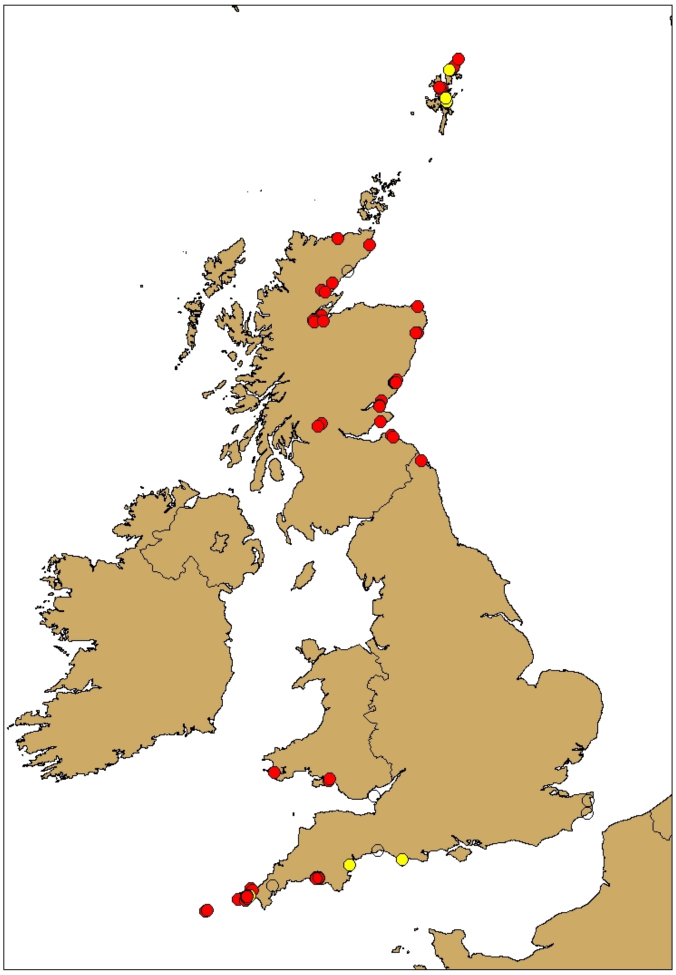
British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

A catalogue of tsunamis in the UK

Marine, Coastal and Hydrocarbons Programme

Commissioned Report CR/07/077N



BRITISH GEOLOGICAL SURVEY

MARINE, COASTAL AND HYDROCARBONS PROGRAMME

COMMISSIONED REPORT CR/07/077 N

A catalogue of tsunamis in the UK

D Long and CK Wilson

Keywords

UK, tsunami, catalogue, tsunami deposits, earthquake, landslide, geohazards.

Front cover

Sites of tsunami events in the UK. Red circles good evidence for tsunami. Yellow circles tsunami event uncertain. Open circles non-tsunamis previously attributed.

Bibliographical reference

LONG, D AND WILSON, CK. 2007. A catalogue of tsunamis in the UK. *British Geological Survey Commissioned Report*, CR/07/077. 29pp.

Edinburgh British Geological Survey 2007

BRITISH GEOLOGICAL SURVEY

The full range of Survey publications is available from the BGS Sales Desks at Nottingham, Edinburgh and London; see contact details below or shop online at www.geologyshop.com

The London Information Office also maintains a reference collection of BGS publications including maps for consultation.

The Survey publishes an annual catalogue of its maps and other publications; this catalogue is available from any of the BGS Sales Desks.

The British Geological Survey carries out the geological survey of Great Britain and Northern Ireland (the latter as an agency service for the government of Northern Ireland), and of the surrounding continental shelf, as well as its basic research projects. It also undertakes programmes of British technical aid in geology in developing countries as arranged by the Department for International Development and other agencies.

The British Geological Survey is a component body of the Natural Environment Research Council.

British Geological Survey offices

Keyworth, Nottingham NG12 5GG

☎ 0115-936 3241 Fax 0115-936 3488
e-mail: sales@bgs.ac.uk
www.bgs.ac.uk
Shop online at: www.geologyshop.com

Murchison House, West Mains Road, Edinburgh EH9 3LA

☎ 0131-667 1000 Fax 0131-668 2683
e-mail: scotsales@bgs.ac.uk

London Information Office at the Natural History Museum (Earth Galleries), Exhibition Road, South Kensington, London SW7 2DE

☎ 020-7589 4090 Fax 020-7584 8270
☎ 020-7942 5344/45 email: bgslondon@bgs.ac.uk

Forde House, Park Five Business Centre, Harrier Way, Sowton, Exeter, Devon EX2 7HU

☎ 01392-445271 Fax 01392-445371

Geological Survey of Northern Ireland, Colby House, Stranmillis Court, Belfast BT9 5BF

☎ 028-9038 8462 Fax 028-9038 8461

Maclean Building, Crowmarsh Gifford, Wallingford, Oxfordshire OX10 8BB

☎ 01491-838800 Fax 01491-692345

Columbus House, Greenmeadow Springs, Tongwynlais, Cardiff, CF15 7NE

☎ 029–2052 1962 Fax 029–2052 1963

Parent Body

Natural Environment Research Council, Polaris House, North Star Avenue, Swindon, Wiltshire SN2 1EU

☎ 01793-411500 Fax 01793-411501
www.nerc.ac.uk

Foreword

This report is the published product of a study by the British Geological Survey (BGS) produced as a contribution to EU Framework 6 STREP project TRANSFER Work Package 1. TRANSFER (Tsunami Risk and Strategies for the European Region) is a project examining the tsunami processes in the European area to assess the tsunami hazard, vulnerability and risk assessment, and to identifying how the best strategies to reduce tsunami risk can be delivered to local communities and civil defence agencies. This catalogue attempts to list tsunami events and events previously reported as possible tsunamis detected around the coast of the UK during the Holocene. It includes events detected by their geological evidence, human observations or by measurements recorded by tidal gauges.

Acknowledgements

Comments on this listing have been gratefully received from the following:

Prof A.G. Dawson, Aberdeen University

Dr R.M.W. Musson, British Geological Survey,

Prof D.E. Smith, Oxford University,

Dr P. Woodworth, Proudman Oceanographic Laboratory

Contents

1 Introduction

It is often thought that as the UK is located on a passive continental margin it is not subjected to geohazards usually associated with active margins. One of the most dramatic and unpredictable of marine geohazards are tsunamis. They are translational waves that travel at great speed in deepwater but as they approach the coastline and enter shallow water the wave slows down but increases dramatically in height. When they strike the coast they can be very destructive, both in their initial impact and as they withdraw sucking any loose material out to sea.

Any tsunami starts with the rapid displacement of water volume. Therefore, for a tsunami to occur, some source is required that causes such a displacement. This can be one of three things:

- A sudden vertical movement of the sea floor as the result of faulting;
- Sudden movement of a large amount of material underwater, as in an underwater landslide;
- A large amount of material entering the sea rapidly.

The first case is mostly restricted to earthquakes that cause fault rupture (vertical or with a vertical component) extending to the sea bed. It is also possible for blind thrust faulting to create folds or ridges at the free surface, even when the fault itself does not extend to the surface, and this could have a similar effect. In the second case, underwater landslides may be triggered by earthquakes; even by moderate earthquakes if the slope is sufficiently unstable. However it is possible that they may be triggered by other events such as the dissociation of gas hydrates (Kvenvolden, 1988), or underwater volcanic eruptions where the material could be quite variable e.g. lava, hot waters or gas. In the third case, the most probable circumstance is a large terrestrial landslide that enters the sea (volcanic slope collapse, Coastal landslide or cliff fall being a possible cause). An alternative cause would be the impact of a large asteroid, but asteroid impacts of sufficient magnitude are extremely rare even on a geological time scale.

A recent study for the Department for Environment Food and Rural Affairs (DEFRA), (Kerridge et al., 2005) showed that although the risks of a tsunami striking the coasts of the UK are very low, they can not be ignored. Even if the likely wave heights are comparable to those of typical storm surges and therefore covered in many places by flood defence infrastructures, a tsunami wave could occur on top of a storm surge and therefore have the potential to exceed defences. Also, if a tsunami struck when conditions were calm communities would not be as prepared as they are when a storm had been building up.

The most significant tsunami to strike Europe in modern times occurred in 1755 when the wave caused much devastation to the coasts of Portugal, Spain and Morocco. The wave also struck the southwestern parts of the British Isles with local maximum run-ups of 2-3m in the Scilly Isles and in Cornwall. Tsunamis generated by earthquakes in the same area west of the Straits of Gibraltar of a lesser magnitude have caused much smaller run ups in the UK. The extensive continental shelf around the UK slows down such waves. Studies in SW Iberia indicate that similar events occur with a frequency of 1000-2000 years (Luque et al., 2001). Therefore there is a possibility that a prehistoric tsunami could have struck the southwestern part of the UK.

About 8200 years ago the UK was affected by a tsunami generated by a massive submarine landslide off the coast of Norway. Run-ups varied from a few metres in southeast Scotland to more than 20m in Shetland. Studies have shown that this slide, the Storegga Slide, is just the latest of several megaslides to have affected the continental margin over the last half million years. The geological model indicates that another glacial period will be required to allow the build out of the volume of sediment needed for failure again in the Storegga area (Solheim et al., 2005).

2 Evidence for tsunamis

2.1 TSUNAMI DEPOSITS

When a tsunami wave strikes a coastline it is often heavily laden with sediment entrained from the seafloor. Tsunami waves typically disturb the seafloor at greater water depths than storm waves and their energy will move material into suspension that is not normally disturbed. When the wave strikes the coast and subsequently withdraws it often leaves behind a layer of the entrained sediment.

Sediments have been identified associated with the Holocene Storegga Slide tsunami along the coasts of northern UK and the 1755 Lisbon earthquake tsunami in the Scilly Isles (Foster et al., 1991). These can often be recognized as a thin landward tapering horizon that includes marine material (e.g. marine microfossils) within sediments deposited above sealevel, such as lacustrine or peat units. The horizon may include ripped-up clasts of the surrounding material and boulders possibly source from offshore.

Physical evidence of a tsunami event provides an opportunity to date events. The Holocene Storegga Slide tsunami has been dated by radiocarbon dating of sediments that bracket the event (Smith et al., 2004) or of transported material contained in the deposit. In the later case, dating moss still containing chlorophyll provides good evidence for an age of material alive when the tsunami struck (Bondevik, 2002). Examination of entrained material has even suggested the season of the event (Dawson and Smith, 2000; Bondevik et al., 1997). Deposits of the Lisbon tsunami in the Scilly Isles have been dated by OSL methods supporting the historic age of the deposit (Banergee et al., 2001).

Deposits also provide an opportunity to measure the extent and other characteristics of a tsunami event not observed or reported in historical documents, e.g. using particle size analysis to estimate velocity and extent of individual waves within the tsunami.

2.2 HISTORICAL OBSERVATIONS

There are many reports of unusual movements of the sea. Some were documented soon after the event such as the 1755 Lisbon earthquake and tsunami when the Royal Society gathered together numerous reports throughout the UK. Others may have been written down some time later reporting second hand events. However even as recently as Victorian times there was often uncertainty in phenomena and their correlation or not, including earthquakes, atmospheric changes and storms (Melville, 1996). It should be noted that place-names may well have changed over the years and positioning observations can be difficult. Also in the past, dates and times were not consistent across the country but reflected local conventions.

2.3 TIDE GAUGES

Tide gauges provide a record of changes in sea level around the coast, often located on piers. Some sites around the UK have records extending back continuously more than 100 years. The stations were established and are operated to record low-frequency processes such as tides and storm surges. However, tide gauges can record tsunami events that are smaller in amplitude than that likely to be noted by human observations. Since the first part of the 18th century tide gauge records were in the form of paper charts providing a continuous record, which should have, in principle, provided a good source of tsunami information. However, in many places, once the charts had been digitised for their tidal information (usually digitised with hourly sampling which is too low a frequency to resolve tsunami events), they were often destroyed or allowed to decay.

Since the 1970s charts have been replaced by electronic sampling at most UK sites, averaging 15 minutes of measurements, although there are plans to reduce the period averaged to 5 minutes. There are also plans for separate pressure sensors measuring very frequently (probably 1 Hz) at 4 UK sites as part of the Defra study and TRANSFER and the IOC European tsunami activity. They are Newlyn, Cromer, Holyhead and either Stornoway or Lerwick (P.Woodworth, POL, *pers comm.*).

3 Events

A range of events has been reported at various sites around the UK within the Holocene record and attributed to being a tsunami. For some events there is a strong link between the UK coastal evidence and the source of the tsunami so there is a high confidence that the event was a tsunami. For some it can be shown that the linkage is impossible and therefore the event has been wrongly termed a tsunami and can be explained by other causes. For some events there is no obvious source of a tsunami and these are classified as uncertain.

These events have been dated either into years BP (before present, referenced to 1950 AD) where an age has been determined from radiocarbon dating and then extrapolated into calendar years, which have a level of uncertainty in the region of ±200 years, or as calendar years where historical records allow the determination of the actual date.

3.1 ~8150 BP

Along the eastern and northern coasts of Scotland numerous sites have been identified with a thin continuous layer of marine sediments (Smith et al., 2004). A similar horizon has been detected along much of the western coast of Norway (Bondevik et al., 1997), and at sites in the Faroes (Grauert et al., 2001), Iceland (Hansen and Briggs, 1991) and Greenland (Wagner et al., 2007). This is event is attributed to the failure of 3500km^3 of sediments on the mid-Norwegian margin known as the Holocene Storegga Slide (Dawson et al., 1988; Long et al., 1989).

The Holocene Storegga Slide is dated offshore to 7250±250 ^{14}C yr BP (Haflidason et al, 2005) and its associated tsunami deposit is dated onshore to 7250–7350 ^{14}C yr BP (Bondevik et al 1997). This is approximately 8150 calendar years ago. Note this contrasts with previous dating results carried out during the 1980s on the Storegga Slide that concluded that there were three distinctive slide events (Bugge et al, 1987, and Jansen et al, 1987). The latest interpretations indicate that the Holocene Storegga Slide is just the most recent of a series of mega-slides (>2000 km^2) that have occurred offshore mid-Norway since the end of the Pliocene, with a frequency of roughly once every 100,000 years over the last 0.5 Myr (Bryn et al., 2003; Solheim et al., 2005).

The deposits generally consist of fine to medium grained sand, often showing a fining upwards sequence that can be repeated up to five times interpreted as sedimentation by individual waves within the train of waves that comprise the tsunami event. The tsunami deposit layer is generally less than 10cm in thickness but may be up to 70cm thick. The sands include microfossils that are indicative of shallow marine conditions. These fossils are often broken indicative of turbulent conditions. Where the layer has been deposited within coastal peats ripped clasts of peat can be seen (e.g. Maryton). At the Maggie Kettle’s Loch section it can be very clearly shown that the peat clasts are associated with the second wave indicating that the coastal peats were eroded by the first wave, cuasing blocks of peat to be floating about when they became incorporated within the deposits of the second wave (Bondevik et al., 2003).

There is a general decrease in run up heights from north to south. The highest sediment run ups occur in inlets, (~20m) at sites around Sullom Voe, a large north facing inlet (Bondevik et al., 2003) reducing to a few metres run up in the vicinity of the Firth of Forth. Lower values may exist further south but from Northumbria southwards the former shoreline is now offshore and any tsunami deposits from this event would have been vulnerable to erosion and reworking during the subsequent marine transgression. However as several of the sites in Shetland show, the layer can be preserved below the present day sealevel by subsequent sedimentation even with marine transgression. The extent of inundation and altitude can be difficult to estimate but by examining how the deposit occurs within lake basins, lake thresholds provide altitude control. In coastal sequences where the deposit transgresses from within intertidal muds into coastal peats such as at Fullerton (Smith et al., 1980) or Creich (Smith et al., 1992) the transgression provides a position for the high water mark on the day the wave struck (Long et al., 1989). The actual run up of the wave would have exceeded the extent of preserved sediments so these provide only a minimum inundation.

Examination of clasts within the deposit can also indicate the season of the event as well as provide dating. The stage in the development of buds (Bondevik et al., 1997) and fruit (Dawson and Smith, 2000) and the size of fish bones (Bondevik et al., 1997) at sites in Norway and Scotland entrapped within the tsunami deposits suggest that the tsunami struck in late autumn.

This is considered a tsunami event.

3.2 ~5500 BP

A thin horizon of marine sand has been found at two sites in Shetland (Garth Loch and Loch of Benston) less than half a kilometre apart and attributed to a tsunami event that has been termed the Garth Tsunami (Bondevik et al 2005). This tsunami deposit occurs above tsunami deposits from the ~8150 BP Storegga Tsunami event and is up to 65cm thick. Dating of a twig within the deposit in the Loch of Benston and from just below the deposit at Garth Loch revealed similar radiocarbon ages (4965±55 ^{14}Cyr BP and 4895±70 ^{14}Cyr BP respectively) extrapolated to ~5500 calendar years BP. According to the constructed sea level curve the runup for this event was probably more than 10 m.

A possible tsunami deposit of similar age has been noted on the coast of mid-Norway near Bergsøy that may correlate with this ~5500 BP event (Bondevik et al., 2005). No source has been suggested for this event other than originating in the North / Norwegian Sea. It is worth noting that Halflidi et al. (2005) reported several small slides on the northern flank of the Storegga Slide with ages about 5000 ^{14}Cyr BP.

This is considered an uncertain tsunami event.

3.3 ~1500 BP

A thin sand horizon (up to 5cm thick) has been found at two sites in Shetland, 40kms apart, Basta Voe and Dury Voe, extending to 5.5m and 5.6m above high tide respectively, and attributed to a tsunami event (Bondevik et al., 2005; Dawson et al., 2006) and termed the Dury Voe event but no source for the tsunami has been identified. Dawson et al. (2006) suggest a local submarine landslide off the eastern coast of Shetland. However, existing morphological seafloor information is not sufficiently detailed enough to test this hypothesis.

This is considered an uncertain tsunami event.

3.4 6TH APRIL 1580 AD

An earthquake affected southeast England and parts of the near continent for 6th April 1580. As many of the reports were from London, this event has been called the "London Earthquake" (Davison, 1924) although an assessment of the reports indicates that the epicentre was within the Straits of Dover (Neilson et al., 1984). Claims have been made that the earthquake "triggered a tsunami that inundated Dover, Boulogne and Calais, leading to hundreds of deaths". Varley (1996) states categorically that the earthquake produced a tsunami (which he refers to as a tidal wave) at Calais, Boulogne and Dover. Neilson et al (1984) are more cautious, considering that due to uncertainty about the coincidence in time of inundation and earthquake, the flooding report may have had some other cause (presumably meteorological). Melville et al (1996) are dismissive of the idea of a tsunami from this event. Evidence suggests (Melville et al 1996) that contemporary sources conflated descriptions of the earthquake with the effects of a storm that occurred very shortly afterwards. This is all the more likely since at this period it was not known that earthquakes were very short-lived phenomena, and to a 16th century writer it would have been natural to consider the seismic shock and a storm a day later as being part of the same occurrence.

Undoubtedly the earthquake caused agitation of the water in harbours at Dover and Sandwich harbours (Neilson et al 1984). It is most likely that this movement was a seiche and not a tsunami as there is no evidence of any seabed displacement in the area and the strength of the earthquake (5.8 ML (Musson, 1994)) was insufficient to cause a tsunami directly.

This is considered a non-tsunami event.

3.5 30TH JANUARY 1607 AD

At 9am on 30 January 1607, the lowlands surrounding the Bristol Channel suffered the worst coastal flooding on record. The floodwaters caused extensive damage to Bristol, many surrounding villages on the Somerset levels, and Barnstaple in North Devon. Flooding extended some 40km along both banks of the Bristol Channel to a depth of 2–3m. and it has been claimed that a tsunami may have been responsible (Bryant and Haslett, 2002; Haslett and Bryant, 2004). The exceptional high tide (14.36m above chart datum) combined with the severe weather points to a storm surge as the more likely explanation. The most authoritative account says that a westerly gale blew for 16 hours although some records state that a strong south-west wind blew unbroken for three days (Horsburgh and Horritt, 2005).

It is unlikely that an earthquake could have caused a tsunami directly as seismic events around Britain are not expected to be large enough to generate significant surface rupture to initiate a tsunami. Also there are no reports of damage to buildings to indicate a local earthquake. If it was a distant earthquake and its epicentre located further away then if it triggered a tsunami it could be expected that the wave would be wide ranging and not restricted to the Bristol Channel. If the origin is a submarine landslide, extensive bathymetric surveys do not reveal any evidence of a slide within the Bristol Channel. Large landslides usually occur on the upper slopes of continental margin such as seen south of Ireland. A tsunami from such a source could be expected to have simultaneously struck the coasts of Ireland, UK and France.

This is considered a non-tsunami event.

3.6 1ST NOVEMBER 1755 AD

The largest seismic event to have struck Europe in last few hundred years was noted from Scotland to Austria and north Africa, either felt as ground motion or seen as seiches in baths, lakes and enclosed harbours. However the greatest damage occurred in western Iberia. The earthquake is estimated to have had a magnitude 8.5 Ms and probably centred on the Azores-Gibraltar boundary between the African and Eurasian plates. The earthquake struck at 9:50am (local time) destroying many buildings in Lisbon, Cadiz and Morocco, however it was followed by a tsunami 20 minutes later at Lisbon. The event is referred to as the Lisbon Earthquake. The tsunami was observed along the western Iberian coast and Morocco and in the UK and Ireland and even across the Atlantic in the Caribbean and South America. The earthquake and tsunami killed between 60,000 and 100,000 people. Reports of the event in Britain were gathered together by the Royal Society in London and provide useful record. The reports are predominantly of the seiche noted about 11 o'clock in the morning in various harbours around the UK as well as many lakes and ponds, however there several reports from the coast of south west of England and Wales in the afternoon and evening when a series of waves were noted.

The observations describe dramatic movements of the water. Borlase (1755) described the arrival of the waves in Mount's Bay:

> *"…the first and second refluxes were not so violent as the third and fourth waves at which time the sea was as rapid as that of a mill-stream descending to an undershot wheel, and the rebounds of the sea continued in their full-fury for fully 2 hours … alternatively rising and falling, each retreat and advance nearly of the space of 10 minutes, till five and a half hours after it began"*.

Evidence of sediment deposition is implied by the observations of Huxham (1755) in Stonehouse Creek, Plymouth who described the

> *"…tearing up of mud and sand banks in a very alarming mannar"*.

Also Foster et al. (1991, 1993) provide clear evidence of sediment deposition in the Big Pool on St Agnes in the Isles of Scilly.

This is considered a tsunami event.

3.7 31ST MAY 1759 AD

Dawson et al., (2000) quote Perrey (1849) as saying that an unusual coastal flood took place at Lyme Regis on 31st May 1759 where the sea "*…flowed in and out three times during an hour…*". However no other account have been found to corroborate this report in neighbouring areas, nor is any earthquake noted for this date.

This is first of a set of extreme marine floods events have been identified by Dawson et al (2000) who conducted extensive searches in SW England, only some of which have been attributed by them to past tsunamis.

This event is considered a non-tsunami event.

3.8 31ST MARCH 1761 AD

A similar suite of reports to that of the 1755 event was noted in south west Cornwall on 31st March 1761 (Borlase, 1762). He states that

> *"On the Tuesday, the 31st of March 1761, about five o'clock in the afternoon, there was a very uncommon motion of the tide in Mount's-bay, Cornwall. […] After the tide has ebbed about four hours and half, (for the time is not determined with precision) instead of continuing to retreat gradually, as usual, till it had completed the six hours ebb, on a sudden it advanced as it is usually at the time of the Moon, at an hour and half high-water. It then retreated nigh to the point of low-water, then it advanced again, and retreated, making five advances, and as many recesses, in the space of one hour; viz. from about five to six o'clock; which was the whole time, that these uncommon stretches of the tide continued. But the first motion was most considerable, the sea advancing the first time to a quarter ebb; but the second advance was but as far as the sea reaches at half ebb. A small sloop of 30 tons burthen, at that time laden and dry in Penzance pier, by the first surge, was fleeted;*

by which it appears, that the waters rose at this place six feet perpendicular, that sloop requiring six feet of water to fleet it. At the pier of St Michael's mount, three miles to the east of Penzance the tide was observed, at the same time, to rise and fall about four feet. At Newlyn, (a mile west of Penzance) the tide rose to the same height nearly, as at Penzance. At Moushole pier, (three miles SW of Penzance) it was only observed, that the sea was in great agitation, and the fishing boats in danger. At the islands of Scilly, the sea was judged to raise about four feet; but the agitation to have continued longer than in Mount's-bay, viz. more than two hours".

Similar waves were reported at several sites along the southern coast of Ireland, up to 1.2m in height and consisting of up to five waves. This event coincides with reports of a tsunami in Portugal with waves up to 2.4m in height at Lisbon, following a 7.5Ms earthquake with an epicentre at 34.5°N 13°W (Baptista et al., 2006).

This is considered a tsunami event.

3.9 9TH OR 10TH AUGUST 1802 AD

There are several reports in south west England indicating turbulent waters for either 9th or 10th August 1802 that was originally suggested as being due to a distant earthquake. With rises and falls of 35cm at Weymouth and 60cm at Teignmouth in a very short period of time (Dawson et al., 2000).

This is considered an uncertain tsunami event.

3.10 31ST MAY 1811 AD

Dawson et al., (2000) note reports from Plymouth recording sudden rises and falls with an amplitude of 4 to 8 feet (1.2 to 2.4m) over a period of four hours from 3am, with further affects at 9am. Milne (1844) notes that the event coincided with a period of gales and low pressure. Therefore the event is likely to have been storm induced.

This is considered a non-tsunami event.

3.11 5TH JULY 1843 AD

Dawson et al., (2000) mention oscillations of the sea around the south west had been reported, including Penzance and Plymouth, where it consisted of rises and falls for two to three hours (Edmonds, 1845). Flooding was reported in several places but there is no known earthquake associated with it and it coincides with a widespread storm (Milne 1844). In addition there are extensive reports of agitated seas around Scotland and also Bristol and Tynemouth (Milne, 1844).

This is considered a non-tsunami event.

3.12 23RD MAY 1847 AD

Edmonds (1869) noted that in Mount's Bay rises and falls of 3 to 5 feet (0.9-1.5m) occurred all day and similar effects at Plymouth in the evening. This has been linked with reports of a slight tremor felt in the Scilly Isles, Penzance and Mount's Bay in the night before. Musson (1989) suggested that a large offshore earthquake occurred and the abnormal waves are associated with it. However locating an epicentre for the earthquake is not possible, nor is determining how that induced the size of the tsunami wave reported. Also it is difficult to explain the time delay for an wave in the evening at Plymouth to come from the earthquake felt the night before.

This is considered an uncertain tsunami event.

3.13 4TH OCTOBER 1859 AD

Dawson et al., (2000) plot localities where agitation of waves were reported on both the southern and northern coasts of Cornwall and Devon, and also further afield in the Bristol Channel (Swansea and Bridgewater) were recorded by Edmonds (1860, 1862) and noted by Dawson et al., (2000). These rises and falls were noted over several hours. Edmonds also notes that a thunderstorm did occur and so it possible that may be assumed that was present.

This is considered a non-tsunami event.

3.14 29TH SEPT 1869 AD

Dawson et al., (2000) report that Perrey (1872) records a series of waves seen in the Isles of Scilly, Newlyn, Penzance and Truro over a period of 4 – 5hrs. There is no obvious source for this event.

This is considered a non-tsunami event.

3.15 24TH JANUARY 1927 AD

A magnitude of 5.7 ML earthquake with an epicentre in the Viking Graben area was attributed to having caused a tsunami like event at Helmsdale in eastern Scotland:

> *At the time of the shock the bar at the mouth of the Helmsdale River was calm, but at 5.30 a.m.* [12 minutes after the earthquake] *great rollers began to come in from the south-east*. (Tyrell 1932)

Ambraseys (1983) searched the available tide gauges, and found no trace of any fluctuation; however, his most northerly data set was at North Shields. The distance from the earthquake epicentre to Helmsdale is 400 km, so it is inconceivable that waves originating in the Viking Graben could have reached Helmsdale in only 12 minutes (Kerridge et al., 2005).

This is considered a non-tsunami event.

3.16 25TH NOVEMBER 1941 AD

The tide gauge at Newlyn, Cornwall shows a tsunami occurred on 25th November 1941 following an earthquake west of Portugal, magnitude 8.2 Ms. The tsunami consisted of seven waves with a maximum amplitude of about 20cm and lasted about four hours. Tide gauge records, although poor quality, from Le Havre suggest that the tsunami travelled up the English Channel (Dawson et al., 2000).

This is considered a tsunami event.

3.17 23RD MAY 1960 AD

A tsunami was generated the by Chile earthquake of 22nd May 1960, at Magnitude 9.6 Mw the largest earthquake ever recorded. The tsunami, together with coastal subsidence and flooding, caused tremendous damage along the Chile coast, where about 2,000 people died. The waves spread outwards across the Pacific, 15 hours later the waves flooded Hilo, on the island of Hawaii, where they built up to thirty feet and caused 61 deaths along the waterfront. After 22 hours the waves flooded the coastline of Japan where 3m high waves caused 200 deaths. The waves also caused damage in other parts of the Pacific. Subsequent analysis of tidal gauges has shown the waves travelled around the world and were detected in the North Atlantic including Newlyn the day after the source earthquake (Van Dorn 1984).

This is considered a tsunami event.

3.18 28TH FEBRUARY 1969 AD

On 28 February 1969, an earthquake west of Portugal (7.3 Ms) generated a tsunami that was recorded along the western coast of Spain and Portugal with a maximum amplitude of almost 1m (Baptista et al., 1992). It is probable that this tsunami also reached SW England as Dawson and others (2000) note that the tide gauge record for Newlyn for this period reports heavy seiching on a day characterized by calm sea conditions.

This is considered a tsunami event.

3.19 26TH MAY 1975 AD

The tide gauge at Newlyn, Cornwall shows a tsunami occurred on 26th March 1975 following an earthquake west of Portugal, magnitude 7.9 Ms. The tsunami was clearly seen in the Azores, Portugal and Spain (Baptista et al., 1992). The tsunami that was measured at Newlyn UK consisted of eight waves with a maximum amplitude of about 6cm and lasted nearly four hours (Dawson et al., 2000).

This is considered a tsunami event.

3.20 27TH DECEMBER 2004 AD

The magnitude 9.3 Mw Sumatra earthquake of 26th December 2004 initiated a tsunami that caused upwards of 225000 deaths in south east Asian. The tsunami travelled around the world and was observed on the North American Atlantic coast (Rabinovich et al., 2006) and also on the West African coast (Joseph et al., 2006) but seemed to lose steam by the time it reached the European Atlantic coastline. It was detected on tide gauges in the English Channel (UK and France) more than 30 hours after the triggering earthquake. The tsunami wave was possibly also recorded at Milford Haven although there was a moderate storm surge at the time, which may have created a confused signal (Woodworth et al., 2005).

This is considered a tsunami event.

4 Tsunami catalogue

This catalogue has been created by searches of published papers and examination of existing databases. Existing databases include the US National Geophysical Data Center NOAA/WDC Historical Tsunami database http://www.ngdc.noaa.gov/seg/hazard/tsu_db.shtml. Reports within the Tsunami Runup data base that are known to be reports of seiches have been excluded. Also some reports of tsunami run-ups have been mis-positioned e.g. the event of 31st March 1761 at Carrick in County Wexford, Ireland has been mis-recorded as occurring at Carrickfergus, UK. The catalogue produced for GITEC has also been examined, reports with great uncertainty have been ignored.

Positioning has been recorded to 0.1km accuracy using the British National Grid and subsequently converted to geographical co-ordinates using WGS84. This allows sites with several boreholes that have recovered a tsunami deposit or containing a coastal section to be noted as a single point. It also allows a general location for historical observations respecting that only a general area associated with a place name is available.

The evidence at each site/event is classified as deposits, observations or tidal measurements. The deposits are further subdivided into “S” where the deposits are seen in a section or “B” where they are buried but recognized in one or more boreholes.

The catalogue could be extended by listing additional attributes particularly for tsunami deposits by recording the height of deposit, thickness of deposit, its extent inland, uncertainties of the dating evidence.

5 GIS files

The shape files have been set up for use with ESRI's ArcGIS so that sites of tsunamis can be selected by event, evidence type and degrees of uncertainty.

This allows distribution maps to be produced for various attributes, e.g. confidence, data type and event (Figures 1, 2 and 3 respectively).

References

Most of the references listed below are held in the Library of the British Geological Survey at Keyworth, Nottingham. Copies of the references may be purchased from the Library subject to the current copyright legislation.

AMBRASEYS, N.N., 1983. Evaluation of seismic risk. In: Ritsema, A.R. and Gurpinar, A. (Editors), *Seismicity and seismic risk in the offshore North Sea area*. Reidel, London, pp. 317-346.

BANERJEE, D., MURRAY, A.S. and FOSTER, J.L.D., 2001. Scilly Islands, UK: optical dating of a possible tsunami deposit from the 1755 Lisbon earthquake. *Quaternary Science Reviews*, Vol. 20, 715-718

BAPTISTA, M.A, MIRANDA, P. and VICTOR, L. M. 1992. Maximum Entropy Analysis of Portuguese Tsunami Data, the tsunamis of 28.02.1969 and 26.05.1975. *Science of Tsunami Hazards*, Vol. 10, 9-20

BAPTISTA MA, MIRANDA JM, LUIS JF, 2006. In Search of the 31 March 1761 Earthquake and Tsunami Source, *Bulletin of the Seismological Society of America* Vol. 96, 713-721

BONDEVIK, S. SVENDSEN, J.I. JOHNSEN, G. MANGERUD J. and KALAND, P.E. 1997 The Storegga tsunami along the Norwegian coast, its age and run-up, *Boreas* Vol. 26, 29–53.

BONDEVIK, S.. MANGERUD, J., DAWSON, S., DAWSON, A., and LOHNE, Ø. 2003 Record-breaking height for 8000-year-old tsunami in the North Atlantic. *Eos* Vol. 84, 289-293

BONDEVIK, S., MANGERUD, J., DAWSON, S., DAWSON, A. and LOHNE, O. 2005 Evidence for three North Sea tsunamis at the Shetland Islands between 8000 and 1500 years ago. *Quaternary Science Reviews* Vol. 24, 1757-1775

BORLASE, W. 1755. On the coast of Cornwall, *Philosophical Transactions of the Royal Society of London*, Vol. 49, 373-379

BORLASE, W. 1762. Some Account of the extraordinary Agitation of the Waters in Mount's-bay, and other Places, on the 31st of March 1761: In a Letter for the Reverend Dr. C Lyttelton, *Philosophical Transactions of the Royal Society*, Vol. 52, 418-431

BRYANT, E.A. and HASLETT, S.K. 2002. Was the AD 1607 coastal flooding event in the Severn Estuary and Bristol Channel (UK) due to a tsunami? *Archaeology in the Severn Estuary*, Vol. 13, 163-167.

BRYN, P., SOLHEIM, A., BERG, K., LIEN, R., FORSBERG, C.F., HAFLIDASON, H., OTTESEN, D. and RISE, L. 2003. The Storegga Slide Complex: repeated large scale sliding in response to climatic cyclicity. *In*: J. LOCAT and J. MIENERT, Editors, *Submarine Mass Movements and their Consequences*, Advances in Natural and Technological Hazards Research vol. 19, Kluwer Academic Publishers, Dordrecht. 215–222.

DAVISON, C. 1924 *History of British Earthquakes.* Cambridge.

DAWSON, A.G., LONG, D., and SMITH, D.E. 1988. The Storegga Slides: evidence from eastern Scotland for a possible tsunami. *Marine Geology*, Vol. 82, 271-276.

DAWSON, A.G., MUSSON, R.M.W., FOSTER, I.D.L., and BRUNSDEN, D. 2000. Abnormal historic se-surface fluctuations, SW England *Marine Geology* Vol. 170, 59-68

DAWSON, A.G., DAWSON, S and BONDEVIK, S. 2006. A late Holocene tsunami at Basta Voe, Yell, Shetland Isles. *Scottish Geographical Journal*, Vol. 122, 100-108.

DAWSON, S., and SMITH, D.E., 2000. The sedimentology of Middle Holocene tsunami facies in northern Sutherland, Scotland, UK. *Marine Geology* Vol. 170, 169-179.

EDMONDS, R. 1845. On remarkable lunar periodicities in earthquakes, extraordinary oscillations of the sea and great atmospherical changes. *Transactions of the British Association for the Advancement of Science* 20-22

EDMONDS, R., 1860. An account of the extraordinary agitations of the sea in the west of England, on the 25th and 26th of June, and the 4th of October ; with notices of the earthquake shocks in Cornwall on the 11th of November, and the 21st of October 1859. *Edinburgh New Philosophical Journal* Vol. 12, 1-15.

FOSTER, I.D.L., ALBON, A.J., BARDELL, K.M., FLETCHER, J.L., JARDINE, T.C., MOTHERS, R.J., PRITCHARD, M.A., and TURNER, S.E., 1991. High energy coastal sedimentary deposits: an evaluation of depositional processes in southwest England. *Earth Surface Processes and Landforms* Vol. 16, 341-356.

FOSTER, I.D.L., DAWSON, A.G., DAWSON, S., LEES, J., and MANSFIELD, L., 1993. Tsunami sedimentation sequences in the Scilly Isles, southwest England. *Science of Tsunami Hazards* Vol. 11, 35-46.

GRAUERT, M., BJÖRCK, S., AND BONDEVIK, S. 2001 Storegga Tsunami deposits in a coastal lake on Suduroy, the Faroe Islands. . *Boreas* Vol. 30, 263-271

HAFLIDASON, H., LIEN, R., SEJRUP, H.P., FORSBERG, C.F., and BRYN, P., 2005. The dating and morphometry of the Storegga Slide. Marine and Petroleum Geology. Vol. 22, 123-136.

HANSOM, J.D., BRIGGS, D.I., 1991. Sea-level change in Vestfirdir, North West Iceland. In: Maizels, J.K., Caseldine, C. (Eds.), *Environmental Change in Iceland: Past and Present*. Kluwer, Dordrecht,pp. 79–91.

HASLETT, S.K. and BRYANT, E.A. 2004. The AD 1607 coastal flood in the Bristol Channel and Severn Estuary: Historical Records from Devon and Cornwall (UK). Archaeology in the Severn Estuary, Vol. 15, 81-89.

HORSBURGH, K. and HORRITT, M. 2006. The Bristol Channel floods of 1607 – reconstruction and analysis. *Weather*, 61(10), 272-277.

HUXHAM, J. 1755. In Devonshire and Cornwall, at Plymouth and other parts, *Philosophical Transactions of the Royal Society*, Vol. 49, 371-373

JANSEN, E., BEFRING, S., BUGGE, T., EIDVIN, T., HOLTEDAHL H. and SEJRUP, H.P. 1987. Large submarine slides on the Norwegian Continental Margin: Sediments, transport and timing, *Marine Geology* Vol. 78: 77–107

JOSEPH, A., ODAMETEY, J.T., NKEBI, E.K., PEREIRA, A., PRABHUDESAI1, R.G., MEHRA1, P., RABINOVICH, A.B., VIJAYKUMAR, PRABHUDESAI, S. and WOODWORTH, P.L. 2006. The 26 December 2004 Sumatra Tsunami Recorded on the Coast of West Africa. *African Journal of Marine Science*, Vol. 28(3-4), 705-712.

KERRIDGE, D and 21 OTHERS 2005, The threat posed by tsunamis to the UK, Study commissioned by the Defra Flood Management Division, 165pp, Department for Environment Food and Rural Affairs (Defra), London.

KVENVOLDEN, K.A., 1988. Methane hydrates – a major reserve of carbon in the shallow geosphere? *Chemical Geology*, Vol. 71: 41-51.

LONG, D., SMITH, D.E. and DAWSON, A.G. 1989. A Holocene tsunami deposit in eastern Scotland. *Journal of Quaternary Science*. Vol. 4, 61-66.

LUQUE, L., LARIO, J., ZAZO, C., GOY, J.L. DABRIO, C.J. and SILVA, P.J. 2001 Tsunami deposits as paleoseismic indicators: examples from the Spanish coast. *Acta Geologica Hispanica*, Vol. 36, 197-211

MELVILLE, C.P., LEVRET, A., ALEXANDRE, P., LAMBERT, J. and VOGT, J., 1996. Historical seismicity of the Strait of Dover – Pas de Calais. *Terra Nova*, Vol. 8, 626-647.

MILNE, D 1844. On a remarkable oscillation of the sea, observed at various places on the coasts of Great Britain in the first week of July 1843. *Transactions of the Royal Society of Edinburgh*, Vol. 15, 609-638.

MUSSON, R.M.W., 1994. A catalogue of British earthquakes. *British Geological Survey Research Report* WL/94/04.

MUSSON, R.M.W., 1989. Seismicity of Cornwall and Devon. *British Geological Survey, Global Seismology Report*. WL/89/11.

NEILSON, G, MUSSON, R.M.W. and P.W. BURTON, PW. 1984. The “London” earthquake of 1580, April 6: *Engineering Geology* Vol. 20, 113-141

PERREY, A., 1849. Note sur les tremblements de terre ressentis en 1848, Memoirs Academie, Dijon (part 2, pp. 1-40).

PERREY, A., 1872. Note sur les tremblements de terre en 1869, avec supplements pour les annees anterieures de 1843 a 1868, Memoires cour. Bruxelless, vol. 22, no. 4, 116pp.

RABINOVICH, A.B., THOMSON, R.E. and STEPHENSON, F.E. 2006.The Sumatra tsunami of 26 December 2004 as observed in the North Pacific and North Atlantic oceans. *Survey in Geophysics*, Vol. 27, 647–677

SMITH, D.E., MORRISON, J., JONES, R.L., and CULLINGFORD, R.A., 1980. Dating the main postglacial shoreline in the Montrose area, Scotland. In: Cullingford, R.A., Davidson, and D.A., Lewin, J. (Eds.), *Timescales in Geomorphology*. Wiley, Chichester, pp. 225–245

SMITH, D.E., FIRTH, C.R., TURBAYNE, S.C., and BROOKS, C.L., 1992. Holocene relative sea-level changes and shoreline displacement in the Dornoch Firth area, Scotland. *Proceedings of the Geologists' Association* Vol. 103, 237–257.

SMITH, D.E., SHI, S., CULLINGFORD, R. A., DAWSON, A. G., DAWSON, S., FIRTH, C.R., FOSTER, I. D. L., FRETWELL, P. T., HAGGART, B. A., HOLLOWAY, L. K. and LONG, D. 2004. The Holocene Storegga Slide tsunami in the United Kingdom. *Quaternary Science Review* Vol. 23, 2291-2321

SMITH, D.E., FOSTER, I.D.L., LONG, D., and SHI, S., in press Reconstructing the pattern and depth of flow onshore in a palaeotsunami from associated deposits, *Sedimentary Geology* (2007), doi: 10.1016/j.sedgeo.2007.01.014

SOLHEIM, A., BERG, K., FORSBERG, C.F., and BRYN, P., 2005 The Storegga Slide complex: repetitive large scale sliding with similar cause and development. *Marine and Petroleum Geology*. Vol. 22, 97-107.

TITOV, V., RABINOVICH, AB, MOFJELD, HO, THOMSON, RE and GONZÁLEZ, FI. 2005. The Global Reach of the 26 December 2004 Sumatra Tsunami. *Science*, Vol.309, 2045-2048

TYRELL, G., 1932. Recent Scottish earthquakes. *Transactions of the Geological Society of Glasgow*, Vol. 19, 1-41.

VAN DORN, WG 1987. Tide gage response to tsunamis. Part II: Other oceans and smaller seas. *Journal of Physical Oceanography* Vol. 17, 1507–1516

VARLEY, P.M., 1996. Seismic risk assessment and analysis. In: C.S. Harris, M.B.Hart, P.M. Varley and C.D. Warren (Editors), *Engineering geology of the Channel Tunnel*. Telford, London, pp. 194-216.

WAGNER, B., BENNIKE, O., KLUG, M. and CREMER, H. 2007. First indication of Storegga tsunami deposits from East Greenland. *Journal of Quaternary Science*, Vol. 22, 321–325

WOODWORTH, PL, BLACKMAN, DL, FODEN, P, HOLGATE, S., HORSBURGH, K., KNIGHT, PJ, SMITH, DE,. MACLEOD, EA, and BRADSHAW, E. 2005 Evidence for the Indonesian tsunami in British tidal records. *Weather*, Vol. 60, 263–267

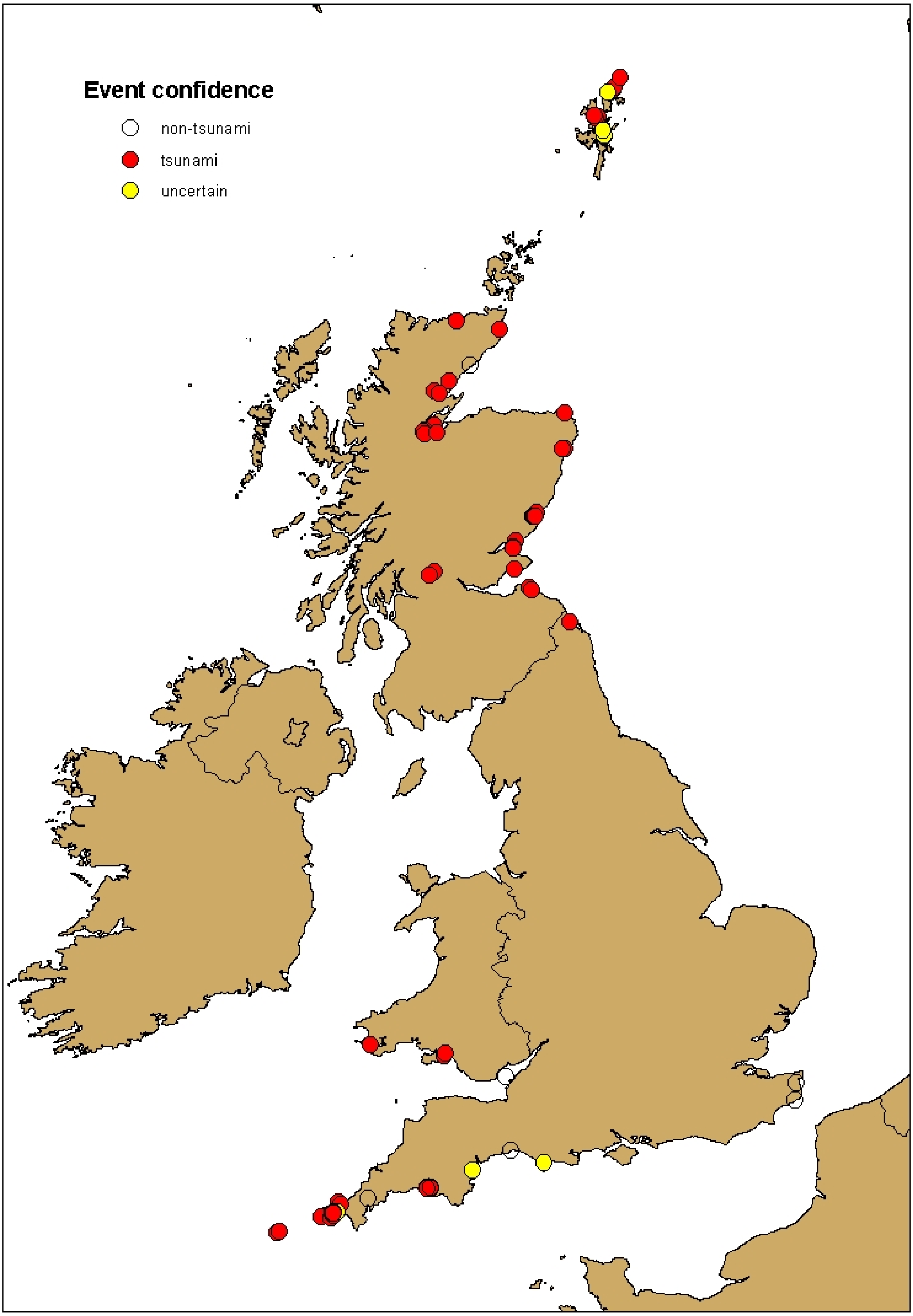


Figure 1 Location of tsunami events in the UK highlighted by a confidence evaluation

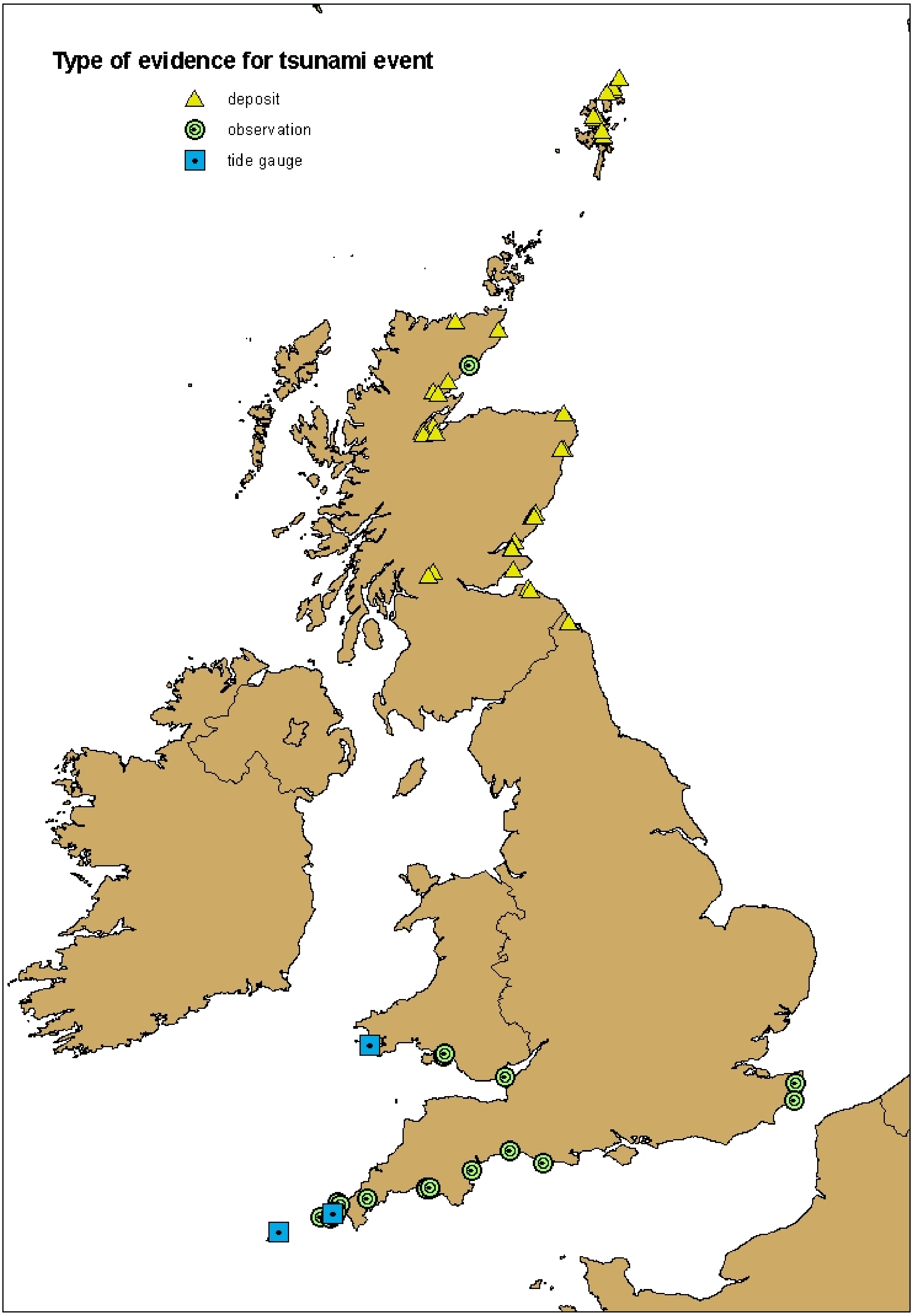


Figure 2 Tsunami events in the UK highlighted by the evidence claimed for the event

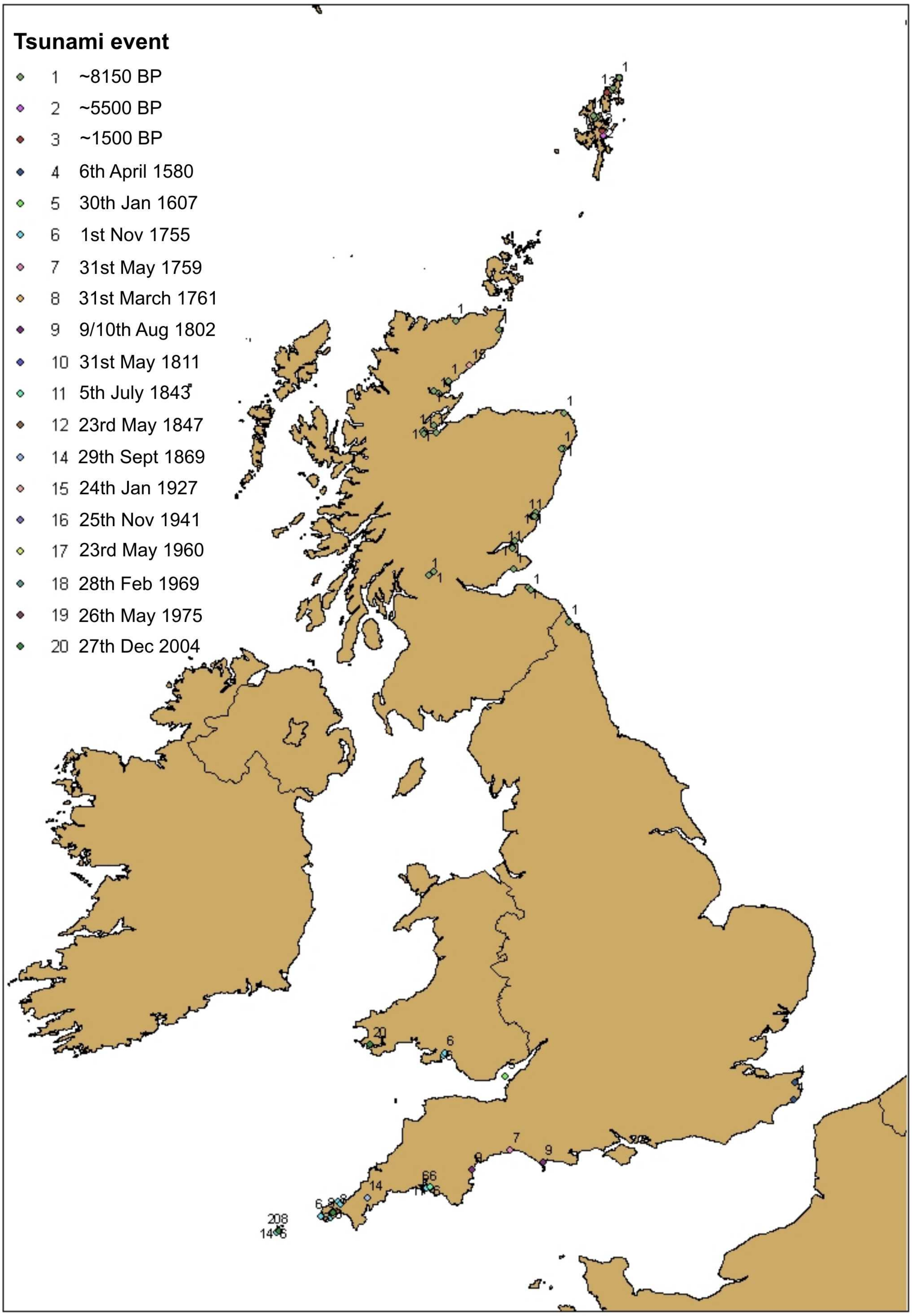


Figure 3 Tsunami events in the UK

Catalogue

Table 1 Catalogue of tsunami reports in the UK

site	event	confidence	name	National Grid easting	National Grid northing	Latitude WGS84	Longitude WGS84	evidence	type	age	time	wave height	comment	reference
1	1	tsunami	Snarravoe,	456900	1201400	-0.9579	60.6923	deposit	B	~8150yr BP				Bondevik et al 2005
2	1	tsunami	Burragarth	457300	1203800	-0.9499	60.7138	deposit	B	~8150yr BP				Smith 1993, Smith et al 2004
3	1	tsunami	Norwick	465100	1214100	-0.8035	60.8051	deposit	B	~8150yr BP				Smith 1993, Smith et al 2004
4	1	tsunami	Scatsta Voe	439600	1172700	-1.2805	60.4367	deposit	S	~8150yr BP			Run up probably >20m above palaeo sea level	Birnie 1981, Smith 1993, Smith et al 2004
5	1	tsunami	Garth's Voe	440900	1174100	-1.2565	60.4492	deposit	S	~8150yr BP			Run up probably >20m above palaeo sea level	Birnie 1981, Smith 1993, Smith et al 2004
6	1	tsunami	Otter Loch	437600	1172700	-1.3168	60.4369	deposit	B	~8150yr BP			Run up probably >20m above palaeo sea level	Bondevik 2002
7	1	tsunami	The Houb, Sullom Voe	436500	1174700	-1.3364	60.4550	deposit	S	~8150yr BP			Run up probably >20m above palaeo sea level	Bondevik 2002 Bondevik et al 2003
8	1	tsunami	Maggie Kettle's Loch	436700	1175600	-1.3326	60.4631	deposit	S	~8150yr BP			Sand layer with clasts of peat, run up probably >20m above palaeo sea level	Bondevik 2002; Bondevik et al 2003
9	1	tsunami	Garth Loch	447000	1153800	-1.1504	60.2663	deposit	B	~8150yr BP				Bondevik et 2005
10	1	tsunami	Loch of Benston	446500	1153600	-1.1595	60.2645	deposit	B	~8150yr BP				Bondevik et 2005
11	1	tsunami	Strath Halladale	289000	962600	-3.9069	58.5377	deposit	B	~8150yr BP			Intraclast suggests an autumn event	Dawson and Smith 1997; Dawson and Smith 2000
12	1	tsunami	Wick River	334200	952200	-3.1276	58.4535	deposit	B	~8150yr BP				Dawson and Smith 1997
13	1	tsunami	Smithy House	281100	899100	-4.0100	57.9656	deposit	B	~8150yr BP				Smith et al 1992
14	1	tsunami	Creich	264900	888800	-4.2777	57.8685	deposit	B	~8150yr BP				Smith et al 1992
15	1	tsunami	Dounie	269600	886100	-4.1971	57.8456	deposit	B	~8150yr BP				Smith et al 1992
16	1	tsunami	Munlochy Bay	264700	852900	-4.2609	57.5462	deposit	B	~8150yr BP				Firth 1984
17	1	tsunami	Bellevue	253700	848100	-4.4417	57.4997	deposit	B	~8150yr BP				Firth 1984
18	1	tsunami	Tomich	252500	847200	-4.4611	57.4912	deposit	B	~8150yr BP				Firth 1984
19	1	tsunami	Barnyards	252500	847000	-4.4610	57.4894	deposit	B	~8150yr BP			Minimum 2m run-up above palaeo high water mark	Haggart, 1982
20	1	tsunami	Moniack	254200	843900	-4.4308	57.4621	deposit	B	~8150yr BP			Minimum 4m run-up above palaeo high water mark	Haggart, 1982
21	1	tsunami	Castle St., Inverness	266800	845300	-4.2217	57.4786	deposit	S	~8150yr BP			Archaeological site "white sand" layer	Wordsworth, 1985, Dawson et al 1990
22	1	tsunami	Water of Philorth	401400	864100	-1.9765	57.6670	deposit	B	~8150yr BP				Smith et al., 1982
23	1	tsunami	Waterside	400700	826700	-1.9884	57.3310	deposit	B	~8150yr BP				Smith et al., 1983
24	1	tsunami	Tarty Burn	398200	827100	-2.0299	57.3346	deposit	B	~8150yr BP				Smith et al., 1999
25	1	tsunami	Dryleas	370600	760600	-2.4806	56.7363	deposit	B	~8150yr BP			Fine sand layer	Smith and Cullingford, 1985
26	1	tsunami	Dubton	370000	760200	-2.4904	56.7326	deposit	B	~8150yr BP			Fine sand layer	Smith and Cullingford, 1985
27	1	tsunami	Puggieston	369800	760300	-2.4937	56.7335	deposit	B	~8150yr BP				Smith and Cullingford, 1985
28	1	tsunami	Old Montrose	366700	756500	-2.5438	56.6992	deposit	B	~8150yr BP			Fine sand layer	Smith and Cullingford, 1985
29	1	tsunami	Fullerton	367500	756000	-2.5307	56.6947	deposit	B	~8150yr BP				Smith et al., 1980
30	1	tsunami	Maryton	368300	756600	-2.5177	56.7002	deposit	S	~8150yr BP			Sand layer with clasts of peat	Smith et al., 1980
31	1	tsunami	Broughty Ferry	347400	731300	-2.8539	56.4710	deposit	S	~8150yr BP			Archeological site of sand layer on Mesolithic - an exceptional flood	Hutcheson 1886; Lacaille, 1954, Smith et al 2004
32	1	tsunami	Craigie	345500	724200	-2.8833	56.4070	deposit	B	~8150yr BP				Haggart, 1978
33	1	tsunami	St Michael's Wood	345300	723900	-2.8864	56.4043	deposit	B	~8150yr BP				Haggart, 1978
34	1	tsunami	Silver Moss	345400	723500	-2.8847	56.4007	deposit	B	~8150yr BP				Chisholm, 1971
35	1	tsunami	Goodie Water	262400	700400	-4.2168	56.1764	deposit	B	~8150yr BP			Fine sand layer	Holloway, 2002

site	event	confidence	name	National Grid easting	National Grid northing	Latitude WGS84	Longitude WGS84	evidence	type	age	time	wave height	comment	reference
36	1	tsunami	Cocklemill Burn	346200	700900	-2.8672	56.1977	deposit	S	~8150yr BP				Tooley and Smith, 2005
37	1	tsunami	Over Easter Offerance	257700	696200	-4.2902	56.1373	deposit	B	~8150yr BP				Sissons and Smith, 1965
38	1	tsunami	Lochhouses	361600	682100	-2.6162	56.0303	deposit	B	~8150yr BP				Newey, 1965
39	1	tsunami	Hedderwick	364000	678700	-2.5773	55.9999	deposit	S	~8150yr BP			Fine sand and shell hash layer	New data D.E.Smith pers comm
40	1	tsunami	Broomhouse Farm	403700	645200	-1.9411	55.7003	deposit	B	~8150yr BP				Horton et al., 1999
41	2	uncertain	Loch of Benston	446500	1153600	-1.1595	60.2645	deposit	B	~5,500yr BP				Bondevik et al 2005
42	2	uncertain	Garth Loch	447000	1153800	-1.1504	60.2663	deposit	B	~5,500yr BP				Bondevik et al 2005
43	3	uncertain	Basta Voe	451100	1198800	-1.0648	60.6698	deposit	S	~1500 BP				Dawson et al 2006, Toothill 1994
44	3	uncertain	Dury Voe	446100	1160100	-1.1653	60.3229	deposit	S	~1500 BP				Bondevik 2002; Bondevik et al 2005
45	4	non-tsunami	Sandwich	633600	159000	1.3501	51.2817	observation		6th Apr 1580			most likely a harbour seiche	Nielson et al 1984
46	4	non-tsunami	Dover	631700	140700	1.3111	51.1181	observation		6th Apr 1580			most likely a harbour seiche	Nielson et al 1984
47	5	non-tsunami	Bristol Channel	250000	160000	-4.1528	51.3188	observation		30 Jan 1607	900		extensive flooding	Bryant and Haslett 2002, Haslett and Bryant, 2004, Horsburgh and Horritt 2006
48	6	tsunami	Isles of Scilly, Big Pool	87800	8600	-6.3480	49.8954	deposit	B	1st Nov 1755				Banagee et al 2001; Dawson et al 1991, 2000; Foster et al 1993
49	6	tsunami	Stonehouse Creek, Plymouth	246100	54000	-4.1642	50.3651	observation		1st Nov 1755	1600			Huxham, 1755, Dawson et al 2000
50	6	tsunami	Creston, Plymouth	250000	53400	-4.1091	50.3608	observation		1st Nov 1755	1600		Sea withdraw 4-5 ft, sea returns in 8 mins.	Huxham 1755
51	6	tsunami	Crunhill, Plymouth	245400	53400	-4.1738	50.3596	observation		1st Nov 1755	1600		Sea withdraws and returns, breaks cable	Huxham 1755
52	6	tsunami	St Mount’s Bay	151700	30000	-5.4738	50.1174	observation		1st Nov 1755	after1400		Sudden advance of the sea, retreat by 6 foot depth, took 5.5 hrs to settle	Borlase 1755
53	6	tsunami	Penzance	147800	30200	-5.5284	50.1176	observation		1st Nov 1755	1445		Sea rose 8ft	Borlase 1755
54	6	tsunami	Newlyn	146100	28300	-5.5509	50.0998	observation		1st Nov 1755			Sea rose 10ft	Borlase 1755
55	6	tsunami	Mousehole	146700	26500	-5.5413	50.0839	observation		1st Nov 1755			Similar to Newlyn	Borlase 1755
56	6	tsunami	Gwavas Lake	148000	28500	-5.5245	50.1024	observation		1st Nov 1755			The ketch Happy veer’d round estimate sea velocity at 7mph	Borlase 1755
57	6	tsunami	Lands End, Cornwall	134000	25400	-5.7177	50.0685	observation		1st Nov 1755			Agitation perceived	Borlase 1755
58	6	tsunami	Larmorna Cove, Cornwall	144900	24000	-5.5647	50.0607	observation		1st Nov 1755			Large blocks of granite deposited above high water	Edmonds 1845
59	6	tsunami	St Ives	152000	40900	-5.4767	50.2154	observation		1st Nov 1755			On north side sea rose 8-9ft	Borlase 1755
60	6	tsunami	Hayle	155800	37600	-5.4214	50.1874	observation		1st Nov 1755	after 1500		Surge 7 ft high	Borlase 1755
61	6	tsunami	Swansea	265100	192300	-3.9485	51.6129	observation		1st Nov 1755	1845		Agitation,	Borlase 1755
62	6	tsunami	Whiterock, Swansea	266300	174700	-3.9245	51.4550	observation		1st Nov 1755	1700-1900		Floating of beached vessels, vessels turned onto river bank	Borlase 1755
63	7	non-tsunami	Lyme Regis	334000	92000	-2.9351	50.7233	observation		31st May 1759			sea flowed in and out three times during an hour	Perrey 1849
64	8	tsunami	Penzance	147800	30200	-5.5284	50.1176	observation		31st Mar 1761			Sea rose 6 feet	Borlase 1761
65	8	tsunami	Mousehole	146700	26500	-5.5413	50.0839	observation		31st Mar 1761			great agitation	Borlase 1761
66	8	tsunami	Newlyn	146100	28300	-5.5509	50.0998	observation		31st Mar 1761			Sea rose almost as much as at Penzance	Borlase 1761
67	8	tsunami	St Michael's Mount	151700	30000	-5.4738	50.1174	observation		31st Mar 1761			Tide rose and fell 4ft at pier	Borlase 1761
68	8	tsunami	Isles of Scilly	90200	10900	-6.3165	49.9172	observation		31st Mar 1761			Sea rose 4 feet and agitation lasted 2 hours	Borlase 1761
69	9	uncertain	Weymouth	368000	79000	-2.4523	50.6093	observation		9th Aug 1802		0.35		Dawson et al 2000
70	9	uncertain	Teignmouth	294000	72500	-3.4961	50.5421	observation		10th Aug 1802		0.6		Dawson et al 2000
71	10	non-tsunami	Plymouth	250000	54000	-4.1094	50.3661	observation		31st May 1811		2.4	coincides with widespread gales	Dawson et al 2000
72	11	non-tsunami	Penzance	147800	30200	-5.5284	50.1176	observation		5th July 1843				Edmonds 1845
73	11	non-tsunami	Plymouth	250000	54000	-4.1094	50.3661	observation		5th July 1843				Edmonds 1845
74	12	uncertain	St Mount’s Bay	151700	30000	-5.4738	50.1174	observation		23rd May 1847			Rises and fall 0.9-1.5m noted all day following slight tremor felt night before	Edmonds 1869

site	event	confidence	name	National Grid easting	National Grid northing	Latitude WGS84	Longitude WGS84	evidence type	age	time	wave height	comment	reference
75	12	uncertain	Plymouth	250000	54000	-4.1094	50.3661	observation	23rd May 1847			Waves similar to St Mount’s Bay noted in the evening	Edmonds 1869
76	14	non-tsunami	Isles of Scilly	90200	10900	-6.3165	49.9172	observation	29th Sept 1869				Perrey 1872
77	14	non-tsunami	Newlyn	146100	28300	-5.5509	50.0998	observation	29th Sept 1869				Perrey 1872
78	14	non-tsunami	Penzance	147800	30200	-5.5284	50.1176	observation	29th Sept 1869				Perrey 1872
79	14	non-tsunami	Truro	183000	44000	-5.0446	50.2554	observation	29th Sept 1869				Perrey 1872
80	15	non-tsunami	Helmsdale	302900	915200	-3.6483	58.1154	observation	24th Jan 1927			large rollers noted following an earthquake	Tyrell, 1932
81	16	tsunami	Newlyn	146800	28600	-5.5413	50.1028	tide gauge	25th Nov 1941	2200	0.2		Dawson et al 2000
82	17	tsunami	Newlyn	146800	28600	-5.5413	50.1028	tide gauge	23rd May 1960		0.025		Van Dorn 1987
83	18	tsunami	Newlyn	146800	28600	-5.5413	50.1028	tide gauge	28th Feb 1969				Dawson et al 2000
84	19	tsunami	Newlyn	146800	28600	-5.5413	50.1028	tide gauge	26th May 1975	1525	0.06		Dawson et al 2000
85	20	tsunami	Newlyn	146800	28600	-5.5413	50.1028	tide gauge	27th Dec 2004	745	0.15		Woodworth et al 2005
86	20	tsunami	St Mary's, Isle of Scilly	90200	10900	-6.3165	49.9172	tide gauge	27th Dec 2004			less certain than at Newlyn	Woodworth et al 2005
87	20	tsunami	Milford Haven	188500	205000	-5.0613	51.7034	tide gauge	27th Dec 2004	938	0.16	may be confused by a storm surge	Woodworth et al 2005

ref no reference

Banerjee, D., Murray, A.S., Foster, J.L.D., 2001. Scilly islands, UK: optical dating of a possible tsunami deposit from the 1755 Lisbon earthquake. Quaternary Science Reviews, Vol. 20, 715-718.

Birnie, J.F., 1981. Environmental Changes in Shetland since the end of the Last Glaciation. Unpublished Ph.D. Thesis, University of Aberdeen.

Bondevik, S., Dawson, A.G., Dawson, S., Drange, I., Lohne, O., Mangerud, J. and J.-I. Svendsen 2002 Records of palaeotsunamis around the Norwegian Seas. Norsk Hydro Contract: NHT-B44-07822-00, 124pp

Bondevik, S., Mangerud, J., Dawson, S., Dawson, A.G., Lohne, O., 2003. Record-breaking height for 8000-year-old tsunami in the North Atlantic. Eos, Transactions, American Geophysical Union Vol. 84 (31), 291–292.

Borlase, W. 1755. Letter to the Rev Charles Lytteton. Philosophical Transactions of the Royal Society of London, Vol. 49, 373-379

Borlase, W. 1762. Some Account of the extraordinary Agitation of the Waters in Mount’s-bay, and other Places, on the 31st of March 1761: In a Letter for the Reverend Dr. C Lyttelton, Philosophical Transactions of the Royal Society, Vol. 52, 418-431.

Bryant, E.A. and Haslett, S.K. 2002. Was the AD 1607 coastal flooding event in the Severn Estuary and Bristol Channel (UK) due to a tsunami? *Archaeology in the Severn Estuary*, Vol. 13, 163-167.

Chisholm, J.I., 1971. The stratigraphy of the post-glacial marine transgression of NE Fife. Bulletin of the Geological Survey of Great Britain Vol. 37, 91–107

Dawson, A.G., Dawson, S and Bondevik, S. 2006. A late Holocene tsunami at Basta Voe, Yell, Shetland Isles. Scottish Geographical Journal, Vol. 122 (2), 100-108.

Dawson, A.G., Foster, I.D.L., Shi, S., Smith, D.E. & Long, D. 1991. The identification of tsunami deposits in coastal sediment sequences. Science of Tsunami Hazards, Vol. 9, 73-82.

Dawson, A.G., Musson R.M.W., Foster I.D.L. and Brunsden, D. 2000. Abnormal historic sea-surface fluctuations, SW England. Marine Geology Vol. 170, 59-68

Dawson, A.G., Smith, D.E. & Long, D. 1990. Evidence for a tsunami from a mesolithic site in Inverness. Journal of Archaeological Science, Vol. 17, 509-512.

Dawson, S., Smith, D.E., 1997. Holocene relative sea-level changes on the margin of a glacio-isostatically uplifted area: an example from northern Caithness, Scotland. The Holocene Vol. 7 (1), 59–77.

Dawson, S., Smith, D.E., 2000. The sedimentology of Middle Holocene tsunami facies in northern Sutherland, Scotland, UK. Marine Geology Vol. 170, 169-179.

Edmonds, R., 1846. An account of an extraordinary movement of the sea in Cornwall, in July 1843, with notices of similar movements in previous years, and also of earthquakes which have occurred in Cornwall. Br. Assoc. Advancement Sci. Vol. 38, 112-121.

Firth, C.R., 1984. Raised shorelines and ice limits in the inner Moray Firth and Loch Ness areas, Scotland. Unpublished Ph.D. Thesis, Council for National Academic Awards, Coventry (Lanchester) Polytechnic.

Foster, I.D.L., Dawson, A.G., Dawson, S., Lees, J., Mansfield, L., 1993. Tsunami sedimentation sequences in the Scilly Isles, southwest England. Science of Tsunami Hazards Vol. 11, 35-46.

Haggart, B.A., 1978. A Pollen and Stratigraphical Investigation into a Peat Deposit in St. Michael’s Wood, near Leuchars, Fife. Unpublished M.A. Thesis, University of St. Andrews.

Haggart, B.A., 1982. Flandrian sea-level changes in the Moray Firth area. Unpublished Ph.D. Thesis, University of Durham.

Haslett, S.K. and Bryant, E.A. 2004. The AD 1607 coastal flood in the Bristol Channel and Severn Estuary: Historical Records from Devon and Cornwall (UK). *Archaeology in the Severn Estuary*, 15, 81-89.

Holloway, L.K., 2002. Sedimentary environments in the western Forth valley during the Late Devensian and early Holocene. Unpublished Ph.D. Thesis, Coventry University.

Horsburgh, K. and Horritt, M. 2006. The Bristol Channel floods of 1607 - reconstruction and analysis. *Weather*, 61(10), p. 272-277.

Horton, B.P., Innes, J.B., Shennan, I., Gehrels, W.R., Lloyd, J.M., McArthur, J.J., Rutherford, M.M., 1999. In: Bridgland, D.R., Horton, B.P., Innes, J.P. (Eds.), The Quaternary of North-East England. Field Guide, Quaternary Research Association, pp.146–165.

Hutcheson, A., 1886. Notice of the discovery of a stratum containing worked flints at Broughty-Ferry. Proceedings of the Society of Antiquaries of Scotland, Vol. 20, 166–169.

Huxham, J. 1755. In Devonshire and Cornwall, at Plymouth and other parts, Philosophical Transactions of the Royal Society, Vol. 49, 371-373

Huxham, J., 1755. Letter to Mr William Watson, FRS. Philos. Trans. R. Soc. Lond. Vol. 50, 371-373.

Lacaille, A.D., 1954. The Stone Age in Scotland. Oxford University Press, Oxford.

Neilson, G, Musson, R.M.W. and P.W. Burton, PW. 1984. The "London" earthquake of 1580, April 6: Engineering Geology Vol. 20, 113-141

Newey, W.W., 1965. Post-glacial vegetational and climatic changes in part of south-east Scotland as indicated by the pollen-analysis and stratigraphy of some of its peat and lacustrine deposits. Unpublished Ph.D. Thesis, University of Edinburgh.

Sissons, J.B., Smith, D.E., 1965. Peat bogs in a post-glacial sea and a buried raised beach in the western part of the Carse of Stirling. Scottish Journal of Geology Vol. 1, 247–255.

Smith, D.E., 1993. Norwick, Unst; Burragarth, Unst; Sullom Voe, Mainland. In: Birnie, J., Gordon, J., Bennett, K., Hall, A. (Eds.), The Quaternary of Shetland. Quaternary Research Association Field Guide, pp. 52–56.

Smith, D.E., Cullingford, R.A., Brooks, C.L., 1983. Flandrian relative sea level changes in the Ythan valley, northeast Scotland. Earth Surface Processes and Landforms Vol. 8, 423–438.

Smith, D.E., Cullingford, R.A., Seymour, W.P., 1982. Flandrian relative sea-level changes in the Philorth valley, North-East Scotland. Transactions, Institute of British Geographers NS7, pp.321–336.

Smith, D.E., Firth, C.R., Brooks, C.L., Robinson, M., Collins, P.E.F., 1999. Relative sea-level rise during the Main Postglacial Transgression in NE Scotland, UK. Transactions of the Royal Society of Edinburgh: Earth Sciences 90, 1–27.

Smith, D.E., Firth, C.R., Turbayne, S.C., Brooks, C.L., 1992. Holocene relative sea-level changes and shoreline displacement in the Dornoch Firth area, Scotland. Proceedings of the Geologists’ Association 103, 237–257.

Smith, D.E., Morrison, J., Jones, R.L., Cullingford, R.A., 1980. Dating the main postglacial shoreline in the Montrose area, Scotland. In: Cullingford, R.A., Davidson, D.A., Lewin, J. (Eds.), Timescales in Geomorphology. Wiley, Chichester, pp. 225–245

Smith, D.E., Shi, S., Cullingford, R. A., Dawson, A. G., Dawson, S., Firth, C.R., Foster, I. D. L., Fretwell, P. T., Haggart, B. A., Holloway, L. K. and Long, D. 2004. The Holocene Storegga Slide tsunami in the United Kingdom. Quaternary Science Reviews Vol. 23, 2291-2321.

Tooley, MJ and Smith, DE 2005 Relative sea-level change and evidence for the Holocene Storegga Slide tsunami from a high-energy coastal environment: Cocklemill Burn, Fife, Scotland, UK. Quaternary International Vol. 133-134, 107-119

Toothill, NP 1994 Holocene storm surge or tsunami deposit at Basta Voe, Shetland Isles, unpublished BSc thesis, Dept of Geography, Coventry University 98pp

Tyrell, G., 1932. Recent Scottish earthquakes. Transactions of the Geological Society of Glasgow, Vol. 19(1): 1-41.

Van Dorn WG 1987. Tide gage response to tsunamis. Part II: Other oceans and smaller seas. Journal of Physical Oceanography Vol. 17, 1507–1516

Woodworth, PL, Blackman, DL, Foden, P, Holgate, S., Horsburgh, K., Knight, PJ, Smith, DE,. Macleod, EA, and Bradshaw, E. 2005 Evidence for the Indonesian tsunami in British tidal records. Weather, Vol. 60(9):263–267

Wordsworth, J., 1985. The excavation of a Mesolithic horizon at 13–24 Castle Street, Inverness. Proceedings of the Society of Antiquaries of Scotland Vol. 115, 89–103.