Chapter 8 The Quaternary of North Wales

Introduction

Except for the Quaternary sediments exposed around the coasts of Anglesey and north-west Wales — see Chapter 7, North Wales is best known for its upland glacial and periglacial landforms. The glacial landforms of Snowdonia were amongst the first in Britain to be investigated in relation to the Glacial Theory (for example, Bowman 1841; Buckland 1842; Darwin 1842) and they have since featured in a number of important geomorphological studies (for example, Davis 1909; Seddon 1957; Unwin 1970; Gray 1982a; Gemmell et *al.* 1986). There is also evidence for the Pleistocene evolution of the region.

Deposits pre-dating the Ipswichian Stage

Evidence for environmental conditions prior to the Late Devensian is sparse in North Wales apart from Pontnewydd Cave in the Elwy Valley, where deposits have yielded a molar of early Neanderthal Man dated to *c.* 200,000 BP (Green *et al*. 1981; Green 1984). This suggests occupation of the cave during Oxygen Isotope Stage 7. In addition to the oldest known human evidence from Wales, the sequence provides a Middle Pleistocene sedimentary record. Stratigraphic, faunal, and dating evidence from Pontnewydd provides an important Pleistocene record and the only known Lower Palaeolithic finds from a stratified context. Work by H S Green of the National Museum of Wales has resulted in detailed descriptions and an interpretation of the Pontnewydd sequence.

The Ipswichian Stage

Evidence for conditions during the Ipswichian Stage in North Wales is sparse. The only documented North Wales sites with evidence are the caves at Pontnewydd and Cefn. Although Sutcliffe regarded some of the mammal remains from Pontnewydd as representing a typical Ipswichian assemblage, recent excavations have not confirmed the age of the fauna as Ipswichian (Currant *in* Green 1984). Indeed, there is considerable evidence to suggest that the cave entrance at Pontnewydd may have been closed during the Ipswichian (Green 1984). The best evidence so far available for this time is from the nearby Cefn Caves where a fauna including hippopotamus and straight-tusked elephant has been recorded (Falconer 1868; Neaverson 1942). Although the precise stratigraphical context of these finds is unknown, they provide palaeontological information which may be useful for elaborating longer term aspects of regional Pleistocene evolution (Bowen 1973a, 1974; Peake et *al.* 1973).

The Devensian Stage

Late Devensian deposits are widespread in North Wales and their broad distribution has been known for some time (Bowen 1974). In common with the coastlands of north-west Wales, it has long been recognised that the North Wales coast was subjected to complex fluctuations and interactions between ice flows moving outwards from the Welsh uplands and Irish Sea ice moving generally southward. Evidence for the interplay of these ice masses, in the form of superimposed tills of Welsh and Irish Sea origin, is common along the North Wales coast, particularly around Llandudno and Conway (Whittow and Ball 1970; Fishwick 1977). Whittow and Ball (1970) suggested these tills were formed during separate glaciations, but Fishwick (1977) argued there is no evidence to suggest that glacial deposits beneath the Irish Sea till along the coast are older than Late Devensian. It was therefore envisaged that till deposits along the north coast were related principally to the onshore movement of Late Devensian Irish Sea ice which incorporated deposits from an earlier Welsh glaciation as it moved south. This Irish Sea glaciation was powerful enough to penetrate the Vale of Clwyd to deposit shelly drift at *c.* 300m on Halkyn Mountain near Wrexham (Strahan 1886) and at over 300m on Gloppa Hill near Oswestry (Wedd *et al.* 1929). At the same time, it is generally believed that Welsh ice covered most of the Welsh uplands: for example, the Arenig region (Rowlands 1970), the Berwyn (Travis 1944),

Montgomeryshire (Brown 1971) and the south Shropshire hill country (Rowlands 1966; Brown 1971). Studies of ice wastage phenomena in the region have also been provided by Embleton (1957, 1961, 1964a, 1964b, 1964c) in north-east Wales, and by Brown and Cook (1977) and Thomas (1984) in the Wheeler Valley and Mold areas.

The broad distribution and provenance of the glacial sediments of the region is known (Bowen 1974). A relative lack of good exposures and interglacial indicators, including weathering and biostratigraphic horizons, has hampered correlation and interpretation in the region. In many respects the debates about the age of the drifts in North Wales are similar to those in the north-west Wales coastlands; namely, is there evidence for a readvance of Late Devensian ice? In this context the cave site at Tremeirchion in the Vale of Clwyd could be important. Here, Rowlands (1971) obtained a radiocarbon date of c. 18,000 BP, from material apparently sealed within the cave by Irish Sea till. If correct, the date provides evidence to show Irish Sea glaciation after 18,000 BP, when ice moved southwards into the Vale of Clwyd to the limit marked by the Bodfari-Trefnant moraine (Rowlands 1955). Although correlation of this glacial phase with the Scottish Readvance (Pocock *et al.* 1938) is not now accepted, the evidence from Tremeirchion has been used to support a Late Devensian readvance (Bowen 1974), and it is consistent with evidence described from the Ll■n Peninsula (for example, Saunders 1968a, 1968b) see Chapter 7. It is also interesting to note the close correspondence of the Tremeirchion date with those obtained from Dimlington in Yorkshire (Penny *et al.* 1969) which have been used to provide a maximum age for the principal advance of Late Devensian ice in eastern England, during the 'Dimlington Stadial' (Rose 1985).

North-east Wales is one of the potentially most rewarding areas for elaborating Late Pleistocene glacial history. This potential stems partly from its proximity to the Cheshire-Shropshire lowland, an area that has figured prominently in investigations of the Late Pleistocene. It is, however, beyond the scope of the present work to review such developments in that area, and reviews are available elsewhere (for example, Worsley 1970, 1977, 1985; Bowen 1974). It is important to note, however, that north-east Wales, and the Wrexham area in particular, forms an important link between the complex Cheshire-Shropshire lowland sequences and the more fragmentary records found elsewhere in North Wales. These important aspects of regional stratigraphy are more fully discussed in the introductory section to the GCR site at Vicarage Moss. Recent work in the Wrexham area (Dunkley 1981; Wilson et *al.* 1982; Thomas 1985) has demonstrated the complexity of the deposits there, with evidence for sequential wasting of Late Devensian ice, interrupted by brief ice advances at the margin of an oscillating ice-sheet (Thomas 1985). To some extent this evidence throws doubt on the more simplistic 'monoglacial' and 'tripartite' schemes erected by earlier workers in the area, and demonstrates a range of conditions at or near the margin of the Late Devensian ice-sheet — but see Chapter 2. Until better evidence is available to the contrary, it may be as well to regard multiple glacigenic sequences along the North Wales coastal margin in the same manner, namely as broadly Late Devensian in age, without sub-division.

The uplands

During the Late Devensian, local ice masses in Snowdonia and Arenig were subordinate to a major ice dispersal centre — the Merioneth ice cap (Greenly 1919; Foster 1968). This is believed to have contributed westerly and easterly flows from just east of Arenig Fawr and Rhobell Fawr (Foster 1968; Bowen 1974). Both Foster and Rowlands (1970) showed, as did Greenly, that the greatest thickness of ice occurred in the neighbourhood of Trawsfynydd. Foster (1968) demonstrated that the erratic content of tills in the Harlech Dome reflected deposition from different layers within the westerly moving limb of the Merioneth ice; with the upper portions of the ice crossing the Rhinog Mountains and entering Cardigan Bay, and the lower layers entering the Vale of Trawsfynydd and Mon Eden. Similarly, it was established (Rowlands 1970) that an easterly extension of the Merioneth ice cap overrode lower lying parts of the north-east Wales massif, being sufficiently powerful for a time to obstruct southward moving Irish Sea ice and prevent it from entering the Vale of Clwyd.

Exposures in glacial deposits occur widely within the network of selected GCR sites in Snowdonia, and these have been chosen primarily to represent three main aspects of the Quaternary for which the area has become nationally important.

First, three sites — Snowdon (Yr Wyddfa), Y Glyderau, Y Carneddau, represent an outstanding range of large-scale glacial erosional features. These spectacular upland landforms include classic examples of cirques, aretes and troughs,

all modified by glacial and periglacial processes. These three principal upland sites demonstrate a range of landforms which have resulted from varying conditions controlled by such factors as altitude, aspect, geological composition and structure. Snowdon, for example, demonstrates a classic 'Alpine' arrangement of cirques radiating from a horn and separated by precipitous aretes. One cirque complex within this erosional assemblage also demonstrates a classic example of a 'cirque stairway'. The adjacent massif of Y Glyderau is a departure from this pattern, with a series of cirques, including Cwm Idwal, showing a marked structural alignment. These cirques fed ice into the spectacular Nant Ffrancon trough. In contrast, the easternmost part of the main Snowdonian massif is represented by landforms in the Carneddau range. Although cirque forms are also well represented here, for example Cwm Dulyn and Cwm Melynllyn, the landscape is far less rugged in nature and contains many broad-shouldered ridges. Y Carneddau exhibits an outstanding assemblage of fossil and contemporary periglacial landforms, for which the site has primarily been selected.

Second, although small and medium-scale features formed by the agencies of glacial erosion, particularly striae and roches moutonnées, are well represented within these three large upland sites, they are exceptionally well developed within the Snowdon site at Llyn Llyddaw (Gray and Lowe 1982) and in the Llanberis Valley at Llyn Peris. The latter site demonstrates an unparalleled range of small-scale erosional features including striae, friction cracks and forms associated with subglacial meltwater erosion.

Third, the selected upland sites of Snowdon, Y Glyderau and Y Carneddau contain an outstanding range and diversity of depositional landforms, formed largely during the Late Devensian late-glacial. Cirque glaciation during Younger Dryas times is by no means limited to these north Snowdonian sites, and landforms belonging to this phase are widely documented elsewhere in Wales — in the Arenig Mountains (Rowlands 1970), around Cadair Idris (for example, Watson 1977a); and in the Brecon Beacons (for example, Lewis 1970b; Ellis-Gruffydd 1972; Walker 1980, 1982a, 1982b).

The principal features of this late-glacial landform assemblage, the cirque moraines and protalus ramparts, however, are among the finest examples of their kind in Britain, and are well represented within the three main Snowdonian sites. These depositional landforms have long been known from the region (for example, Darwin 1842; Ramsay 1860; Daykins 1900), with Kendall's (1893) treatise *On a moraine like mound near Snowdon* representing one of the first descriptions of a protalus rampart in Britain. The presence of both inner and outer moraine arcs in many of the Snowdonian cirques, and a mixture of 'sharp' and 'diffuse' moraine forms was noted by workers mapping their distribution (Seddon 1957; Unwin 1970). They concluded from this distribution and the morphology of the features that both protalus ramparts and moraines dated from two separate events. Analysis of pollen bearing sequences by Godwin (1955) and Seddon (1957, 1962) was fundamental in establishing this sequence of Late Devensian late-glacial vegetational events. This led to the suggestion that the outer and generally 'diffuse' moraines and protalus features might date from Pollen Zone I or to a recessive stage of the Late Devensian ice-sheet, with the inner 'fresh' features dating to the Younger Dryas (Pollen Zone III) (Seddon 1957, 1962; Unwin 1970).

More recently, Gray (1982a) has remapped these features, and provided evidence for thirty five Younger Dryas cirque glaciers in northern Snowdonia. Gray demonstrated that many of these small glaciers left complex depositional evidence to mark their maximum limits, including not only end-moraines but boulder limits and the down-valley extent of hummocky moraine — the Snowdon, Y Glyderau and Y Carneddau sites have, in part, been chosen to reflect the considerable variety of these depositional landforms. Gray further suggested that the highly variable evidence marking these glacier limits threw doubt on the widespread existence in the region of pre-Younger Dryas moraines (the 'Older Series' of Unwin (1970)). Palynological and radiocarbon dating evidence (Burrows 1974, 1975; Crabtree 1969, 1972; Ince 1981, 1983) from the region has also helped to place tighter constraints on the age of the final cirque glaciation of the uplands, and the majority of cirque moraines and protalus ramparts are now widely held to date from the short Younger Dryas, between *c.* 11,000–10,000 BP.

At Cwm Dwythwch, however, just north of the main Snowdon massif, Seddon (1962) described a typical full Late Devensian late-glacial sequence behind a large cirque moraine. This site, therefore, displays the only reliable relatively dated evidence from Wales for a cirque moraine of demonstrably pre-Younger Dryas age.

Late Devensian late-glacial and Holocene environmental history

Pollen analysis has been used in North Wales to reconstruct vegetational and environmental history during the Late Devensian late-glacial and Holocene. The network of selected pollen sites, some with radiocarbon calibration, provides evidence for conditions across North Wales from the wastage of the Late Devensian ice-sheet. In terms of the diversity of topography and climate in North Wales, both past and present, the range of sites illustrates both the broad patterns of environmental change and regional variations.

Evidence for palaeoenvironmental conditions during the late-glacial of the Late Devensian is recorded in the major upland GCR site at Nant Ffrancon in the Glyderau (Seddon 1962; Burrows 1974, 1975). It is supplemented by the sequences at Cwm Dwythwch, Clogwynygarreg and Cors Geuallt. Cwm Dwythwch provides evidence for ascribing a cirque moraine to a pre-Younger Dryas episode. Clogwynygarreg and Cors Geuallt also lie outside the mapped Younger Dryas limits of Gray (1982a), and place further limits on the possible age of the final cirque glaciation in the uplands. Clogwynygarreg records a near complete late-glacial sequence, including what appears, on the basis of the sediments, to be a single interstadial — the 'late-glacial interstadial' (Ince 1981). A minimum age for Late Devensian deglaciation in the area is indicated by a radiocarbon determination of 13,670 ± 280 BP (Birm 884) (Ince 1981). The pollen record shows a gradual improvement in conditions associated with the 'late-glacial interstadial'. A change from organic to clastic sedimentation, and a decline in *Juniperus* pollen mark the onset of the Younger Dryas (*c.* 11,000 BP) — a brief cold pulse when glaciers again occupied many of the upland cirques (Ince 1981).

This simple threefold lithology may represent the division of the pre-Allerød, Allerød and post-Allerød episodes of the Continental late-glacial (Moore 1977), which shows a single warm phase preceded and followed by colder climatic ones but see Chapter 1. This is not recorded everywhere, which shows the need for a range of sites to reconstruct late-glacial conditions. At Glanllynnau — Chapter 7, for example, both Coope and Brophy (1972) and Simpkins (1974) suggested that what appeared to be a single 'late-glacial interstadial' might represent a combination of the Continental Bølling and Allerød Interstadials (Moore 1977). In Snowdonia, similar complexity has been recorded at Nant Ffrancon (Y Glyderau), where Burrows (1974, 1975) described what he interpreted as the Bølling 'oscillation'. A similar pre-Allerød climatic oscillation, possibly equivalent to the Bølling, has also been recorded from Cors Geuallt (Crabtree 1969, 1972). Moore (1975b, 1977) and Ince (1981), however, have questioned the validity of this evidence, particularly the radiocarbon dates from Nant Ffrancon. The network of GCR late-glacial sites represents these aspects of regional floral and environmental diversity which establish the relative timing of late-glacial climatic and environmental changes in Wales.

Within the principal upland sites of Snowdon, Y Glyderau and Y Carneddau, a number of pollen analytical sites with sequences from the beginning of the Holocene have been studied, which are the basis for environmental reconstruction in the uplands. These include the radiocarbon dated Holocene profiles at Cwm Cywion and Llyn Llyddaw (Ince 1981, 1983), and those at Cwm Idwal (Godwin 1955), Cwm Clyd (Evans and Walker 1977) and Cwm Melynllyn (Walker 1978). The last two sites also record detailed diatom evidence for changing Holocene environmental conditions.

The Holocene vegetation succession in North Wales reflects the development of temperate deciduous forest in response to climatic amelioration after the Younger Dryas. The early Holocene, *c.* 10,000 BP, is usually marked by expansion in *Juniperus* and *Betula* (Moore 1977) with a rise in *Corylus* very shortly after, although Moore (1972b) noted that the precise relationship between these rises varies both with altitude and latitude across western Britain. The mid Holocene sees a sharp expansion in *Betula* which at most Welsh sites declines again rapidly with the invasion of other trees. At Cwm Idwal, however, this *Betula* peak is more protracted. The birch and hazel woodlands are replaced eventually by forests of birch, oak, elm and alder (Ince 1983) and *Alnus* assumes a major, if not dominant, role in the pollen records of many Snowdonian profiles (Moore 1977). Deteriorating environmental conditions and human interference from about 5,000 years BP onwards resulted in the gradual decline of upland forests and the development of open-grassland and heathland which characterises the area today (Moore 1977; Ince 1981, 1983). The Holocene pollen profiles within the large upland GCR sites of Snowdon, Y Glyderau and Y Carneddau, and those from the selected pollen sites at Cwm Dwythwch, Cors Geuallt and Clogwynygarreg are important in establishing the timing of regional variations in these major vegetational and environmental changes.

Tufa

Tufa deposits in North Wales were mapped and described at an early stage (Maw 1866; Strahan 1890; Wedd and King 1924) and their potential for palaeoenvironmental reconstruction recognised (for example, Jackson 1922; McMillan 1947; Millot 1951; Bathurst 1956). A number of tufa localities has been recorded in the region, around Prestatyn and the Wheeler Valley (Neaverson 1941; McMillan 1947). Those at Caerwys and Ddol provide contrasting records: Caerwys represents the only known example of tufa formation from the Late Devensian late-glacial in Wales. The tufa and buried soils at these sites provide an exceptional biostratigraphic record (molluscs, leaf-beds and vertebrate faunas) recently re-examined by Preece (1978), Preece *et al.* (1982), McMillan and Zeissler (1985) and Pedley (1987). These accounts of the biostratigraphy and carbonate sedimentology of the tufa are complemented by radiocarbon calibration, and provide one of the most extensive and detailed records of environmental changes in Wales since the wastage of the Late Devensian ice-sheet.

Periglacial landforms

Upland North Wales is a classic area for periglacial landforms and processes. Many landforms, such as solifluction terraces and scree slopes, are widespread (Ball 1966; Ball and Goodier 1970), but other indicators of periglacial action, for example, patterned ground, are also well developed, although they are limited in extent. The network of GCR sites in the region reflects the considerable importance of non-glacial, cold-climate processes for landform evolution in North Wales during the Late Pleistocene and Holocene, even in historical and modern times. Although the major upland landform sites of Snowdon and Y Glyderau contain an impressive assemblage of periglacial features, including scree slopes, block screes (Pont-y-Gromlech), frost-shattered summits and tors (Y Glyderau) and a fine series of vegetated stripes (Y Garn), the scale and diversity of forms does not generally match that developed in the adjacent Carneddau massif. Many of the periglacial landforms in the Carneddau, including well developed screes, blockfields, tors and solifluction lobes and terraces, are classic examples of their kind. Although dating evidence is not yet available, it is believed that many features were formed during periglacial conditions following wastage of the Late Devensian ice-sheet and during the Younger Dryas (Ball 1966; Ball and Goodier 1970; Scoates 1973). Some features (patterned ground at Waun-y-Garnedd) are currently active and provide evidence for contemporary frost-assisted processes (Pearsall 1950; Tallis and Kershaw 1959; Ball and Goodier 1970; Scoates 1973). The factors influencing the distribution and maintenance of a range of landforms in the Carneddau associated with periglacial activity, have been discussed in detail by Scoates (1973).

Although the Carneddau provide a range of fossil and contemporary frost-assisted features in a compact area probably unparalleled elsewhere in Wales, three further sites in North Wales, at Moelwyn Mawr, Rhinog Fawr and Y Llethr, add a contrasting range of landforms, including for example, the only known occurrence in Wales of a fossil rock glacier (Lowe and Rose *in* Gray *et al.* 1981), and a fine series of unsorted vegetated stripes (Taylor 1975).

Sites in the Rhinog Mountains at Y Llethr and Rhinog Fawr also provide landform evidence for periglacial conditions and frost-assisted activity on a number of different occasions. Sorted stone stripes at Rhinog Fawr, thought to date from the Late Devensian late-glacial (Ball and Goodier 1968, 1970), are the finest.examples in Wales, and they are developed at a larger-scale than similar features elsewhere in Britain. In contrast, landforms at nearby Y Llethr may provide unique evidence in Wales for formation during a later cold period in historical times (Goodier and Ball 1969; Ball and Goodier 1970), perhaps during the climatic deterioration of the little Ice Age' between c. 1550 and 1750 A.D. (Manley 1964; Lamb 1967).

This selected network of sites therefore provides substantial evidence for a wide range of landforms associated with periglacial conditions and frost-assisted processes from the Late Devensian late-glacial to the present day.

References