Verschijnt tweemaandelijks

GEOLOGIE EN MIJNBOUW VOLUME 49(4), p. 285-296 1970

WEICHSELIAN STRATIGRAPHY AND RADIOCARBON DATING IN SOUTH WALES[1])

B.S. JOHN[2]) AND I.D. ELLIS-GRUFFYDD[3])

ABSTRACT

There are many difficulties involved in both the interpretation and correlation of Weichselian deposits in South Wales – a fact illustrated by the multiplicity of viewpoints in the literature. It is suggested that the Weichselian stage was characterised by (1) an early prolonged periglacial phase, possibly with local upland glaciation and with some climatic fluctuations; (2) a major glaciation in which Irish Sea ice and Welsh ice played different relative roles in different areas; and (3) a shorter periglacial phase with some corrie glaciation in the uplands.

There are four radiocarbon dates for the Late-glacial. The dates from Port Talbot (Glam.) confirm the age of organic deposits from Swansea Bay and provide an approximate date for the onset of the Flandrian transgression; and the date from Aberaeron (Cards.) points to the existence of Zone II organic deposits beneath solifluction earth and above glacial drifts of probable Weichselian age. There are also four dates for the Middle Weichselian, supporting other evidence for an interstadial at this time and for a later extensive glaciation by the Irish Sea glacier in Cardigan Bay. There is no unequivocal age determination for the organic content of the calcareous Irish Sea till. Palaeobotanical investigations undertaken so far have revealed that a wide range of organic material exists in the glacial drifts, including a significant amount of Tertiary pollen and spores and many fragments of Tertiary lignite. It is therefore difficult to relate the palaeobotanical evidence with any confidence to either the stratigraphy or the radiocarbon dates. However, an interglacial deposit discovered *in situ* at West Angle (Pembs.) may provide another pointer to the true age of the South Wales drifts; and the radiocarbon date for the human skeleton from Paviland (Glam.) should also be of major significance for the establishment of a reliable Weichselian chronology.

[1]) This is a modified version of a paper presented to the Quaternary Research Association's symposium on "Radiocarbon Dating and the Weichselian", London, January 1969.

[2]) Department of Geography, University of Durham, England.

[3]) Department of Geography and Geology, Sir John Cass College, London.

1. INTRODUCTION

The counties of South Wales (Fig. 1) may claim some significance for Pleistocene studies in that they coincide with the zone of contact between the southern and western extensions of Mid-Wales ice and the south-eastern margins of the Irish Sea glacier. The counties are topographically diverse, thereby complicating not only the precise sequence of the Weichselian events represented in different localities, but also the relative roles of "local" and "foreign", and "upland" and "lowland" ice. Consequently, stratigraphic correlations for the Weichselian are notoriously difficult – a fact amply illustrated by the multiplicity of viewpoints in the literature.

As suggested some years ago by Zeuner (1959), the dating of the ubiquitous raised beach of this area is critical to the elucidation of Weichselian chronology. If the beach is of Ipswichian (Eemian) age, then all drifts stratigraphically above it may be assigned with confidence to the Weichselian (John, 1968a). If, on the other hand, the beach is dated to the Hoxnian interglacial, the overlying drifts must represent *two* distinct glacial stages (Mitchell, 1960). Although the age of the raised beach is still open to question, many fieldworkers now favour an Ipswichian age – a dating which would seem to support the placing of most of the glacial and periglacial drifts of South Wales within the Weichselian. A tentative

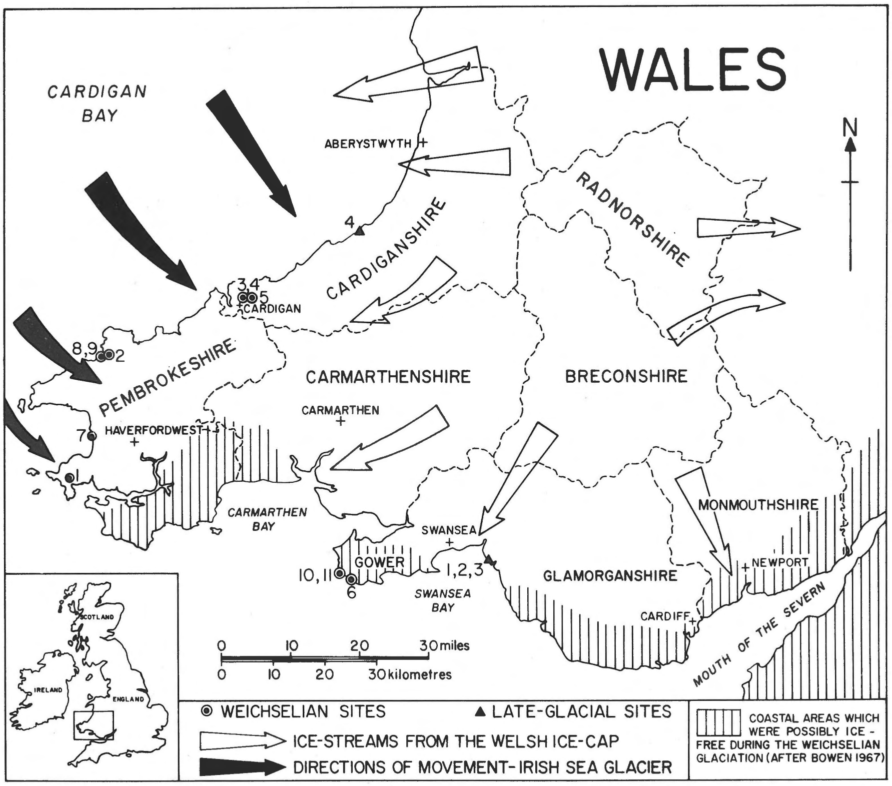

Fig. 1
South Wales – location map, showing Weichselian directions of ice-movement and possible ice-free areas. The numbered sites correspond with those on Tables 2 and 3.

correlation of the drift successions from specific areas within South Wales is made in Table 1.

From the coastal drift successions (North Pembrokeshire, South Cardiganshire, and West Gower) we suggest that there was a widespread glaciation during the Late Weichselian which may have affected all but a few southern areas (Fig. 1) (Bowen, 1967). Probably this glaciation was preceded by a prolonged periglacial phase and followed by a less prolonged and less intensive phase of renewed solifluxion. This generalised sequence of events is supported by a considerable body of evidence, but is by no means proved. Indeed, other workers consider that there are good grounds for assigning most of the glacial deposits of South-West Wales to an earlier "Older Drift" glaciation (equivalent in age to the continental Saalian). For example, Mitchell (1960) and Stephens and Synge (1966) have shown Cardigan Bay as entirely free of Irish Sea ice during the Weichselian. Other authors (e.g. Wirtz, 1953; Bowen and Gregory, 1965) have advanced related viewpoints, although admitting Weichselian Irish Sea ice to a limited area around the Teifi estuary (Fig. 2). Watson and Watson (1967) consider that most of the drifts of the Cardiganshire coast are periglacial slope deposits which must be assigned to the full span of the Weichselian; accordingly they believe that the coast between New Quay and Towyn must have been quite free of ice at this time. However, they too are inclined to accept Wirtz's suggestion that Irish Sea ice impinged upon the coastline in the vicinity of the Teifi estuary. West (1968), in a recent summary, also appears to doubt the existence of Weichselian Irish Sea ice along the Cardigan Bay coast, the coastal tills having been correlated with the Saalian (Gippingian) glacial stage. On the other hand Charlesworth (1929) postulated a more extensive Weichselian Irish Sea glaciation which culminated at the South Wales End-moraine on the North Pembrokeshire coast (Fig. 2); and John

TABLE 1

A suggested correlation of Late Pleistocene drift successions in South Wales.

STAGE	STRATIGRAPHY					SEQUENCE OF EVENTS 6
	North Pembrokeshire 1	South Cardiganshire 2	South Wales Uplands 3	West Gower 4	Swansey Bay - Vale of Glamorgan 5	
Flandrian	Blown sands/ hillwash	Sandy loams/ hillwash	Soils and upland peats	Upper sandy loam	Soils, peats and organic muds	Fluctuating temperate conditions
Zone III	Upper head and rubble-drift	Upper head etc	Corrie moraines head and scree	Upper head and		Short cold phase
Zone II		Organic silts				Warmer phase
Zone I		Rubble drift				Climatic fluctuations
Weichselian *Late*	Sand and gravels Irish Sea tills and local tills	Welsh and Irish Sea glacial deposits	Sands and gravels Local sandy tills	Soliflucted tills	Local Welsh glacial deposits (Swansey Bay)	Major Glaciation
26,000 yrs BP						
Middle	Upper facies of lower head?	?	?		?	Interstadial complex?
	Slight weathering?					
50,000 yrs BP		Further periglacial and local glacial deposits ?				
Early	Thick lower head			Soliflucted palaeosol	Head deposits	Prolonged phase of periglacial action (+upland glaciation?)
Ipswichian (Eemian) Interglacial	Raised beach	Raised beach ?	?	Palaeosol Patella Beach	Palaeosol (Vale of Glam). Patella Beach	Interglacial - raised beach deposition and weathering of bedrock.

1. B.S. John.
2. Modified after Williams (1927), Watson and Watson (1967) Mitchell (1962).
3. I.D. Ellis-Gruffydd.
4. Modified after D.Q. Bowen (1966, 1967), George (1933), Zeuner (1959), Ball (1960).
5. Modified after Griffiths (1940), Trottman (1963), Godwin and Willis (1964), Zeuner (1959), Crampton (1966).
6. There are indications of Late Weichselian climatic fluctuations in N.W. Wales which interrupted the process of overall deglaciation (Saunders, 1968; Whittow and Ball, 1967). In South Wales there may also be traces of the Bölling Oscillation at Waen Ddû Breconshire (Trottman, 1963).

(1968b) has argued that the ice-sheet extended even further to the south.

Similarly inland there is controversy as to the nature and extent of Weichselian deposits. Lewis (1966b) has argued for a small Weichselian ice-cap of improbable dimensions centred upon Mid-Wales (Fig. 2). On the other hand the majority of workers accept that the greater part of the South Wales upland zone was heavily indundated by local ice during the Weichselian, with major outlet glaciers occupying the Teifi, Towy, Usk, Wye and other valleys (Charlesworth, 1929; Griffiths, 1940; Mitchell, 1960; Pringle and George, 1948; Woodland and Evans, 1964; Bowen, 1967). Furthermore, there is considerable evidence to suggest that small glaciers occupied the corries within the highland

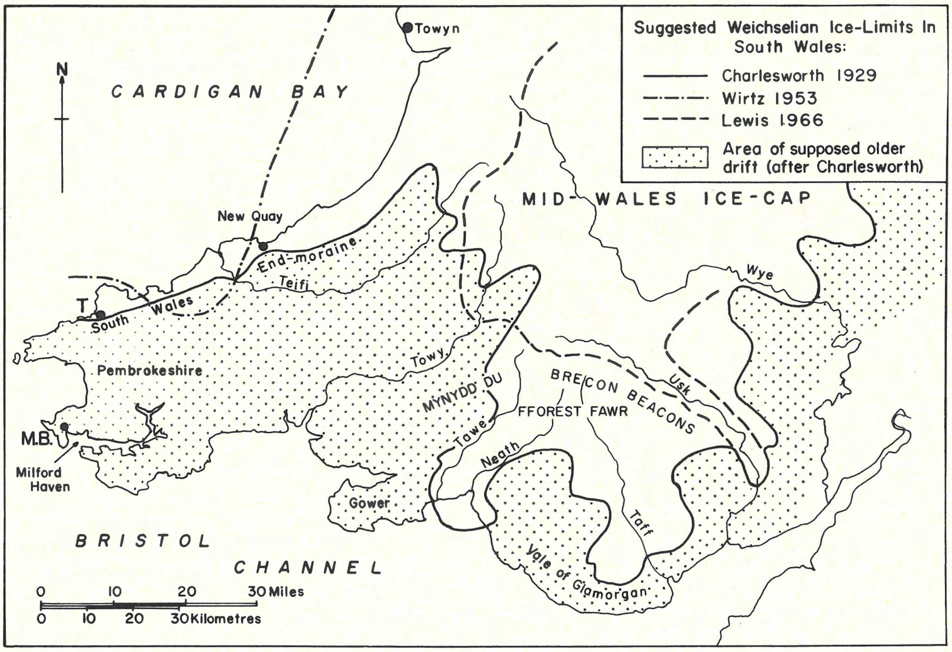

Fig. 2
Weichselian ice-limits and ice-free areas as suggested by various authors. T = Tre-llys. M.B. = Mullock Bridge.

zone of the Brecon Beacons – Fforest Fawr – Mynydd Du during the Late-glacial phase (Lewis, 1966a; Ellis-Gruffydd, Ph. D. thesis in preparation). It would appear that these glaciers were broadly synchronous with the periglacial phases identified on the South Wales coasts (Table 1).

Thus there exists a multitude of divergent viewpoints on the Weichselian in South Wales, which might be resolved into three broad schools of thought:

(a) a school which accepts Charlesworth's (1929) hypothesis of an extensive "Older Drift" glaciation and a more limited "Newer Drift" (Weichselian) glaciation whose limit is marked by the South Wales end-moraine.
(b) one which envisages a more extensive Weichselian glaciation by the Irish Sea glacier, the Mid-Wales ice-cap or both.
(c) one which considers that South Wales was largely unaffected by Weichselian Irish Sea ice and influenced to only a limited extent by the Mid-Wales ice-cap.

Clearly these differences of opinion cannot be resolved by resort to purely morphological or stratigraphic criteria; glacial landforms differ greatly between one part of South Wales and another, and there is not yet any completely reliable basis for stratigraphic correlation throughout this region. Furthermore, it is debatable whether North Pembrokeshire, Gower or the Cardiganshire coast should be taken as the South Wales "type area", for the drift sequences in each area reflect the very different relative roles of Irish Sea and local ice.

In the absence of any firm agreement on the use of qualitative criteria for the establishment of a Weichselian chronology for South Wales, one must attach some significance to two more precise dating tools: the analysis of organic material within the drifts, and radiocarbon dating. In the following discussion the authors summarise the published radiocarbon dates for the region, and examine these briefly in the light of related palynological and other studies. It is hoped that by considering this data in the context of the drift stratgraphy for specific areas, a Weichselian chronology may emerge which merits more general acceptance than any of the multitudinous chronologies that have appeared in the recent literature.

II. DATA FOR THE LATE-GLACIAL

Few Late-glacial radiocarbon dates are available for South Wales although several sites have been investigated and "dated" by reference to the well-established Late-glacial pollen stratigraphy (for example, Trottman, 1963; Bartley, (1960). The published dates on Table 2 are referable to two sites, namely Port Talbot (Glam.) and Aberaeron (Cards.). These are located on Fig. 1. Detailed palynological data have been published for only the former site.

In 1960/61 an exploratory boring for a harbour development scheme at Baglan Burrows, near Port Talbot, encountered peat beds at considerable depths below present sea-level. Subsequently two cores (numbered 19 & 4) were examined by Godwin and Willis (1964) via pollen analysis and radiocarbon dating. In both cores the stratigraphy was remarkably similar, consisting of a basal peat resting upon "... dense rounded gravel in a matrix of sandy silt..." (Godwin and Willis, 1964, p. 124) at a depth of –63. 1 ft. O.D. and –64.6 ft. O.D. in bores 19 and 4 respectively. In bore 19 the basal peat was ca. 20 cm. thick whereas in bore 4 152.40 cm. was recorded. The basal peat was overlain by a sequence of sands, silts and clays to heights of 24.4 ft. O.D. and 28.4 ft. O.D. in bores 19 and 4 respectively.

Four carbon-14 age determinations were undertaken on samples of the basal peat encountered in bore 19. However, only one is of immediate relevance in that the remaining three are referable to the Flandrian. The one significant sample, composed of compressed fresh-water *Phragmites* peat taken near the base of the peat bed, was dated at 10,350±170 years B.P. (Q-660). The remaining three samples of compressed fresh-water peat, taken at successively higher stratigraphical positions, were dated at 9,920±170 years B.P. (Q-661) (across pollen zone boundary IV/V), 8,990±170 years B.P. (Q-662) (across pollen zone boundary V/VI), and 8,970±160 years B.P. (Q-663) (within pollen zone VI) respectively.

Two further dates were obtained from bore 4 although unfortunately Godwin and Willis were unable firmly to establish the position of the 15 cm. section (from which samples were taken for analysis) relative to the entire thickness of the basal peat.

The first sample (Q-664) consisted of fine-detritus mud containing macroscopic plant remains which were characteristic of a fen community. The second sample (Q-665), taken 9 cm. above the first, was of a similar character. The samples were dated at 11,980±180 years B.P. (Q-664) and 11,260±170 respectively. The pollen spectra associated with these samples were considered to be typically Late-glacial in aspect and together with the carbon-14 dates were taken to indicate an Alleröd age (zone II) for the analysed peat deposit.

Godwin and Willis considered that the evidence from Port Talbot, which is supported by other pollen analyses from Swansea Bay (Godwin, 1940), suggests that layers of fresh-water peat and muds accumulated locally from zone II to zone VI upon an irregular surface of gravelly drift. At this time sea-level must have been more than 64 feet (19 m.) below present Ordnance Datum. Furthermore the

TABLE 2

Radiocarbon Dated sites in South Wales (samples of Late Glacial age).

Site	Radiocarbon Age Determination	Dated Material	Associated studies of organic Material	References
1. Port Talbot, Glam. (SS 740910)	10,350 ± 170 years B.P. (Q-660)	Compressed fresh-water *Phragmites* peat.	Analyses of pollen and macro-remains.	Radiocarbon 6, 1964, P. 124
2. Port Talbot, Glam. (SS 740910)	11,980 ± 180 years B.P. (Q-664)	Compressed fine-detritus mud.	„	„
3. Port Talbot, Glam. (SS 740910)	11,260 ± 170 years B.P. (Q-665)	Compressed fine-detritus mud	„	Radiocarbon 6, 1964, P. 125
4. Aberaeron, Cards. (SN 464636)	11,200 ± 160 years B.P. (I-3120)	Organic silt	Pollen analysis	Radiocarbon 11, 1969, P. 67

late-glacial/Flandrian boundary between pollen zones III and IV was established at ca. 10,350±170 years B.P., which is in close agreement with the situation at Scaleby Moss (G o d w i n et al., 1957). Post pollen zone VI (i.e. post-dating 8,970±160 years B.P.) the eustatic rise in sea level terminated the phase of fresh-water peat and mud deposition, replacing it by a series of marine sands, silts, and clays.

The significance of the data from Swansea Bay lies not only in the establishment of a late-glacial climatic sequence for the area expressed in terms of an absolute time-scale, but also in the accurate recording of the late-glacial sea-level and the onset of the Flandrian transgression.

The radiocarbon date from Aberaeron appears to be important, but it cannot be fully discussed until the associated stratigraphic and palynological studies have been published. However, from the section published by M i t c h e l l (1962, p. 200, Section 8) it seems that the Zone II deposit beneath 8 ft. (2.5 m.) of "solifluction earth" and directly above sands, gravels and till may be of great value as a datum layer. The overlying material must be Zone III or later in age, while the underlying glacial deposits are most logically assigned to the Late Weichselian (as suggested on Table 1).

III. DATA FOR THE WEICHSELIAN

As far as the authors are aware, there have been eleven attempts to date deposits of Weichselian or earlier age in South Wales (Table 3). The investigated sites are located on Fig. 1.

(a) *Carbon-14 dates from bulk shell samples*

The first two radiocarbon dates obtained were from Mullock Bridge and Tre-llys in Pembrokeshire, two sites where shelly gravels are found incorporated within fluvio-glacial outwash of debatable age. According to C h a r l e s w o r t h (1929), Tre-llys is located within the hummocky sand and gravel topography of the Newer Drift "South Wales end-moraine", while Mullock Bridge lies well to the south within the area of "Older Drift" (Fig. 2). From the stratigraphic and morphological relationships of the dated material at these sites, it is suggested that the Irish Sea ice of the Weichselian glaciation extended at least as far south as Milford Haven, and that the drift deposits of North Pembrokeshire should be largely assigned to the Weichselian (J o h n, 1965). By implication it is thought that the "South Wales end-moraine" in this area can have no significance as a major glacial limit.

There is little doubt that radiocarbon age determinations on bulk samples of shell should be treated with some caution, especially for dates exceeding 30,000 years B.P. Indeed, B o w e n (1966) and S h o t t o n (1967a) have already questioned the validity of the Mullock Bridge and Tre-llys dates on the grounds that they may be contaminated. While these fears may yet prove to be well-founded there does seem to be a convergence of evidence which suggests that the dates may be reliable:

i. On the grounds of drift stratigraphy alone it seems that the glacial drifts of Pembrokeshire should be assigned to the same glaciation, namely the Late Weichselian glaciation of Northern Europe (J o h n, 1969).
ii. Faunal analysis of the samples of marine mollusca indicates a lack of extinct species, and a distinct preponderance of species of recent affinity (i.e. post-Lower Pleistocene) (J o h n, 1969). It seems, therefore, that the ice which dredged up the mollusca from the floor of the Irish Sea and Cardigan Bay did so relatively late in the Pleistocene.
iii. Both samples consisted of a mixture of species of "cold" and "temperate" aspect, often from mutually exclusive habitats and probably of widely differing ages. The radiocarbon age determinations must, therefore, have produced "mean" dates which may overestimate by a considerable degree the age of the youngest mollusca in the samples (J o h n, 1965). Again this may indicate that the glaciation in question occured well after ca. 38,000 years B.P.
iv. None of the shell fragments in the samples was badly pitted, and the majority showed no trace of surface pitting. This was taken to indicate that there had been a lack of severe contamination by percolating groundwater in the two gravel pits (O l s s o n and B l a k e, 1961). The N.P.L. dating procedure apparently confirmed this, for the radiocarbon ages obtained for the middle and inner thirds of the shell sample after leaching showed, in each case, a very close correspondence.
v. At both Tre-llys and Mullock Bridge shelly gravels have been discovered less than two meters beneath

TABLE 3

Radiocarbon Dated sites in South Wales (samples of Weichselian or earlier age).

Site	Radiocarbon Age Determination	Dated material	Associated studies of organic material	References[1]
1. Mullock Bridge, Pembs. (SM 811080)	$37{,}960\ ^{+1700}_{-1400}$ years BP (NPL-80)	Bulk sample of marine mollusc fragments from fluvioglacial outwash.	Faunal analysis of marin mollusc assemblage.	John, B.S. (1965)
2. Tre-llys, Pembs. (SM 89349)	$37{,}310\ ^{+1515}_{-1278}$ years BP (NPL-97)	Bulk sample of marine mollusc fragments from fluvioglacial outwash.	Faunal analysis of marine mollusc assemblage.	John, B.S. (1965)
3. Banc-y-Warren A, Cards. (SN 202482)	$31{,}800\ ^{+1400}_{-1200}$ years BP (I-2559)	Peaty organic mud from fluvioglacial outwash.	Palynological analysis of organic layer.	Brown, M.J.F. et al. (1967)
4. Banc-y-Warren B, Cards. (SN 202482)	>39,900 years BP (I-2802)	Peaty organic mud from fluvioglacial outwash.	Palynological analysis of organic layer.	Radiocarbon 11 (1) (1969) P. 65
5. Cil-maenllwyd, Cards. (SN 203482)	$33{,}750\ ^{+2500}_{-1900}$ years BP (I-2564)	Wood fragments from fluvioglacial outwash.	Palynological analysis of outwash sands, & studies of macro-remains.	John, B.S. (1967)
6. Paviland, Glam. (SS 436858)	18,460 ± 340 years BP (BM-374)	Bone powder from human skeleton.	Archaeological investigations (Sollas, 1913)	Oakley, K.P. (1968)
7. Druidston, Pembs. (SM 862173)	>36,000 years BP (I-1687)	Marine mollusc fragments from calcareous Irish Sea till.	Faunal analysis of marine mollusc assemblage.	Radiocarbon 10(2) (1968) P. 265
8. Aber-mawr 1, Pembs. (SM 883347)	>40,300 years BP (NPL-98)	Wood fragments from calcareous Irish Sea till.	Examination of wood fragments; faunal analysis of marine mollusc assemblage.	Radiocarbon, 8 (1966) P. 344
9. Aber-mawr 2, Pembs. (SM 883347)	>54,300 years BP (GrN-5281)	Wood fragments from calcareous Irish Sea till.	Examinations of wood fragments; faunal analysis of marine mollusc assemblage.	–
10. Fall Bay, Glam. (SS 414873)	21,815 ± 629 years BP (Birm-46) (b)	Marine mollusc fragments from "Patella" beach.	Faunal analysis of marine mollusca (George, 1932)	Radiocarbon 10(2) (1968) P. 201
11. Fall Bay, Glam. (SS 414873)	22,796 ± 827 years BP (Birm-46)(c)	Marine mollusc fragments from "Patella" beach.	Faunal analysis of marine mollusca (George, 1932)	"

1. For sites which have not yet been published in detail, the relevant volume and page of "Radiocarbon" is given.

the ground surface. Using an admittedly qualitative criterion, this appears to favour an interpretation of the deposits as Weichselian rather than Saale, for gravels of the latter age must surely have experienced subsequent complete decalcification to a much greater depth in the oceanic climate of west Wales.

To the authors, therefore, it seems that the Tre-llys and Mullock Bridge dates may, at present, cautiously be accepted in view of the support which they receive from other lines of evidence. Certain of the marine mollusc species must have been alive in the Irish Sea – Cardigan Bay area after 38,000 years B.P. (i.e. during the so-called "Upton Warren Interstadial complex"), and were probably incorporated into glacial drift during a major ice advance after 38,000 years B.P.

(b) *Carbon-14 dates from the Banc-y-Warren kame complex*

There are three radiocarbon age determinations from the Banc-y-Warren kame complex which overlooks the town of Cardigan (dates 3, 4, and 5 on Table 3). Of these the finite dates are for samples of peaty organic mud and wood fragments obtained from fluvio-glacial outwash material in adjacent sand-pits. From the mode of occurrence of the organic remains they are certainly derived, having been incorporated into glacial drift during the area's last glaciation. Dates 3 and 5 have been published (Brown et al., 1967; John, 1967) and there has been some discussion in the literature on the relationship between the Cil-maenllwyd date and the pollen content of the associated sands (John, 1968c; Boulton, 1968). The basis of this discussion lies in the very mixed nature of the Cil-maenllwyd pollen assemblage, including some re-worked Carboniferous and Mesozoic spores and pollen. In view of this there are obviously grave dangers in using this pollen data to reconstruct past interstadial or interglacial conditions in the Cardigan Bay area prior to the last glaciation. Other information from the area reinforces this impression. A further "wood fragment" from Cil-maenllwyd has kindly been identified by Professor Shotton and Dr Strachan in Birmingham as Tertiary lignite, and was found to be associated with bissacate pollen grains with affinities to Oligocene and Miocene material from the Mochras bore-hole (Wood and Woodland, 1968). Material-collected by Brown et al. from the horizon of peaty organic mud at Banc-y-Warren has also been subjected to pollen analysis. Slides prepared by Miss F. Bell were found to contain little of definite Pleistocene derivation and hence were passed on to Dr W. H. Zagwijn for examination. He commented that the assemblage of spores seemed to have been more or less completely derived from Tertiary beds and that the source beds are likely to have been of Middle Oligocene age. Noteworthy was the great amount of striate and trilete spores, especially *Cicatricosisporites dorogensis,* which is said to range not further than the mid-Oligocene. Also included were "other bald trilete spores of the *Planisporites* type, several pollen types of *Myricaceae* (triporate) and similarly *Engelhardia*-like species". Some *Castanea*-types were said to resemble *Pollenites (Cupuliferoipollenites) fusus.* Forms typical of Eocene beds were not seen.

In addition, slides of Banc-y-Warren material were prepared by Miss A. J. Davies of King's College London. Her analysis revealed the organic silt to be very pollen-rich, with the pollen and spores in a good state of preservation. Of the tree pollen, *Pinus* was found to be the most abundant, accounting for 56% of the total pollen count (200 grains). Pollen of the *Corylus* type (23%) and *Fraxinus* type (8%) were also relatively abundant. There were also scattered grains of *Betula* (1%) and *Picea* (1%). Non-tree pollen was restricted to *Potamogeton* (7%) Filicales (3%) and two trilete spores of unidentifiable type. In many respects this pollen count is similar to that published by John (1967) for Cil-maenllwyd.

The analyses of organic material from these two sites point to the existence of two somewhat distinct pollen spectra: a Tertiary element[1] and one that might be of Pleistocene interglacial/interstadial derivation. Similar "mixed" assemblages have been described by Simpson and West (1958) from the Chelford Sands and by Allison et al. (1952) for certain horizons associated with the Arctic plant bed of the Lea valley. Indeed, at Nazeing some horizons were found to contain "abundant derived Tertiary pollen . . . but little satisfactory evidence of the contemporary flora" (Allison et al., 1952, p. 181). This situation can be matched in The Netherlands (where van Gijzel et al. (1960) have described a predominantly Tertiary pollen flora in till), Denmark (where Andersen, 1965, has noted variable percentages of extinct pollen in different late Pleistocene till horizons), and in the United States (where Cushing, 1964, discovered Cretaceous pollen in the glacial drifts of Minnesota).

Thus the discoveries from Cil-maenllwyd and Banc-y-Warren are by no means unique, and there is no reason to doubt the reliability of the two finite ages simply on the grounds that the sands contain Tertiary macro-remains and pollen. The existance of Tertiary material at Chelford and Nazeing has not led

---

[1]) The source area for this material must be the floor of the Irish Sea basin and Cardigan Bay. Tertiary and Mesozoic sediments of considerable thickness have been confirmed by a variety of studies (Blundell and King, 1967; Wood and Woodland, 1968).

to any great scepticism concerning the radiocarbon dates for these sites, and it remains true of the Banc-y-Warren area as elsewhere, that the glacial drifts must be younger than the youngest of the derived organic remains which have been incorporated.

Two further points should be made concerning the likelihood of sample contamination in this area:

1. It is possible that the organic materials from these sites have been subject to some measure of contamination by percolating groundwaters since deposition in fluvio-glacial sands and gravels. However, it seems more likely that the juxtaposition of Tertiary material has led to contamination of the samples by "old" carbon, leading to falsely old age determinations. This may have been the case with sample 4 on Table 3.
2. As suggested by Dr Boulton (1968), the organic material may have been subject to contamination prior to its incorporation within glacial deposits. This would certainly minimise the degree of correlation between the two dates and the related palynological evidence. However, such contamination may serve to improve the validity of the dates for establishing the maximum age of the Banc-y-Warren glacial drifts.

If, therefore, one accepts the reliability of these two dates one must also accept the concept of a Middle Weichselian interstadial in the Irish Sea area, and a later Irish Sea glaciation. In all respects the dates are closely comparable with those from Mullock Bridge and Tre-llys, and with those from a variety of sites around the peripheries of the Welsh massif (see, for example, Shotton, 1967b; Saunders, 1968; Boulton and Worsley, 1965; and further age determinations reported as the "Irish Sea Basin" series in *Radiocarbon* 1969, p. 64-65).

(c) *The "Red Lady" of Paviland*

An age determination which may prove to be of importance to our understanding of the Weichselian in South Wales has recently been published for a human skeleton from the Paviland Cave, Gower (Oakley, 1968; No. 6 on Table 3). According to Sollas (1913) this skeleton, traditionally termed the "Red Lady", appears to have been associated with a Late Aurignacian culture. If, therefore, this culture was thriving only 18,000 years ago, it may indicate that the western part of the Gower Peninsula was inhabited by man at about the maximum of the Weichselian glaciation. This, in turn, would provide support for Bowen's (1967) thesis that the area lay beyond the Weichselian ice-margin. However, this view cannot be substantiated until further studies have been undertaken, for it is extremely difficult to relate the cave stratigraphy to the glacial drifts of the area (Sollas, 1913; George, 1932).

(d) *Attempts to date "Irish Sea" till*

Three organic samples from the calcareous "Irish Sea" till of west Wales were submitted for dating with the results indicated under 7, 8 and 9 on Table 3. Stratigraphically, as suggested earlier, there seems little doubt that the till is related in age to the overlying fluvio-glacial outwash material. This has been interpreted as Late Weichselian, and one may assume that the calcareous till is the representative of the same Weichselian glaciation by the Irish Sea glacier. This correlation is apparently supported by the existence in the Druidston till of a marine mollusc assemblage (including *Trophonopsis clathratus, Cardium edule, Turritella communis,* and *Macoma balthica*) which is closely similar to the larger assemblages at Tre-llys and Mullock Bridge. Furthermore, the shallow depth of leaching and decalcification in coastal till exposures and the moderate development of associated cryoturbation features would seem to indicate a recent age. In spite of its recent aspect, however, the small bulk sample of marine molluscs from Druidston (sample 7) yielded an infinite age. The mollusc assemblage may in reality have been older than those from Mullock Bridge and Tre-llys; it may have had a radiocarbon age slightly beyond the range of the equipment at Isotopes Inc., or it may have been subject to contamination by "old" carbon.

Some of the abundant wood/lignite fragments from the Aber-mawr Irish Sea till were examined at the Royal Botanic Gardens, Kew. The fragments were badly decomposed, but it was possible to ascertain that they were of coniferous species unlike any existing at the present day in north west Europe. This was confirmed by the infinite radiocarbon ages for the Aber-mawr samples (8 and 9), demonstrating that the organic remains at the site may be, for the most part, of Early Pleistocene or Tertiary age. In this case, therefore, there is some measure of agreement between the palaeobotanical and radiocarbon evidence, pointing to the existence of ancient derived material similar to that in the Banc-y-Warren area.

Finally, it must be admitted that age determinations 7-9 have no significance for the establishment of a Weichselian chronology. In spite of the strong possibility that the calcareous till is of the same age as the overlying fluvio-glacial materials, this is not yet borne out by the radiocarbon evidence in South Wales. It is still feasible, therefore, that the Irish Sea till *may* be the representative of an earlier glaciation, as suggested by W i r t z (1953).

IV.CONCLUSIONS

For the Late-glacial, the radiocarbon dates discussed above provide reliable support for an already accepted sequence of events based on stratigraphic and palaeontological studies. However, for earlier phases there exists a much larger possibility of error. There are four "finite" dates from glacial drifts which the authors have interpretated at face value, but about which others may well feel more dubious. Balanced against them are four "infinite" dates and a growing body of palaeobotanical evidence which points to the existence in the South Wales drifts of a great deal of derived Tertiary material. However, the authors feel that the overall evidence is weighted slightly in favour of a sequence of events as outlined earlier, i.e. it is believed that the evidence presented is more easily interpreted in terms of an extensive Weichselian glaciation than in terms of a Saalian glaciation. This view is, moreover, supported by much related data from adjacent regions.

Before the views presented in this paper can be fully accepted, there is need for one further line of verification – namely the accurate dating of the raised beach referred to at the beginning of this paper. So far there have been two attempts to date the "Patella" beach of Gower (Samples 10 and 11). Both have yielded misleadingly young ages (21,815 ± 629 and 22,796 ± 827 years B.P.) and S h o t t o n et al. (1968) suggest that the samples must have been subject to contamination. A suite of apparently related deposits at West Angle, near the mouth of Milford Haven, may hold greater promise. Here a raised beach is overlain by a sequence of estuarine organic silts and clays which contain pollen of an interglacial character (J o h n, 1968a). On stratigraphic grounds the deposits have tentatively been interpreted as representative of an Ipswichian (Eemian) transgression within Milford Haven. However, the pollen assemblage may contain certain Hoxnian elements (Dr. J. Turner, personal comm.), and it is hoped that a more detailed investigation of the deposits in the near future will resolve the problem of their age.

Thus at present the drift stratigraphy and the radiocarbon dates for South Wales combine to provide a reasonable Weichselian chronology which matches, in many respects, the chronology for the western European mainland. On the other hand many more detailed palaeobotanical analyses must be undertaken before the outstanding problems can be resolved, for it seems that the few isolated studies reported here have told us just as much about the Tertiary as about the non-glacial climates of the Quaternary!

ACKNOWLEDGEMENTS

We would like to acknowledge the generous advice which we have received concerning the organic remains discussed in this paper. In particular we thank Mr D. F. W. Baden-Powell, Miss F. Bell, Dr G. S. Boulton, Miss A. J. Davies, the Director of the Royal Botanic Gardens (Kew), Dr A. Hibbert, Professor F. W. Shotton, Dr I. G. Simmons, Dr I. Strachan, Dr J. Turner, and Dr W. H. Zagwijn. We are grateful to the Royal Society, University College, London, and the University of Durham for financial help towards the cost of radiocarbon dating.

REFERENCES

Allison, J., Godwin, H. and Warren, S. H. (1952) – Late-glacial deposits at Nazeing in the Lea Valley, North London. Phil. Trans. Roy. Soc. Land. 236 B, 169-240.

Andersen, S. T. (1965) – Pollen Analysis and Till stratigraphy at Lindø, Denmark. Geol. Soc. America Sp. Paper 84, 65-78.

Ball, D. F. (1960) – Relic-soil on limestone in South Wales. Nature, Lond. 187, 497.

Bartley, D. D. (1960) – Rhosgoch Common, Radnorshire – stratigraphy and pollen analysis. New Phytologist 59, 238-262.

Blundell, D. J. and King, R. F. (eds) (1967) – The Geology of the Irish Sea area (Third Colloquium, Resumés of Communications). Univ. of Birmingham.

Boulton, G. S. (1968) – A Middle Würm Interstadial in South-west Wales (letter). Geol. Mag. 105 (2),

190-191.
Boulton, G. S. and Worsley, P. (1965) – Late-Weichselian glaciation in the Cheshire-Shropshire Basin. Nature, Lond. 207, 704-6.
Bowen, D. Q. (1966) – Dating Pleistocene events in South West Wales. Nature, Lond. 211, 475-476.
—— (1967) – On the supposed ice dammed lakes of South Wales. Trans. Cardiff Nat. Soc. 93, 4-17.
Bowen, D. Q. and Gregory, K. J. (1965) – A glacial drainage system near Fishguard, Pembrokeshire. Proc. Geol. Assoc. 76, 275.
Brown, M. J. F., Ellis-Grufydd, I. D., Foster, H. D., and Unwin, D. J. (1967) – A new radiocarbon date for Wales. Nature, Lond. 213, 1220-21.
Buckley, J. D. and Willis, E. H. (1969) – Isotope's Radiocarbon Measurements VII. Radiocarbon II (1). 64-65.
Charlesworth, J. K. (1929) – The South Wales End-moraine. Quart. J. geol. Soc. Lond., 85, 335-358.
Crampton, C. B. (1966) – Certain effects of glacial events in the Vale of Glamorgan, South Wales. J. Glac. 6, 261-266.
Cushing (1964) – Redeposited pollen in late-Wisconsin pollen spectra from east-central Minnesota. Amer. Journ. Sci. 262, 1075-1088.
Ellis-Gruffydd, I.D.–Ph.D. Thesis in preparation. University of London.
George, T. N. (1932) – The Quaternary beaches of Gower. Proc. Geol. Assoc. 43, 291-324.
—— (1933) – The glacial deposits of Gower. Geol. Mag. 70, 208-232.
van Gijzel, P. et al. (1960) – Geological investigations of boulder-clay of Eastern Groningen. Leidse Geol. Meded. 24, 721-759.
Godwin, H. (1940) – A Boreal transgression of the sea in Swansea Bay. New Phytol. 39, 308-321.
Godwin, H. and Willis, E. H. (1964) – Cambridge University Natural Radiocarbon Measurements VI, Port Talbot, Glamorgan series. Radiocarbon 6, 123-125.
Godwin, H., Walker, D., and Willis, E.H. (1957) – Radiocarbon dating and post-glacial vegetational history: Scaleby Moss. Proc. Roy. Soc. 147 B, 352-365.
Griffiths, J. C. (1940) – The glacial deposits west of the Taff, South Wales. Univ. of London Ph.D. Thesis (unpub.).
John, B. S. (1965) – A possible Main Würm glaciation in West Pembrokeshire. Nature, Lond. 207, 622-623.
—— (1967) – Further evidence for a Middle Würm Interstadial and a Main Würm glaciation of South-west Wales. Geol. Mag. 104, 630-3.
—— (1968a) – Age of raised beach deposits of South-western Britain. Nature, Lond. 218, 665-667.
—— (1968b) – Directions of ice movement in the southern Irish Sea Basin during the last major glaciation: an hypothesis. J. Glac. 7, 507-510.
—— (1968c) – A Middle Würm interstadial in south-west Wales – a reply to G. S. Boulton. Geol. Mag. 105, 398-400.
—— (1969) – "The Glaciation of Pembrokeshire" in Lewis, C.A. (ed). "The Glaciations of Wales and Adjoining Regions". Longmans (in the press).
Lewis, C. A. (1966a) – Ph.D. Thesis, National University of Ireland (unpub.).
—— (1966b) – The Breconshire End-moraine. Nature, Lond. 212, 1559-1561.
Mitchell, G. F. (1960) – The Pleistocene history of the Irish Sea. Advmt. Science 68, 313-325.
—— (1962) – Summer Field Meeting in Wales and Ireland. Proc. Geol. Assoc. 73, 197-213.
Oakley, K. P. (1968) – The Date of the "Red Lady" of Paviland. Antiquity 42 (168), 306-307.
Olsson, I. and Blake, W. (1961) – Problems of radiocarbon dating of raised beaches, based on experience in Spitsbergen. Norsk Geog. Tidss. 18, 1-18.
Pringle, J. and George, T. N. (1948) – South Wales. British Regional Geology (2nd. Ed.) H.M.S.O.
Saunders, G.E. (1968) – Glaciation of possible Scottish Readvance age in North-West Wales. Nature, Lond. 218, 76-78.
Shotton, F. W. (1967a) – The problems and contributions of methods of absolute dating within the Pleistocene period. Quart. J. geol. Soc. Lond. 122, 357-383.
—— (1967b) – Age of the Irish Sea Glaciation of the Midlands. Nature, Lond. 215, 1366.
Shotton, F.W., Blundell, D.J., and Williams R.E.G. (1968) – Birmingham University Radiocarbon Dates II. Radiocarbon 10(2), 200-206.
Simpson, I. M. and West, R. G. (1958) – On the stratigraphy and palaeobotany of a late-Pleistocene organic deposit at Chelford, Cheshire. New Phytol. 57, 239.
Sollas, W. J. (1913) – Paviland Cave – an Aurignacian station in Wales. Trans. Roy. Anthrop. Inst. 43, 339-374.
Stephens, N. and Synge, F. M. (1966) – Pleistocene shorelines, in Dury, G.H. (ed.), Essays in Geomorphology, 1-51.
Trottman, D. M. (1963) – Data for Late-glacial and Post-glacial history in South Wales. Ph.D. Thesis, University of Wales (Swansea) (unpub.).
Watson, E. and Watson, S. (1967) – The Periglacial origin of the drifts at Morfa-Bychan, near Aberystwyth. Geol. Journ. 5, 419-40.
West, R. G. (1968) – Pleistocene Geology and Biology. Longmans. 257-259.
Whittow, J. B. and Ball, D. F. (1967) – Aspects of glacial drift distribution in North Wales in relation to the geology of the Irish Sea basin (abstract); in Blundell, D. J. and King, R. F. (eds.) "The Geology of the Irish Sea Area".
Williams, K.E. (1927) – The glacial drifts of western Cardiganshire. Geol. Mag. 64, 205-227.
Wirtz, D. (1953) – Zur Stratigraphie des Pleistocäns im Westen der Britischen Inseln. Neues. Jahrb. Geol. Paläontol. 96, 267-303.
Wood, A. and Woodland, A.W. (1968) – Borehole at Mochras, west of Llanbedr, Merionethshire. Nature, Lond. 219, 1352-4.
Woodland, A. W. and Evans, W. B. (1964) – The Country around Pontypridd and Maesteg (3rd ed.) H.M.S.O. The Geology of the South Wales Coalfield, Part IV, 275-292.
Zeuner, F. E. (1959) – The Pleistocene Period, (2nd. edn.) London, 145-146.