Quaternary Newsletter
Article
QRA Quaternary Research Association

Was there a Late Devensian ice-free corridor in Pembrokeshire?

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Abstract

An ice-free enclave or corridor covering most of Pembrokeshire has featured in many of the recent reconstructions of glacial activity in western Britain during the LGM. This appears to be a hangover from the days when the terms "Older Drift" and "Newer Drift" were frequently used in the literature. However, the supposed ice-free corridor is not well supported in published studies, and it causes difficulty for those involved in ice-sheet modelling. With the aid of new field observations from scores of sites across West Wales, it is suggested that there is no convincing evidence in support of the ice-free hypothesis. The regional Quaternary stratigraphy in Central and South Pembrokeshire matches that of North Pembrokeshire and the St Brides Bay coast, and it is suggested that the whole of the peninsula was inundated by the ice of the Irish Sea Ice Stream travelling broadly NW to SE at the time of peak glaciation, around 26,000 years ago.

Introduction

In recent attempts to define the LGM limit in the western part of the British Isles there is one very strange anomaly, namely an ice-free enclave or corridor covering most of central and southern Pembrokeshire and extending south-eastwards towards the Bristol Channel (Lockhart, 2019; Chiverrell *et al*, 2020; Scourse *et al*, 2021). The LGM limit shown in Figure 1 is mirrored in many other publications. In the large paper summarising the findings of the BRITICE-CHRONO project (Clark *et al*, 2022) the authors commented on the difficulty they had in reconciling their modelling work with evidence collected in the field, but it appears that they were largely dependent upon fieldwork observations made several decades ago (Mitchell, 1960; Bowen, 1970, 1982; John, 1971; Campbell & Bowen, 1989).

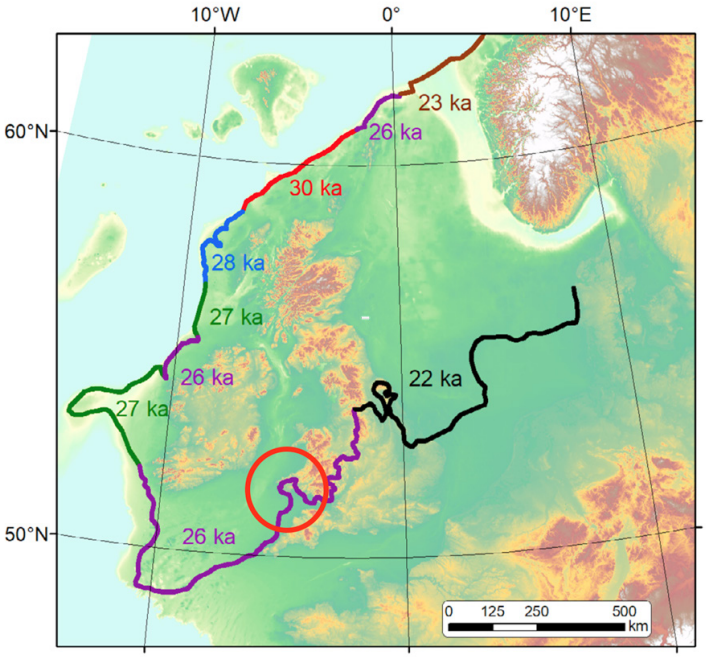

Figure 1. The 26 ka ice limit for the southern part of the British / Irish Ice Sheet, as drawn by the BRITICE-CHRONO team. Source: Clark *et al*, 2022. Most of the Pembrokeshire peninsula is shown as ice-free. The red circle shows the current study area.

The assumption of an ice-free enclave or corridor comes initially from an assertion by Charlesworth (1929) that Pembrokeshire, south of his "South Wales End Moraine", was an area of "Older Drift". This was carried through by DQ Bowen and others who thought that there was a pre-Devensian "Penfro Till Formation" (part of the Albion Glacigenic Group) across the landscape to the south of Mynydd Preseli (Bowen, 1999, 2005). However, the type localities cited by the BGS (Llandre and West Angle) have never been adequately described in the literature. At Llandre (SN092203), in a small flooded gravel pit, there is no till, and at West Angle (SM854032) the recorded stratigraphy was misinterpreted by Campbell & Bowen (1989). This may be because a steep erosional contact between a reddish glacial diamicton and a series of underlying interglacial silts and clays was

not visible when the site was examined by Bowen (see below). There are indeed ancient till deposits in Pembrokeshire, but not at those two named sites. The three known ancient till exposures, all cemented, are at Black Mixen, Lydstep (SN088974), Ceibwr (SN108457) and Witches Cauldron (SN102451) (Fig. 2). None of these ties into the late Quaternary stratigraphy of West Wales, suggesting that they pre-date the Last Interglacial.

Whatever the shortcomings of the BGS lithostratigraphy might be, the great majority of researchers (and I include myself) have until very recently opted for an acceptance of an LGM ice-free area to the south of Mynydd Preseli in Pembrokeshire (Campbell & Bowen, 1989; McCarroll, 2001; John, 2019a; Scourse *et al*, 2021; Clark *et al*, 2022). As for the delimitation of glacial limits, the situation is best described as chaotic (Fig. 3)

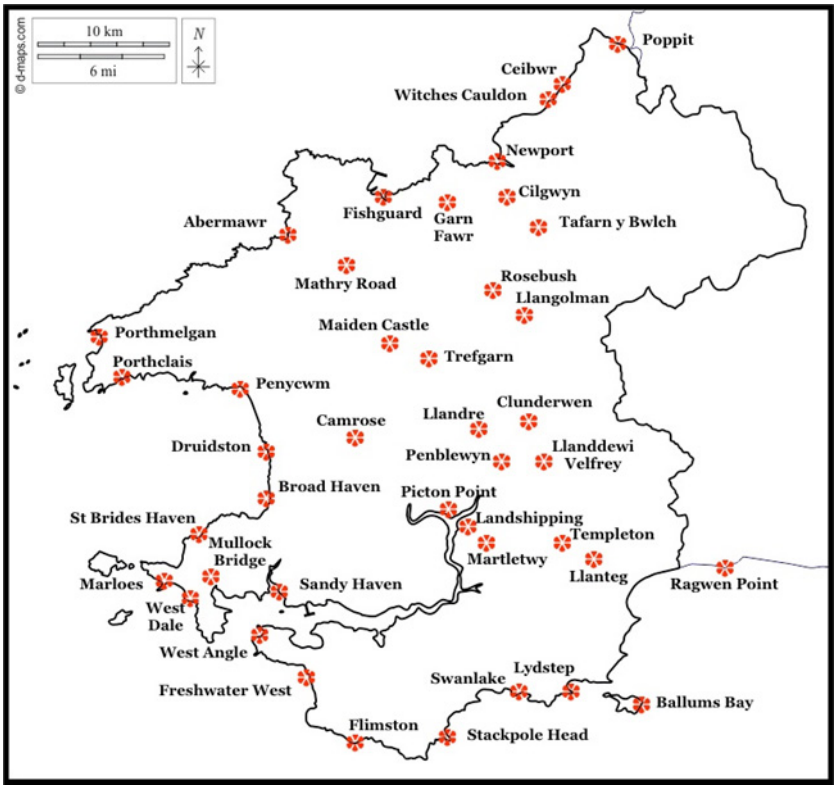

Figure 2. Locations of key Quaternary sites referred to in the text. See Appendix 1 for locational details.

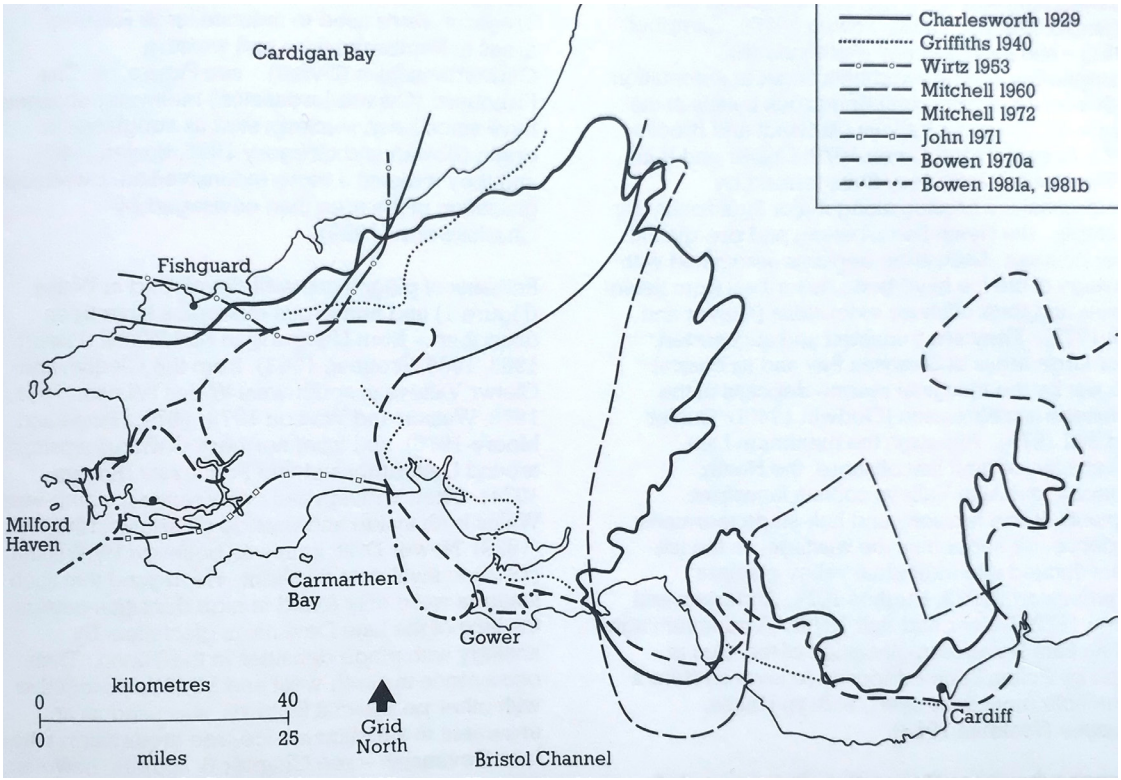

Figure 3. A confusion of suggested Devensian ice limits in West Wales. Source: Campbell and Bowen, 1989.

For some years I have been investigating the hypothesis of an ice-free or permafrost enclave or corridor across most of South Pembrokeshire at the height of the Late Devensian glaciation. The accumulating evidence is outlined below. It is hoped that this will provide a reasonable answer to this dilemma, and encourage new fieldwork and other contributions to the debate.

Glaciological considerations

If there really was an ice-free LGM corridor as shown in Figures 1 and 4, it is difficult to see how it can be explained by reference to the laws of ice physics. An ice edge as shown, running diagonally across Mynydd Preseli, is unsupported by any evidence and would in any case be an anomaly. At the LGM (c 26 ka) it is now accepted that the ice of the Irish Sea Ice Stream reached the Celtic Sea shelf edge, some 450 km to the south-west. For forward flow to be maintained, there must have been a continuous ice surface gradient from the St George's Channel and Mynydd Preseli to the shelf edge. It is now believed that the LGM ice surface altitude was possibly c 1500m in Snowdonia (Hubbard *et al*, 2011; Glasser *et al*, 2018; Clark *et al*, 2022) and c 1000m in north Pembrokeshire, as suggested in the latest BRITICE-CHRONO modelling. The ice must have spread laterally far to the east of the ice edge position shown in some reconstructions. Ice flow parallel to the ice edge, as shown in a number of maps (eg Lockhart, 2019; Van Landeghem and Chiverrell, 2020) was highly unlikely (Fig. 5) since there is no evidence of Welsh ice covering the Pembrokeshire peninsula and "blocking" ice from the west.

Off the west Pembrokeshire coast the ice was not constrained within a bedrock trough or any other deep topographic depression; the Celtic Deep is a relatively minor feature. It therefore makes glaciological sense for the eastern part of the LGM Irish Sea ice stream

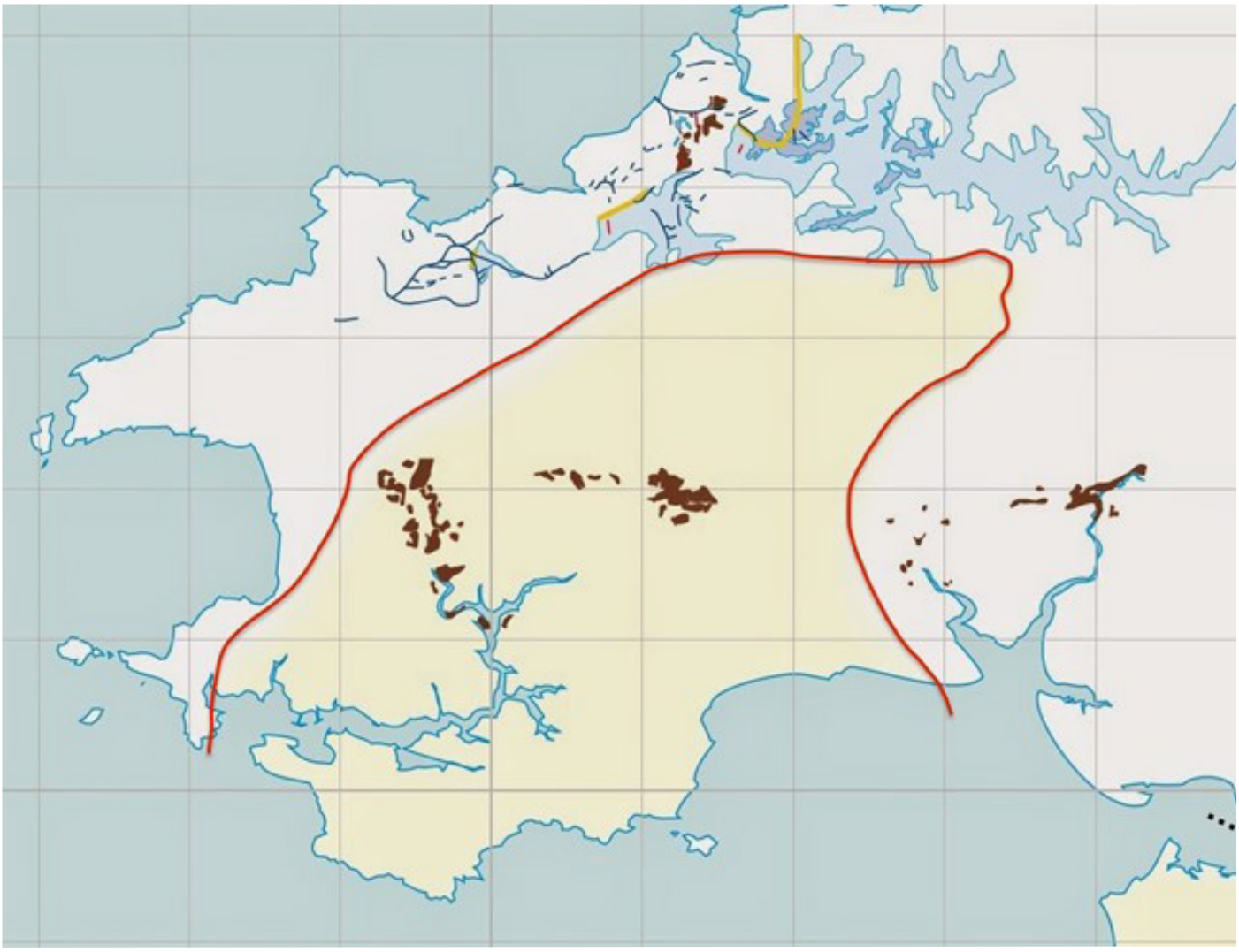

Figure 4. The BRITICE-CHRONO (2004) map of glacial deposits in the supposed Devensian ice-free area of West Wales. The cream coloured areas are assumed to have been unglaciated in the Devensian. Patches shown in brown are interpreted as pre-Devensian glacial and glaciofluvial deposits — but many similar deposits have been ignored in the mapping. Thanks to BRITICE-CHRONO / Creative Commons.

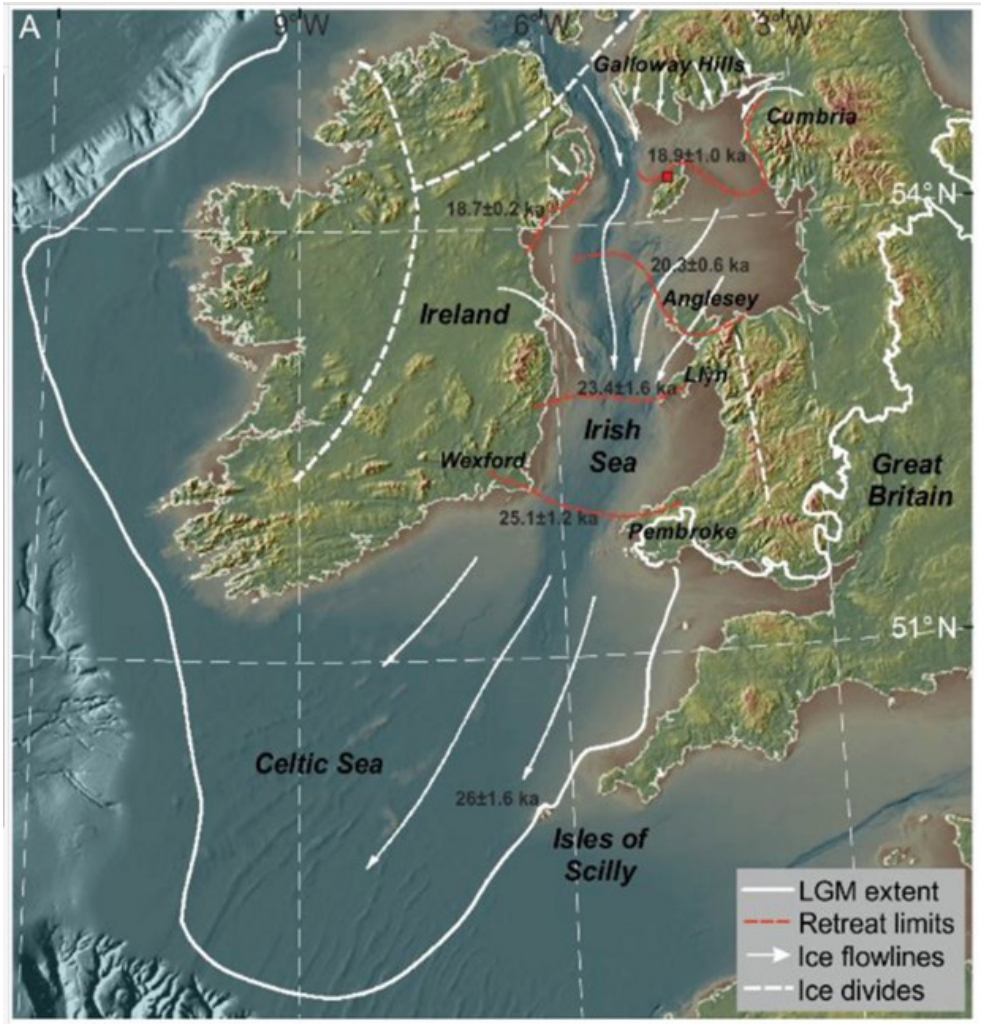

Figure 5. Hypothetical ice streaming directions through St George's Channel and the Celtic Deep. Thanks to Jenkins *et al* 2018 / Creative Commons. It is likely that there was much more lateral spreading on the eastern flank, unless the Bristol Channel was filled with Welsh ice. Across Pembrokeshire the field evidence all points to ice movement towards the SE, not the SW.

to have flowed not south-westwards but broadly south-eastwards, into Carmarthen Bay and the outer reaches of the Bristol Channel (John, 1968, 2018a and 2018b). So might this ice have affected central and south Pembrokeshire? It must have done, unless there was a steep and spectacular ice ramp or ice cliff in St Bride's Bay.

Field Observations and Interpretations

1. There are many more extensive spreads of glacial and fluvio-glacial deposits than those shown on Figure 4, in the areas deemed to be outside the LGM limit. Some of the deposits appear to be unweathered, and some even have surface expression, as at Llangolman (SN116269), Rosebush (SN071229) and Clunderwen (SN120192). They are by no means all "degraded or denuded" and they are not restricted to hilltops or interfluves, as was suggested by Charlesworth (1929). The extensive exposure of till running eastwards from Martletwy (SN049113) via Templeton (SN112115) to Llanteg (SN181103) runs across a number of terrain types. Some deposits incorporate weathered or rotten clasts, and there is a possibility that there has been considerable recycling of older materials. The evidence of these extensive superficial deposits is accessible on the BGS map viewer.

2. On the coasts of St Bride's Bay, and around the mouth of Milford Haven, sites such as Broad Haven (SM860144), Druidston (SM863172), St Bride's Haven (SM802111), Dale (SM799043), Westdale (SM800058), Mullock Bridge (SM811082) and Marloes (SM782076) tell a consistent story. At Sandy Haven (SM860072), assumed by many to be outside the LGM ice limit, the Quaternary succession is as follows:

6. Modern soil
5. Fine-grained colluvium (aeolian? slope wash?) up to 1m thick
4. Thin slope breccia generally c 1m thick, incorporating glacial debris
3. Sandy gravelly diamicton (till) up to 4m thick, incorporating slope breccia
2. Slope breccia and colluvial deposits -- many different facies
1. Raised beach cobbles -- c 20 cm thick (disturbed?)

Erratics and sediment sequences show — as on the north Pembrokeshire coast — a substantial ingress of ice from the west and north-west, pressing some distance inland. At Marloes there are glaciotectonic structures in the glacial deposits.

3. The proposition that glacier ice was streaming from north to south, or NE to SW, is not supported by bedrock striae recorded in coastal locations. At six sites along the north Pembrokeshire coast (namely Poppit, Newport, Parrog, Abermawr, Porthmelgan and Whitesands) detailed measurements show that the predominant direction of ice flow was NW - SE, and this accords with the records of glacial erratic movement published by Geological Survey field workers more than a century ago (Dixon, 1921) and by Griffiths (1940).

4. Roadworks in the Redstone - Penblewyn - Llanddewi Velfrey area, north of Narberth, in 2022, reveal up to 8m of stony clay-rich diamictons and sand and gravel deposits across the landscape but unmapped by the BGS. Near Penblewyn Roundabout (SN123167) a sheet of sticky blue-grey and relatively unweathered diamicton is exposed at the surface; it has a similar texture and colour to the Irish Sea till exposed at Abermawr (SM883347), Druidston (SM863172) and Porthmelgan (SM727279). Faceted and striated boulders and cobbles are found in temporary roadworks exposures. One prominent boulder of red sandstone has a weathering crust which has been striated, suggesting that older deposits have been recycled and incorporated by overriding ice. Other deposits with a reduced content of silts and clays, and a higher proportion of sands and gravels, are interpreted as meltout tills, flowtills and glaciofluvial accumulations. These appear just as fresh and unweathered as the glacial deposits exposed in North Pembrokeshire coastal sections, and there is no reason thus far to assume that they are any older.

5. The diamictons in the valleys and on the clifftops of the South Pembrokeshire coastal plateau are so abundant and so fresh in appearance that they are most likely related in age and origin to those on the North Pembrokeshire cliffs. At Swanlake (SS045980) the exposures in the cliffline adjacent to the beach mostly comprise ORS rockfall and slope breccia accumulations, but adjacent to one of the footpath gullies there is an exposure of uncemented clay-rich diamicton with abundant erratic pebbles, some of which show evidence of pressure fractures. Above this, erratic pebbles are incorporated into matrix-supported slope deposits. On the flat Carboniferous Limestone clifftops around Stackpole Head (SR992943) and Stackpole Warren (SR984942) there is a sandy and silty diamicton occasionally over 1m thick, containing pebbles of all shapes and sizes.

The main rock types represented are limestone, shale and mudstone, ORS sandstones and grits, and flints. The deposits are uncemented. In a number of locations the most striking characteristic of the diamictons is the presence of abundant well rounded quartz pebbles and cobbles which must be related to the Oligocene quartz pebble accumulations found in clay pits on the coastal plateau near Flimston (SR927952). In the graveyard at Flimston there are seven igneous erratics, some of which have been used as headstones for graves. They have come from the St David's area (Dixon, 1921), and most of them were collected from within a few km of the churchyard. They are heavily weathered and abraded. On the nearby clifftops there are abundant exposures of unconsolidated diamicton, up to 2m thick, with well rounded quartz pebbles set

Figure 6. Stony sandy diamicton with striated erratics and locally derived quartz pebbles on a flat-topped clifftop near Bullslaughter Bay, South Pembrokeshire. This is not a gash breccia, nor is it cemented, nor is it a slope deposit, and it is interpreted as an *in situ* Devensian till.

in a sandy and gravelly matrix. The BGS surveyors recorded the presence of striated igneous pebbles. There are other exposures of reddish diamicton up to 3m thick and containing abundant rounded and faceted erratic pebbles on the clifftops near Huntsman's Leap (SR961929), Mewsford Point (SR942938), and Bullslaughter Bay (SR941943) (Fig. 6). The only deposits overlying these diamictons are reddish sandy loams and blown sand, generally less than 1m thick. At Stackpole Quay (SR993956), at an altitude of c 35m, there is a deposit of gravelly diamicton about 3m thick, incorporating igneous erratics. All of these diamictons studied are uncemented, even when capping limestone cliffs where carbonate cement is abundant. They have to be interpreted as fresh tills similar in appearance to the tills on the south coast of the St David's Peninsula, with lithological variations in tune with local source materials. They are not recycled or redeposited slope accumulations, since many of them rest on a flat plateau surface. Thus they should probably be interpreted as Late Devensian in age.

6. Other key locations outside the postulated LGM ice limit include the sandy beaches at Freshwater West (SR880005), Lydstep (SS087977), and Amroth, (SN161068), where clay-rich diamictons with abundant faceted erratic cobbles and boulders are seen beneath Holocene peat beds and "submerged forest" remnants which are intermittently exposed between HWM and LWM. At Ragwen Point (SS219071) near Pendine in Carmarthen Bay, the following sequence of deposits is seen:

9. Modern soil and colluvium —30 cm
8. Upper slope breccia — up to 2m
7. Patchy blue-grey clay-rich diamicton (till) — c 2m. (in part slumped to beach level)
6. Lower slope breccia and rockfall debris — up to 4m
5. Hardpan / cemented silty layers c 40 cm
4. Dark organic silts 30 cm
3. Iron-stained sandy layer (cemented) 1m
2. Buff coloured sandrock with cavities and rockfall inclusions 2m
1. Raised beach with large embedded boulders and sandrock layers 2m

At West Angle (SM854032) the Quaternary sequence is interpreted as follows:

10. Soil and colluvium — c 1m
9. Dark red stratified horizon — 3m, late glacial
8. Dark red diamicton (non-stratified) — till c 3m
7. Orange silt and clay series — 2m, interglacial dune slack environment (freshwater)
6. Grey silt and clay series — 2m, interglacial dune slack environment (freshwater)
5. Peat and peaty silt — 60 cm, interglacial dune slack environment (freshwater)
4. Stony grey silts — c 1.5 m thick with slope breccia — interglacial
3. Stained bedded sands and gravels — c 1.5 m thick — interglacial shoreline deposits
2. Rounded pebbles / beach shingle — c 1.8 m thick — interglacial raised beach
1. Sand — more than 1 m thick — interglacial sandy beach

Contrary to the claims of earlier researchers including DQ Bowen (1974), there is no ancient till at this site beneath the raised beach and interglacial silt and clay sequence. But there is a striking erosional contact deformed by glaciotectonics towards the northern end of the cliff exposure, visible only after careful excavation, showing slabs or lenses of interglacial silts and clays incorporated into dark red till by overriding ice. Bowen clearly saw a part of one of these lenses and assumed that it belonged to an in situ interglacial layer which was younger than the till that it now rests upon.

At each of these sites the diamictons interpreted as tills occupy stratigraphic positions identical to their equivalents in North Pembrokeshire, and they are are so close to the surface that they must be interpreted as late Devensian in age. There is no reason, anywhere, for them to be interpreted as recycled or redeposited ancient tills. The interglacial sediments at West Angle are interpreted as Ipswichian in age, but the pollen analyses are difficult to interpret (Stevenson and Moore, 1982). New work is needed, but unfortunately the peaty sediments now appear to have eroded away.

7. The diamicton in Ballum's Bay (SS147966) on Caldey Island which was discussed in QN 149 with Prof John Hiemstra and others is unconsolidated and is similar in texture and appearance to other deposits on the island. It is stratigraphically younger than the adjacent cemented raised beach and slope breccia deposits in Ballum's Bay which are reasonably interpreted as Ipswichian and Early Devensian in age (Hiemstra *et al*, 2019; John 2019a). There is no reason why the diamicton should not be interpreted as an *in situ* till, since no firm evidence has been brought

forward to show that it is reconstituted or recycled. Its reddish colour is down to the incorporation of Devonian sandstone debris, which means that it has been transported by ice from the west.

8. The stony clay-rich diamictons and the sands and gravels around Picton Point (SN002118) and Landshipping (SN008114), in the centre of the county at the confluence of the two Cleddau rivers, are indistinguishable from the related deposits of North Pembrokeshire, and appear to have been emplaced during a relatively recent glaciation. They cannot adequately be explained without invoking a complete ice cover across Pembrokeshire. There is also coherent till near Camrose. The sheets of fluvioglacial gravels that partly fill the Western Cleddau valley both to north and south of the Trefgarn Gorge (SM960250) are here interpreted as deposits linked to catastrophic Late Devensian ice wastage and southwards drainage diversion. These gravels might well be amenable to OSL dating.

9. There are apparent trimlines and glacial deposits at a variety of altitudes on the northern flank of Mynydd Preseli, up to an altitude of at least 340m, and possibly as high as 420m. In the past I have interpreted that as the altitude of the highest Devensian ice surface associated with Irish Sea ice, but I now consider it more likely to indicate a transition from a cold-based to a warm-based ice cover. This would accord with the modelled BRITICE-CHRONO ice surface reconstruction at c1000m. Ice must have filled the Cwm Gwaun depression and its pre-existing meltwater channels, and there are apparent morainic features above and on the south side of the main channel, and at Pont Ceunant (SN046375), Cilgwyn (SN075363) and Tafarn y Bwlch (SN083333). It is also possible that the other morainic ridges and glaciofluvial mounds in and around the Preseli uplands may be associated with retreat stages or short-lived readvances around 25,000 yrs BP, either associated with a Preseli ice cap or with invasive ice from Cardigan Bay (Scourse *et al*, 2021). These stages are still to be defined, as are their links with the fluvioglacial sands, gravels and lacustrine deposits in the Cardigan area.

10. Ice moulded or streamlined bedrock surfaces are abundant, and they are not restricted to Preseli. Examples can be seen on Carnllidi, near Strumble Head, in Lower Town Fishguard, on Dinas Mountain (Fig. 7), on Carningli, at Carnedd Meibion Owen and on Carn Goedog, Carn Alw and Carn Meini on the Preseli upland. The "denuded tors" between Dinas and Newport are often cited as evidence of a Late Devensian ice cover; and the fragile appearance of Maiden Castle tor (SM955248), near Trefgarn, is cited as evidence that it cannot have been glaciated so recently. But tor survival and modification is a very complex matter, and a cosmogenic dating programme is needed in order to establish which features are inherited, and which are genuinely of Devensian age (Hall and Sugden, 2006; Gunnell *et al*, 2013).

Figure 7. Striated and ice moulded rock surface on the dolerite tor of Garn Fawr, Mynydd Dinas. The bedrock is heavily fractured unspotted dolerite. Altitude 300m.

11. Similarly, the evidence of glacial erratic transport and distribution cannot safely be cited in support of any LGM reconstructions (Griffiths, 1940). But there is now a good database of erratic boulders with known geological provenances that have ended up in other places, broadly to the south or south-east. The distances of travel also vary greatly. Igneous boulders (such as those at Flimston, St Bride's Haven, Druidston and Broad Haven) have almost certainly followed zig-zag courses during the Quaternary glacial episodes, and may have been moved on at least three separate occasions.

12. If Pembrokeshire to the south of Mynydd Preseli had been ice-free for the duration of the Ipswichian interglacial and the Devensian cold phase, we would expect the known Quaternary deposits to have been capped with slope breccia and colluvium; there are some patches but they are no thicker or more prominent than those of the north coast. Furthermore, there are no extensive occurrences of patterned ground, or other evidence of prolonged permafrost conditions across a full glacial cycle. There are churned gravels and fossil ice wedges in the gravel pit at Llangolman (SN116268), but they are no more extensive or prominent than the periglacial features seen in glaciofluvial terraces at Mullock Bridge and Mathry Road (SM923312) which are interpreted as Late Glacial in age (John, 1970).

13. If the concept of complete ice cover on Pembrokeshire during the LGM is to stand up, it must also fit with the evidence obtained in the South Pembrokeshire and Gower bone caves including Eel Point, Ogof yr Ychen, Coygan and Paviland (Walker, 2019). It looks as if the evidence does hold, although great care must be taken because of the uncertainties surrounding radiocarbon age determinations and calibrations. Elizabeth Walker thinks that there might have been human occupation of some caves on the limestone coast prior to 30,000 years ago, and Schulting *et al* (2005) refer to occupation by the "Red Lady of Paviland" and by humans at Eel Point on Caldey Island after 26,000 yrs BP and many other caves by about 12,000 years ago. There appears to have been a gap, so it is suggested tentatively that the human occupation and tundra animal evidence does fit around a short-lived glacial episode culminating around 26,000 years ago (Scourse *et al*, 2021).

14. There are no linear features such as terminal or marginal moraines along any of the postulated Irish Sea Ice Stream LGM ice edges in West Wales. The "South Wales End Moraine" has long since been dismissed as a significant ice edge marker (John, 1970).

Discussion

From an assessment of multiple sites inland and on the coast, this is the regional Quaternary stratigraphy for South Pembrokeshire:

8. Sandy loam and blown sand
7. Upper slope breccia (uncemented)
6. Fluvioglacial sands and gravels -- mostly inland exposures
5b. Meltout till / flowtill— many coastal exposures
5a. Lodgement till from LGM (Devensian) glaciation — inland exposures
4c. Lower slope breccia (cemented in some localities)
4b. Cemented sands (sandrock)
4a. Slope breccia incorporating raised beach cobbles (cemented)
3. Cemented raised beach (Ipswichian)
2. Older glacial deposits -- mostly destroyed, but exposed at Lydstep (Black Mixen)
1. Raised beach platform (complex modifications over several interglacials?)

This stratigraphy is essentially the same as that established for North Pembrokeshire, in the area long since accepted as having been affected by Irish Sea ice during the LGM. If we cannot identify any strong distinguishing features in the landscape and Quaternary sediments to the south of Mynydd Preseli, then we cannot sustain the narrative involving an LGM ice-free corridor or enclave. The lack of identifiable constructional landforms associated with glaciation (eg moraines, kames and eskers) in South Pembrokeshire may be cited as evidence for the lack of a Devensian ice cover; but there are no such features in the St David's Peninsula and on Pencaer either, and these areas have never been referred to as "Devensian ice free enclaves". Clearly, we still do not fully understand why glacial deposits and landforms seem to be clustered into some areas and not others!

But there is one persistent question that has to be answered: What if the South Pembrokeshire "glacial deposits" are all recycled or redeposited tills of great age, moved during the last glacial cycle by slope processes? After all, the pseudo-stratified slope deposits of Morfa Bychan, on Cardigan Bay have

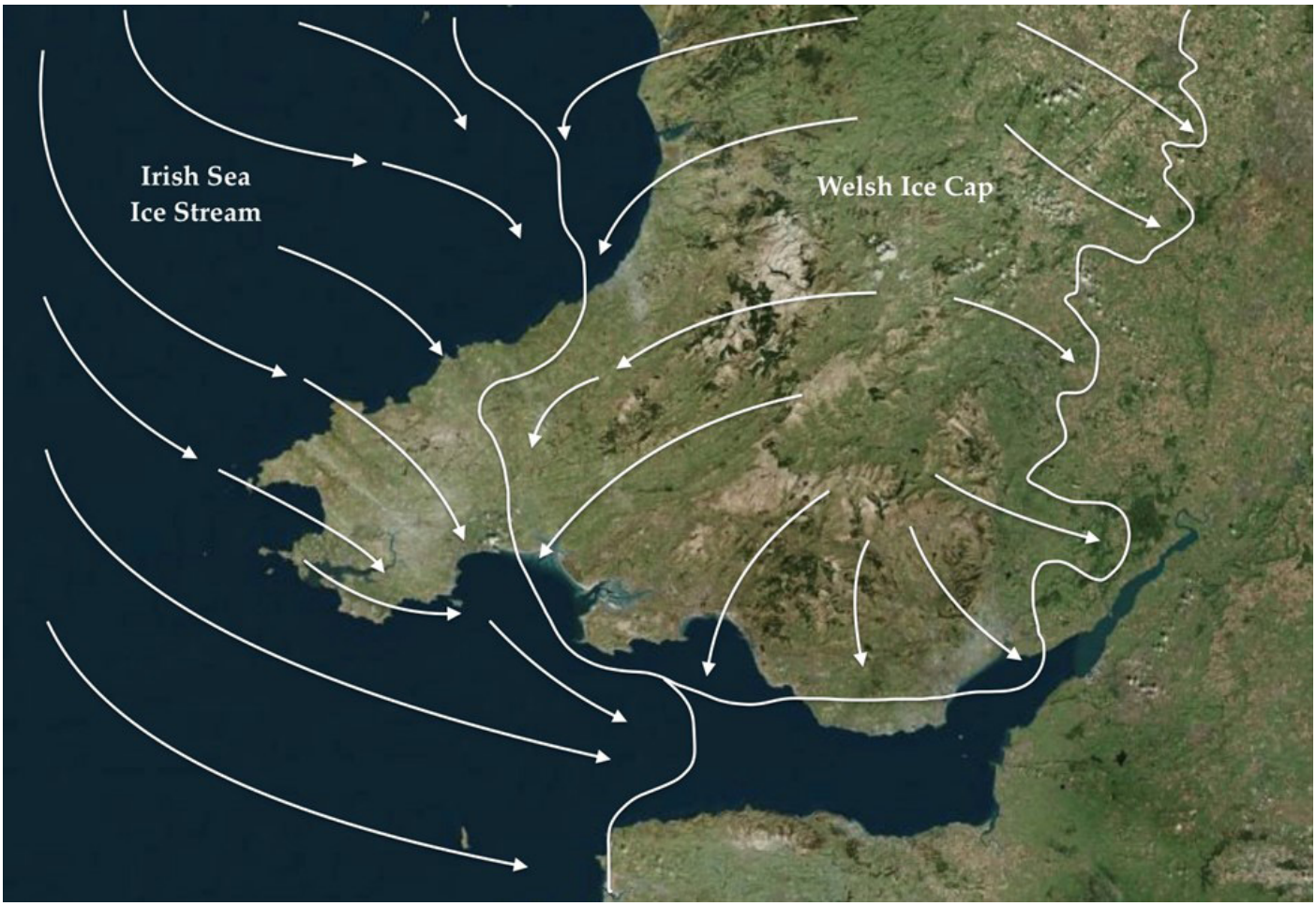

Figure 8. Hypothetical flowline pattern of glaciation for West Wales at the time of the Devensian LGM. Ice edge oscillations on the eastern flank of the Welsh Ice Cap may not have been synchronous with those on the western flank.

been interpreted by Watson (1970) as slope deposits incorporating older glacial materials; and Hiemstra and Shakesby (2015) have suggested that the deposits at Rotherslade, Gower, are not *in situ* glacial deposits but materials remobilised and re-deposited with the aid of meltwater under paraglacial conditions. The pseudo-stratified deposits at Westdale (SM799057) may be interpreted in a similar fashion. However, very few of the West Wales Quaternary deposits can be interpreted as lodgement tills, and where till does occur in cliff exposures it is sometimes deformed and is often associated with glaciofluvial deposits. So the mobilisation and redistribution of glacially derived materials was commonplace, and tells us much about the chaotic conditions that must have prevailed at a time of catastrophic ice wastage around 25,000 years ago.

There is just one known deposit in the study area that is clearly in a secondary position. As noted above, at Ragwen Point a grey clay-rich diamicton interpreted as a till is seen at beach level surrounded by sandy brown slope breccia mixed with colluvium. Both deposits have clearly slumped recently from higher up the cliff as a result of ongoing coastal erosion.

If the South Pembrokeshire tills were really re-deposited pre-Ipswichian glacial deposits they would almost certainly have been cemented (especially in carbonate-rich environments) and they would be expected to appear more or less randomly in Devensian slope deposits either as lenses or as erratic clusters. There is no such sedimentary association, although here and there (as at Whitesands) we find "boulder beds" associated with the raised beach (at the base of the Quaternary successions) and which may well be linked with destroyed Wolstonian or Anglian glacial deposits.

Conclusion

If Late Devensian ice from the N or NW covered the northern uplands of Pembrokeshire and had a surface elevation of c 1000m, it would make no sense for the ice edge to be at or near present sea level around the mid and south Pembrokeshire coast. Nor does it make any sense for an ice edge to be parked around the 200m contour in the vicinity of Wolfscastle

and Letterston, as suggested by the BGS (2010). If the ice was coming in from the NW, it MUST have inundated the whole of Pembrokeshire to the south of Preseli, given that the ice was dynamic and fast-flowing (Boulton & Hagdorn, 2006; Scourse *et al*, 2021). The ice edge might of course have been slightly lower on the southern flank of the uplands, once the disintegration of the Irish Sea Ice Stream had commenced.

The Preseli trimline is a subtle one, and the presence of thin local tills suggest that there was a Preseli ice cap early and late in the Devensian glacial cycle, as suggested in the modelling by Henry Patton *et al* (2017) in association with studies of the Welsh ice cap. The junction between the Preseli ice and the Irish Sea ice is unlikely to have been static, and it will be interesting to see what further fieldwork and modelling work might reveal.

The field evidence from the south Pembrokeshire coast and from inland sites suggests that the deposits tie in lithologically and stratigraphically with those of North Pembrokeshire, and there appears no reason to differentiate between them as the products of older and newer glacial episodes.

The simplest interpretation of the accumulating field evidence is that there was no Late Devensian ice-free enclave or corridor in south Pembrokeshire (Fig. 8). It is therefore suggested that the WHOLE of the peninsula was ice-covered around 26,000 years ago, and it is quite possible that the ice cover also extended across Carmarthen Bay and the Gower Peninsula. It is also suggested that there was no Early Devensian glacial episode that affected the Pembrokeshire peninsula. This was a time dominated by snowfields, permafrost and the accumulation of brecciated slope deposits.

It is hoped that this hypothesis will encourage further research, including the cosmogenic dating of erratics and exposed rock surfaces in Pembrokeshire. But here is another question: where are the glacial and related deposits that might be considered as the equivalents of the Wolstonian and Anglian unconsolidated strata described in eastern England?

Notes

I am grateful to Dr Bethan Davies for her helpful comments on the original draft of this article, and I have learned much from discussions with many of those whose works I have cited. I also thank members of the BRITICE-CHRONO team for consent to use a number of their published illustrations.

In this short paper it is not possible to detail the field evidence from multiple sites. However, detailed descriptions and interpretations from scores of named locations are contained in the author's blog site, via the search facility: https://brian-mountainman.blogspot.com/ The site is archived by the National Library of Wales as a resource for data and debate in the fields of Quaternary studies, glacial geomorphology and archaeology.

Appendix 1

Geographical coordinates for key locations: mentioned in the text:

Abermawr 51.970615, -5.082866
Amroth 51.730007, -4.663867
Ballum's Bay 51.637549, -4.678081
Broad Haven 51.787828 -5.103833
Bullslaughter Bay 51.610258, -4.976904
Camrose 51.83896, -5.00800
Ceibwr 52.07798, -4.76285
Cilgwyn 51.993226, -4.801698
Clunderwen 51.992041 -4.889001
Dale 51.787828 -5.103833
Druidston 51.813198, -5.103692
Flimston 51.612919, -4.988760
Flimston Claypits 51.617696, -4.995016
Freshwater West 51.663545, -5.065606
Huntsmans Leap 51.599311, -4.944953
Landshipping 51.765169, -4.888542
Llanddewi Velfrey 51.822520, -4.690913
Llandre 51.84822,-4.77129
Llangolman 51.908453, -4.740323
Llanteg 51.76123, -4.63508
Lydstep 51.643456, -4.764696
Maiden Castle 51.884524 -4.974400
Marloes 51.723541, -5.214248
Martletwy 51.760678, -4.845621
Mathry Road 51.940011, -5.023764
Mewsford Point 51.60603, -4.97217
Mullock Bridge 51.729463 -5.169435
Parrog 52.022244, -4.848200
Penblewyn 51.817070, -4.727234
Picton Point 51.768802, -4.896984
Pont Ceunant 51.999691, -4.849897
Porthmelgan 51.903608, -5.303722
Ragwen Point 51.735029, -4.580841
Rosebush 51.928104, -4.805773

Sandy Haven 51.723364, -5.102251
St Brides Haven 51.729463 -5.169435
Stackpole Head 51.611409, -4.900273
Stockpole Quay 51.623525, -4.901412
Stackpole Warren 51.611481, -4.914393
Swanlake 51.646656, -4.825613
Tafarn y Bwlch 51.965316, -4.792336
Templeton 51.771486, -4.741989
Trefgarn Gorge 51.880155, -4.967766
West Angle 51.685550, -5.106653
Westdale 51.708268, -5.186299
Whitesands 51.895342, -5.295662
Witches Cauldron 52.070961, -4.771064

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