling hills in the west.

### 3.1.1 The Dulais valley

The Dulais valley is marked by number of features suggestive of meander loop point-bars cut into the solid rocks, the most striking of which is at Allt-Goch farm, Pont Silian [59000 50100] (Figure 3). Similar structures also occur at Goitre Isaf farm [59900 51400], near Bettws Bledrws, and Glandulas Uchaf farm [62300 54000] near Olmarch. The presence of such structures strongly suggest that the Dulais valley was not cut by the glacier which provided its Quaternary fill, but must therefore represent a pre-extant course of the Pleistocene Afon Teifi.

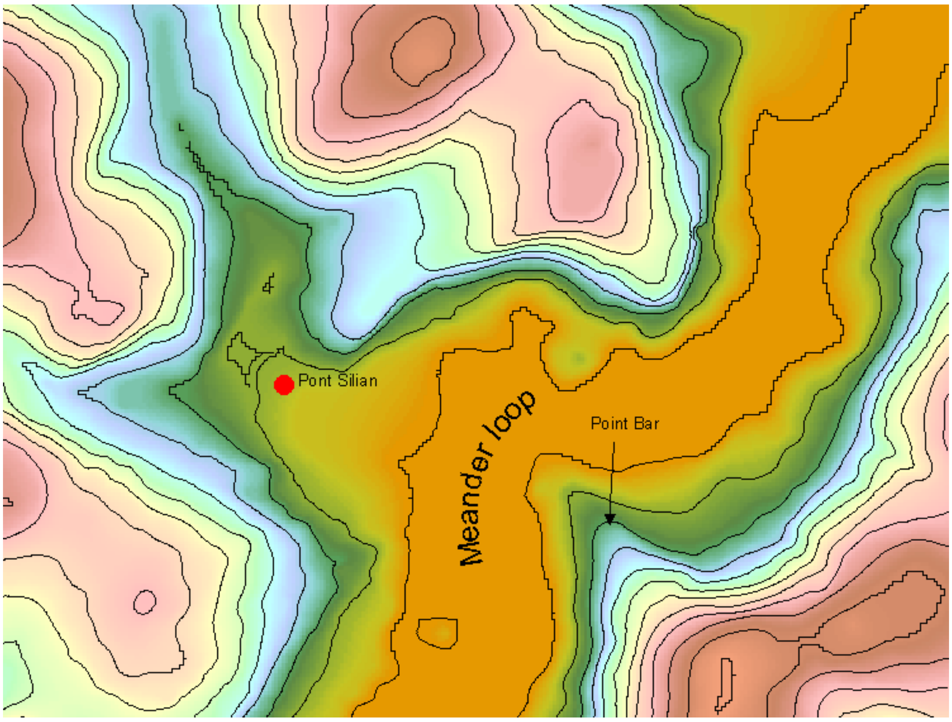


**Figure 3.** Contours showing meander loop in bedrock at Pont Silian, Afon Dulais valley.

At Cockshead [63200 55400] north of Olmarch, the northward head of the Dulais valley terminates in a narrow rock gorge which separates the Dulais from a loop of the modern-day Teifi (Figure 4). The position of rockhead within this gorge is constrained by borehole evidence (SN65NW Nos. 1-4 inc). The floor of the gorge is not currently an active drainage tract, but is elevated above the modern-day level of both the Teifi and Dulais by over 10m, and therefore is considerably above the terminal thalweg elevation of the Pleisocene Teifi in either valley. Further, the south-eastern slope of the gorge is mantled with a thin veneer of ice-contact glaciofluvial gravel, and a thin strip of alluvium floors the southern end. The presence of gravel within the gorge suggests that it either pre-dated, or was contemporaneous with, glaciation; the presence of alluvium suggests that it was subsequently exhumed after deglaciation.

South-east of Olmarch, the bedrock interfluve which separates the Dulais and Teifi valleys is breached by trough around 0.75km wide, now infilled with a plug of Quaternary sediment (Figure 4) (herein informally named the ‘Olmarch trough’). South of the Olmarch Uchaf farmhouse, the union of this trough with the south-eastern wall of the Dulais valley is marked by the presence of a bedrock promontory, representing a palaeomeander loop, which curves outward to the north-west. This architecture suggests that the trough was cut by the Pleistocene Teifi, flowing from the modern-day valley north-westwards through the trough and into the modern-day Dulais valley (Figure 4).

### 3.1.2 The Teifi valley

Unlike the Dulais valley, marked promontory features suggestive of meander loops are not evident within the modern Teifi valley. There is, therefore, little evidence that the valley south of the Olmarch trough was cut by flowing water during the Pleistocene; it may equally have been excavated during glacial advance and subsequently preferred by the Holocene river. North of the trough the valley morphology likely reflects a Pleistocene origin as the Dulais Valley does not continue north of the gorge at Cockshead.

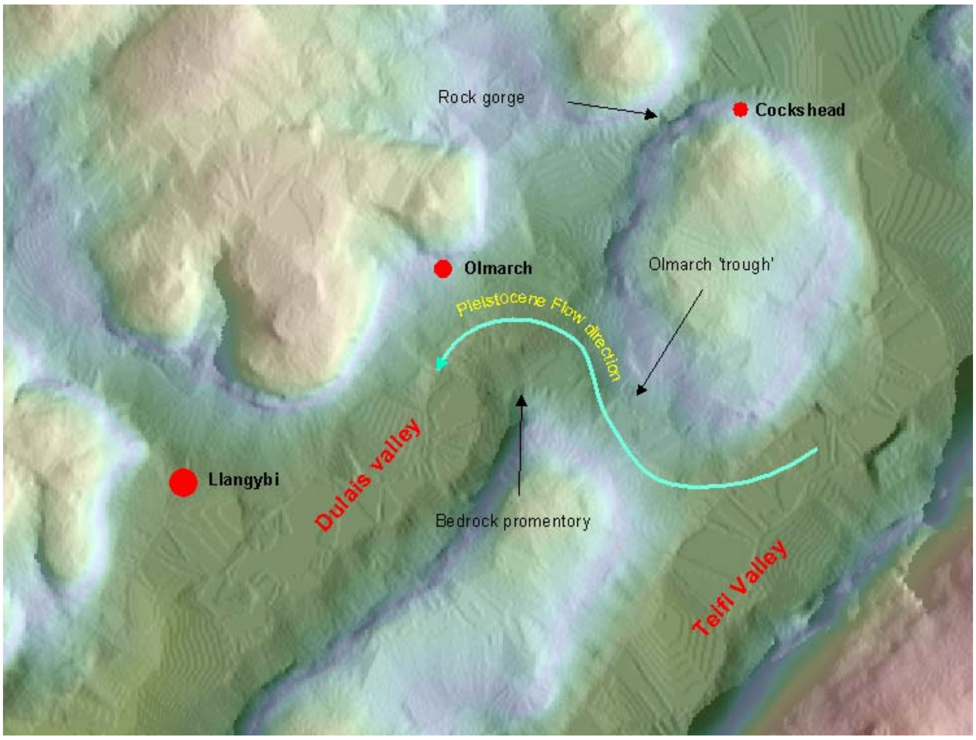


**Figure 4.** coloured DTM hillshade of the head of the Dulais valley showing the Cockshead rock gorge and the Olmarch trough.

West of Llandewi Brefi [66300 55300], the valley circumnavigates either side of a low hill veneered with Quaternary sediment but cored with bedrock. This feature may well reflect a Pleistocene meander, or equally may reflect glacial erosion. Similarly to the gorge at Cockshead, the gap between this feature and the eastern wall of the valley at Llandewi Brefi is infilled with glacial sediment, suggesting that it was extant at least during glaciation, but has not been subsequently preferred by the Holocene river. The modern Afon Teifi now flows around the western rim of the hill.

## 3.2 GLACIAL & PERIGLACIAL MODIFICATION

The bedrock of both valleys has been subject to significant glacial and periglacial modification. Numerous lineaments are recognisable from aerial photography on the low ridge between the Dulais and Teifi valleys, being expressed on the ground as shallow u-shaped valleys; these undoubtedly represent the excavation of planes of weakness (faults and fold axes) within the bedrock during ice advance. Like the river valleys, they show a general southwest-northeast trend concurrent with regional structure. Much of the bedrock at outcrop on the valley flanks is deeply weathered and shattered, reflecting freeze-thaw degradation in a periglacial climate. Further, in many cases bedding is cambered and overturned into the valleys, particularly on more elevated slopes (e.g. old quarry at Olmarch Uchaf farm, [62300 53500]), which may be a consequence of gravity collapse following glacial overdeepening of the valleys or possibly attributable to the action of overlying ice during glaciation.

# 4 Landform Assemblages

## 4.1 METHODOLOGY

The late-Devensian and Holocene fill of the Teifi valley represents a spectrum of glacial, glaciofluvial, glaciolacustrine, fluvial and lacustrine depositional processes. The relations between processes active within a given sedimentary environment are used to recognise and map a series of discrete deposits within the Teifi valley. Because exposures are uncommon and representative sections virtually absent in many of these deposits, it is difficult to define and delimit them on a lithological basis. Thus, geomorphological features and landforms are utilised and the deposits described as landform assemblages (Eyles, 1983). Herein an individual assemblage unit is defined as:

‘A distinct area of ground which may be demarcated by the recognition of a suite of associated geomorphological criteria considered to characterize the landforms and ground conditions resultant from the action of one or more depositional and/or post-depositional processes characteristic of a specific sedimentary environment.’

Note that this approach is not attempting to correlate individual landforms with lithology or any other physical property, but with *depositional process*; and associated groups of landforms are not correlated to stratigraphic or lithological transitions but only to *sedimentary environment*. In rigorous sedimentological terms therefore, the landform assemblage unit, as here defined, is equivalent to a facies association.

Nevertheless, in order to produce a meaningful geological map, some assumptions and extrapolations regarding broad associated lithotypes are made. Where a section is seen through a deposit, it is reasonable to assume that all other deposits with a commensurate geomorphological character are thus likely to possess a commensurate lithological character. This approach is validated where sections are seen through two or more deposits interpreted as being the product of similar environments.

The units thus recognised, their diagnostic criteria and postulated lithology as used during the recent survey, are presented below, with their mapface category and symbol indicated. Figures 5 to 7 present schematic summaries of the architectural relationships between assemblages.

## 4.2 TILL SHEETS (TILL, )

*Diagnostic geomorphology:* Elevated, flat to gently undulating, waterlogged ground, often rutted if stocked; vegetation comprises rough grass and rushes; drainage via small streams & bogs; frequent implementation of field drains. The wide upland grassland between Clwt-y-Patrwm farm [62500 52400] and Pencaerodyn farm [62400 52700] is a typical example of till terrain.

*Description:* The till deposits of the area are of the type generally known as ‘Welsh Till’ (e.g. Waters *et al*, 1997), being a largely unstratified diamicton comprising sub-rounded to sub-angular clasts of local Palaeozoic grey sandstone, and occasionally incorporating clasts of Devil’s Bridge mudstone, set in a grey (weathering to brown) matrix. The proportions and size of the clasts are very variable as is the nature of the matrix. In one of the better exposures, a stream section at Goetre Uchaf farm [60500 51500], 2m of brown, sandy clay with large (30cm) boulders of local sandstone was observed. In comparison, a cutting behind Goetre Uchaf farmhouse [60100 51600] revealed 2m of unstratified, clayey sandy gravel; a similar lithology was observed in a field drain near Tan-y-fforest farmhouse [60700 52400]. Two auger holes driven into a till sheet at concomitant elevation, 50m apart at Cefn Llwyn farm [64500 54300], recorded 80cm of silty sand and 80cm of gravely clay respectively. Exposure is poor and no attempt has been made to subdivide till deposits structurally or lithologically. The highly variable nature of the deposit may reflect complex depositional and reworking processes.

*Interpretation:* The till deposits described above are all considered to be the products of subglacial deposition at the base of a flowing ice sheet or glacier. Supraglacial tills (so-called 'flow tills') are not included within this classification. Till at surface is most commonly seen on the interfluve ridge between the Teifi and Dulais valleys ('upland till sheets', figures 5 & 6), although it likely also fills valley floors beneath the present cover of deglaciation gravels ('valley till', Figures 5, 6 & 7).

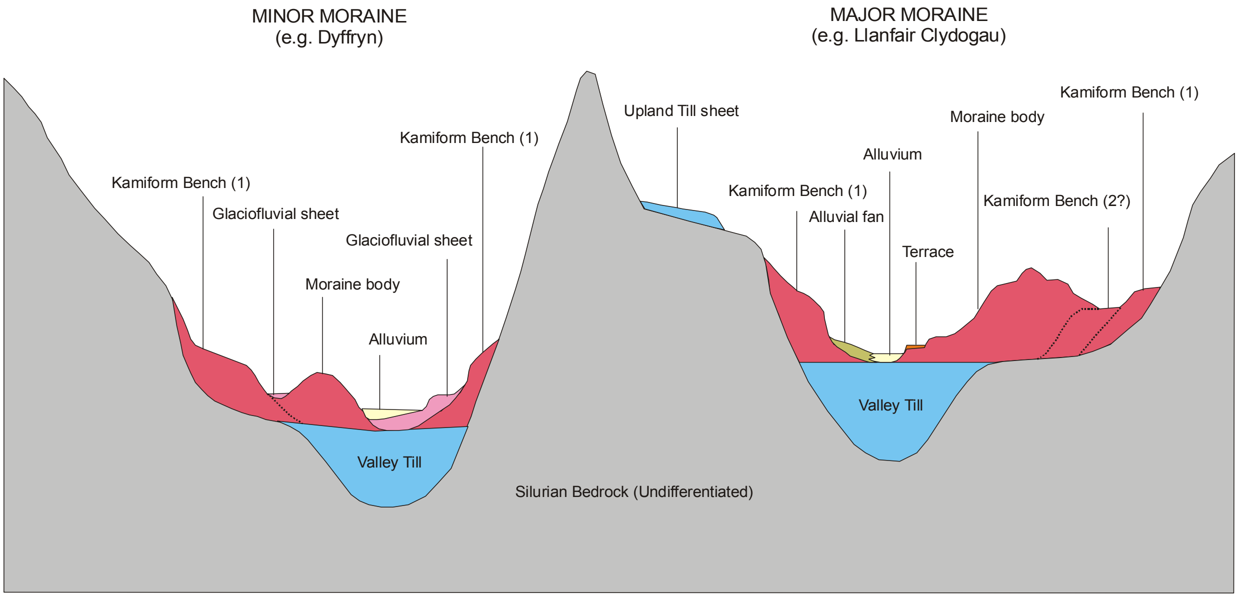


**Figure 5**. Schematic cross-section showing moraines and tills in the Dulais (left) and Teifi (right) valleys.

## 4.3 KAMIFORM BENCHES (GLACIOFLUVIAL ICE-CONTACT DEPOSITS, )

*Diagnostic geomorphology:* Elevated benches flanking the valley sides, usually flat-topped with occasional sub-conical kamiform hummocks and shallow kettle-like depressions, and a steep frontage slope; well drained, favourable to the development of grassy pastures. An excellent series of kamiform benches may be seen on the hillsides above Llwyn [65400 55100] and Bronhelem [65800 55400] farms at Llandewi Brefi.

*Lithology:* The gravels which comprise kamiform benches are highly variable. They are composed dominantly of sub-rounded pebbles and cobbles of local grey lower Palaeozoic sandstone, although clasts of red (upper Palaeozoic?) sandstone are not uncommon, and clast size can reach up to 50cm or more. Gravel clasts are often coated with a manganese film which represents an incipient cement. Significant mud is rare. In many sections the deposits are simply crude-bedded gravel sheets with sand and silt admixed in a matrix or occasionally present as thin lenticular stringers. However at Penddol farm [63400 53000], a cutting behind the farmhouse reveals well-developed sheet deposits (Figure 6) with a series of truncated lateral accretion surfaces in silt and fine sands representing the initial migratory dune macroforms, and being superseded by a debrite of poorly-stratified coarse bouldery gravel. The origin of the structure is uncertain; it may represent a debrite infill of a channel or slurrying at the edge of a truncated fluvial sheet. The debrite material is deformed, and may have suffered compressive glaciotectonism and/or significant cryoturbation.

*Interpretation:* The kamiform benches represent ice marginal deposits; their variable nature suggests a variety of depositional processes. They may be in part accretionary lateral moraines derived from debris bands within the glacier, augmented by channelised stream flow on the glacier margin (Figure 6). Kamiform cones and occasional shallow kettle-holes testify to the infilling and melting of depressions in the ice surface and the calving of ice blocks respectively. The crudeness of stratification within the majority of gravel sheets suggests very rapid deposition from fast-flowing meltwater streams in flood, possibly during warmer summer months. By comparison, the thin sandy and silty lenses may represent low-flow during autumn and spring. If the structure at Penddol farm is an incised channel, it might suggest a more prolonged and systematic flow regime; such channels may have acted as distributary ice-lateral feeder channels for proglacial deposits when no more accommodation was available on the glacier's flanks.

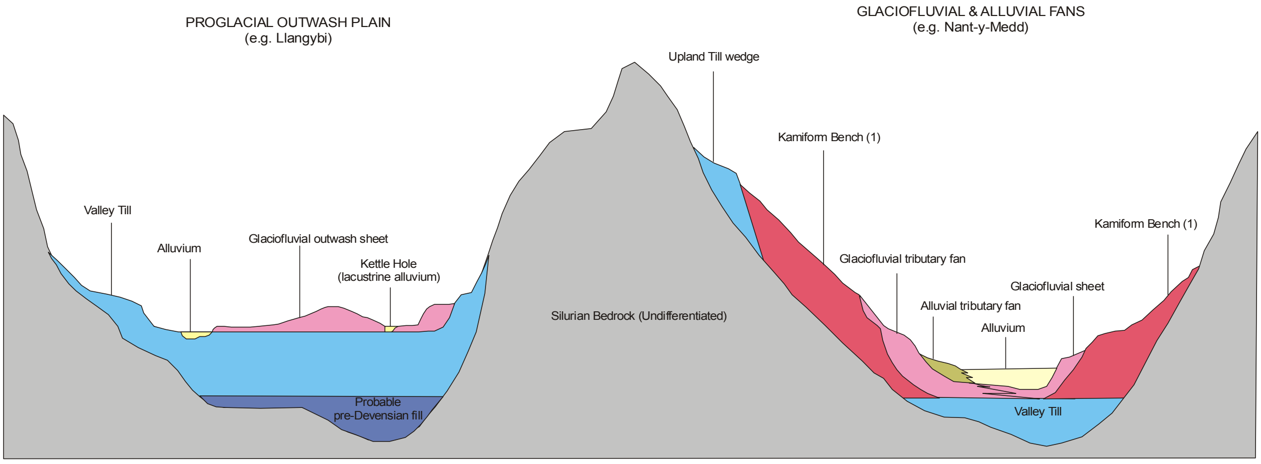


**Figure 6**. schematic cross-section showing an outwash plain in the Dulais valley (left) and fan deposits in the Teifi valley (right).

## 4.4 MORAINE COMPLEXES (GLACIOFLUVIAL ICE-CONTACT DEPOSITS, )

*Diagnostic geomorphology:* In the Teifi valley, large (1-1.5km wide by 0.75km long) hills swinging outward from a kamiform bench and blocking much of the valley, rising up to 30m above the level of the modern Afon Teifi; often steep-sided where a narrowed river channel breaches the structure, and rising to a distinctive series of kamiform cones upon a wide benched base. In the Dulais valley, a series of kamiform cones or protuberances from benches blocking much of the valley, and incised by the Dulais. The type moraine within the Teifi valley has been named the Llanfair Clydogau Moraine during the present survey, making up the hills some 300m north of the town of its name [62600 51500]. The best example in the Dulais valley is seen at Dyffryn farm [58300 49800].

*Description:* Within the Teifi valley the 'type' Llanfair Clydogau Moraine comprises a wide, benched and ramparted base succeeded vertically by a sriking series of kame cones, the topmost of which rises 30m above the Afon Teifi, which is deflected around the western side of the moraine through a narrow gorge in the structure at Parcneuadd farm [62300 51900] (Figure 5).There are unfortunately no sections through the Llanfair Moraine; however, there are numerous sections exposed in the Aber-Carfan Moraine, a similar structure north of Llandewi Brefi, which has been dissected repeatedly by the meandering Teifi and also by the builders of the old Milford to Manchester railway. A 8m-high gravel quarry cut into the face of the moraine [66200 56900], where not covered in scree and spoil, reveals a 2m section through poorly stratified sandy gravel sheets, containing sub-rounded boulders up to 80cm in size. Bedding is somewhat distorted, with incipient circular forms suggestive of clast sorting during convective cryoturbation.

In the Dulais valley, moraines are seen at Dyffryn (Figure 5) and Coed Parc [58900 51100] farms, together with a highly disintegrated and fluvially-disected example at Olmarch Isaf farm

[62200 54200]. Here they take the form of single kame cones swinging valleyward from a kamiform bench. A section through the kame at Coed Parc revealed finely-laminated sands and clean, washed gravels intercalated in southward-migrating dune macroforms around 2m high.

*Interpretation*: Moraines represent deposits in contact with the glacial snout which accumulated in association with a static ice front. Stasis of the ice front must reflect the equilibration of glacial flow and melt rates and this state of equilibrium must have persisted long enough for the accumulation of up to 30m of sediment on and in front of the glacial snout; it may also have been aided by the calving of the glacial front and the subsequent slow melt of stagnant ice. The evolution of the moranic architecture in the Teifi valley is unclear; the bench-like basal ramparts may represent offlapping debris sheets derived principally from remobilisation of supraglacial dirt-band material (i.e. 'flow till' material) and sand and gravel fed from the channelised lateral ice-contact streams, or they may represent discrete dirt bands developed within the glacier during compressing flow at the snout, subsequently deposited as ramparts following ice stagnation and melting. The development of kame cones on the uppermost and rearmost parts of the moraine may represent differential melting of the ice-front, producing 'pockets' ('ice-karst' topography) infilled with sediment which remained preserved as a cone after deglaciation. The moraine structures in the Dulais valley reflect only this latter process and it is unlikely that great proglacial talus deposits accumulated there.

## 4.5 GLACIOFLUVIAL OUTWASH SHEETS AND FANS (GLACIOFLUVIAL SHEET DEPOSITS, )

*Diagnostic geomorphology:* sheets are wide, open flatlands, elevated up to 10m above modern rivers; generally little relief with the exception of distinct isolated kettle depressions ranging from a few to several hundred metres in size; frequent consequent development of small lacustrine basins. Fans are low-angle, gently dipping flats, sometimes moderately benched, angled into the valley from tributaries or gullies.

*Description:* Glaciofluvial sheets within the Teifi valley, when best preserved, take the form of broad, low relief, gravel deposits interpreted as outwash plains. The best examples of these are seen preserved in the Teifi valley north of Llandewi Brefi between Ystrad-Dewi [64800 56700] and Pant [66200 56200] farms, and in the Dulais valley between Llangybi and Olmarch (Figure 6). A section through the Llandewi Brefi outwash plain in an old gravel working at Pant farm [66000 56400] revealed a 5m face comprising southward dipping foreset beds of poorly-sorted coarse sand and gravel, with occasional boulders up to 50cm in size. No sections are known in the Dulais valley outwash plain.

Glaciofluvial fans and cones are of similar lithology, although they often contain a substantially more silty or muddy matrix. Good examples are seen at Betws Bledrws [59500 52000], Nant-y-Medd farm [61300 50500], and a wide, benched fan centred upon Glanrhocca farm [63200 54500]. An excellent example is seen beneath the abandoned farmhouse (now owned by Pen-Parc farm at Silian) on the slopes of Allt Ffos-glai [59700 50900]. Here some 5m of orange-brown clayey gravels are exposed, being incised by a small modern tributary stream.

Together with identifiable sheets and fans, in many parts of the valley low-relief flats, elevated above terrace level, lie between the alluvial strip and kamiform deposits on the valley flanks. These deposits are difficult to characterise but likely represent the eroded remnants of other outwash plain deposits.

*Interpretation:* The glaciofluvial deposits represent a variety of sedimentary processes involving outwash from ice. Outwash plains represent proglacial drainage and the transport of material down-valley away from the glacial snout by meltwaters. The deposits are genetically-related to kamiform benches and moraines, although their lithology is less variable and the gravels are better-sorted and cleaner. This, together with the increase in sand within outwash plains relative to ice-contact deposits, supports their interpretation as a more distal facies. The dipping forsets observed in the quarry at Pant farm undoubtedly represent the development of a downstream-accretionary (longitudinal) barform. Such units are typical of braided streams or rivers (Miall, 1996). This is concurrent with the general interpretation of glaciofluvial outwash deposits (e.g. Ettienne, 2001). The macroform observed at Pant quarry is at least 5m high, and this thus provides a minimum estimated height for the bar (with the proviso that the section records only a snapshot of its internal structure); thus 5m water depth is a reasonable postulation for summer meltwater flood flow on this outwash plain.

Glaciofluvial fans represent outwash from small, probably isolated and stagnant, ice-blocks lodged in crevices and small tributaries at the valley margins. The large benched outwash fan at Glanrhocca may be tentatively interpreted as the washout product of a block of stagnant ice lodged in the Olmarch trough, wherein the benching represents retrogressive (onlapping) deposition as the ice-block progressively melts.

### 4.5.1 Kettle holes

*Diagnostic geomorphology:* Circular to oblong surficial depressions, commonly in outwash sheets and fans, less commonly in ice-contact deposits; often with lacustrine or peaty development in base, but can be well-drained.

*Description:* Kettle holes are a geomorphologic feature intimately associated with glaciofluvial deposits (Figure 6), hence they are discussed here. They are produced when ice calves from a retreating front, becomes buried by gravel, and later melts leaving a hole. The bottom of the hole often becomes lacustrine or boggy as it traps runoff and accumulates fines. The best kettle holes are seen at Olmarch Isaf farm in the Dulais valley [61500 53700] where the dry-bottomed structure is called 'the pant' by its owners; however the most spectacular example is seen at Nant-y-Dderwen farm (informally named the Glan Teifi kettlehole) [65800 56700] where a kettle hole some 300m long, 100 m wide and around 15m deep, with a basal peat bog fill, is seen. Indeed, the large embayment which has been converted into a boating lake at Pant farm may be an even bigger kettle which has been subsequently breached by the Teifi.

*Interpretation:* kettle holes represent the enclosure of isolated blocks of calved stagnant ice by subsequent sediments; as such their presence may reflect rapid phases of glacial retreat, leaving a scatter of ice-blocks on a proglacial plain which became enclosed by glaciofluvial sediments during an outwash phase associated with a subsequent static ice-front. Some kettles, particularly the Olmarc Isaf example, may also represent the stagnation of ice calved from the static ice-front and transported onto the plain by meltwaters.

## 4.6 GLACIOLACUSTRINE BASINS

*Diagnostic geomorphology:* Wide, flat, low-lying plains wherein elevation is commensurate with river level for considerable distances; consequent widely-distributed alluvial veneer. bogs, scrub grassland, and shrubby alluvial plain woods dominate unless improved to form meadows with numerous field drains.

*Description*: Little is known about the lithofacies of these wide plains as they are in all cases covered with a veneer of Holocene alluvium; the lithology is nowhere exposed at surface. They are interpreted as glaciolacustrine, to probably late-Late Devensian post-glacial, lakes as they clearly represent basin features and the modern rivers, which are largely terracing and incising the Pleistocene fill of the valley, are therefore unlikely to have provided their fill. The two principal lake basins within the Teifi valley have been named Llyn Garthenor (basin centre approx. [64000 56000]) (Figure 7), occurring at Coed Garthenor north of Cockshead, and Llyn Caron (basin centre approx. [66800 59500]), west of Tregaron. Augering Llyn Garthenor retrieved blue-grey clays with small fine gravel lenses underlying a blanket of peaty alluvium. Deep augering was not possible due to the presence of a resistant horizon at c. 1m depth. However, a series of shallow boreholes drilled to investigate the embankment of the old Milford-

Manchester railway in 1974 (SN65NW 1-24 inc.) provide subsurface data for Llyn Garthenor. They record up to 3m of soft brown to grey or green clays, with intercalated clayey gravels, overlying a minimum of 2m of clayey silt. None of the boreholes encountered bedrock beneath the glaciolacustrine succession.

Spreads of alluvium are also seen throughout the Teifi and Dulais valleys, commonly behind moraine deposits, for example north of Llanfair Clydogau; between Llyn Caron and the Abercarfan moraine; between Llanfair Clydogau and the church at Cellan; north of Llangybi; east of Tregaron, in the Brennig valley; and at Coed Parc farm. These areas of widened floodplain may similarly be developed over smaller-scale glacial to late-Late Devensian basins ponded behind unbreached moraines.

*Interpretation:* The genesis of these lakes is likely similar to Cors Caron, wherein a stiff blue-grey lacustrine clay underlies the extensive peat deposits (Godwin & Mitchell, 1938; Davies et al, 1997). This clay is of unknown thickness and is thought to be of late glacial lacustrine origin (Davies et al, 1997). The peat bed immediately overlying it was radiocarbon dated by Hibbert and Switsur (1976) at 10 200 +/- 200 BP, (i.e. basal Holocene), thus it seems likely that clay accumulated in a standing waterbody from glacial times to the Holocene, perhaps c. 18 000 to 10 000 BP. Like Cors Caron, water was likely impounded in Llyn Garthenor and Llyn Caron by a terminal moraine or gravel plug. In the case of Garthenor it was probably a mound of kamiform gravels strung across the valley between Pentre Brain [263600 255200] and Godre'r Garth [64400 55600] farms. In the case of Llyn Caron the obstruction may still be clearly envisaged at the bridge over the Teifi on the A485 south of Tregaron [67300 59100] where the road passes over the modern Teifi, which runs through a narrow gorge it has cut in a gravel rampart. In both cases the glacial lakes lie downstream of an extensive sandur plain; this likely accounts for the intercalation of gravels in the subsurface at Garthenor, a feature not known at Cors Caron which, due to its size, would have been less affected by coarse sedimentation at its distal end.

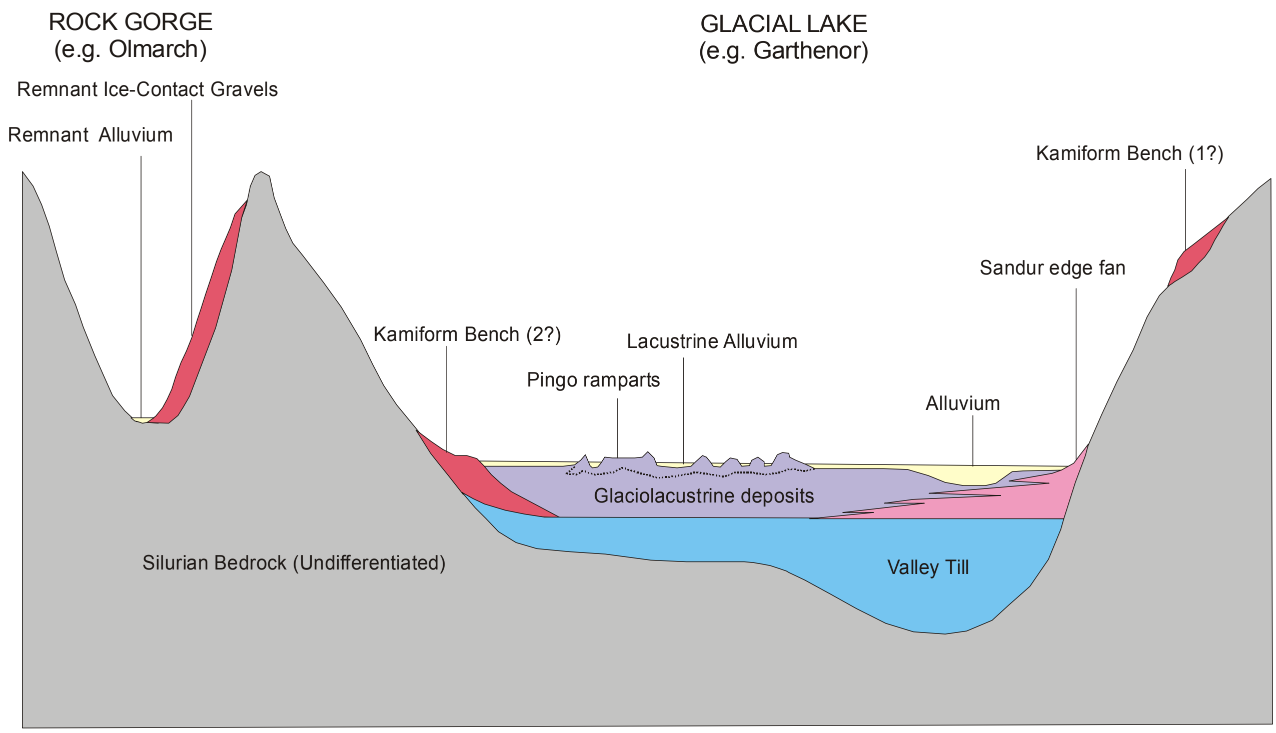


**Figure 7**. Schematic cross-section showing the Cockshead rock gorge and Llyn Garthenor.

### 4.6.1 Pingos (presently unclassified)

*Diagnostic geomorphology:* anastamosing low ridges up to 2m high and several metres in width, often forming sub-circular ramparts, partly or wholly enclosing shallow peat or lacustrine alluvium-filled basins.

*Description:* At Llanio Isaf farm [64000 56000], the flat surface of Llyn Garthenor is modified into a series of depressions and ramparts making up a large pingo field (Figure 7). This pingo field was identified (although not described) by Watson and Watson (1974). Pingos form via geliturbation, that is, the upward-bulging of the ground surface as a consequence of ground-ice growth during periglacial/cold climates. Subsequent melting of the ground ice causes the lateral shedding of sediment to form a rampart enclosing a central depression.

*Interpretation*: The presence of pingos is important in the interpretation of the depositional history of Llyn Garthenor. Pingos grow most favourably in silt lithologies (e.g. Paul & Barras, 2003), supporting the interpretation of the Garthenor succession as lacustrine. Secondly, pingos represent periglacial action, and are here formed from the topmost sediment within the Garthenor fill. Therefore the pingos may mean that the lake aggraded to fill accommodation whilst the Teifi valley was still locally glaciated, and the pingos formed in the periglacial environment concomitant with glaciation. However, if the base of the Holocene alluvial veneer at Garthenor is correlated with the known base Holocene in Cors Caron, then the pingos might be suggested as evidence of a brief pre-Holocene periglacial influence in the region, and would thus be interpreted as latest-Pleistocene products of the Loch Lomond stadial event.

## 4.7 PEAT BOGS (PEAT, )

*Diagnostic geomorphology:* flat to gently undulating waterlogged bogs, dominated by tussock grass and sphagnum mosses.

*Description:* Peat bogs comprise a variable thickness of dark brown to black sediment representing vegetation composted in a reduced, waterlogged environment. Peat is not widely distributed within the area as bogs are often drained and destroyed during land improvement. The largest preserved area of bog is developed over till at Goetre Uchaf farm [260400 251800]. Minor accumulations of peat are present in the base of some kettle-holes and pingos although they are not of significant extent.

*Interpretation:* The peat bogs of the Teifi valley represent the growth of hydrophilic vegetation in waterlogged environments, i.e. above any substrate which is relatively impervious. They are neither thick nor extensive and, with the possible exception of accumulations in kettle-holes and pingos, are likely of Holocene age.

## 4.8 ALLUVIAL TERRACES (RIVER TERRACE DEPOSITS, )

*Diagnostic geomorphology:* Flat, bench-like features flanking the modern alluvial plain and elevated above it by no more than 1-2m; commensurately, lying at a minimum 2-3m below the level of glaciofluvial sheet deposits or kamiform benches.

*Description:* Alluvial terrace features are not well developed within the Teifi valley but are recorded at Tregaron [68000 59600] where a terrace underlies the heart of the original town. Others are seen in association with the Abercarfan Moraine [66200 57700], cut into the surface of Llyn Garthenor [64000 55300], and at Penddol and Llwyn-Cnau [60000 49100] farms in the Teifi valley. No terracing has been observed in the Dulais valley.

*Interpretation*: The terraces are largely geomorphological surfaces, representing the planation of a floodplain by the Teifi during a period of higher base level, and now being largely abandoned in response to downcutting and the planation of the current active alluvial strip. Thick deposits of older alluvium are unlikely to lie upon the terraces and their lithology is essentially that of whatever substrate they are cut in. Their age is uncertain, although Davies *et al* (1997) stated that the terraces of the Llanillar and Rhyader districts were 'mostly Holocene in age'. It seems unlikely that the Afon Teifi is static enough to have maintained its current floodplain architecture for 10 000 years, so this statement is probably appropriate.

## 4.9 ALLUVIAL CONES (ALLUVIAL FAN DEPOSITS, )

*Diagnostic geomorphology:* Low-to-moderately dipping delta or teardrop-shaped cones emergent from tributary valleys.

*Description:* Alluvial cones largely comprise small accumulations of debris at the mouths of tributary streams. Most are not now active and are being actively incised by the tributary. A good example is seen at Parcneuadd farm [62300 51900] (Figure 6). However, cones of much larger extent are inferred at the mouths of several of the principal tributary streams, and in particular the Brefi at Llandewi Brefi [64500 54800]. Here the Brefi stream approaches its confluence with the Teifi across an ever-widening delta-shaped flat. The stream is, however, entrenched in its channel. It runs in a gully incised through its alluvial flats below at Garth farm; here the landowner holds that the river was more prone to lateral bank incision than flooding. The thalweg of the Brefi drops by 10m in approximately a kilometre between Llwyn and Garth farms, i.e. a gradient of 1 in 100 as it approaches its confluence. The alluvial flats around it are thus interpreted as a large abandoned cone, although the angle of declination is so small that a mappable boundary cannot be delineated.

*Interpretation:* The alluvial cones developed in the Teifi valley are largely inactive and are being incised, and must be inferred to have been abandoned as a result of the lowering of the Teifi thalweg evidenced by the terracing in the main valley. As such they may well be broadly contemporary with these abandoned terraces and represent an earlier Holocene depositional mode in the Teifi valley.

## 4.10 ALLUVIAL PLAINS AND BASINS (ALLUVIUM, )

*Diagnostic geomorphology:* In the case of riverine alluvial plains, wide, flat plains occasionally interrupted by palaeomeanders but elevated slightly above normal water surface in an adjacent active river channel; in the case of lacustrine alluvial basins, an enclosed basin floor which is, or might be supposed to be or have been, at least ephemerally wet. Rushes and scrub woodlands are common in unimproved areas but most alluvial plains have been greatly drained and improved to produce grassy meadows.

*Description:* Riverine alluvium largely comprises relatively stone-free silty clays and sands. Thin clayey gravels may also be present. It rarely exceeds 2m in thickness and is generally much less, the estimated average being around 40cm. Good sections are seen on the banks of the Teifi at Aber-carfan farm [66500 57100]. Lacustrine alluvium is less stony and often incorporates peat lenses in the base of kettle-holes. The best sections in lacustrine alluvium are seen at Olmarch Fawr farm.

*Interpretation:* Alluvium represents the most recent Holocene deposits of the modern fluvio-lacustrine system within the Teifi and Dulais valleys. The deposits of relatively stone-free clay and sand likely represent the products of seasonal flooding, whilst the intercalated gravels may represent more powerful but episodic flood deposition. The presence of palaeomeanders testify to the repeated avulsion of a dynamic river.

## 4.11 HEAD SHEETS (HEAD, )

*Diagnostic geomorphology:* Cones or sheets of translocated material on or at the base of significant slopes without any evidence of the presence of a former distributary stream.

*Description:* Head is something of a catch-all domain representing soliflucted, failed or more general gravity flow deposits; it includes periglacial screes, mass movement deposits, creep deposits and oddities such as anthropogenic hillwash and colluvium. Sections through these depoits are seldom observed. Near Blaencyswch farm [62800 53200], a road cutting exposes 80cm of head, interpreted as remobilised till, overlying 20cm of sand of uncertain affinity. Sheets of solid mudstone chippings form a solid scree head which mantles the valley slopes around the position of the solid-drift contact. An example is seen at the base of Olwen Wood [58600 49700].

*Interpretation:* Head represents the product of degredation, weathering and solifluction of solid rock and Quaternary sediments within the Teifi valley; as such, it is likely to have been deposited from the moment of initiation of the valley in the mid-Tertiary to the modern day. It is therefore difficult to date head deposits with any degree of certainty. However, the pre- and post-glacial periglacial ‘envelope’, together with the return of periglacial conditions during the Loch Lomond stadial event, would certainly have resulted in increased rates of weathering and consequent deposition of head; it is therefore probable that much of the head reflects periglacial action.

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