WHAT WAS THE LARGEST BRITISH EARTHQUAKE?

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Abstract: The issue of "largest observed earthquake in a region" is both important for seismic hazard analysis and also of journalistic and popular interest. Identifying the relevant event is not always straightforward in intraplate regions such as the UK, where the historical earthquake catalogue is short with respect to the seismic cycle. In Britain, the largest 20th century event (i.e. instrumentally recorded) was the North Sea earthquake of 7 June 1931. However, there are several pre-instrumental earthquakes that affected Britain which may have been as large or larger. However, the task of estimating magnitude from often very scant historical accounts is difficult, and leads to much speculation. In this paper, the evidence for four such earthquakes is reviewed, but it is not possible to come to a firm conclusion regarding any of them.

Introduction

The question as to the largest earthquake experienced in the UK is one that is frequently asked by the media and public, and the answer usually given is the 7 June 1931 North Sea earthquake, at 5.8 Mw. The effects of this event were much more widespread than those of the 1992 Roermond (Netherlands) earthquake, which was the largest event to be felt in the UK in the modern instrumental period. With a well-determined magnitude of 5.3 Mw, the Roermond event makes a useful comparison. In contrast, the largest UK event with onshore epicentre was the 19 July 1984 Lleyn Peninsula event at 5.0 Mw.

In the pre-instrumental era, however, the answer is much less certain, partly due to the difficulty of estimating magnitude from limited macroseismic data, especially in the case of offshore events. It is assumed here that magnitude can best be inferred from the area or radius for intensity 3 or 4; this may not hold for events with high epicentral intensity, but it is difficult to calibrate alternatives adequately.

Four events have been proposed as candidates for largest historical earthquake in the UK, and these will be reviewed in this paper. These are: 20 February 1247, 11 September 1275, 19 September 1508 and 6 April 1580. These will now be considered in turn, in reverse chronological order. Locations are shown in Figure 1.

The possibility of large prehistoric earthquakes is not considered here; see Davenport and Ringrose (1985) and Stewart (2001) for a review of this subject.

6 April 1580

The earthquake of 6 April 1580, with epicentre in the Dover Straits, is one of the best known historical British earthquakes, partly due to its having been felt strongly in London, where two children were killed. It was also felt strongly (with damage) in France and the Low Countries. Due to the economic importance of the epicentral area today, the possibility of a recurrence of this earthquake is a matter of obvious concern, and it has been the subject of several evaluations (e.g. Neilson et al. 1984, Melville et al. 1996, Musson 2008a).

The felt effects are quite well documented, and the total area affected by intensity 4 EMS (European Macroseismic Scale – Grünthal 1998) is around 335,000 km^2. From the formula in Musson (1996) this converts to 5.8 ML, or 5.5 Mw, converting from ML to Mw using the

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equation from Grünthal et al. (2009), which seems to be the best conversion for use in the UK.

However, one recent French study (Roger 2011) estimates 6.9 Mw for this earthquake, which would make it the largest NW European historical earthquake, ahead of 1356 Basel (6.5 Mw). This magnitude value is based on French attenuation studies, but the felt area does not seem to have been significantly larger than that for the Roermond event. This does assume that log felt area continues to scale with magnitude for higher magnitudes (say, above 5.5 or 6 Mw), which may not be the case (Frankel 1994), but in the absence of well-recorded large earthquakes in NW Europe it is difficult to be sure. However, comparisons with the effects of other intraplate earthquakes of magnitude 7, for instance, the Grand Banks event of 18 November 1929 (Smith 1966) do not support the notion that the 1580 earthquake could have been as large as 6.9 Mw.

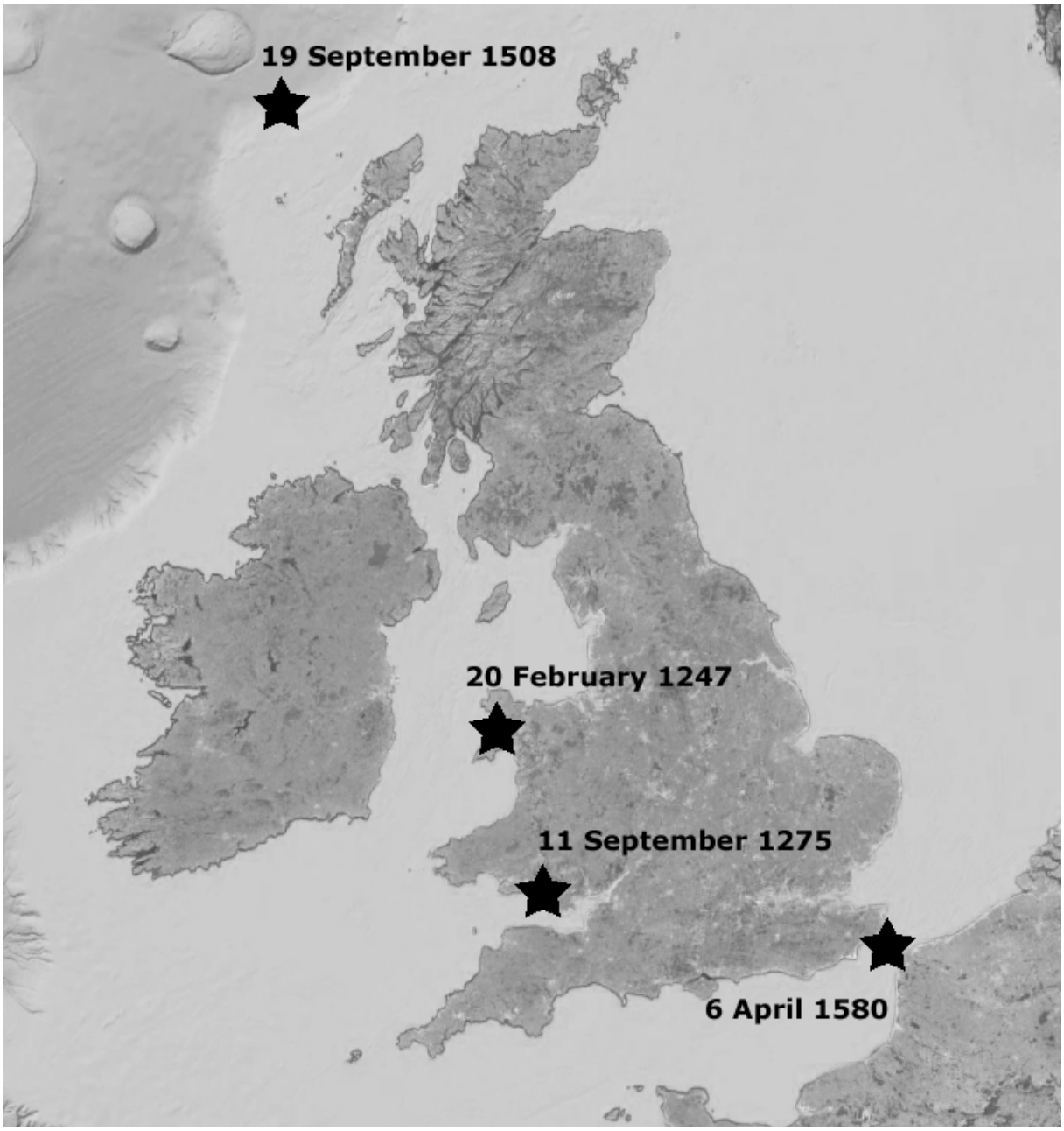

Figure 1. Locations of the four historical earthquakes discussed in this paper

19 September 1508

The earthquake of 19 September 1508 is extremely poorly documented, known from only three abbreviated sources (Leslie 1578, Holinshed (1577) and Balfour (1825). Very unusually for a British earthquake, it is described as felt throughout both England and Scotland, which led Ambraseys and Melville (1983) to locate it in N England/ S Scotland. But such an event would have been likely to cause damage; all that is mentioned is that the shaking was of long duration and was especially felt in churches (Musson 2004, 2008a). This suggests a large distant earthquake with more long-period vibration than usual for British earthquakes, and is consistent with a large passive-margin earthquake like the 1929 Grand Banks event.

If the felt effects of the 1929 event are transposed to an epicentre on the passive margin west or northwest of the Outer Hebrides, all the strongest effects would occur in areas of low literacy, and the intensity in the nearest centres of historical reportage (Central Scotland) would be no more than 5 EMS (Musson 2008b).

The evidence is thus consistent with a passive margin earthquake with a magnitude about 7 Mw. However, one could get similar effects from a magnitude 5.5 Mw event in the Viking Graben, and unless reports are discovered mentioning this earthquake in Ireland or Norway, it is impossible to make any conclusion as to which of these two interpretations is the correct one, beyond the obvious fact that earthquakes of 5.5 Mw in NW Europe are relatively more frequent (the 24 January 1927 Viking Graben event being a relevant example).

11 September 1275

Most studies of historical British earthquakes (e.g. Principia 1982, Arup 1993) treat the earthquake of 11 September 1275 as a Somerset event, on the basis of the fact that the earthquake demolished the tower of St Michael's on Glastonbury Tor. However, a church tower perched on top of a steep and narrow hill is an architectural and topographic anomaly, and it would be unwise to assign a high intensity to such an observation, unsupported by other evidence. The other places mentioned by name in the original chronicles are all well to the east – London, Winchester and Canterbury. This, together with a remark by Thomas Wykes (Luard 1869) that the shock was strongest on the south coast of England and less strong in the north, led Musson (2008a) to suggest an epicentre on or off the south coast of England, comparable with the 1750 Portsmouth or 1963 Chichester earthquakes, but with a much higher magnitude of at least 5 Mw.

Now, new evidence has come to light, suggesting an epicentre further *west*. This is in the form of notes by an 18th century antiquarian, Edward Gamage, rector of St Mary Church and St Athan in Glamorgan from 1717 to 1734. Gamage prepared some notes on the history of the Stradling family, based on original Welsh MSS kept in the library of St Donats castle. The castle subsequently became ruined, and the MSS were lost. Gamage's notes are also lost, but he prepared a digest in a letter to Iolo Morganwg in 1726, and this was published by Morganwg's son (Williams 1837).

Gamage refers to an earthquake in the time of Sir John Stradling which caused immense damage in Glamorgan and Somerset, caused extensive cliff collapse near St Donats, and injured the castle also, the repairs causing considerable expense.

There are some obvious problems with this account. The original sources are all lost, and may be confused or exaggerated. The earthquake is not dated; "in the time of Sir John Stradling" could mean any time in the second half of the 13th century, but the overwhelming probability is that 11 September 1275 is referred to. If the account is taken at face value, it

appears that the damage in Somerset much exceeded the collapse of St Michael's, and was as bad if not worse north of the Bristol Channel (St Donats does not occupy a topographically sensitive site and was badly damaged). Moving the epicentre closer to St Donats raises the possibility that this was a Swansea earthquake, and that the many subsequent known Swansea earthquakes from 1727 onwards are a relic feature of a large earthquake in 1275, in the manner proposed for intraplate seismicity generally by Ebel et al. (2000).

If this is the case, if one takes the observations from London and Canterbury as indicating at least intensity 4 EMS, then the magnitude must have been at least 5.5 Mw. If the intensity at London and Canterbury was 5 EMS, the magnitude must have been around 6 Mw, and this is consistent with a report written in Oxfordshire (the Osney Annals; Luard 1869) that houses and churches in many places in England were thrown down ("subvertebantur") – and also that people were killed, which is something almost never reported (Musson 2003).

So while a Swansea epicentre for the 1275 earthquake and a magnitude of 6 Mw is somewhat speculative, it is consistent with all the evidence. Damage, even collapse, "in many places in England" does suggest that the effects of this earthquake were out of the ordinary, and that there is good reason to suppose this was the largest British earthquake.

20 February 1247

In the earthquake catalogue prepared for the SHARE (Seismic Hazard Harmonisation in Europe) project (Stucchi et al. 2013), the largest British earthquake recorded is none of those previously mentioned, but an event on 20 February 1247, with an epicentre off the west coast of Anglesey (NW Wales) and a magnitude of 5.9 Mw.

This earthquake has been subject to various interpretations in the past. Melville (1983), for instance, treats it as having an epicentre in SW Wales on the basis of a rather vague report of damage to the cathedral at St David's (again, not of itself a reliable indication of high intensity). Musson (2008a) suggests that the epicentre was in Snowdonia, and this earthquake was analogous to the large (~ 5 Mw) events there in 1690, 1852 and 1984. The fact that Snowdonia has such a record of activity makes this hypothesis all the more plausible; as also the report that the earthquake was felt in Scotland (Färber 2000).

The parameters in SHEEC (SHARE European earthquake catalogue) need to be treated with caution. The earthquake parameters for this catalogue were derived in an objective manner from intensity datapoints, and therefore the values are transparent and reproducible. The problem is that such methods are blind to metadata. The high magnitude for this event is dependent on two "damage" observations, widely separated, the one in St David's (SW Wales) and another in Downpatrick (Northern Ireland). The first of these observations is questionable as to exactly what sort of damage occurred, and the second rests entirely on vague folklore of doubtful reliability (Musson 2008a). Thus it is questionable whether one can conceive of a damage area extending all the way between these two points, but the SHEEC epicentre is a point halfway between St David's and Downpatrick, and the magnitude is calculated on the assumption that the intensity was 6 EMS at both points.

Thus, like many another medieval earthquake, the uncertainty on the parameters is huge, making the event of doubtful utility in hazard studies. The epicentre could really have been anywhere in Wales. The arguments in favour of an epicentre in Snowdonia are that other large earthquakes have consistently occurred there, it would favour the event being felt in Scotland, and the slight possibility that the folklore concerning Downpatrick cathedral has some factual basis. But there is no real basis for a magnitude of 5.9 Mw – a value around 4.9-5.2 Mw would be sufficient.

Discussion

Dealing with medieval earthquakes in intraplate areas like Britain is difficult, because the sorts of information recorded by medieval annalists is not the sort of information the modern seismologist really wants. To the medieval writer, an earthquake was a prodigy; something sent from God as a punishment or warning or an omen. If the latter, it was important to record exactly when the event occurred so that it could be matched with later eventualities (Musson 1998). Information on the area over which the earthquake was felt, and the effects it produced on ordinary structures, was of little interest. Effects on structures important to a medieval monk (like cathedrals) might be mentioned, but these are of little use to the seismologist (Grünthal 1998). One must recall how most of the news reports about the 1997 Umbria Marche earthquakes focussed on the damage to the basilica at Assisi, which was actually on the edge of the felt area.

This applies even to the largest events. The description of the 1275 earthquake in the Osney annals is one of the few mentions of damage to secular buildings from this period, suggesting that this may have been an exceptional event. But where one puts the epicentre depends to a great deal on how one interprets Gamage's letter to Morganwg, in the absence of his original MS sources.

Even if this earthquake was a magnitude 6 Mw event, it is still possible that it was exceeded by the 1508 earthquake, except that one cannot be more positive than to say that the interpretation of this as a large passive margin earthquake is not contradicted by the slender evidence. Thus, the question that forms the title of this paper has no definitive answer yet. The earthquakes of 1247 and 1580 are probably not viable candidates; 1275 and 1508 are. However, even if the 1508 earthquake was the larger of the two, the 1275 earthquake had more impact in terms of damage, and even loss of life.

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