

Quaternary of Wales

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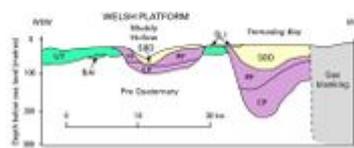
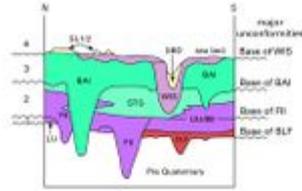
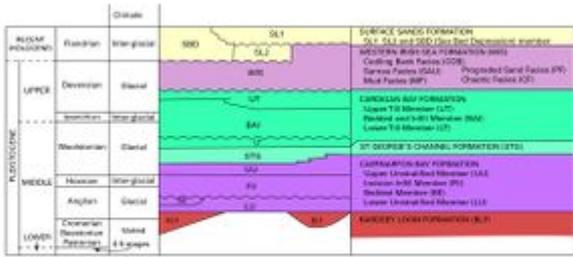
Age in thousands of years BP*	Chronostratigraphy	Irish Sea Province	Wales Province	South-Cowes	Lower Cowes
107	Loch Lomond (Ychydol) / Younger Dryas	Low level / Irish Sea deposits	Irish Sea, Ireland and British deposits	Irish Sea	Old Red Sandstone
11*	Wendover / (Bosworth)	Cardiff / (Sylfaenydd)	North Wales coast		
12*	Deighton / (Bosworth)		Cardiff / (Sylfaenydd)		
36*		Albermarle T4, T5, T6, T7, T8, T9, T10, T11, T12, T13, T14, T15, T16, T17, T18, T19, T20, T21, T22, T23, T24, T25, T26, T27, T28, T29, T30, T31, T32, T33, T34, T35, T36, T37, T38, T39, T40, T41, T42, T43, T44, T45, T46, T47, T48, T49, T50, T51, T52, T53, T54, T55, T56, T57, T58, T59, T60, T61, T62, T63, T64, T65, T66, T67, T68, T69, T70, T71, T72, T73, T74, T75, T76, T77, T78, T79, T80, T81, T82, T83, T84, T85, T86, T87, T88, T89, T90, T91, T92, T93, T94, T95, T96, T97, T98, T99, T100	Langland Bay and Broughton Bay / (Sylfaenydd)		Wales / (Sylfaenydd)
50*	Middle Devensian		Cardiff / (Sylfaenydd)		Long Hill / (Sylfaenydd)
50*	Early Devensian	Red Wharf Bay / (Sylfaenydd)	Cardiff / (Sylfaenydd)		Wales / (Sylfaenydd)
122	Predevensian	Red Wharf Bay / (Sylfaenydd)	Langland Bay and Broughton Bay / (Sylfaenydd)	Irish Sea / (Sylfaenydd)	Wales / (Sylfaenydd)
132	"Wolston" / (Sylfaenydd)	Penarth / (Sylfaenydd)		Irish Sea / (Sylfaenydd)	Wales / (Sylfaenydd)
400	Middevensian			Irish Sea / (Sylfaenydd)	
400	Anglian	South Wales / (Sylfaenydd)		Irish Sea / (Sylfaenydd)	
480	Chamberlain			Irish Sea / (Sylfaenydd)	

* conventional uncalibrated radiocarbon years. calibrated years based on dated layering (for cores, see figs 101 and 102) are given in brackets

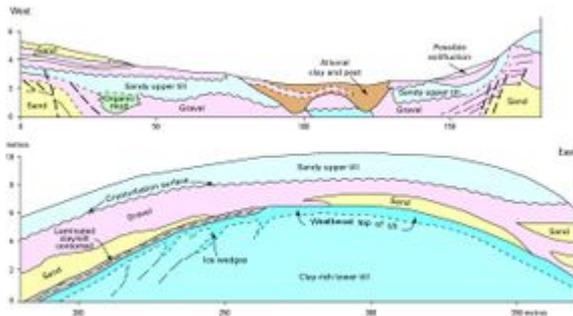
Pleistocene chronostratigraphy (adapted from Campbell and Bowen, 1989). P916230.



Glaciation of Wales: flow direction of the Welsh and Irish Sea ice (compiled from various sources). P916210.



Offshore Quaternary stratigraphy (after Tappin et al., 1994). P916211.

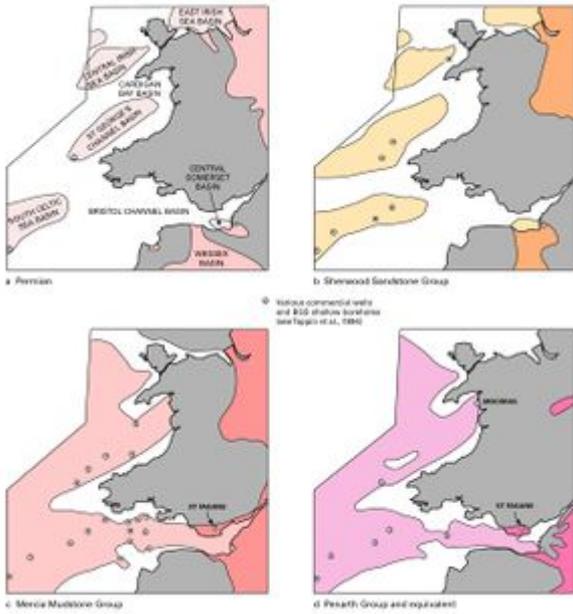


Quaternary deposits exposed in cliff sections at Glanllynau. Note: exaggerated vertical section (adapted from Young, Gibbons and McCarroll, 2002). P916212.



Pass of Llanberis looking north-west. Classic U-form of a glaciated valley with ribbon lakes, Llyn Peris and Llyn Padarn in the

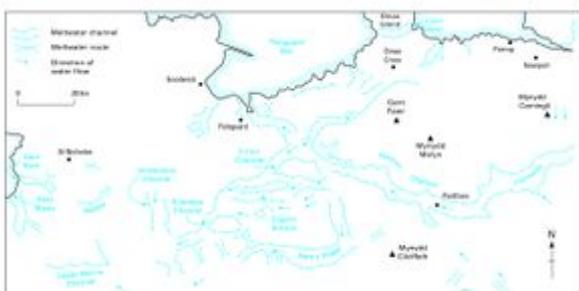
distance and scattered perched blocks across the grassy surface in the foreground. P662438.



Distribution of Permian and Triassic strata around Wales (adapted from Tappin et al., 1994). P916200.



Glacially scoured surface of Cambrian Bronllwyd Grits Formation exposed when the lake was drained during the construction of the Dinorwic Pump Storage scheme, Llyn Peris. P662439.



Melt water channels in the vicinity of Fishguard (adapted from John, 1970). P916213.



Patterned ground, stone polygons periglacial features preserved at Foel Grach, Carneddau. P662441.

Introduction

The progressive climatic deterioration across Wales throughout Palaeogene and Neogene times reached its nadir when, as a result of dramatic cooling, ice that accumulated in upland areas and at high latitudes spread southwards from Scandinavia across much of northern Europe. Sediments derived from these ice sheets are attributed to the Pleistocene Epoch and the overlying, 'Recent', deposits to the Holocene. Historically these two epochs have formed the Quaternary with its beginning taken at 1.8 million years before present. However at the time of writing, it has been proposed that the beginning of the Quaternary should be taken at 2.6 Ma which was the onset of the fluctuating episodes of cold and warm climate. In northern Europe, the ice movement was complex with alternating periods of temperate, cool, cold and periglacial conditions, and it was not until the Anglian stage (some 0.48 Ma) that there was direct evidence of glaciation in Wales. Although there is indirect evidence of earlier ice ages in both late Ordovician and Carboniferous times, the Quaternary is the first time when ice sheets enveloped Wales and the adjacent sea. This is the period when *Homo sapiens* evolved and in which we now live.

Pleistocene

Throughout upland Wales, the evidence of glaciation is overwhelming in the cwms, U-shaped valleys, moraines, roches moutonnées and other erosional features, which are entirely the signature of the last, Devensian glaciation that obliterated the evidence of earlier ice cover ([P916230](#)). Concurrent with the development of local Welsh ice, the larger Irish Sea ice sheet encroached Wales from the north and extended southwards across Anglesey and Llŷn into Cardigan Bay, and eastwards passing through the Cheshire plain. Farther south, the ice sheet transgressed from Cardiganshire into Pembrokeshire to impinge on Gower and south Glamorgan ([P916210](#)). The contact between the Welsh ice and Irish Sea ice was complex, and the unravelling of the different and commonly ambiguous deposits has been the subject of considerable controversy. The southern limit of the Devensian Welsh ice lay close to the south coast, and beyond the ice margin, in south Glamorgan, Gower and south-west Pembrokeshire, there are remnant deposits of an earlier, pre-Ipswichian glaciation.

Until the recent extensive exploration of the offshore areas, the above outline formed the basis of all investigations into the complexity of the surfaces and stratigraphy of the Pleistocene in Wales. Now, the offshore exploration has provided a database that has completely revised the approach to an understanding of these features. The most significant contribution has been the detail of the pre-Devensian events with a stratigraphy from the pre-Anglian, near the base of the Middle Pleistocene, through the Devensian ([P916211](#)).

The earliest evidence of the Pleistocene on mainland Wales has long been considered to be the deposits of the 'Older Drift'. These deposits are predominantly tills of the Irish Sea ice and they occur mainly in those areas outside the limit of the Late Devensian ('Newer Drift') glaciation. In south Wales, Irish Sea till with shells and clasts of Pembrokeshire igneous rocks have been determined about West Angle Bay in south Pembrokeshire, in the Gower and as far east as Pencoed in the Vale of Glamorgan. In the Gower, these early deposits were followed by the construction of the Paviland moraine, which includes numerous boulders of Namurian sandstones derived from the north crop of the coalfield. The moraine is the oldest (possibly Anglian) remnant of north-south Welsh ice movement. However, the most comprehensive evidence of the earlier Pleistocene events lies within the cave deposits, such as those at Minchin Hole and Bacon Hole in the Gower. Sections through these deposits have shown an early inner beach deposit unconformably overlain by the Patella and Neritoides beaches, of interglacial, Ipswichian age, which are probably equivalent of the nearby Horton and Langland and Broughton raised beaches. The Gower cave deposits have yielded the most complete faunal record for the Ipswichian and early Devensian in Wales; a wide range of mammalian fossils include bison, giant ox and hyena, and fossil remains of birds include curlew, dunlin and shearwater. In addition, worked ivory fragments and polished bone fragments indicate occupation by Palaeolithic man. In north Wales, similar mammalian faunas including hippopotamus bones, dated to the mid-Ipswichian, some 125 000 years ago, have been found in the Cefn and Pontnewydd caves above the Elwy valley. In Pontnewydd Cave, a human molar has been determined, and numerous artefacts, including handaxes, suggest that the cave was used as a butchering site by Palaeolithic man, about 30 000 years ago. The possible Ipswichian age for the raised beach deposits on wave-cut platforms as at Poppit Sands in Pembrokeshire, Red Wharf Bay on Anglesey, and Porth Oer on Llyn, has been used to constrain the overlying Irish Sea till to the Devensian Stage.

As with the earlier stages, evidence of the Early and Mid Devensian stages is mainly restricted to the coastal sections and the cave deposits outside the limit of the Late Devensian ice sheet. In the Gower the stages are represented by cemented breccias in Bacon Hole Cave, and in north Wales, on Llyn, possibly by the lowest of two tills in a cliff section at Glanllynau ([P916212](#)). In contrast, the signature of the later Devensian ice sheet dominates the Welsh landscape. Ice movement was controlled by topography, and particularly by the major valleys that existed at the end of the Neogene Period. In north Wales, the pattern was essentially radial, eastwards into the low ground of Cheshire-Shropshire, northwards into the Irish Sea and westwards into Cardigan Bay. The pattern suggests that the thickest ice lay between the Arenig Mountains and Harlech Dome but, subsequently, subsidiary loci, with high cwm glaciations, were established in the main massifs in Snowdonia, the Harlech Dome, the Arans and Cadair Idris. South of the Dyfi valley the pattern is slightly more obscure, possibly as a consequence of the smoothness and lower elevation of the late Neogene surface. However, a dominant influence was the ice cap across the Plynlimon-Drygarn range, which supplied ice westward, through the Dyfi, Rheidol, Ystwyth, Aeron and Teifi valleys into the Irish Sea Ice Sheet in Cardigan Bay; eastwards the main outlet was into the Severn valley and, via Rhayader and Builth, into the Wye valley. The complex pattern of erosional and depositional features associated with the Tywi, Usk and Wye glaciers is the result of convergent patterns, with common capture and, locally, flow reversal from the temporary confrontation between large and small bodies of ice. The long, southerly directed, dip-slope feature of the Fans and Brecon Beacons fed ice across the uplands and valleys of the coalfield, although a small ice cap across Craig y Llyn

fed ice into the Neath and Cynon valleys on its north side. All the deposits of the Welsh ice were locally derived.

The erosional effects of the glaciation can be seen clearly in the highest ground, and most spectacularly in Snowdonia. Here, the radial growth of cwms, Glaslyn, Glas, Du'r Arddu, and Clogwyn, about the Snowdon summit leaves little of the earlier smooth profile, which is preserved in places across both the Glyders and Carneddau. Similarly, the perfectly proportioned Cwm Cau on the south side of Cadair Idris was excavated into a generally smooth surface at the top of the massif. In mid-Wales, cwms such as Cwm Rheidol form the heads of many of the valleys and, in south Wales, the scarps of both the Old Red Sandstone and the Pennant Sandstone are littered with cwms, many of which, as elsewhere, are occupied by moraine dammed lakes; Llyn y Fan Fawr lies beneath the scarp of Mynydd Ddu at the head of the Tawe valley, and Llyn Fawr lies beneath the Pennant Sandstone scarp of Craig y Llyn. Most of the high cwms contain well featured moraines, and those in Cwm Idwal were influential in convincing Charles Darwin, in the early 19th century, that glaciation was the last major geological process to have moulded the Welsh landscape. In south-east Wales, the large arcuate moraines at Llanfihangel Crucorney, north of Abergavenny, and at Glais, in the Tawe valley, mark the maximum extent of the late Devensian ice.

The glaciers sculpted and overdeepened the valleys into characteristic U-shaped profiles, and most of the north Wales examples, such as the Llanberis ([P662438](#)), Nant Ffrancon ([P007200](#)) and Conwy valleys, display successive rock basins in their longitudinal profile. In the Conwy valley, bedrock is at 35 m at Llanrwst and some 130 m at Dolgarrog, just 7 km downstream. It is likely that similar depths occur in most of the valleys in north-west Wales. Similarly, in south Wales, boreholes and geophysical surveys in all the major valleys prove pronounced overdeepening. In Snowdonia, the sculpting power of the debris-laden base of the ice is most clearly seen in the striated rock surfaces and roches moutonnées that are ubiquitous features throughout the high cwms, but the most spectacular striated surfaces are those that were temporarily exposed ([P662439](#)) for the first time in about 10 000 years when Llyn Peris was drained during the construction of the Dinorwic Pump Storage Scheme.

Where the influence of the Irish Sea ice was significantly more powerful than the Welsh ice, it encroached well into the Welsh mainland. In north Wales, the pressure of Welsh Ice was sufficient to constrain the Irish Sea ice to a line that coincides approximately to the present-day coastline for most of the contact, but Irish Sea ice did extend into the Vale of Clwyd and for some considerable distance into the Cheshire-Shropshire plain. In north-west Wales, the influence of the Irish Sea ice is recognised mainly across Anglesey and western Llŷn. It is apparent that during the late Devensian glaciation, the Welsh ice extended onto Llŷn, well outside the main distributaries in the Nant Ffrancon, Llanberis and Gwyrfaï passes, and many coastal sections such as those at Glanllynau and Gwydir Bay show evidence of the fluctuating ice front. At Glanllynau, the cliff section exposes two tills ([P916212](#)), of a single glacial episode, separated by fluvio-glacial sand and gravel. Kettleholes in the vicinity contain grey silty clay that has yielded palynological data and information on beetle faunas that indicate a level close to, or at, the Pleistocene-Holocene boundary.

The Irish Sea ice in Cardigan Bay was sufficiently powerful to extend high into the Teifi valley and possibly across the col between Llandyssul and Carmarthen to join the Tywi glacier. Farther south, distribution of erratics indicates that the ice rose over the flanks of Mynydd Preseli to spread across south Pembrokeshire into Carmarthen Bay, Gower and the Vale of Glamorgan.

The remnant deposits of the Irish Sea ice on mainland Wales are largely restricted to scattered outcrops of till, sand and gravel in Anglesey and Llŷn. Particularly distinctive are the sections, south of Lleiniog, on the east coast of Anglesey, where some 5 m of till overlies 6 m of coarse sand and gravel; both deposits include a wide range of clasts derived from Scotland, the Lake District and

from the floor of the Irish Sea. From Scotland, the clasts of the riebeckite-microgranite of Ailsa Craig in the Firth of Clyde and the Goat Fell granite from Arran are particularly distinctive. From the Lake District, clasts of the Eskdale granite and Ennerdale granophyre have been determined. From the Irish Sea, there are Jurassic and Cretaceous rocks and a suite of marine shells. In south Wales, the drift includes numerous clasts of volcanic rocks whose provenance lay in the Ordovician outcrops of either north Wales or Pembrokeshire.

The highest penetration of the Irish Sea ice on to the mainland occurs at an elevation of 400 m OD on Moel Tryfan on the western edge of Snowdonia. Here within the complex of the Alexandria Slate Quarry are marine shells and sands that were probably derived from the base of the ice sheet and redeposited from the meltwater streams adjacent to, or beneath, the wasting ice sheet. Unfortunately, the exposures within the complex of the Alexandria Slate Quarry have deteriorated, and the most complete descriptions of extensive shelly fauna are those of the first study published in the early 19th century. At that time, the shells were quoted, in the heated discussions of the Glacial Theory, as evidence of the Biblical flood.

Meltwater channels formed both in drift deposits and in rockhead, and are a common feature of the Welsh topography, particularly in the less elevated areas. Commonly the channels are dry and steep sided, and their intricate patterns provide a great deal of information about the glacial drainage system. One of the most spectacular systems lies about the Gwaun valley ([P916213](#)); the lack of correlation between the channel orientations and contours indicates that in many instances the subglacial water was under great hydrostatic pressure.

The difficulties in understanding the detail of both the Irish Sea and Welsh ice sheets arise because both probably comprised several glacial phases interspersed with more clement interglacial phases. The evidence for this complexity is most clearly seen in the coastal sections about Cardigan Bay from Llŷn to north Pembrokeshire, and at various localities between Langland Bay and Broughton Bay in the Gower. In Cardigan Bay, the original concept of a lower and upper glacial till separated by fluvial sands and gravels, deposited when the ice cover had retreated, is too simplistic. The problem is exacerbated by the nature of the deposits: unconsolidated tills with widely variable proportions of clay, sand and clasts, and patches or impersistent layers of sand, gravel and cobbles. Such lithologies do not lend themselves to clear environmental interpretation, and even less so to stratigraphical correlation. Consequently, there seems to have been as many interpretations as workers. The supposed 'correlation' between the deposits of north and south Wales has been based on the assumption that the 'raised beach' deposits of Porth Oer on Llyŷn, and Red Wharf Bay on Anglesey are equivalent to the Patella beaches of Gower, and are of Ipswichian (last interglacial) age, with the overlying glacial deposits being of Late Devensian age. However, the equivalence of the north Wales deposits has not been substantiated.

During the late stages of glaciation, meltwater flowing from the Welsh ice sheet as it retreated from the Cardigan Bay coastline was impeded by the Irish Sea ice and temporary lakes were formed. The largest of these lay in the Teifi valley whose profile indicates successive lake levels down from the vicinity of Tregaron to the coastline at Cardigan. Recently, the understanding of these lake deposits has been improved as a result of the engineering work subsequent to the landslip through Llandudoch (St Dogmaels) to the south-west of Cardigan. Boreholes proved a sequence of laminated silt and clay, sand, gravel and till. Laminated silt and clay, up to 103 m OD, are interpreted as annual and seasonal varve deposits in a lake that changed its shape with the fluctuations at the front of the Irish Sea ice sheet. At its maximum development the lake drained southwards, into Pembrokeshire, into a lake at a lower level in the Nevern valley, west of Newport. Elsewhere, as at the confluence of the Ely, Taff and Rhymney rivers in suburban Cardiff, widespread outwash fans were deposited by meltwater.

Head and other mass movement deposits mantle both upland and lowland slopes. Much of this originated as periglacial deposits, although talus (scree), solifluction and landslip continue to form. Repeated freezing and thawing in cold climatic conditions has produced the conspicuous block-fields seen in some mountainous areas. Patterned ground is another remnant of very cold conditions and may take the form of stone stripes, circles or polygons ([P662441](#)).

Offshore, the absence of Miocene to early Pleistocene deposits has been attributed to uplift and erosion during this interval. A significant thickness of Middle and Upper Pleistocene deposits occurs in St George's Channel, with less in Cardigan and Liverpool bays. In the Bristol Channel, there are large areas with no Middle and Upper Pleistocene deposits. The sequence is most clearly understood from seismic profiles, which display the unconformable relationship with the pre-Quaternary strata. The subdivision of the sequence into six formations ([P916211](#)) is based largely on the seismic profiles with some supporting borehole data. The formations show considerable lateral variations and interdigitation, and further subdivision into facies and informal members has been possible. The deposits are of widely differing lithologies, ranging from till through coarse cobbles and boulders to sand, silt and clay. Within the sequence, three erosional surfaces, with major incisions in excess of 100 m, has allowed four depositional cycles to be recognised and the overall stratigraphy is broadly similar to that of the North Sea.

The Mochras Borehole intersected some 80 m of till and pebbly gravel, and subsequently these have been correlated mainly with the Western Irish Sea Formation. The thickest element, of clast-supported tills, was assigned to the Sarnau facies, which forms the low, smooth-topped ridges or sarnau that extend seaward from the coastline. Mochras lies at the landward side of Sarn Badrig. The ridges have been interpreted as median moraines between glaciers exiting from major valleys, and as the remnants of late-glacial sandurs. In St George's Channel, pebbly mud of the St George's Channel Formation is overlain by till of the Cardigan Bay Formation, which locally includes a thick central unit of silt and sand. Thinner sequences of the Cardigan Bay Formation have been determined onshore and offshore at Llandudno and in Caernarfon Bay. The uppermost Surface Sands Formation is restricted mainly to the nearshore and intertidal areas, as in the shelly sands in Tremadog Bay, where it is up to 30 m thick. The lower part of the formation reflects shallow-water or subaerial conditions, but the upper parts are the product of present-day (Holocene) marine processes. For much of the nearshore areas between south Glamorgan and south Pembrokeshire, the Surface Sands Formation is the dominant element of the thin Pleistocene sequence. Inshore the formation passes into intertidal sands, mudflats and salt-marshes.

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