Chapter 7 Quaternary stratigraphy: north-west Wales

Introduction

The coastal margins of north-west Wales are one of the key areas for the elaboration and interpretation of Late Pleistocene and Holocene events and processes. In common with Gower, the coasts of Anglesey and the L1–9n Peninsula exhibit complex sequences of glacial, periglacial and some interglacial sediments which show changing environmental conditions during the Late Pleistocene, In particular, these sediments provide evidence for the interaction of Irish Sea and Welsh ice masses, and they, in addition, record changes in relative sea-levels. A number of themes are important. First, the area figured prominently in the development of the Glacial Theory and attempts to sub-divide the Pleistocene. Second, recent studies have elaborated the provenance and directions of movement of various ice masses affecting the area. Third, attempts have been made to establish a chronology for the region, based largely on lithostratigraphy and radiocarbon dating. One sequence, at Glanllynnau, has been compared with modern glacial depositional systems. A comprehensive chronology for the region, however, has not been developed, a situation made worse by a general lack of interglacial indicators and the uncertain significance of a number of weathering horizons. The Late Pleistocene record in north-west Wales is particularly important for demonstrating possible evidence for a readvance of Late Devensian Stage ice.

Early sub-division

Historically, the area is important in two respects. It figured prominently in the development of the Glacial Theory; Trimmer's (1831) early account of the shelly sand and gravel deposits on Moel Tryfan marked an important milestone in glacial geomorphological research, because it began approximately seventy years of fierce debate centred on the contending theories of the 'glacialists' and 'diluvialists'. Moreover, the site continued to play a central role in the development and resolution of the debate.

The area is also notable for some of the earliest attempts in Britain to sub-divide the Pleistocene sequence. By the 1850s, enough was known about the glacial deposits in North Wales for Ramsay to postulate a threefold division — 1) a Lower Boulder Clay deposited by local Welsh glaciers, 2) the Middle Sands and Gravels and the shelly till of Moel Tryfan and 3) an Upper Boulder Clay deposited by a readvance of small valley glaciers (Davies 1969). Although Ramsay accepted a glacial origin for the boulder clays, he still found it necessary to invoke a period of marine submergence to account for the shelly drift deposits on Moel Tryfan. Thomas Belt's (1874) perceptive paper concerning the Moel Tryfan deposits, however, did much to advance the Glacial Theory, but even as late as 1910, Edward Hull, former director of the Irish Geological Survey, still regarded the shelly drift as evidence for marine submergence (Davies 1969).

Following these early pioneering studies in North Wales, Jehu (1909) and Greenly (1919) published detailed accounts of the Pleistocene deposits of the Ll■n Peninsula and Anglesey, respectively. Jehu (1909) considered that Ll■n had been glaciated twice by ice from northern Britain (Northern or Irish Sea ice). At many sites around the Ll■n coast he described Upper and Lower Boulder Clays separated by Intermediate Gravels and Sands; the latter he considered to have formed probably during interglacial melting of the first ice-sheet. Jehu assumed that similar advances of Welsh ice had also issued from Snowdonia. Above all, he established that the Pleistocene deposits in northwest Wales had resulted from the interaction of ice masses from the Irish Sea Basin and Snowdonia. Greenly (1919) produced a comprehensive account of the Pleistocene geology of Anglesey and established that the island had been overrun by Irish Sea ice on two occasions. Using glacial striae and erratics trains as indicators of former ice movement directions, Greenly was able to show that Anglesey had been glaciated by Irish Sea ice from the north-east while coeval ice from Snowdonia may have impinged upon the south-east coast of the island. Like Jehu (1909), Greenly (1919) suggested that the directions of movement of the Irish Sea ice-sheet had been similar during both glaciations. The tripartite sub-division of deposits on Ll■n by Jehu (1909) is particularly relevant, because many of the GCR stratigraphical sites in the region were originally described and interpreted using this classification. Both Gwydir Bay and Dinas Dinlle, for example, were regarded by Jehu as showing all three members of the tripartite scheme.

Recent approaches to Pleistocene problems

Although most studies agree that Ll■n and probably much of north-west Wales was affected by ice from two main sources during the Late Pleistocene, interest in the coastal sections in recent years has centred upon a) establishing a chronological framework for Late Pleistocene events and b) determining the characteristics and extent of the ice masses affecting the region. Consequently, the GCR site coverage in the coastlands of north-west Wales demonstrates the major sedimentary units and the most important themes that have featured in the emerging Pleistocene chronology.

Ice-sheets and ice movement directions

Studies of till fabric patterns and clast lithology at sites throughout Dim (Saunders 1963, 1968b, 1968d; Simpkins 1968) have helped to determine more clearly former patterns of ice movement directions. During the first inferred glaciation, Irish Sea ice is believed to have moved onto Ll■n from the north and north-west, while much of Arfon and south-east Ll■n was crossed by ice from the Snowdonian massif. During the second inferred advance, there is some evidence to suggest that the Irish Sea ice-sheet moved onto both the North Wales coast and the Ll■n Peninsula from the north and east, and that it was probably confluent with south-west moving Welsh ice in the Menai Straits region (Whittow and Ball 1970). During this second phase, it has been suggested that neither the Welsh nor Irish Sea ice masses was as extensive as previously, and certain parts of Ll■n may have remained ice-free. The GCR sites at Hen Borth, Red Wharf Bay and Lleiniog on Anglesey, show the dominant onshore and generally south-west movement of the Irish Sea ice, probably during the last of the inferred major glacial events. In the same context, coastal stratigraphical sites on Ll■n also demonstrate the movements of the Irish Sea and Welsh ice-sheets at different times. From fabric and clast lithology measurements (for example, Saunders 1963, 1968b, 1968d; Simpkins 1968), in combination with lithostratigraphic interpretations, three patterns of ice-movement have been identified. First, the coastal sections in northern Ll■n show evidence for a generally southward movement of Irish Sea ice. The evidence suggests that sites in the west, for example Porth Oer, were exclusively overrun by Irish Sea ice, whereas from Gwydir Bay northwards to Dinas Dinlle, the combined effects of Irish Sea and Welsh (Snowdonian) ice-sheets are evident. Second, on the southern coast of the peninsula, sites in the east such as Morannedd and Glanllynnau show evidence for glaciation by ice of Welsh provenance, from sources in Snowdonia. Third, exposures such as those at Porth Ceiriad and Porth Neigwl on the southern coast, show that the western part of the peninsula (in the area around St Tudwal's) may have been a zone of transition between Welsh and Irish Sea ice-sheets on one or more occasions.

The work of Saunders (1968b, 1968d), Simpkins (1968) and Whittow and Ball (1970) has also established that an upper till on Ll■n is found widely outside Synge's (1963, 1964) proposed maximum limit for Late Devensian (Late Weichselian) ice.

Chronology

While the broad pattern of Late Pleistocene ice movements is well established, their timing is less certain, as is the precise extent of each glaciation. In determining a chronology for the region, the well exposed coastal sites are important. In an investigation of the coastal stratigraphy around Ll■n, Synge (1963, 1964) suggested that ice of Late Devensian age only impinged on its northern coastal margins. More weathered and cryoturbated glacial sediments to the south of this limit at, for example, Criccieth (Morannedd) and Glanllynnau, were, therefore, considered to be older. Synge's classification was based on correlation with a stratigraphic model developed in Ireland, in which raised beach sediments such as those at Porth Oer in western Ll■n were ascribed to the Hoxnian Stage. Such a view, however, has not been widely accepted, and most workers including Saunders (1968a, 1968b, 1968c, 1968d) and Bowen (1973a, 1973b, 1974, 1977a, 1977b) considered the raised beach sediments at Porth Oer to be of Ipswichian age and the till on Ll■n to have been deposited during the Devensian Stage. These views have developed from three main lines of evidence outlined below.

Regional correlations

Bowen (1973a, 1973b, 1974, 1977a, 1977b) proposed a classifiction for the Pleistocene of Wales. In this, the widespread raised beaches of South Wales were ascribed to the Ipswichian Stage. Raised beach sediments in North Wales have been recorded only at Porth Oer, and at Red Wharf Bay in eastern Anglesey. Like Saunders (1968a), Bowen (1973a, 1973b, 1974, 1977a, 1977b) considered that the glacial and periglacial sediments which overlie the raised beach at Porth Oer and Red Wharf Bay were Devensian in age. Bowen also supported Saunders' contention that the Bryncir-Clynnog moraine as well as additional deposits to the south represented a readvance of a Late Devensian ice-sheet.

Weathering horizons

Weathering horizons described from a number of coastal sections in north-west Wales have had a major bearing on classification. Simpkins (1968) classified the Pleistocene deposits in central Caernarvonshire into formal lithostratigraphic units. These units have been applied over wider areas and they have been subsequently used in the individual accounts of the GCR sites. According to Simpkins (1968) the earliest glacial advance in Ll■n was shown by the Criccieth (Welsh) till found along the southern Ll■n coast at, for example, Criccieth and Glanllynnau. Weathering of the surface of the Criccieth Till suggested a possible pre-Devensian age to Simpkins, who like Synge (1963, 1964) believed the weathering to have occurred in an interglacial. The Criccieth Till is overlain by Welsh fluvioglacial sediments of the Mon Wen Formation and by the Llanystumdwy Till ascribed to the Devensian by Simpkins (1968). In contrast, Saunders (1968a, 1968d) partly on the basis of radiocarbon evidence (see below), suggested that the surface of the Criccieth Till had been weathered during an interstadial in the Devensian, a view upheld by Whittow and Ball (1970) and Bowen (1973a, 1973b, 1974, 1977a, 1977b).

On the northern coast of Ll■n, Simpkins described a similar threefold sequence to that of Jehu (1909) with a succession of — 1) lower Irish Sea till (Trevor Till), 2) fluvioglacial sediments (Aberafon Formation), and 3) an upper Irish Sea till (Clynnog Till). No weathering horizon was seen by Simpkins (1968) in this sequence and the tills were, therefore, considered to have been deposited by two closely-spaced advances of the Late Devensian ice-sheet. Saunders (1968a, 1968b, 1968c, 1968d), however, recognised evidence for weathering between deposition of the two till units at Gwydir Bay and interpreted the sediments in terms of two distinct glacial advances separated by an interstadial period with warmer conditions. The GCR sites reflect the importance of weathering horizons for establishing a Pleistocene classification for the region, especially at Glanllynnau and Morannedd, Gwydir Bay and Dinas Dinlle.

Radiocarbon dating

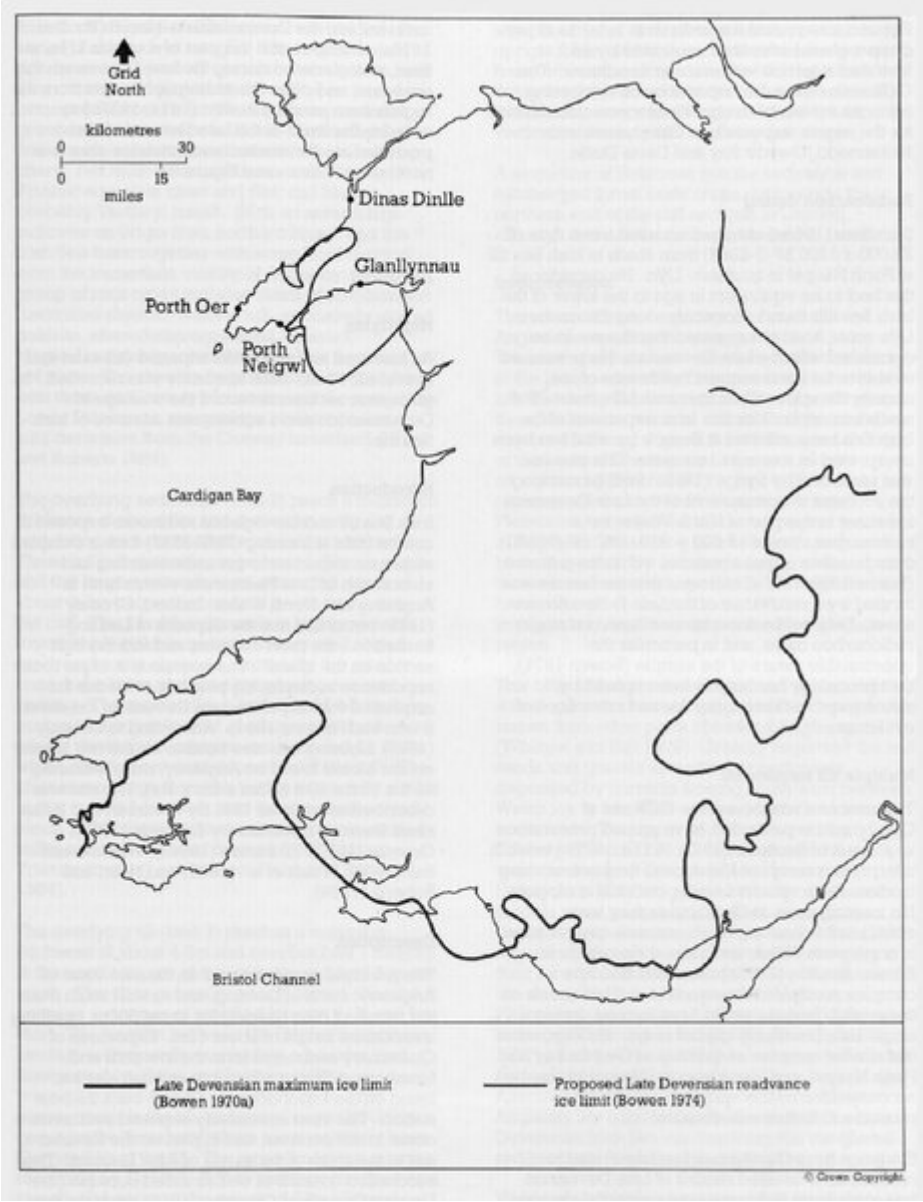
Saunders (1968a) obtained a radiocarbon date of 29,000 ± 1200 BP (1–3262) from shells in Irish Sea till at Porth Neigwl in southern Ll■n. He considered this bed to be equivalent in age to the lower of the Irish Sea tills found commonly along the northern Ll■n coast, and he suggested that this could be correlated with the Late Devensian. He presented evidence for a subsequent readvance of ice, namely the upper till on the north Ll■n coast. The southernmost limit for this later expansion of the Irish Sea ice is marked at Bryncir by what has been interpreted as a terminal moraine. This moraine was regarded by Synge (1963, 1964) as marking the southern maximum limit of the Late Devensian ice-sheet in this part of North Wales, but a radiocarbon date of 16,830 + 970 — 860 BP (1–2801) from possible organic material within the moraine (Foster 1968, 1970a) indicates that the feature was formed by a readvance of the Late Devensian ice-sheet. Despite the uncertainties based on single radiocarbon dates, and in particular the questionable nature of the sample (Bowen 1974), the chronology has largely been upheld by subsequent workers using this and other lines of evidence.

Multiple till sequences

The area as a whole, and the GCR site at Glanllynnau in particular, have gained prominence as a result of Boulton's (1972, 1977a, 1977b) work in interpreting complex Pleistocene sequences using modern Arctic glaciers as depositional analogues. His investigations at Glanllynnau may have considerable bearing on Pleistocene classification in north-west Wales, and indeed elsewhere in Britain. Boulton (1977a) demonstrated how a complex multiple drift sequence at Glanllynnau on the south Ll■n coast could have formed during a single Late Devensian glacial event. He suggested that similar complex sequences at Gwydir Bay and Porth Neigwl, and elsewhere in Ll■n could also be accounted for by this simple model, without recourse to further sub-division.

Evidence from Glanllynnau has been used to reconstruct a detailed record of Late Devensian late-glacial and Holocene environmental changes (Simpkins 1968, 1974; Coope and Brophy 1972). Radiocarbon, pollen and particularly fossil beetle evidence from the sequence have made the site a cornerstone for Late Devensian late-glacial studies in lowland North Wales, as well as giving the site national importance. Faulting structures in the late-glacial sequence provide crucial evidence to tie the glacial and late-glacial sequences together; showing that buried glacier ice did not finally melt until well into the Devensian late-glacial (Boulton 1977a). It follows that this part of southern Ll■n, at least, was glaciated during the Late Devensian, this evidence, and other lithostratigraphic data from the region were used by Bowen (1974, 1977b) to estimate the limits of the Late Devensian and possible Late Devensian readvance ice-sheets in north-west Wales — see (Figure 27).

References



(Figure 27) Late Devensian and Late Devensian readvance ice limits (from Bowen 1974, 1977b)