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Reconnaissance of historic (post-AD 1000) high-energy deposits along the Atlantic coasts of southwest Britain, Ireland and Brittany, France

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Abstract

Sand and gravel deposits from the Atlantic coasts of southwest Britain, Brittany and western Ireland are identified as potential indicators of historic (post-AD 1000) ocean-sourced high-energy events, such as storm surges and tsunami. This is an important historic period as it includes the climatic perturbations of the Medieval Warm Period and the Little Ice Age, and also seismogenic events, such as the Lisbon tsunami of 1755. Ten new sites are identified from various coastal settings and dated using eight new radiocarbon dates alongside previously published data. Generally, sites do not appear to record multiple high-energy events, suggesting that either only the most extreme and/or recent events are registered. A number of radiocarbon dates from marine shell yield modern ages when corrected for the marine reservoir effect. Rather than necessarily indicating recent deposition, this may reflect a poor understanding of terrestrial carbon input into coastal and estuarine waters, and the practice of applying broad regional ΔR values at the local scale. Two groupings of radiocarbon dates are recognised; a *Medieval Group* and a *Post-Medieval Group*, which might reflect events within known climatic perturbations and/or tsunami occurrences. These events may include the Lucia Flood of 1287, the All Saint's Day Flood of 1570, the 1607 Flood, the Great Storm of 1703, and the Lisbon tsunami. Some older (pre-AD 1000) deposits indicate the potential to construct frequency/magnitude records of high-energy events throughout the Holocene. Data presented here support the view that salt marshes within the Bristol Channel and Severn Estuary were completely eroded away early in the 17th century.

Keywords: high-energy deposits; Bristol Channel; Severn Estuary; Brittany; tsunami; storm surge

1. Introduction

The Atlantic coast of northwest Europe is affected by ocean-sourced high-energy events, such as storm conditions (Lamb, 1991) and, to an unknown but lesser extent, tsunami (Dawson et al., 2004; Bryant and Haslett, in press). Both are known to have impacted the physical landscape and human infrastructure of the region (Lamb, 1991; Dawson et al., 2004). The occurrence of such high-energy events is relatively well recorded for the last few centuries. However, historical meteorologists have poured over diaries and other obscure documents to establish older historic events (Lamb, 1991). Here we explore the archive provided by the sedimentary record

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along wave-dominated coasts of southwest Britain, Ireland and Brittany, specifically searching for high-energy deposits laid down within the post-AD 1000 period with a view to identifying sites for further investigation and ultimately adding to our understanding of the frequency and magnitude of high-energy events within the region. The post-AD 1000 period is particularly interesting as it includes known climatic perturbations, such as the Medieval Warm Period (Hughes and Diaz, 1994) and the Little Ice Age (Grove, 2004), and as well as the 1755 Lisbon seismogenic tsunami that is known to have affected the region (Chester, 2001).

Of particular interest to us is the Bristol Channel and Severn Estuary, in southwest Britain (Fig. 1), which together comprise a funnel-shaped embayment that possesses a tidal range in excess of 14 m. This coastal configuration and tidal setting enhances surge heights related to storms tracking east and northeastward through the region and so may be especially sensitive to Atlantic high-energy events. A number of historic storms have produced surges that have caused widespread flooding in adjacent coastal wetlands, such as in 1703 and 1981 (Proctor and Flather, 1989). The most severe historic coastal flood to affect this region occurred on 30th January 1607, which many historic writers consider to have been caused by a storm. However, Bryant and Haslett (2003) review contemporary accounts, alongside published physical anomalies from the region, and raise the possibility that the 1607 flood was due to a tsunami. Although this theory has been much debated recently (e.g. DEFRA, 2005; Eldred, 2005; Haslett and Bryant, 2005; Keys, 2005; McGuire, 2005; Robinson, 2005; Horsburgh and Horritt, 2006; Bryant and Haslett, in press), it is clear that, whether due to a storm or tsunami, the Bristol Channel and Severn Estuary have experienced infrequent historic high-energy events and that the geomorphic and/or stratigraphic signatures of these may be present in the coastal landscape. Identifying and analysing such signatures may also provide an understanding of the particular physical impacts of such events in the region and, in the case of the 1607 flood, may offer a means of identifying its cause.

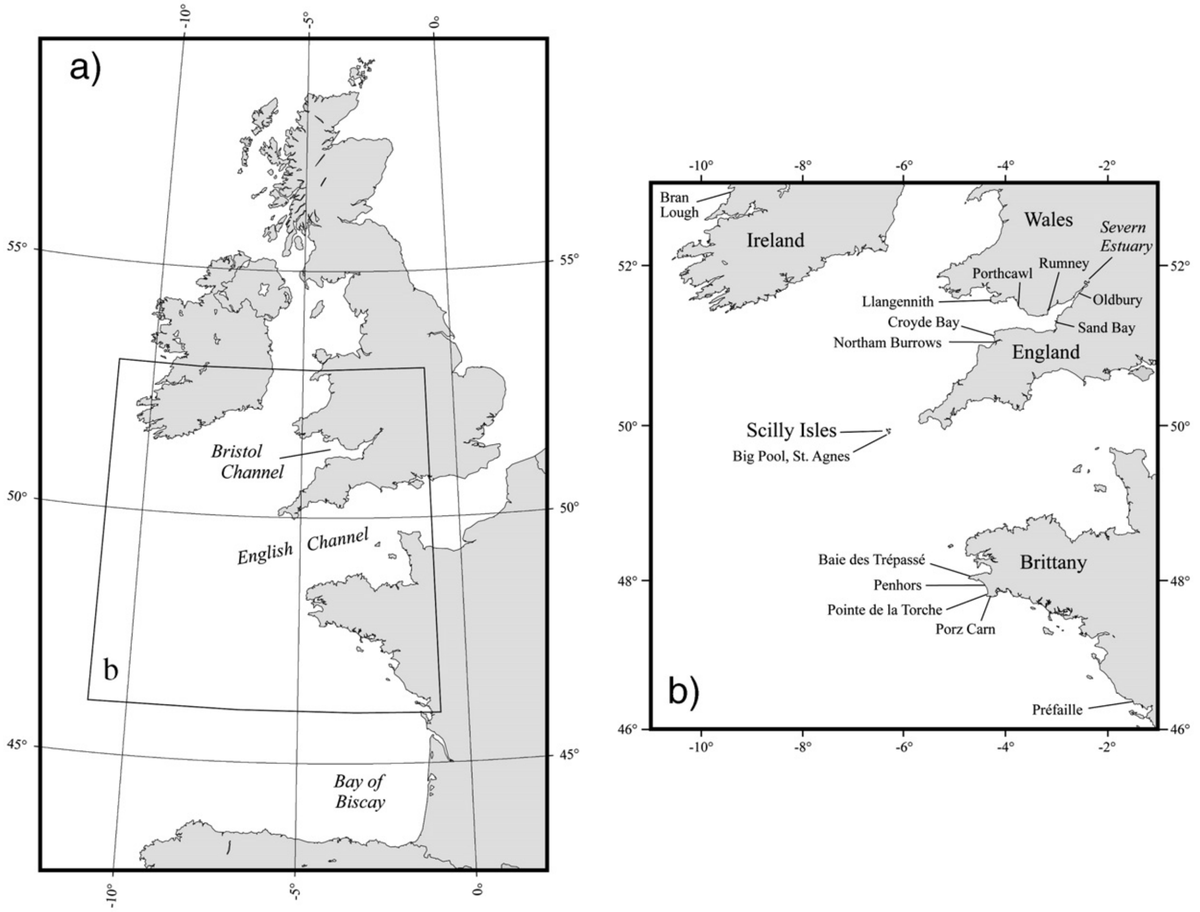

Fig. 1. The (a) general location and (b) the study area and sites mentioned in the text.

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Relatively coarse sediment layers occurring in coastal deposits have generally provided a signature of the impact of high-magnitude, low frequency events, such as a storm or tsunami (Clague and Bobrowsky, 1994; Dawson, 1994; Pinegina et al., 1996). These sediment layers occur either covering or embedded within coastal plains, marshes, dunes and cliffs, with a thickness typically ranging from 1 to 40 cm. For tsunami, the lowest wave heights that can unequivocally generate these deposits are about 1.5 m in height. This is enough to overwash flat coastlines and marshes, and potentially lay down spatially coherent layers of sediment both alongshore and inland. The majority of these deposits consist of sand, although silt, gravel (including boulders) and even muds have been noted (Goff and Chagué-Goff, 1999). The recent 2004 Indian Ocean tsunami event, in many places evinced this signature laying down a sand layer up to 0.70 m thick in Sumatra and 0.25 m thick in Sri Lanka. However, in Thailand, the tsunami laid down sand layers only a few centimetres thick despite having flow depths in excess of 3 m. Storm surges may locally produce similar deposits in flooded areas and, additionally, layers of aeolian transported sediment may also be associated with storms. Therefore, although variable in terms of texture and thickness, such sediment layers may provide evidence for the minimum spatial extent of the impact of historic high-energy events.

The general aim of this paper is to undertake a reconnaissance study to identify and initially evaluate sites that may potentially provide evidence of high-energy coastal events within three areas of NW Europe (Fig. 1); southwest Britain (Bristol Channel, Severn Estuary, and Scilly Isles), Brittany (northwest France), and Ireland. This is achieved here through:

1. Basic field descriptions of sites with information of the general physical setting (including an estimation of elevation), stratigraphy, palaeontology and archaeology where appropriate.
2. Preliminary dating of most deposits through radiocarbon assay on samples collected in the field.
3. Preliminary exploration of depositional setting of suitable deposits through laboratory-based micropalaeontological techniques, particularly the palaeoenvironmental potential of foraminifera in these contexts.
4. Consideration of some previously published sites alongside those newly identified in the field reconnaissance.

A goal of this study is to provide an inventory of sites that indicate potential high-energy deposits that warrant future systematic analysis, including precise altitudinal and topographic surveying, detailed palaeoenvironmental analyses, rigorous dating using a variety of methods, such as chemostratigraphy and Optically Stimulated Luminescence (OSL) in addition to standard and Accelerator Mass Spectrometry (AMS) radiocarbon techniques. Such a systematic treatment of the new sites presented here is some years off, although two are already underway, and therefore the timely publication of this reconnaissance will contribute to the ongoing debate and add valuable preliminary data that will assist future research into high-energy deposits in NW Europe.

2. Southwest Britain

Seven new sites with potential high-energy deposits are identified from this area, from Croyde Bay and Westward Ho! in north Devon; Llangennith, Porthcawl and Rumney in South Wales; Oldbury-on-Severn in Gloucestershire; and Sand Bay in Somerset (see Fig. 1). In addition, Big Pool, a previously published site from St. Agnes on the Scilly Isles, is included.

2.1. Croyde Bay

Croyde Bay comprises a large beach and dune system bounded north and south by rocky headlands of Devonian metamorphics mantled in places by Pleistocene raised beach and head deposits (Greenwood, 1972). On the southern shore of the bay a 0.33 m thick coarse shelly sand and gravel deposit (Fig. 2a) occupies a 4.1 m deep ledge eroded into cliffs of Pleistocene head that rise a further 1.95 m in height behind the ledge. The deposit occurs 1.42 m above the rock platform that itself is positioned high in the tidal frame and locally vegetated with terrestrial plants. However, remnants of the shelly sand and gravel deposit occur on the high platform, extending 18.6 m seaward of the cliff face, suggesting a formerly much larger extent of the deposit, possibly reaching a maximum thickness of 1.75 m. The deposit appears to be relatively unstratified with gravel clasts floating in a shelly sand matrix, although there is an overall concentration of coarser material towards the base of the deposit. Examination of a sediment sample under reflected light microscopy revealed fragments of marine molluscs that show signs of etching and dissolution, suggesting that the sediment has been exposed to subaerial weathering for some time since deposition. Indeed, smaller calcareous components, such as foraminifera, appear to have been removed by dissolution. An intact specimen of the relatively large marine mollusc *Littorina littorea* was collected *in situ* from just above the basal contact with the underlying head and submitted for radiocarbon dating (Table 1),

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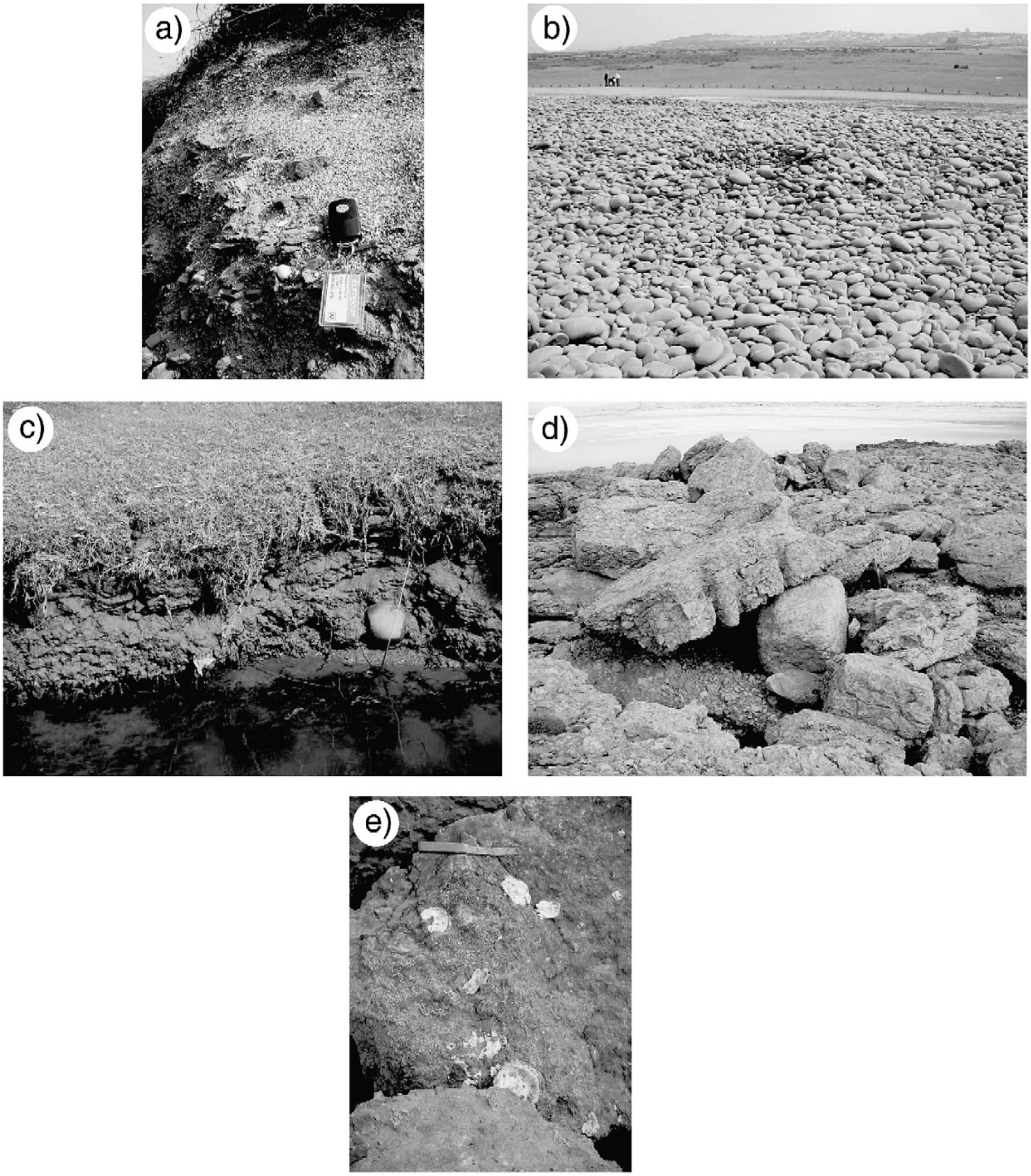

Fig. 2. a) Cliff section of coarse shelly sand deposit at Croyde, southwest Britain, taken in September 2004 (note car keys for scale); b) view east across the back-barrier salt marsh at Westward Ho!, southwest Britain, taken from the crest of the Westward Ho! gravel barrier in September 2004; c) gravel stratified in salt marsh deposits at Westward Ho!, southwest Britain, taken in September 2004 (the large gravel clast is c. 0.15 m in diameter); d) an accumulation of boulders at Sker Point, Porthcawl, southwest Britain, deposited above HAT, taken in April 2005 (note the backpack used for scale is 0.38 m tall by 0.28 m wide); e) oyster shells adhering to boulders at Sker Point, Porthcawl, southwest Britain, taken in April 2005 (note bent spatula for scale is 0.25 m long and the handle is 0.025 m wide).

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yielding a date of 400±40 BP. However, when the marine reservoir correction is applied (with ΔR 22±54) the date is modern.

2.2. Westward Ho! (Northam Burrows)

An extensive salt marsh system lies sheltered behind the north–south orientated Westward Ho! gravel barrier (May, 2003a) on the southern shore of the Taw-Torridge Estuary (Fig. 2b). Tidal access to the marsh is via a tidal creek situated to the east of the barrier, so that high marsh occurs immediately behind the barrier with the intertidal surface descending to the east. From three 1 m cores taken in the marsh, 118–150 m east of the barrier, the sequence within the top 1 m comprises mainly grey silty-clay, but with a distinct fine to medium sand layer, which spans 0.44–0.55 m depth. Under reflected light microscopy, the grey silty-clay contains a similar foraminifera assemblage to that seen in a sample from the modern salt marsh including *Ammonia beccarii limnetes*, *Elphidium williamsoni*, and *Haynesina germanica*, and therefore represents salt marsh deposition. Foraminifera from the sand layer, however, include *Ammonia beccarii batavus*, *Asterigerinata mamilla*, *Cibicides lobatulus*, and *Elphidium macellum*, all inner shelf species (Murray, 1979) and similar to those found in a sample from the contemporary beach in front of the barrier, which only differs in that *Quinqueloculina* spp also occur. The barrier often is breached, most recently in 1962 (Keene, 1997), and the sand layer documented here may record one such event, with inner shelf sediment being transported through the barrier onto the back-barrier marsh surface. Furthermore, the modern tidal creeks possess a scattered cobble lag on their bed and occasionally these cobbles can be seen eroding out of the salt marsh sequence. The example shown in Fig. 2c occurs at a depth of 0.5 m in the sequence, i.e. at a similar depth to the sand layer, but 700 m east of the barrier. However, human agency cannot yet be excluded as an explanation for the occurrence of isolated gravel clasts within the salt marsh system.

2.3. Llangennith

Llangennith is situated in the west of the Gower Peninsula in South Wales on the eastern shore of Carmarthen Bay (May, 2003b) in the Bristol Channel. The coast is characterised by a north–south orientated beach–dune system behind which a wetland called Llangennith Moors has formed. An east–west transect of 1 m cores was made across Llangennith Moor with

Table 1
Radiocarbon dates calibrated using the CALIB 5.0.2 programme (Stuiver et al., 2005) that uses INTCAL04 (Reimer et al., 2004) and regional ΔR values (Hughen et al., 2004; Stuiver et al., 2005)

Site	Material	Lab code	^{14}C age	2σ calibration (INTCAL04)	Source
Southwest Britain					
Bristol Channel/Severn					
Estuary sites					
Croyde	Shell	Beta-207016	400±40 BP	Invalid date	This study
Llangennith	Peat below sand layer	Beta-207019	210±40 BP	AD 1530–1952	This study
Oldbury	Wood	Beta-207021	180±40 BP	AD 1649–1953	This study
Rumney	Bone	Beta-206730	150±40 BP	AD 1666–1953	This study
Porthcawl	Shell	Beta-207023	450±40	Invalid date	This study
Scilly Isles					
Big Pool (St. Agnes)	Top of sand layer	BP-22S	260±40 (OSL dated)	AD 1700–1780	Banerjee et al. (2001)
Big Pool (St. Agnes)	Base of sand layer	BP-90S	380±60 (OSL dated)	AD 1560–1680	Banerjee et al. (2001)
Brittany					
Penhors	Shell	Beta-145237	410±60	Invalid date	This study
Pointe de la Torche	Shell	Beta-145238	520±70	AD 1635–1955	This study
Préfaille	Shell	Beta-132555	260±80	Invalid date	This study
Porz Carn	Shell	GIF-891	1100±90	AD 1070–1428	Giot (1998)
Baie des Trépassé	Peat below sand layer	Beta-57658	840±70	AD1068–1265	Devoy et al. (1996)
Western Ireland					
Bran Lough	Peat above sand layer (core 1)	Beta-62536	360±60 BP	AD 1443–1645	Devoy et al. (1996)
Bran Lough	Peat below sand layer (core 1)	Beta-62537	530±60 BP	AD 1296–1453	Devoy et al. (1996)
Bran Lough	Peat below sand layer (core 4)	Beta-62538	570±60 BP	AD 1293–1436	Devoy et al. (1996)

All shell samples are assumed to be 100% marine carbon.

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Core 1 situated c. 150 m behind the dunes, then four more cores extending east in 30 m intervals across the Moor, producing a 120 m transect. The lithostratigraphy comprised an upper sandy-clayey peat (0.17–0.25 m thick) and a grey-brown sand layer with rusty mottling (0.05–0.13 m thick), underlain by a dark-brown peat. A sample was collected from the top of the lower peat at the contact with the sand layer (Table 1) that yielded a date of 210±40 BP (AD 1530–1952). Microscopic analysis of the sand found subrounded quartz, iron concretions and, as expected with acid bog conditions, no calcareous marine microfossils.

2.4. Porthcawl

Porthcawl is a town situated on the northern shore of the Bristol Channel in South Wales, where to the west of the town a series of Carboniferous Limestone headlands produce an overall northwest–southeast trending coastline (Wilson et al., 1990). The most northwesterly headland is Sker Point where a rock platform supports an extensive imbricated boulder deposit that extends above the level of Highest Astronomical Tide (HAT). Fig. 2d shows large imbricated boulders deposited in the splash zone above HAT as indicated by the growth of *Xanthoria parietina* (orange) lichen that characterises this zone (Cremona, 1988). The lichens are of a relatively large size suggesting the boulders were perhaps emplaced in the splash zone some time ago. These boulders are anomalous here as the local transported beach deposits typically contain cobble and small boulder sized material (Bluck, 1967). On one of the smaller boulders in a boulder accumulation, the remains of oyster shells were found still adhering to the boulder surface (Fig. 2e). A sample was radiocarbon dated (Table 1) and yielded a date of 450±40 BP, which when the marine reservoir correction is applied (with ΔR 22±54) is modern.

2.5. Rumney

Rumney Great Wharf is a salt marsh on the northern shore of the Severn Estuary in South Wales, near to the city of Cardiff. The salt marsh lies seaward of a flood defence wall that protects the low-lying area of the Gwent Levels from marine inundation. The salt marsh is actively eroding and the resulting cliff exposures have been described in detail by Allen (1987). A lower laminated grey silty-clay representing largely pre-Roman (c. 2000 cal. yr BP) estuarine deposition is overlain by post-Medieval brown salt marsh silts. Within these silts, a distinct dark coarse sand layer occurs with thinner partings and an undulating surface (Fig. 3a). It is moderately well sorted, but small clasts of gravel, marine shells, occasional bone and teeth are seen floating in the coarse sand matrix. A sheep's tooth was collected for radiocarbon dating (Table 1) from the sand layer 0.7–0.82 m below the modern salt marsh surface and yielded a date of 150±40 BP (AD 1666–1953).

2.6. Oldbury-on-Severn

Oldbury-on-Severn is situated on the English side of the Severn Estuary, with a similar coastal context to Rumney Great Wharf, described in detail by Allen and Fulford (1992) with a lower laminated grey silty-clay overlain by brown post-Medieval salt marsh sediments underlying the modern salt marsh surface. The contact between these two units represents a historic agricultural land surface that was abandoned with sea defence set-back in the post-Medieval period. However, numerous clasts of rounded gravel occur scattered on this historic land surface and can be seen eroding out of the modern salt marsh cliffs at the stratigraphic contact between the lower and upper units (Fig. 3b). A wooden stake is also seen eroding out of the cliff and appears to have been driven from the historic land surface into the lower grey silty-clay. The stake appears subsequently to have been snapped off at palaeo-ground level, i.e. at the stratigraphic contact, and, therefore, may immediately predate the abandonment of the historic land surface (Fig. 3c). A sample of wood was collected from the stake for radiocarbon dating (Table 1) and yielded a date of 180±40 BP (AD 1649–1953). Microscopic analysis of the brown silty-clay immediately above the stratigraphic contact yielded *Ammonia beccarii*, *E. williamsoni* and *H. germanica*, foraminifera typical of low to mid salt marsh environments.

2.7. Sand Bay

Sand Bay is situated on the southern shore of the outer Severn Estuary and comprises a 2 km long, fine sand beach fringing an extensive mudflat bounded to the north and south by the Carboniferous Limestone headlands of Sand Point and Worlebury respectively (Whittaker, 1983). At the northern end of the bay salt marsh has developed and is prograding seaward. At the southern end, however, a 1.2 m thick, stratified, coarse-clastic deposit forms a 25–35 m wide, vegetated terrace that lies 2.3 m above HAT. The deposit is overlain by a 0.2 m accumulation of dune sand. Modern beach deposits are banked up in front of the cliff face (Fig. 3d). Neither shell nor archaeological material has yet been dated from the deposit, but given its altitude it is possible that it is a historic high-energy deposit.

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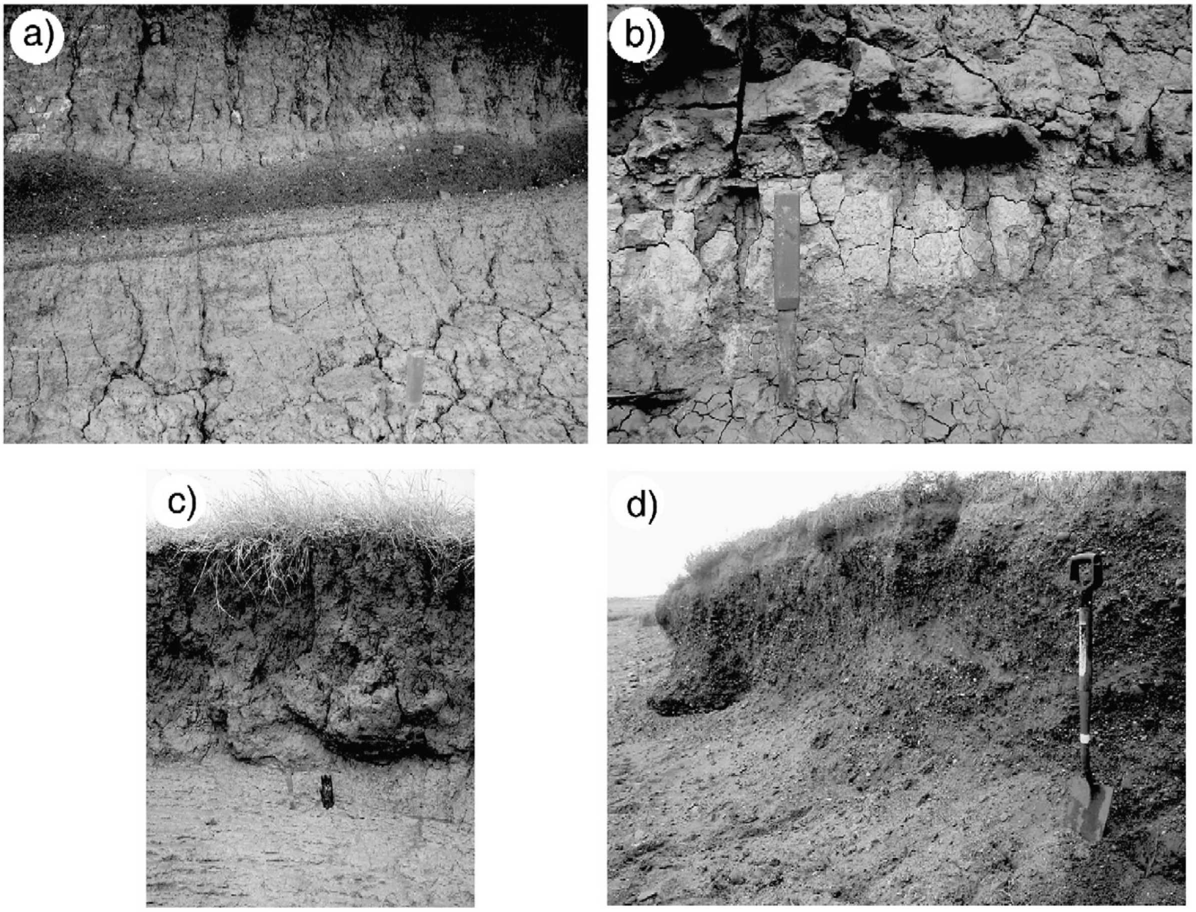

Fig. 3. a) Cliff section of coarse sand layer(s), with undulating upper surface, in salt marsh silts at Rumney, southwest Britain, taken in September 2004 (note the handle of the bent spatula for scale is 0.025 m wide); b) cliff section showing gravel clasts at the lithological contact between the underlying Romano-British Wentlooge Formation and overlying post-Medieval salt marsh silts at Oldbury, southwest Britain, taken in September 2004 (note the handle of the bent spatula for scale is 0.025 m wide); c) cliff section showing a wooden post severed coincident with the lithological contact between the underlying Romano-British Wentlooge Formation and overlying post-Medieval salt marsh silts at Oldbury, southwest Britain, taken in September 2004 (note the handle of the bent spatula for scale is 0.025 m wide); d) cliff section through gravel deposit at Sand Bay, southwest Britain, taken in May 2006 (note spade for scale is 0.97 m long).

2.8. Big Pool

Big Pool is a freshwater lagoon situated landward of dunes on the coast of St. Agnes, a granite island in the Scilly Isles archipelago offshore southwest Cornwall (Fig. 4a). Sediments deposited in the pool have been described by Foster et al. (1991) who record >1 m sequence comprising a 68 cm thick marine sand layer occurring between lower and upper peats. They obtained radiocarbon dates for the peats in order to constrain the age of the sand layer, however, Banerjee et al. (2001) acquired Optically Stimulated Luminescence (OSL) ages on the bottom and top of the sand layer itself (Table 1). These dates indicate that the sand layer was deposited between 380±60 and 260±40 yr BP i.e. AD 1560–1780.

3. Brittany, France

Three new sites with high-energy deposits are described from this area, from Penhors, Pointe de la Torche, and Préfaille along the Atlantic coast of Brittany (see Fig. 1). In addition, the previously published sites of Porz Carn and Baie des Trépassé are also included.

3.1. Baie des Trépassé

This site is located on the tip of Cap Sizun a large granite promontory on the western coast of Brittany. It consists of a sandy bay-head beach with backing dunes (Fig. 4b) and a freshwater back-barrier lagoon with the headlands of Pointe du Van and Pointe du Raz to

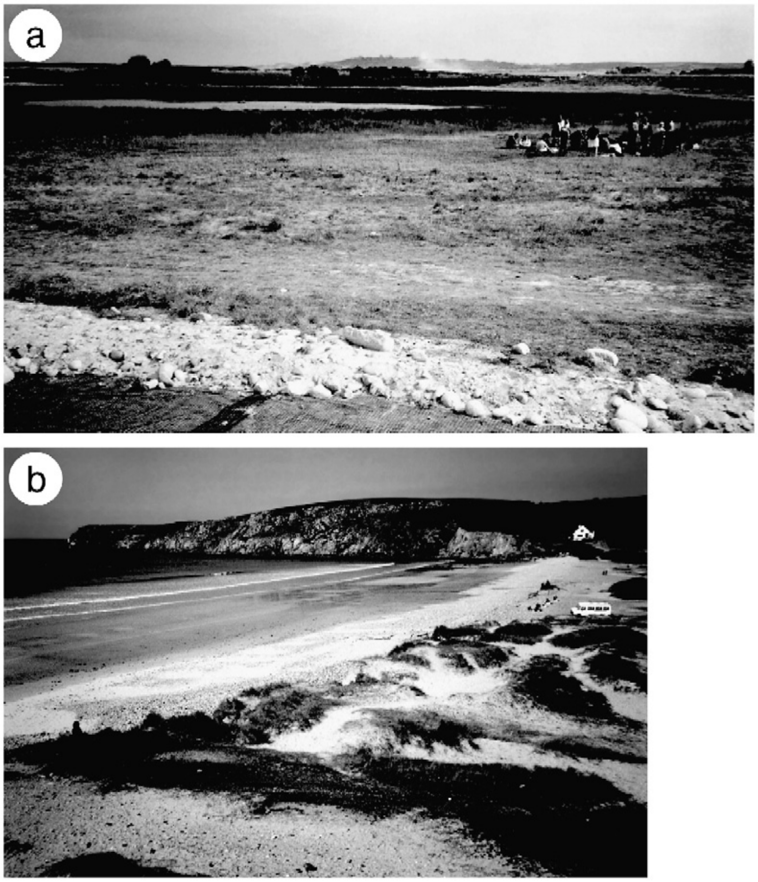

Fig. 4. a) View of Big Pool, St. Agnes, Scilly Isles, southwest Britain, taken in September 1996; b) view north across the beach–dune system of Baie des Trépassés, Brittany, taken in March 1996.

the north and south respectively. Devoy et al. (1996) report a radiocarbon date from peat at the contact below an apparently marine sand layer within the back-barrier lagoon. The date returned is 840±70 BP (AD 1068–1265).

3.2. Penhors

Penhors is situated within the Baie d'Audierne on the western coast of Brittany and lies at the transition within the bay between the erosion-dominated northern headland of Pointe du Raz and the central depositional zone of the bay. Here cliffs rising to c. 5.44 m NGF (Nivellement Général de la France that represents mean sea level at Marseilles) expose a palaeo-shore platform eroded into metamorphic schist (Haslett and Curr, 1998) upon which c. 1.5 m of Quaternary deposits have accumulated. These include 0.15 m of a frost-shattered Eemian beach lying on the basement, passing up into 0.35 m thick Weichselian solifluction 'head' deposits (Haslett and Curr, 2001). This Pleistocene sequence is capped by 1 m of stratified Holocene dune sands with two layers of rounded gravel (small pebbles and shingle) spanning 0.75–0.85 m and 0.4–0.6 m depths (Fig. 5a). The dune sand contains a rich terrestrial gastropod fauna similar to that described from a nearby sequence by Haslett et al. (2000). A sample of the upper gravel layer yielded a sparse marine mollusc fauna comprising 49 specimens of *Gibbula umbilicalis*, six *Patella vulgata*, five *Littorina littoralis*, and four *Nucula lapillus*, species that inhabit the modern foreshore at Penhors. Specimens were submitted for radiocarbon dating and yielded a date of 410±60 BP, which when the marine reservoir correction is applied (with $\Delta R - 20 \pm 44$) is modern (Table 1).

3.3. Pointe de la Torche

This site is situated on a small granite peninsula towards the southern end of the Baie d'Audierne in western Brittany, c. 10 km south of Penhors. Quaternary deposits approximately 1.6 m thick are seen in a low cliff resting on

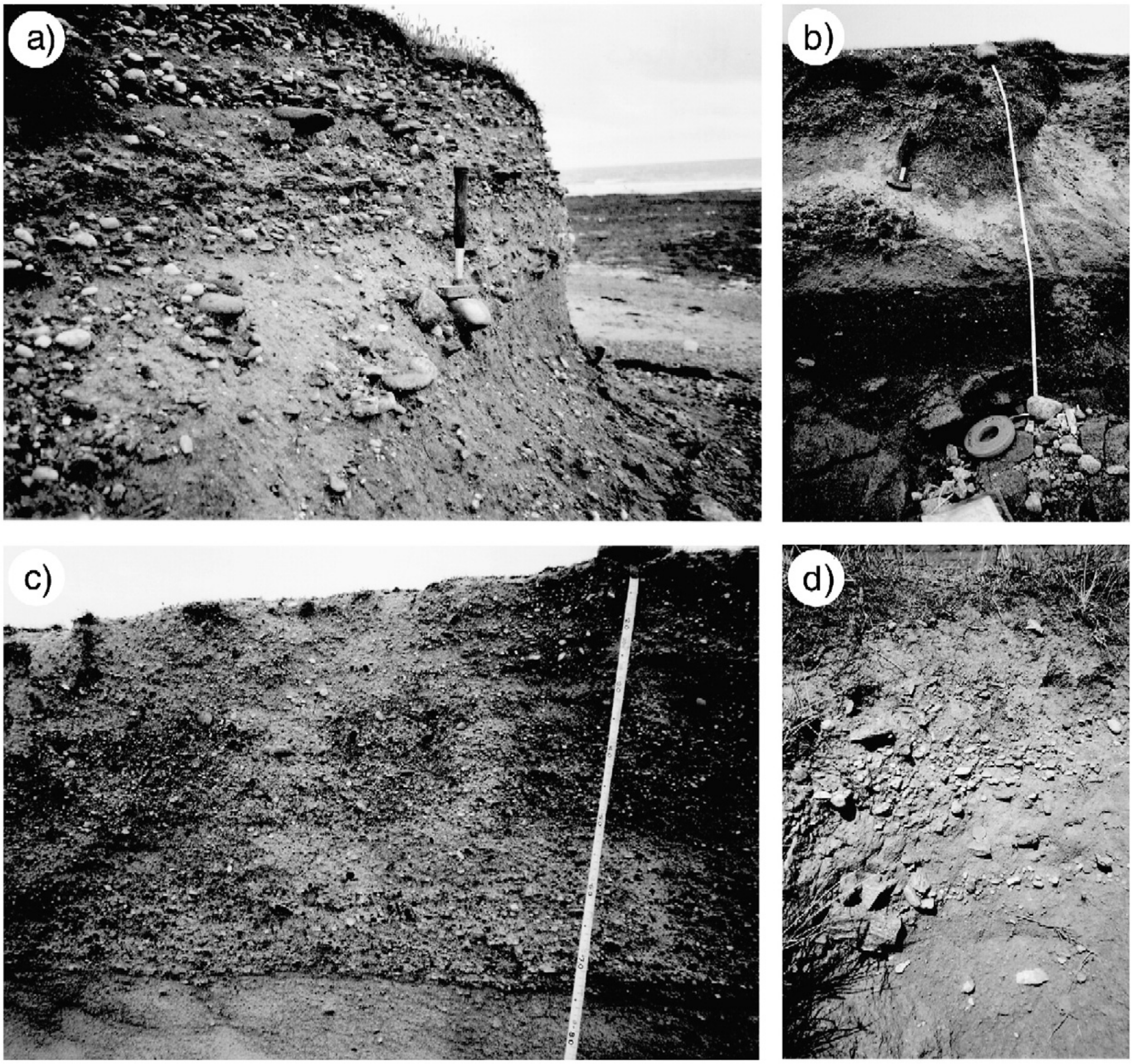

Fig. 5. a) Cliff section through cliff-top gravel deposits at Penhors, Brittany, taken in July 2000 (note the hammer for scale is 0.28 m long and the head is 0.115 m long); b) cliff section through cliff-top gravel deposits at Pointe de la Torche, Brittany, taken in April 1996 (note the hammer for scale is 0.28 m long and the head is 0.115 m long); c) section through intra-dune gravel deposits at Porz Carn, Brittany, taken in April 1996 (0.82 m of the measuring tape is shown, which is 0.012 m wide); d) cliff section showing gravel deposits at Préfaille, Brittany, taken in July 1997 (note coin for scale is 0.025 m in diameter).

a granite palaeo-shore platform, comprising 0.35 m of Pleistocene head overlain by 0.65 m of gastropod-rich dune sand and capped by a 0.50 m unit of gravel and sand containing marine molluscs (Fig. 5b). A sample of the gravel unit yielded 34 specimens of *Littorina littoralis*, 30 *Gibbula umbilicalis*, eight *P. vulgata*, and seven *Nucula lapillus*. Specimens were submitted for radiocarbon dating and yielded a date of 520±70 BP, which when the marine reservoir correction is applied (with $\Delta R - 20 \pm 44$) returns a calendar age of AD 1635–1955 (Table 1). The gravel is topped by 0.1 m of modern dune sand, but the site is deflating due to ground-surface erosion caused by intense tourist usage.

3.4. Porz Carn

Porz Carn is a small sandy embayment adjacent to Pointe de la Torche at the southern end of the Baie d'Audierne, with the granite headland of Penmarc'h lying immediately to the south (see Fig. 1). The bay-head beach is backed by an extensive dune system that is scarped in places. A gravel layer up to c. 0.78 m thick was described

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by Giot (1998) interbedded within the dune and comprising small pebbles and shingle with occasional marine molluscs (Fig. 5c). A radiocarbon date from shell yielded a date of 1100±90 BP, which when the marine reservoir correction is applied (with ΔR −20±44) returns a date of AD 1070–1428 (Table 1).

3.5. Préfaille

Préfaille is located near the town of Pornic along the southeast Brittany coast of the Bay of Biscay. Here a similar morphostratigraphic situation to that of Penhors and Pointe de la Torche occurs with Quaternary deposits overlying a palaeo-shore platform eroded into metamorphic basement. Two discrete layers of small quartz pebbles occur within a 0.7 m thick soil profile (a section of which is shown in Fig. 5d) exposed in the 4 m NGF cliffs along the Corniche de la Roche and elsewhere. The upper and thicker gravel layer yielded marine mollusc specimens of *L. littorea*, *Mytilus edulis*, *Ostrea edulis* and *P. vulgata*. Specimens were submitted for radiocarbon dating and yielded a date of 260±80 BP, which when the marine reservoir correction is applied (with ΔR −20±44) is modern (Table 1).

4. Western Ireland

Devoy et al. (1996) identify a sand layer interbedded within peat in a back-barrier wetland setting at Bran Lough in western Ireland. One radiocarbon date from above, and two from below, the sand layer (at contacts with peat) have been obtained. The details are given in Table 1, but it would seem that the sand layer was emplaced from a marine source (Devoy et al., 1996) between AD 1293 and 1645.

5. Discussion

The character of the potential high-energy deposits identified in this reconnaissance study varies from sands-to-gravels of various sizes. The sand layers contrast distinctly from the autochthonous peats of the back-barrier wetlands and the silts of the salt marsh environment. From the preliminary, and previously published, data presented here it appears that the sand layers at Rumney, Big Pool, Baie des Trépassés, and Bran Lough represent the high-energy incursion of marine waters into marsh and back-barrier wetland settings, whilst the sand layer at Llangennith may alternatively represent the aeolian reworking of sands from seaward dunes during a storm. The gravel deposits contrast also with the silty salt marsh, sandy dune and soil sequences in which they occur and, unlike sand, their emplacement may only be readily explained by high-energy wave activity. Boulder accumulations, such as at Porthcawl, are evidence of such activity at the coast, whilst cliff-top gravels, such as at Croyde, Penhors, Pointe de la Torche, and Préfaille, and gravel layers stratified in dunes (i.e. Porz Carn) and wetland deposits (i.e. Oldbury) attest to the possible overtopping and inland penetration of high-energy waters.

Generally, sites do not appear to record multiple high-energy events. Although a few sites, such as Penhors and Préfaille, display two gravel layers, the lower is always the thinnest, which suggests the pair could have been deposited by different waves within the same event, as is known to occur with tsunami (Bryant, 2001). It seems that the post-AD 1000 sedimentary archive in the region records either only the most extreme high-energy events, and/or the most recent event, eroding previous deposits. If this were not the case, one would expect more numerous high-energy deposits to occur both spatially and temporally within stratigraphic sequences.

To explore the timing of deposition of the high-energy deposits identified here it is necessary to consider first the marine carbonate derived radiocarbon dates separately from dates obtained from terrestrial organic material. This must be done because there are difficulties in correcting marine carbonate samples for the marine reservoir effect from coastal and, indeed, estuarine settings where the influence of freshwater inflow and terrestrial runoff into coastal waters is poorly understood. These effects on shell carbon should be quantified for individual estuaries (Ulm, 2002). In such settings, it is likely that applying the marine reservoir correction factor will yield calendar ages that are too young.

Fig. 6a displays radiocarbon ages for dates obtained from samples of terrestrial organic matter (i.e. peat, wood, and bone). There appear to be three groups of events, a recent group from the Bristol Channel and Severn Estuary (i.e. Rumney, Oldbury and Llangennith), and two older events defined by the dates from Bran Lough and Baie des Trépassés. Fig. 6b shows radiocarbon dates from marine shells, uncorrected for the marine reservoir effect. At least two groups of events are discernible, with an older event defined by the sample from Porz Carn, and a recent group comprising (oldest to youngest dates) Pointe de la Torche, Porthcawl, Penhors, Croyde, and Préfaille. This recent group may be subdivided further as the ages for Pointe de la Torche and Croyde/Préfaille do not overlap, but only by 10 radiocarbon years in the case of Croyde. However, given the uncertainty of the marine reservoir effect and the fact that the corrected and calibrated calendar age for the

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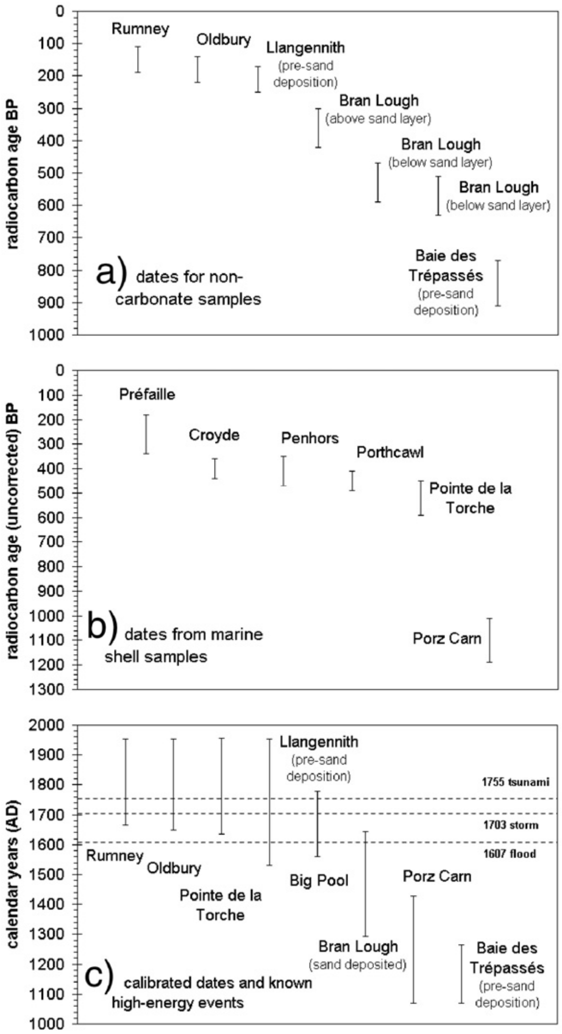

Fig. 6. Plots of a) non-carbonate radiocarbon dates, b) dates from marine shell samples, and c) calibrated dates with known high-energy events indicated (see text for discussion).

Pointe de la Torche sample spans AD 1635–1955, there seems little point in making this subdivision. This group can be considered as one.

Fig. 6c plots the calibrated calendar ages of radiocarbon and OSL dates from Table 1. Four shell dates had to be omitted, because, when they were corrected for the marine reservoir effect, they returned modern dates. This information should be used to formulate future field strategies for the collection and dating of shell material, because unless the sample is sufficiently old a modern date will result. This is clearly a flaw in radiocarbon analysis and one that should be addressed, particularly in dating samples from less than normal marine conditions, where terrestrial carbon may influence the dates (Ingram and Southon, 1996; Ulm, 2002). Indeed, in Queensland estuaries, Ulm (2002) noted that the ΔR value could be up to -155 ± 55, which could significantly affect calibrated results. For example, if this extreme is applied to the radiocarbon date obtained here for shells collected at Pointe de la Torche, the calibrated age changes from AD 1635–1955 to AD 1459–1846. Additionally, if an allowance is made for the incorporation of terrestrial carbon by up to 30% in the shell then a yet older date is returned of AD 1426–1691. On this basis, even the sample from Préfaille, that returned a modern date, yields an age range of AD 1676–1955. Corrected radiocarbon ages of marine shell could be very sensitive to the local correction factor, which at present is often applied at a very broad regional scale.

The calibrated dates in Fig. 6c indicated two groupings: 1) a *Medieval Group* comprising Baie des Trépassés and Porz Carn in Brittany that indicate a high-energy event(s) occurring between the late 11th to early 16th century; and 2) a *Post-Medieval Group* comprising Big Pool, Llangennith, Pointe de la Torche, Oldbury and Rumney that record high-energy events from the late 16th century to the present day. Bran Lough is an exception as the timing of the event that is recorded there, by peats above and below a sand layer, spans the two groups. At the coarse scale, these groups may be expressing events related to major variations of climate, such as the Medieval Warm Period and the Little Ice Age. The Medieval period along the Brittany coast is noted for its massive storms, two of which may be significant here. The Lucia Flood storm of 14 December 1287 significantly eroded marshland in northern France, whilst the All Saints Flood of 1–6 November 1570 affected most of western Europe, killing an estimated 400,000 people (Lamb, 1982; Bryant, 2005).

Although each one of the deposits plotted on Fig. 6c may represent a distinct high-energy event, it is interesting to compare these with known post-medieval events. These comprise the devastating coastal flood of 1607 (Bryant and Haslett, 2003), the Great Storm of 1703 (Brayne, 2003), and the tsunami generated by the Lisbon earthquake of 1755 (Chester, 2001), and are indicated on Fig. 6c. As a minimum, such an exercise assists in the elimination of candidate events, so that it is possible that the Rumney sand layer and the Oldbury and Pointe de la Torche gravel layers were deposited as a result of either the 1703 storm or 1755 tsunami. The sand layers at Llangennith and Big Pool may also have been deposited by these events, but it is also possible that they are the result of the 1607 flood. It is interesting to note that Foster et al. (1991) and Banerjee et al. (2001) consider the Big Pool sand layer to have been deposited by the 1755 tsunami. However, such a precise attribution is not justified on chronological grounds alone. The Bran Lough sand layer may have been deposited by the 1607 flood event, but it could equally well be assigned to the event(s) represented by the older Medieval Group. As with the problems outlined above regarding dating shell material, it appears that little chronological clarity is gained in radiocarbon dating post-medieval samples as the 2σ range can span the last 500 years (e.g. Llangennith). However, some dates do appear to discriminate between the 1607 and later events.

Given the geographical location of the Post-Medieval Group of sites and the relatively firm association of the Big Pool sand layer with the 1755 tsunami (Foster et al., 1991; Banerjee et al., 2001), it does not seem unreasonable to suggest that the high-energy deposits at the Breton sites (Pointe de la Torche, Penhors and Préfaille) may also have been deposited by the 1755 tsunami, which is supported to some extent by the detailed stratigraphy of the deposits and the fact that this coast is known to have been impacted by the tsunami (McGuire, 2005). Although the 1755 tsunami also impacted parts of the South Wales coast, it is perhaps more likely that the high-energy deposits identified at Llangennith, Oldbury, Rumney, Porthcawl and Croyde were deposited during the Great Storm of 1703, aided by a storm surge, which may also be the case for the undated deposit at Sand Bay.

Concerning the Severn Estuary, Allen (1987) considered that the inception of the modern salt marsh at Rumney dated to the 16th century, whereas all other salt marshes in the Severn Estuary had been eroded away before recommencing deposition in the mid-17th century. Allen (1996) later, based on archaeological evidence, suggested that even at Rumney the salt marsh had been lost through erosion and that the modern salt marsh there, also, is no older than the mid-17th century. The present study supports Allen's (1996) findings and refutes the suggestions of Allen (1987) and Bryant and Haslett (2003) that the sand layer may have been deposited by the 1607 flood; however, as suggested above, it may well have been deposited by the Great Storm of 1703 as proposed earlier as an alternative explanation by Allen (1987). The complete erosion of salt marsh in the Severn Estuary prior to c. 1650 may be due to cyclical changes in the estuary or climate/wave regime, but alternatively they may have been scoured by high velocity flow during a high-energy event, with the 1607 flood being a candidate. Many examples of significant intertidal scouring and erosion of salt marshes and mangroves, which may be analogous, are evident in before-and-after aerial/satellite images of Indian Ocean coastlines following the tsunami in 2004.

Older (pre-AD 1000) high-energy deposits that occur within the region are few, but include a sand layer lying at 15.48 m NGF in northern Brittany that Regnauld et al. (1995) attribute to a storm surge dated to 810–550 BC (2460±80 BP; Pa1200) and another dated to 6145 BC (7310±80 BP; lab code not given) from a nearby site (Regnauld et al., 1996). Such records suggest there is great potential in investigating the Holocene coastal sedimentary archives of northwest Europe for high-energy deposits that may add to the understanding of the frequency, source and impact of high-energy events.

6. Conclusions

1. Through reconnaissance field and laboratory work, this study has identified a number of potential historic (post-AD 1000) high-energy deposits from 10 new sites along the Atlantic coast of southwest Britain and Brittany, and the results are discussed alongside some previously published sites from these areas and western Ireland. Eight new radiocarbon dates are presented from sand and gravel deposits from salt marsh, coastal wetland, back-barrier, dune and cliff-top coastal settings. These new sites warrant systematic analysis in the future.
2. Generally, individual sites do not appear to record multiple high-energy events, suggesting that either only the most extreme and/or most recent events are registered in the sedimentary archive of the region.
3. Radiocarbon dating of marine shell material that, from their stratigraphic context, is likely to be of some antiquity, often returns modern dates when corrected for the marine reservoir effect. As reported by other authors, this is likely to be a consequence of the poor understanding of the contribution of terrestrial carbon in coastal and estuarine waters, and suggests that the application of broad regional ΔR values is clearly inappropriate at the local scale.
4. Two groupings of radiocarbon dates are recognised, and assigned here to a *Medieval Group* and a *Post-Medieval Group*. Although this division may be an expression of climate-related events associated with the Medieval Warm Period and the Little Ice Age, it allows the comparison to be made with known individual historic (post-AD 1000) regional ocean-sourced high-energy events, such as the Lucia Flood of 1287, the All Saint's Day Flood of 1570, the 1607 Flood, the Great Storm of 1703, and the Lisbon seismogenic tsunami of 1755.

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5. In the Severn Estuary, this study confirms that no extant salt marsh is older than the mid-17th century and that all pre-existing salt marsh was lost through erosion either through cyclical changes in the estuarine environment or through the impact of a high-energy event, such as the 1607 flood, that through high velocity flow stripped out the salt marsh in a way analogous to examples associated with the Indian Ocean tsunami of 2004.
6. Some older examples of high-energy deposits, taken with the new data presented here, indicate that the region has the potential, within the limitations of the analytical and dating techniques available, to allow for records of frequency and magnitude of Holocene high-energy events to be established.

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References

Allen, J.R.L., 1987. Late Flandrian shoreline oscillations in the Severn Estuary: the Rumney Formation at its typesite (Cardiff area). Phil. Trans. Roy. Soc. B315, 157–174.

Allen, J.R.L., 1996. An early post-medieval timber setting and subrectangular diggings in late Flandrian estuarine sediments, Rumney Great Wharf, Gwent. Arch. Cambren. 145, 152–168.

Allen, J.R.L., Fulford, M.G., 1992. Romano-British and later geoarchaeology at Oldbury Flats: reclamation and settlement on the changeable coast of the Severn Estuary. Archaeol. J. 149, 82–123.

Banerjee, D., Murray, A.S., Foster, I.D.L., 2001. Scilly Isles, UK: optical dating of a possible tsunami deposit from the 1755 Lisbon earthquake. Quat. Sci. Rev. 20, 715–718.

Bluck, B.J., 1967. Sedimentation in beach gravels: examples from South Wales. J. Sediment. Petrol. 37, 128–156.

Brayne, M., 2003. The Greatest Storm: Britain's Night of Destruction, November 1703. Sutton Publishing, Stroud. 235 pp.

Bryant, E., 2001. Tsunami: The Underrated Hazard. Cambridge University Press, Cambridge. 320 pp.

Bryant, E., 2005. Natural Hazards, 2nd ed. Cambridge University Press, Cambridge. 312 pp.

Bryant, E.A., Haslett, S.K., 2003. Was the AD 1607 coastal flooding event in the Severn Estuary and Bristol Channel (UK) due to a tsunami. Archaeol. Severn Estuary 13, 163–167 (for 2002).

Bryant, E.A., Haslett, S.K., in press. Catastrophic wave erosion, Bristol Channel, UK — impact of tsunami? J. Geol.

Chester, D.K., 2001. The 1755 Lisbon earthquake. Prog. Phys. Geog. 25, 363–383.

Clague, J.J., Bobrowsky, P.T., 1994. Tsunami deposits in tidal marshes on Vancouver Island, British Columbia. Geol. Soc. Amer. Bull. 106, 1293–1303.

Cremona, J., 1988. A Field Atlas of the Seashore. Cambridge University Press, Cambridge. 100 pp.

Dawson, A.G., 1994. Geomorphological effects of tsunami run-up and backwash. Geomorphology 10, 83–94.

Dawson, A.G., Lockett, P., Shi, S., 2004. Tsunami hazards in Europe. Env. Int. 30, 577–585.

DEFRA (Department for Environment, Food and Rural Affairs), 2005. The Threat Posed by Tsunami to the UK. HMSO, London. 168 pp.

Devoy, R.J.N., Delaney, C., Carter, R.W.G., Jennings, S.C., 1996. Coastal stratigraphies as indicators of environmental changes upon European Atlantic coasts in the Late Holocene. J. Coast. Res. 12, 564–588.

Eldred, D., 2005. A very British tsunami. Geoscientist 15 (3), 8–9.

Foster, I.D.L., Albon, A.J., Bardell, K.M., Fletcher, J.L., Jardine, T.C., Mothers, R.J., Pritchard, M.A., Turner, S.E., 1991. High energy coastal sedimentary deposits: an evaluation of depositional processes in southwest England. Earth Surf. Process. Land. 16, 341–356.

Giot, P.-R., 1998. La dune ancienne de la Baie d'Audierne. Norois 45, 487–494.

Goff, J., Chagué-Goff, C., 1999. A Late Holocene record of environmental changes from coastal wetlands: Abel Tasman National Park, New Zealand. Quat. Int. 56, 39–51.

Greenwood, B., 1972. Modern analogues and the evaluation of a Pleistocene sedimentary sequence. Trans. Inst. Br. Geogr. 56, 145–169.

Grove, J.M., 2004. Little Ice Ages: Ancient and modern. Routledge, London. 512 pp.

Haslett, S.K., Bryant, E.A., 2005. The AD 1607 coastal flood in the Bristol Channel and Severn Estuary: historical records from Devon and Cornwall (UK). Archaeol. Severn Estuary 15 (for 2004), 81–89.

Haslett, S.K., Curr, R.H.F., 1998. Coastal rock platforms and Quaternary sea-levels in the Baie d'Audierne, Brittany, France. Z. Geomorphol. N. F. 42, 507–515.

Haslett, S.K., Curr, R.H.F., 2001. Stratigraphy and palaeoenvironmental development of Quaternary coarse clastic beach deposits at Plage de Mezpeurleuch, Brittany (France). Geol. J. 36, 171–182.

Haslett, S.K., Davies, P., Curr, R.H.F., 2000. Geomorphologic and palaeoenvironmental development of Holocene perched dune systems in Brittany, France. Geog. Ann. A82, 79–88.

Horsburgh, K., Horritt, M., 2006. The Bristol Channel floods of 1607 — reconstruction and analysis. Weather 61, 272–277.

Hughen, K.A., Baillie, M.G.L., Bard, E., Bayliss, A., Beck, J.W., Blackwell, P.G., Buck, C.E., Burr, G.S., Cutler, K.B., Damon, P.E., Edwards, R.L., Fairbanks, R.G., Friedrich, M., Guilderson, T.P., Herring, C., Kromer, B., McCormac, F.G., Manning, S.W., Ramsey, C.B., Reimer, P.J., Reimer, R.W., Remmele, S., Southon, J.R., Stuiver, M., Talamo, S., Taylor, F.W., van der Plicht, J., Weyhenmeyer, C.E., 2004. Marine04 Marine radiocarbon age calibration, 26 — 0 ka BP. Radiocarbon 46, 1059–1086.

Hughes, M.K., Diaz, H.F. (Eds.), 1994. The Medieval warm period. Climatic Change, vol. 26, pp. 110–342.

Ingram, B.L., Southon, J.R., 1996. Reservoir ages in eastern Pacific coastal and estuarine waters. Radiocarbon 38, 573–582.

Keene, P., 1997. Westward Ho! Against the Sea. Thematic Trails, Oxford. 48 pp.

Keys, D., 2005. The great flood of 1607. BBC History Magazine, pp. 46–47 (March issue).

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Lamb, H.H., 1982. Climate, History and the Modern World. Methuen, London.

Lamb, H.H., 1991. Historic Storms of the North Sea, British Isles and Northwest Europe. Cambridge University Press, Cambridge. 204 pp.

May, V.J., 2003a. Westward Ho! cobble beach, Devon (SS 440 310). In: May, V.J., Hanson, J.D. (Eds.), Coastal Geomorphology of Great Britain, Geological Conservation Review Series, vol. 28, pp. 238–240.

May, V.J., 2003b. Carmarthen Bay, Carmarthenshire (SN 220 070-SN 421 868). In: May, V.J., Hanson, J.D. (Eds.), Coastal Geomorphology of Great Britain, Geological Conservation Review Series, vol. 28, pp. 583–593.

McGuire, B., 2005. Swept Away. New Scientist (22nd October issue), pp. 38–42.

Murray, J.W., 1979. British Nearshore Foraminiferids. Academic Press, London. 68 pp.

Pinegina, T., Bazanova, L., Braitseva, O., Gusiakov, V., Melekestsev, I., Starcheus, A., 1996. East Kamchatka Palaeotsunami Traces. Proceedings International Workshop on Tsunami Mitigation And Risk Assessment, Petropavlovsk-Kamchatskiy, Russia, August 21–24. http://omzg.sscc.ru/tsulab /content.html.

Proctor, R., Flather, R.A., 1989. Storm surge prediction in the Bristol Channel — the floods of 13 December 1981. Cont. Shelf Res. 9, 889–918.

Regnauld, H., Cocaign, J.-Y., Saliège, J.-F., Fournier, J., 1995. Mise en evidence d'une continuité temporelle dans la constitution de massifs dunaires du Sub-Boréal (3600 BP) à l'Actuel sur le littoral septentrional de la Bretagne. Un example dans l'Anse du Verger (Ille-et-Vilaine). C. R. Acad. Sci. Paris 321, 303–310.

Regnauld, H., Jennings, S., Delaney, C., Lemasson, L., 1996. Holocene sea-level variations and geomorphological response: an example from northern Brittany (France). Quat. Sci. Rev. 15, 781–787.

Reimer, P.J., Baillie, M.G.L., Bard, E., Bayliss, A., Beck, J.W., Bertrand, C.J.H., Blackwell, P.G., Buck, C.E., Burr, G.S., Cutler, K.B., Damon, P.E., Edwards, R.L., Fairbanks, R.G., Friedrich, M., Guilderson, T.P., Hogg, A.G., Hughen, K.A., Kromer, B., McCormac, F.G., Manning, S.W., Ramsey, C.B., Reimer, R.W., Remmele, S., Southon, J.R., Stuiver, M., Talamo, S., Taylor, F.W., van der Plicht, J., Weyhenmeyer, C.E., 2004. IntCal04 Terrestrial radiocarbon age calibration, 26–0 ka BP. Radiocarbon 46, 1029–1058.

Robinson, E., 2005. Riding the waves. Geol. Today 21, 167–168.

Stuiver, M., Reimer, P.J., Reimer, R., 2005. CALIB Radiocarbon Calibration: Execute Version 5.0.2html. http://calib.qub.ac.uk/calib/ accessed April–July 2006.

Ulm, S., 2002. Marine and estuarine reservoir effects in central Queensland, Australia: determination of Delta R values. Geoarchaeology 17, 319–348.

Whittaker, A., 1983. Geology of the country around Weston-Super-Mare: memoir of the Geological Survey of Great Britain, sheets 279 with parts of 263 and 295, (England and Wales). British Geological Survey, HMSO, London.

Wilson, D., Davies, J.R., Fletcher, C.J.N., Smith, M., 1990. Geology of the South Wales Coalfield, part VI, the country around Bridgend (2nd Edition). British Geological Survey, HMSO, London, 62 pp.

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