Chapter 4 Quaternary stratigraphy west and south-west Wales

Introduction

Stratigraphic sites around the west and south-west coasts of Wales have been the basis for a variety of reconstructions in the Quaternary history of Wales. Some sequences display important evidence for the interplay of the Welsh and Irish Sea ice-sheets, while others illustrate the importance of periglacial conditions and processes to regional landscape evolution. A number of sites shows evidence for changes in relative sea-level during the Late Pleistocene and Holocene. The network of selected stratigraphical sites is essential in distinguishing between those areas glaciated or unglaciated during the Late Devensian. In this respect, the area is significant in its proximity to the Late Devensian maximum ice limit and thus may be compared with Gower — see Chapter 3.

Early sub-division

The area is historically important for early attempts to sub-divide the Quaternary sequences. Interest was first stimulated by the rich fossil contents of certain local caves, especially the Caldey and Tenby caves, including Little Hoyle and Hoyle's Mouth. Some of the first known excavations were made by Jervis and Pugett as early as the 1840s at the Hoyle Caves, although no accounts were left of their discoveries (Leach 1931). A series of excavations initiated by the Reverend G N Smith in the 1860s stimulated continued interest in these caves, culminating in the excavations led by Green of the National Museum of Wales (Green *et al.* 1986).

Following early interest in the bone caves, attempts were made to sub-divide the Pleistocene sediments of the coastal sequences (for example, Keeping 1882; Prestwich 1892; Hicks 1894; Reade 1896). Particularly important was the work of Jehu (1904) in northern Pembrokeshire (Preseli) and Williams (1927) in western Cardiganshire (Ceredigion). They used a tripartite scheme and proposed a sequence of Lower Boulder Clay, Intermediate Gravels and Sands and Upper Boulder Clay. Jehu believed that this tripartite sequence was evidence for two glacial episodes separated by an interglacial, but Williams suggested that the deposits could simply have accumulated at the margin of an ice-sheet during a single glaciation. This work, together with other observations on drift deposits and raised beaches by Strahan et *al.* (1909), Leach (1910, 1911), Cantrill *et al.* (1916) and Dixon (1921), were important in the first elucidation of Quaternary events in the region. Collectively, they showed that parts of the west Wales coast had been glaciated by Welsh ice from the uplands, but that parts of Pembrokeshire and Cardiganshire had been inundated by ice from the north-west, that is, from the Irish Sea Basin.

The South Wales end-moraine

Following Wright's (1914) formal division of British glacial deposits into an 'Older Drift' and 'Newer Drift', Charlesworth (1929) traced what he considered was the maximum limit of the 'Newer Drift' ice-sheet of 'Magdalenian' age across South Wales. He distinguished between areas glaciated in 'Newer Drift' times and those previously glaciated during an 'Older Drift' glaciation. He established that south-west Wales had been glaciated on two occasions by ice from the Irish Sea Basin. Charlesworth used both stratigraphical and morphological evidence to delimit the extent of the 'Newer Drift' ice-sheet across Pembrokeshire (south-west Dyfed). With the tripartite division still much in vogue, he proposed that the maximum limit of the 'Newer Drift' coincided with the extent of the Upper Boulder Clay. Two other lines of evidence were also used to establish this limit. First, sands and gravels, forming hummocky topography, were regarded as terminal accumulations marking the maximum ice limit. Second, at the height of the 'Newer Drift' glaciation, he believed that Irish Sea ice in Cardigan Bay blocked the drainage from surrounding ice-free areas and resulted in the development of a series of extra-glacial lakes that were connected by ice marginal stream channels and 'direct' overflow channels. As the ice margin retreated, water spilled from one lake to another cutting a spectacular series of channels (the Gwaun-Jordanston system — see (Figure 15), Chapter 5). The distribution of the sands and gravels, the Upper Boulder Clay and the meltwater channels was therefore used by Charlesworth to establish the area of south-west Wales affected by 'Newer Drift' ice. His hypothesis, relating the channels to overflows from glacial lakes, has since been shown to be

partly untenable: the channels have now been interpreted as subglacial meltwater channels, indicating a far greater coverage of Late Devensian ice in the area than previously anticipated (Bowen and Gregory 1965; Gregory and Bowen 1966). The sand and gravel accumulations have also been reinterpreted to show that they did not accumulate at an ice margin (for example, Gregory and Bowen 1966; Bowen 1971b, 1981a, 1982a; Helm and Roberts 1975; Allen 1982; Bowen and Lear 1982).

Stratigraphical correlations

In common with north-west Wales and Gower, the coastal Pleistocene deposits of west and south-west Wales have been important in regional stratigraphical syntheses. Following Wirtz's (1953) delimitation of the maximum extent of Late Weichselian (Late Devensian) ice in north Pembrokeshire, Mitchell's (1960) reconstruction of a Pleistocene history for the Irish Sea provided a considerable stimulus for further work. Mitchell (1960, 1972) proposed a limited Late Devensian glaciation in Wales; with Welsh ice restricted to the Welsh uplands, and Irish Sea ice impinging only along the North Wales coast — delimited on Ll■n by the Bryncir-Clynnog moraine (Synge 1964). Most of the coastal glacial deposits exposed elsewhere around Wales were correlated with the Ballycroneen Till of south-east Ireland and the Fremington Till of North Devon, and all were believed to be Gippingian (Saalian) in age. This reconstruction stemmed from two fundamental lines of reasoning.

First, raised beaches around the Welsh coast, particularly on Gower, were considered to date from two separate interglacials. One beach was described by Mitchell as 'erratic-free' and was considered to be Hoxnian, the other was 'erratic-rich' and of Ipswichian age. According to Mitchell, glacial deposits *in situ* around the Welsh coast only overlie raised beaches of Hoxnian age; Ipswichian beaches are overlain by Devensian periglacial sediments. Bowen (1973a, 1973b) argued that where Ipswichian beaches are absent, Mitchell's model implied that they were lost in unconformity, for example, Gower. In support of his scheme, Mitchell (1960, 1962, 1972) cited the occurrence of an *in situ* interglacial soil of Ipswichian age in the coastal sections near Llan-non (the Llansantffraid Interglacial Soil). The pedological significance of this horizon has since, however, been disputed (for example, Stewart 1961; Rudeforth 1970; Bowen 1974). Secondly, large areas of Wales were believed to have remained free of Late Devensian ice because they show a widespread development of fossil periglacial features such as pingos and ice-wedge casts. (This aspect is more fully discussed in Chapter 5.) Coastal sections in west Wales, particularly those at Llan-non and Morfa-bychan, have figured in the debate over whether the region was glaciated during the Late Devensian, with workers such as Watson and Watson (1967) arguing for a periglacial origin for the drifts in the area, and others (for example, Wood 1959; Bowen 1973a, 1973b, 1974, 1977a, 1977b; Vincent 1976) arguing that substantial parts of the sequences are glacial in origin, albeit rearranged by solifluction.

Bowen (1977c) suggested that many studies (for example, Mitchell 1960, 1972) confused lithostratigraphy (rock stratigraphy) with chronostratigraphy (time-rock stratigraphy). For example, at Abermawr (Preseli), Synge (1963, 1964, 1969) ascribed three lithological units to three different glaciations. Others (for example, John 1970a; Bowen 1974) have ascribed the Abermawr deposits to the Devensian Stage, because no evidence of interglacial conditions is found.

Many of the GCR sites in west and south-west Wales were included in Mitchell's and Synge's reconstructions of Pleistocene events in the Irish Sea Basin. These sites were also used in later studies. During the 1960s and early 1970s, sites in south-west Wales were sampled for radiocarbon dating. However, the age determinations, particularly those on bulk shell samples, have not been universally regarded as reliable (for example, Bowen 1966; Shotton 1967; Boulton 1968). These age determinations, however, were used as definitive for a number of sites (for instance, Abermawr, Druidston, Banc-y-Warren) by John (1965a, 1965b, 1967, 1968c, 1970a), Brown *et al. (1967)* and John and Ellis-Gruffydd (1970). The results were used by John to support an extensive Late Devensian glaciation, covering most of Pembrokeshire. Most of the dates fall between 30,000–40,000 BP. In particular, it is interesting to note that finite dates were obtained only from material incorporated into highly permeable outwash deposits with an inherent potential for post-depositional contamination (Bowen 1974). In contrast, dates from relatively impermeable till facies at Abermawr and Druidston, yielded infinite ages (John 1970a) making the determinations of little value for elaborating Pleistocene chronology. Amino acid analysis of shells from these deposits have shown mixed populations ranging in age between the Early Pleistocene and the Devensian Stage, thus invalidating the use of bulk shell samples for radiocarbon dating

(Bowen 1984).

Lithostratigraphy

Coastal exposures around west and south-west Wales were used in a series of lithostratigraphic studies by Bowen (1973a, 1973b, 1974, 1977a, 1977b). The basis of Bowen's classification was the proposal that the raised beach sediments are of Ipswichian age. By identifying sites where the Ipswichian raised beach was overlain by glacial deposits, in contrast to sites where the beach was overlain exclusively by non-glacial sediments, Bowen (1970a, 1973a, 1973b) was able to extrapolate between coastal sites and, using all available evidence, to delimit the extent of Late Devensian ice across south-west and South Wales. John (1970a, 1970b, 1973) also proposed an Ipswichian age for raised beach deposits around the south-west Wales coast (for instance, at Druidston, West Angle Bay, Broadhaven, Poppit and Porth Clais) and used lithostratigraphy to interpret and equate the coastal sequences. Several sites were considered to show clear evidence for a major invasion of the coastlands by Irish Sea ice (for example, Traeth-y-Mwnt, Abermawr and Druidston). The occurrence of Irish Sea glacial deposits *in situ* above raised beach sediments of proposed Ipswichian age (for instance, at Poppit) thus appeared to confirm a (Late) Devensian age for this glaciation (John 1970a; Bowen 1973a, 1973b, 1974, 1977a, 1977b). These workers also recorded lithological evidence for periglacial conditions (head deposits) both before and after the glacial event. The greater thickness of head deposits lying between the raised beach and till was used as additional evidence for a Late Devensian age for the till.

The interpretation of individual beds within the coastal sequences at GCR sites is, therefore, important in establishing the sequence of Quaternary events in the region, and particularly for reconstructing the maximum extent of Late Devensian ice. Some evidence has been interpreted differently. For example, at Porth Clais John (1970b) interpreted mixed lithology drift overlying a raised beach as a 'land-facies' of the Irish Sea ice-sheet. Alternatively, Bowen (1977b) argued that these sediments were not *in situ,* and suggested that the distance of glacial transport across St David's Head was too small to have allowed development of a 'land-facies' of the Irish Sea ice. At West Angle Bay, different interpretations of sedimentary units also have had a bearing on the reconstruction of the Late Devensian glaciation. A marine sequence of uncertain age (Stevenson and Moore 1982) is overlain by a diamict containing gravel. Both John (1968a, 1969, 1970a) and Bowen (1974, 1977b) proposed an Ipswichian age for the marine sequence at West Angle, but the overlying diamict was interpreted as head (periglacial) (Bowen 1971b, 1974), or as a Late Devensian glacial deposit; either outwash or a gravelly 'land-facies' of the Irish Sea ice-sheet (John 1968a, 1971a). Bowen, therefore concluded that Milford Haven and West Angle Bay lay in the 'extra-glacial' zone during the Late Devensian, but John envisaged that Late Devensian Irish Sea ice had reached at least this far south.

Amino acid geochronology

Amino acid geochronology has been applied in south-west Wales, allowing correlations to be made with Gower and farther afield (Bowen *et al.* 1985; Bowen and Sykes 1988). Amino acid ratios derived from shells taken from raised beach deposits at Broadhaven (Castlemartin), were correlated with others in Gower (Pennard D/L Stage), and ascribed to the Ipswichian Stage and to Oxygen Isotope Substage 5e of the deep-sea record (Bowen and Sykes 1988). Amino acid ratios on shells from glacial sediments at Abermawr and Banc-y-Warren show that the shells range widely in age from the Early Pleistocene to the Devensian Stage (Bowen 1984). The youngest faunal elements within the Abermawr Till and Banc-y-Warren sands and gravels were ascribed by Bowen to Stages 5 and 3 of the deep-sea oxygen isotope record (Shackleton and Opdyke 1973), thus dating the glacial deposits as Late Devensian.

Palynology

Palynological investigations were undertaken at West Angle Bay by Stevenson and Moore (1982), in an attempt to resolve the controversy surrounding the age of the succession. Although a number of pollen zones dominated by temperate forest taxa was recognised, it was not possible to correlate the sequence on this basis. A radiocarbon date of >35,000 BP (Birm 327) from wood in the interglacial succession also fails to establish the age of the beds, although it precludes a Holocene age (Shotton and Williams 1973).

Sedimentology

Sedimentological and stratigraphic studies of the sand and gravel sequence at Banc-y-Warren were carried out by Helm and Roberts (1975) and Allen (1982). These studies arrived at different conclusions regarding the origin of the deposits (Worsley 1984): Helm and Roberts suggested a deltaic origin, but Allen proposed that the sands and gravels had accumulated in a subaerial fluvioglacial environment. Worsley (1984) concluded that a compromise between the depositional models of Helm and Roberts and Allen was possible: most of the deposits consisted of subaerial outwash, and also showed deposition in water in a deltaic facies.

Caves

South-west Wales has long been noted for its richly fossiliferous cave deposits, which attracted much early scientific attention (for example, Smith 1860, 1862, 1864, 1866; Winwood 1865; Dawkins 1874; Laws 1878; Rolleston et *al.* 1878; Prestwich 1892; Leach 1913, 1918b, 1931, 1945; Dixon 1921; Garrod 1926; Lacaille and Grimes 1955). Interest was further stimulated in studies by McBurney (1959), Clegg (1969) (at the now destroyed Coygan Cave), Bateman (1973), Savoury (1973) and Nedervelde et *al.* (1973), and most recently by the multi-disciplinary investigations of the Little Hoyle and Hoyle's Mouth Caves near Tenby (Green *et al.* 1986; Rae *et al.* 1987). These have improved the understanding of Late Devensian and Late Devensian late-glacial palaeoenvironments in southern Dyfed, and provide further evidence for ice-free conditions in the area during the Late Devensian glacial maximum (Green *et al.* 1986). These sites also provide some of the most detailed evidence currently available for the Upper Palaeolithic period in Wales.

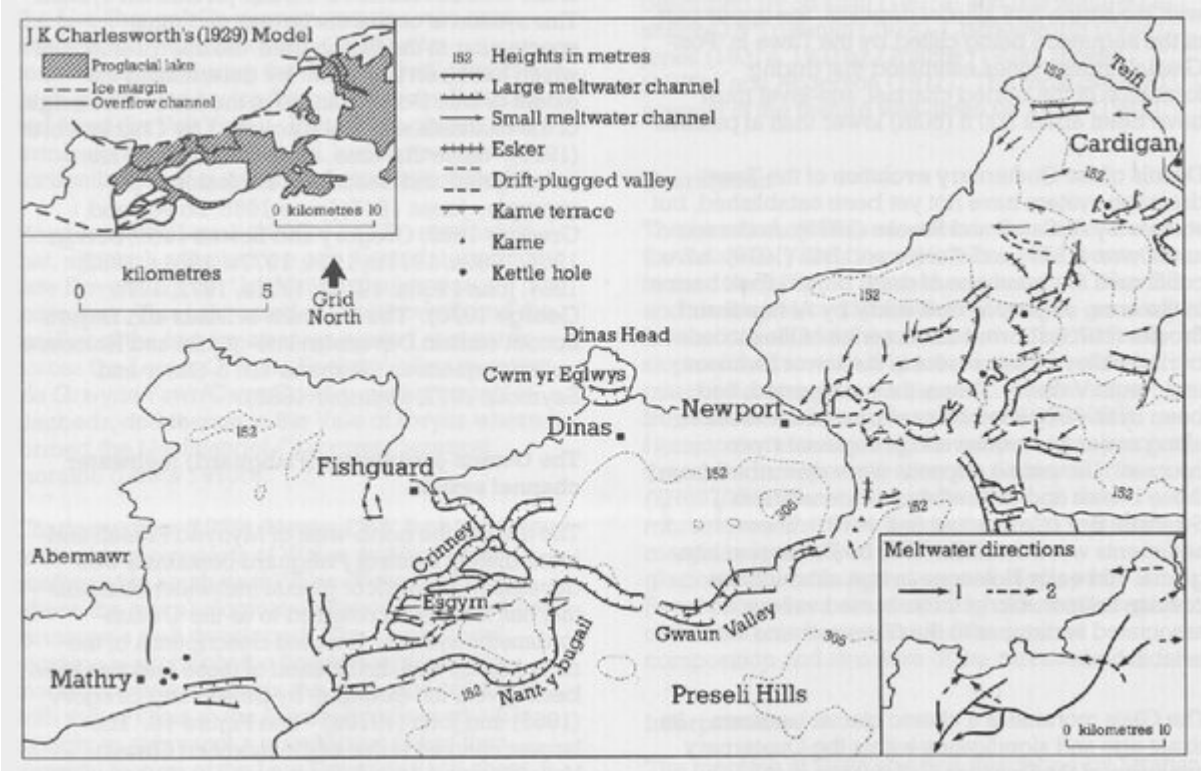
Sea-level studies

This region has also been investigated with a view to understanding Late Devensian late-glacial and Holocene coastal changes. Submerged forest and associated marine and terrestrial beds at Clarach (Taylor 1973; Heyworth *et al.* 1985), at Ynyslas and at Borth Bog (for example, Wilks 1977, 1979; Campbell and Baxter 1979; Heyworth and Kidson 1982) have provided evidence for sea-level and environmental changes. These sites are part of a network that provides data for establishing a picture of late-glacial and Holocene sea-level changes throughout Britain.

Offshore investigations

The reconstruction of Quaternary events has been amplified by studies of submarine deposits off the Welsh coast (Garrard and Dobson 1974; Canard 1977). Discontinuous patches of till which occur on the floor of the Bristol Channel may support the evidence for an extensive pre-Ipswichian glaciation in the area; but, continuous glacigenic deposits on the floor of the Irish Sea have been ascribed to the Late Devensian, and used as evidence for the maximum offshore limit of this Irish Sea ice-sheet (Garrard and Dobson 1974; Garrard 1977). Problems still remain in correlating offshore data with the stratigraphical record of the coastal exposures. The offshore reconstruction of Late Devensian maximum ice limits may also not take into account marine erosion at the distal end of the till sheet during the Holocene transgression (Bowen 1977c). The prominent sarns along the west Wales coast (for instance, Sarn Badrig) also have important implications for Late Pleistocene glacial conditions (Foster 1970b; Bowen 1974). These are discussed more fully in Chapter 6.

References



(Figure 15) The Gwaun–Jordanston meltwater channel system (from Bowen and Henry 1984)