The enigmatic Bala earthquake of 23 January 1974

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The earthquake that shook most of North Wales on the night of 23 January 1974 appears unremarkable from its entry in the UK earthquake catalogue. With a magnitude of 3.5 ML it represents the size of earthquake to be expected in the UK with a return period of about one year. However, the prominent atmospheric lights observed at the time of the shock led at the time to speculation that an aircraft had crashed, and search-and-rescue teams were deployed. Since nothing was discovered, it was concluded that a meteorite was responsible; more imaginative members of the public decided (and still believe) that a UFO had crashed. In this paper the record of events is set out, and the nature of the earthquake is discussed with reference to its geological setting.

KEY WORDS earthquake; intensity; earthquake lights; Wales; faulting; structure

1. INTRODUCTION

North Wales, and in particular the area around Caernarfon, is one of the most seismically active parts of the UK. The Caernarfon area appears to host events at the upper end of the observed UK onshore magnitude range (5.0-5.5 ML) at fairly regular intervals, most recently in 1984, previously in 1852 and 1690, probably in 1534, and conceivably in 1247. However, the central part of North Wales is also subject to some seismic activity. Of historical events in this area, the largest seems to be the earthquake of 18 March 1613, felt in Flint, Denbighshire, and Shropshire (Hall 1883, Roberts 1883); the magnitude was probably about 4.0 ML. Better documented is the Corwen earthquake of 11 April 1888, with a magnitude of 3.7 ML in Musson (1994), more recently revised (BGS, unpublished) to 3.8 ML. The seismicity of N Wales is shown in Figure 1.

In such a context, there is nothing very remarkable about the occurrence of a magnitude 3.5 ML earthquake with epicentre near Bala in 1974. However, the circumstances of its occurrence has made this earthquake somewhat controversial. Up until now detailed scientific discussion of the earthquake has been restricted to unpublished reports, so an open discussion may be timely.

2. NARRATIVE

The exact start of the sequence of events, from instrumental evidence, was 20h 38m on 23 January 1974, a Wednesday. We consider first the sequence of events as reported by the newspaper press, principally the Liverpool Daily Post, which was the main daily paper for the area affected.

By 20h 45m scores of people in N Wales and Cheshire had phoned the police to report a mysterious bang and rumbling (Liverpool Daily Post 28 Jan 1974 p3). At Gwynedd Police HQ, Colwyn Bay, six officers and three civilian staff on duty were soon inundated with calls. “We checked with RAF Valley [Anglesey] and the air traffic control centre at Preston and had to treat as if a plane had crashed” reported the officer on charge (Liverpool Daily Post 28 Jan 1974 p3). Within an hour “about ten” officers had begun searching in the Berwyn Mountains where lights had been reported, and emergency services were alerted (Liverpool Daily Post 28 Jan 1974 p3). The police team was joined by an RAF mountain rescue group and “teams of experts”

(Liverpool Daily Post 25 Jan 1974 p1), the latter apparently including some from Keele University, presumably the following day.

The next day it was reported that Gwynedd police had received a report of what appeared to be a meteorite having come down in flames and exploding on Cader Fronwen, 2 km SE of the village of Llandrillo, 10 km E of Bala (Liverpool Daily Post 24 Jan 1974 p1). Isle of Man police reported observations of a meteorite seen travelling in the direction of North Wales, and this was confirmed by Anglesey coastguards, who described it as green. Coastguards elsewhere, in the Isle of Man, Formby (Lancs) and as far away as Cumberland, received reports of “green flares”; an observer at Formby was certain that a meteorite shower was responsible (Liverpool Daily Post 24 Jan 1974 p1).

Meanwhile, the event had been picked up by the seismometers of LOWNET, which at that time was the main monitoring network for the UK, though restricted to stations around Edinburgh, and also at Eskdalemuir Observatory. First press reports the morning after the event quoted a spokesman from the Institute of Geological Sciences (IGS, now British Geological Survey) under the headline “Earth tremors shake N Wales” (Liverpool Daily Post 24 Jan 1974 p1).

The following day, newspaper reports spoke of disagreement over the cause of the event. On the one hand, it was suggested that the event must have been a meteorite, as nothing else would explain the lights seen. On the other hand, the view from IGS was that, given the preliminary magnitude value of around 4 ML, it would have needed such a large meteorite that it would have been unmistakable. A third theory, that a wartime German bomb had gone off, was discounted. (Liverpool Daily Post 25 Jan 1974 p1). It was now further suggested that many people, especially in the Isle of Man, had actually seen an RAF photo-flash night bombing exercise. It was also noted that many of the light phenomena were reported after the tremor (Liverpool Daily Post 25 Jan 1974 p1). A detailed observation of a “flying sphere” was made at Betwys-y-Coed at 21h 58m, an hour and twenty minutes later (North Wales Weekly News 31 Jan 1974 p3). An even later observation was made at Gobowen, 25 km E of Llandrillo, on 24 January at 09h 15m. This was described as disc with revolving coloured lights, observable for about ten minutes (Evening Leader 30 Jan 1974 p18).

The possibility of finding the meteorite drew in geologists to search the area over the weekend, including staff and students from Leeds, Liverpool and Durham Universities, and various amateurs. Nothing was found (Western Mail 28 Jan 1974, p3). An astronomer from Keele University spent an hour searching the area by helicopter, and concluded there was nothing to be seen. Noting that an impact sufficient to have created the observed shock would have left a large scar, he conceded that an earthquake must have occurred. (Liverpool Daily Post 26 Jan 1974 p1)

Once reports began coming in, the Gwynedd Constabulary opened a major incident log, titled as an explosion at Llandrillo, at 21h 00m. The first entry noted that local police were instructed to remain in the area, that assistance was being despatched, and Merionethshire Fire and Ambulance HQs had been put on stand-by. At 21h 08m the RAF was in touch to request full information on the incident, and reporting that the RAF team at Valley had been placed on stand-by. The possibility of either a civil or a military aircraft having crashed was being considered. At 21h 30m air traffic control in Preston was alerted. Further contact between police and RAF was logged until 23h 30m, when it was reported by the senior officer at Llandrillo that the police search parties were all now down off the mountain, having found nothing; they did see a green glare to the south. (Some of the lights seen on the mountain that night subsequently turned out to belong to poachers.) It was decided that a further token search would be made in the morning. An enquiry was made as to whether any soldiers were training in the area; this proved not to be the case. The movements of the RAF mountain rescue team have been traced from the Valley log by Roberts (2001). Having started from Anglesey, they didn't reach Llandrillo until midnight, and didn't set foot on the mountain until the following morning.

Thus, next morning, according to the police log, the RAF mountain rescue team was out on the Berwyn Mountains at first light, and were joined by several police officers. At 10h 12m the Army Disposal Unit at Hereford was in touch to express an interest should the site of the explosion to be found. However, all searches were without fruit, and the last one was called off at 14h 13m. By now it was ascertained that no aircraft were reported missing, and thus the need for civil assistance could be ruled out. The police logs also contain many more details of calls and enquiries; the above synopsis covers the most salient points concerning the response to the incident. The only other item concerning the response to the event is the enquiry on 25 January from someone at Sheffield University asking about the provenance of a light aircraft apparently taking photographs in the Llandrillo area; this was referred to RAF Huntingdon. This plane has subsequently been identified by Roberts (2001) as having been chartered from RAF Valley by another academic.

The response of IGS, besides gathering and analysing the instrumental data for the event, was to send a survey team of four people to the area around Bala to gather macroseismic data by conducting interviews and distributing questionnaires through community centres. In addition, the macroseismic questionnaire was published in local newspapers in order to get a wide circulation throughout North Wales. The papers used were: Liverpool Daily Post (both Merseyside and Welsh editions), North

Wales Weekly News, Rhyl Journal and Advertiser, Western Mail, and also the Daily Mirror (a national paper). The IGS field team arrived in the area on 26 January and continued working until 30 January. Apparently (according to Roberts 2001) local recollection of strangers arriving shortly after the event and asking questions was interpreted many years later by UFO enthusiasts as evidence of some sort of official cover-up; possibly the only instance of seismologists being mistaken for “men in black”.

As a footnote to this story, it is apparently part of the folklore of this event that Berwyn Mountain was immediately sealed off by the military and not even the police were allowed on the hillside (e.g. http://www.cseti.org/crashes/047.htm). This is clearly contradicted by the police log books. Roberts (2001) has shown that this is a confusion with a later incident on 12 February 1982, when an RAF Harrier jet crashed on Berwyn and the hillside was cordoned off while the wreckage was recovered.

3. THE EARTHQUAKE

During the 1970s regular bulletins of British earthquakes were not issued, and all determinations from 1967 to 1978 were published as a single catalogue by Burton and Neilson (1980), which contains the initial IGS determination of parameters for the 23 January 1974 earthquake. Shortly afterwards, IGS became BGS. The instrumental data were revisited by Turbitt and Innes (1988) and revised, and these are the values given in the present BGS earthquake database (Walker et al. 2003). Table 1 compares the two sets of parameters.

Turbitt and Innes (1988) had access to more data than were used by Burton and Neilson (1980). The earlier study relied on the LOWNET network of stations around Edinburgh. These being far from the epicentre and all in one quadrant, were not ideally placed for an accurate location. The study by Turbitt and Innes (1988) still relied heavily on LOWNET, but added data from Eskdalemuir, the Eskdalemuir array, Durham, Rookhope, Wolverton, Valentia (Ireland) and temporary stations at Stokenchurch monitoring the construction of the M4 motorway west of London. While the earthquake was also recorded in France, Belgium, Germany and Norway, it was found that including these data gave unacceptably high residuals. The station distribution is shown in Figure 2. No fault plane solution could be obtained.

The revised location is shifted 13 km NW of the original determination, giving a position 7 km due west of Corwen (Figure 3). However, given the fact that this location is ± 9 km, little can be made of its exact position. The shift of the depth from 15 km to 7.5 km is also subject to a high uncertainty in the determination.

A sample seismogram is shown as Figure 4.

Turning to the macroseismic data, these were not worked up in detail at the time, though a preliminary isoseismal map (without data points) is given in Turbitt and Innes (1988). They were analysed in detail finally in 1997 as part of a Nuffield Science Bursary project, but not published at that time other than as a project document (Campanile 1997). The analysis followed the standard BGS methodology for processing macroseismic questionnaires (Musson 1992, Musson and Henni 1999). The work was checked and further revised in 2001 in connection with a commercial hazard study.

The total data set comprises 448 questionnaire responses from 112 places. Of these responses, only seventeen were negative and there were four places from which only negative replies were received.

The maximum intensity observed was 5 EMS, at five places: Bala, Carrog, Corwen, Llandrillo and Maentwrog. At Gobowen and Llanfyllin the intensity was probably 5 EMS, but sufficiently uncertain to be assessed as 4-5 EMS. This split value (4 or 5) was also assigned to five other places. The amount of damage was insignificant, but not quite zero. At Llandrillo a window was cracked and one unspecified report of damage was received from Bala. Other damage reports were distant from the epicentre. A ceiling apparently fell in at Penrhyndeudraeth (about 30 km W of Bala) and ceilings were reported cracked at Abergele (40 km N of Bala) and Burton (50 km NE of Bala). Near Bala it was said that loose stones moved down the hillside, an effect which in the author’s experience tends to correlate well with 5 EMS.

The limits of the felt area were as follows: in the west, Aberdaron, in the Lleyn Peninsula; in the north, Ormskirk (near Liverpool), in the east, Telford, Shropshire, and in the south, Church Stretton (also Shropshire). Figure 5 shows the distribution of intensity data points, and Figure 6 shows isoseismals for 5, 4 and 3 EMS (slightly revised for this study from those given in Campanile 1997).

Analysis of the isoseismals to obtain macroseismic parameters using the methods given in Musson (1996) gives values between those of Burton and Neilson (1980) and those of Turbitt and Innes (1988), but more similar to the former. The macroseismic epicentre is in the Berwyn Mountains NE of Llandrillo, and the macroseismic depth is 13 km. However, given the uncertainties on the locations, the divergences are not really significant. The macroseismic magnitude, on the other hand, is on the high side. Using the isoseismal 3 EMS or the isoseismal 4 EMS one obtains a value of 3.9-4.0 ML. There is no obvious reason why this discrepancy should occur; usually for modern earthquakes the macroseismic and instrumental magnitudes are in good agreement; occasionally this fails to be the case (one of the 1979 Carlisle aftershocks is another problem case, Musson and Henni 2002).

4. THE LIGHTS

Figure 7 shows the distribution of places where people noted on questionnaires that they observed lights in the sky at the time of the earthquake. This distribution reflects more the distribution of earthquake effects rather than light effects, as from other evidence it is clear that the lights were seen over a wide area, including places where the earthquake was not felt at all.

The coincidence of aerial lights and an earthquake may seem curious, so it is worth quickly visiting the alternative explanations that could avoid such a coincidence. The first is the supposition that there was no earthquake, and the seismic effects were impact related. As well as contemporary speculation along these lines, the event is still listed as a possible impact event in Stratford's (2004) catalogue. This is immediately disposed of for two reasons. Firstly, the focal depth, even if not well determined, was clearly not superficial. Secondly, a magnitude between 3.5 and 4.0 ML would be equivalent to a blast of between some hundred tons of TNT and a small nuclear weapon, and such an impact could not but leave a significant crater.

The counter explanation is that, if the earthquake was not due to the lights, the lights were due to the earthquake. Earthquake lights are a phenomenon generally only associated with large earthquakes, although there is some suggestion that some British earthquakes, despite their small size, have been associated with some sort of anomalous luminous phenomena (e.g. the 1966 Helston earthquake – Musson 1989). In this case, the lights were well observed over a wider area than the earthquake was felt over, for a considerable part of the evening. There can be no doubt that a meteor shower took place as well as an earthquake that night. Auroral effects can be ruled out as the night was magnetically quiet (Kerridge 2006 pers. comm.).

One could possibly suggest that a small meteorite impact could have triggered an earthquake that was on the point of occurring anyway, but this seems somewhat far-fetched.

This is by no means the first time such a coincidence has occurred in the UK. Leaving aside cases where the shock wave from a meteorite has been mistaken for an earthquake (a very good example is another N Wales case, on 14 April 1931, where the meteorite was actually recovered) there are at least two previous cases where a genuine earthquake has taken place at the same time as a meteor was observed. The best documented of these is the case of the 17 December 1896 Hereford earthquake (5.2 ML). This is discussed by Davison (1899), who states that the meteor, which was seen by numerous observers more or less exactly at the time of the earthquake, travelled on a bearing of 350^{o}, passing over Devizes, Malmesbury, Worcester, Kidderminster, Newport and Northwich to Longridge (near Preston). Davison (1899) dismisses any possibility that any of the reported effects of the earthquake could in fact have been due to the passage of the meteor. The other case is less well known: the 18 August 1892 Pembroke earthquake (5.1 ML), during which a meteor was observed on the Towy estuary, at Ashburton, and possibly at Trecwyn, near Fishguard (Musson et al 1984).

Probably these coincidences should be viewed in the same way as one can view many of the reports of domestic animals behaving strangely before an earthquake – the fact is that domestic animals often behave strangely, but when nothing occurs afterwards, the event is forgotten. When the behaviour is followed by an earthquake, it is interpreted as significant in retrospect. Similarly, meteors are sufficiently common that some coincidences between meteor observations and earthquakes over a long period of time are inevitable, no matter how striking they may seem at the time.

5. THE GEOLOGY

Immediately after the occurrence of the earthquake, the fault that first came under suspicion was the Bala Fault. It seems to be a common phenomenon that British earthquakes are usually attributed at once to the largest fault in the region, without any real evidence. The most extreme case was perhaps the report, broadcast on radio news, that the 26 December 1979 Carlisle earthquake was probably due to movement on the Great Glen Fault (Times, 27 December 1979 p1) 230 km from the epicentre. In practice, problems of hypocentral inaccuracy and a lack of knowledge of faulting at depth makes the association of earthquakes with individual faults extremely difficult, although the situation is much improved for some recent earthquakes due to better monitoring and improved location techniques (Baptie and Ottemöller 2004). The first British earthquake for which one can make a strong case for association with a known surface fault is perhaps the 16 September 1985 Ardentinny earthquake (Redmayne and Musson 1987). Blenkinsop et al (1986) present a case for the 15 April 1984 Felindre earthquake being associated with a specific bounding fault of the Felindre Basin, but in the absence of a fault plane solution, the evidence is less compelling.

Properly, it is better to speak of the Bala Lineament, which consists of three sub-parallel en echelon faults trending SW to NE (Fitches and Campbell 1987); these are the Tal y Llyn, Bala and Bryn Eglwys Faults (Figure 7). This is one of several Caledonian-trending lineaments that cross the Welsh Basin, and is a very old structure that initiated in Precambrian-early Cambrian times. According to Fitches and Campbell (1987), this part of the Welsh Basin was probably tectonically active for much of Lower Palaeozoic time, with the Bala Lineament and analogous structures controlling block margins in a system of horsts and grabens in an extensional tectonic regime. During the Upper Palaeozoic strike-slip faulting was dominant, probably but not certainly left-lateral. Campbell (1993) quotes a figure of 5 km of left-lateral strike-slip movement on the Bryn Eglwys Fault during the Variscan. Evidence for later movement is uncertain. Fitches and Campbell (1987) consider that offshore reactivation of the Bala Lineament was probable in Mesozoic-Cenozoic times, but they find onshore reactivation less likely, though this is suggested by Dobson and Whittington (1987) on sedimentological grounds.

Fitches and Campbell (1987) state that both the Tal y Llyn Fault and the northeast end of the Bala fault have been seismically active in historical times, on the authority of Blenkinsop et al (1986). In fact, Blenkinsop et al (1986) are more tentative: “The cluster of events around Llangollen delineates the northern extension of the Bala Fault, picking out the roughly E-W trend of the Glyn Ceiriog fault … two large events in Cardigan Bay could indicate that the western extension of the Bala Fault is active in this area also.” Of the two events in Cardigan Bay, one is the 23 April 1951 Aberdyfi earthquake (3.1 ML), the exact location of which is rather uncertain, and the other corresponds to no located earthquake, and presumably refers to some tentative location of a medieval earthquake, most likely 20 February 1247, that could in reality be 100 km away – useless for any tectonic speculation. As for the E-W trend around Llangollen alluded to by Blenkinsop et al (1986), examination of Figure 1 shows in fact a roughly NE-SW trend of epicentres. A little historical revision of events with an inherent locational uncertainty serves to destroy one convenient alignment and replace it with another that, despite the fact that it now follows nicely the Caledonian grain of the geological structures, is probably just as spurious.

Furthermore, considering that all of this cluster, bar the 1974 event, are located entirely from macroseismic data, and therefore the data are biased towards the locations of towns and villages, and these are in valleys, and the valleys are controlled by faults, it is no wonder that epicentres appear to correlate with structure.

The further problem relates to the prevailing stress conditions in the UK. It has generally been found (Whittaker et al. 1989, Chadwick et al. 1996) that maximum compressive stress is roughly from the NW, and that the dominant trend in UK seismicity is for strike-slip faulting on N-S or E-W trending faults (Ritchie and Walker 1991, Chadwick et al. 1996). A near-vertical, NE-SW trending fault is thus unlikely to be reactivated. Fitches and Campbell (1987) reproduce a map of lineaments in the Bala area identified from Lansdsat images, and they suggest that these show good correlation with known or inferred faults. There are numerous N-S and E-W lineaments in and around the plausible epicentral area (as identified by the two instrumental locations and the macroseismic epicentre) and any of these could be the host feature for the Bala earthquake.

6. CONCLUSIONS

Revised instrumental and macroseismic data have been presented for the 23 January 1974 Bala earthquake. This event was one of the largest earthquakes in North Wales away from the Caernarfon-Lleyn Peninsula area; the instrumental magnitude was 3.5 ML, the macroseismic magnitude higher at 3.9-4.0 ML. Given the uncertainties, the true value is probably in between. The depth is poorly determined, between 7 and 15 km. No foreshocks or aftershocks were detected. The earthquake attracted controversy due to its coinciding with a bright meteor display; there is no suggestion that any earthquake effects were mistaken for meteor effects or vice versa. Despite reports that a meteorite impacted in the Berwyn Mountains, near the earthquake epicentre, the extensive searches that were made immediately afterwards suggests that this was not the case.

Data are insufficient to suggest a causative fault for the earthquake; it was probably not due to the Bala Fault or Bryn Eglwys Fault, the two most prominent structures in the area, and was more likely on a N-S or E-W fault, by analogy with other regional seismicity. Convenient alignments of historical epicentres are shown to be unreliable, and may relate to topography and human settlement. Consequently there is no evidence at present that the Bala Lineament is active in any neotectonic sense, and it is unlikely that it would be in present stress conditions.

ACKNOWLEDGEMENTS

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FIGURES

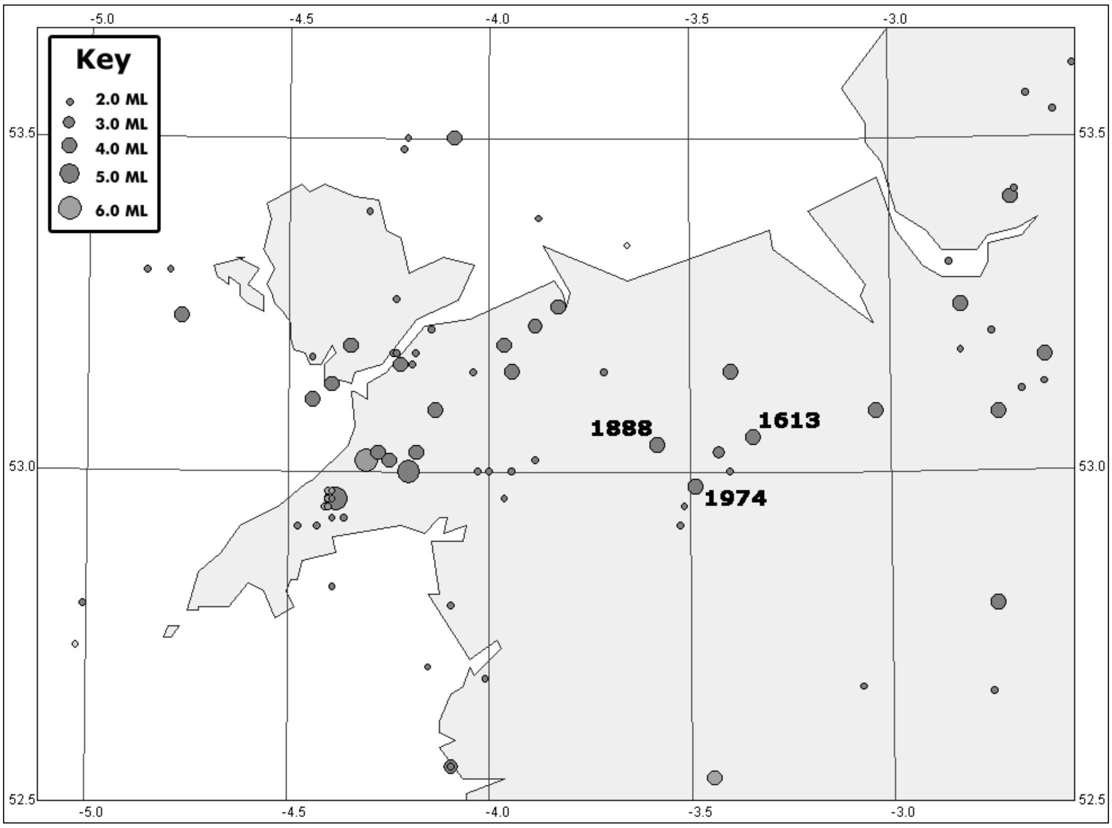

Figure 1

Seismicity of North Wales. Dates are shown for earthquakes discussed in the text.

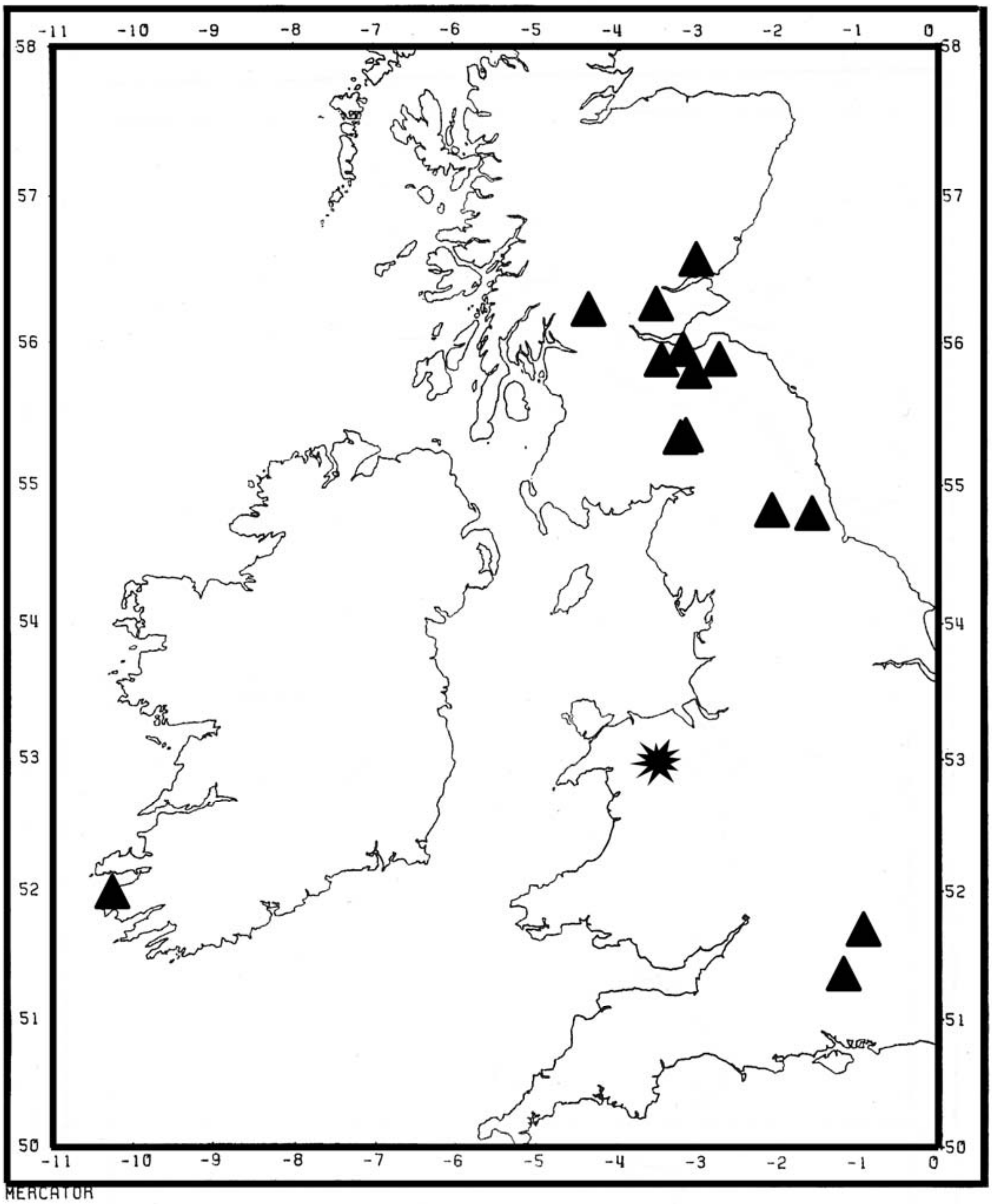

Figure 2

Stations used to determine instrumental parameters for the 23 January 1974 earthquake, adapted from Turbitt and Innes (1988). Star shows the position of the earthquake.

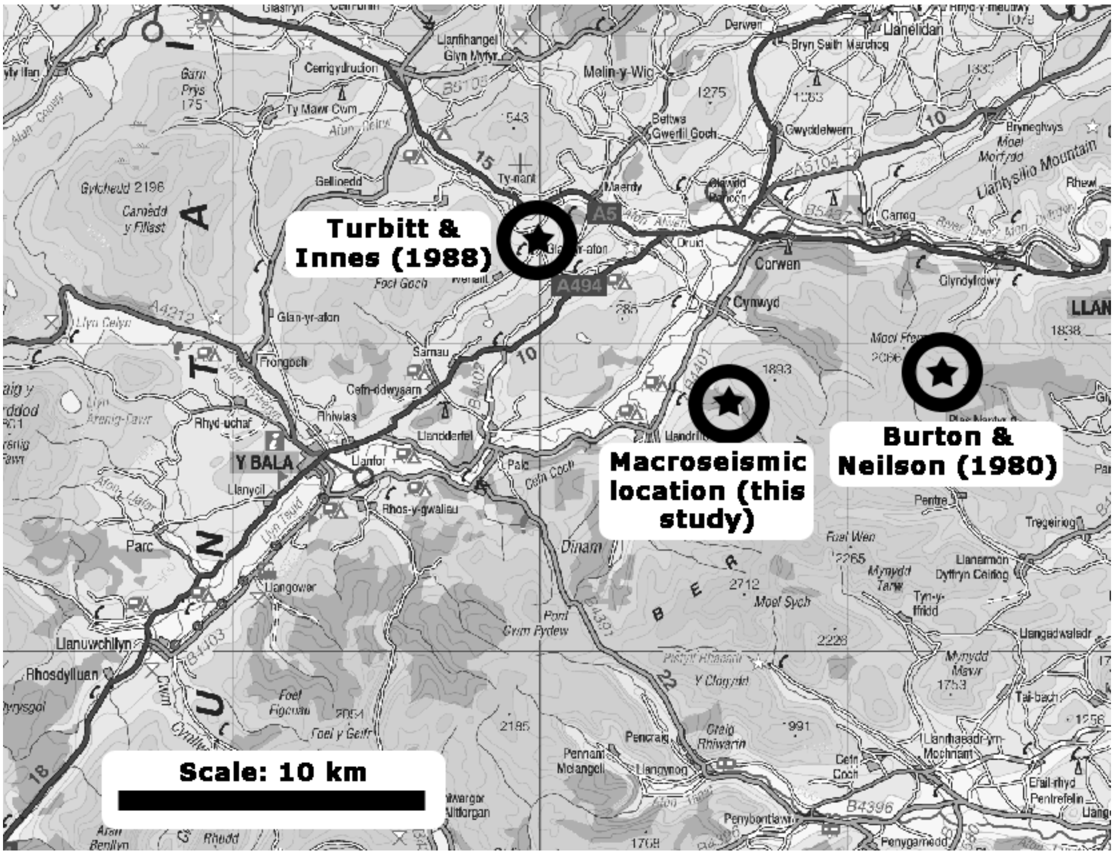

Figure 3

Location map for epicentral determinations of the 23 January 1974 earthquake.

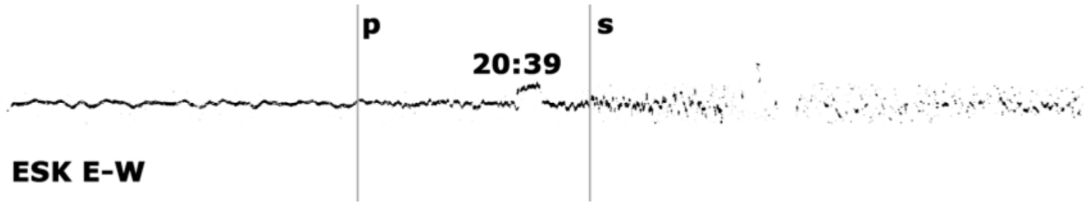

Figure 4

Example seismogram of the 23 January 1974 earthquake – the E-W horizontal component of the short-period WWSSN instrument at Eskdalemuir Observatory. Picks (p and s) are those made by G. Neilson in 1974.

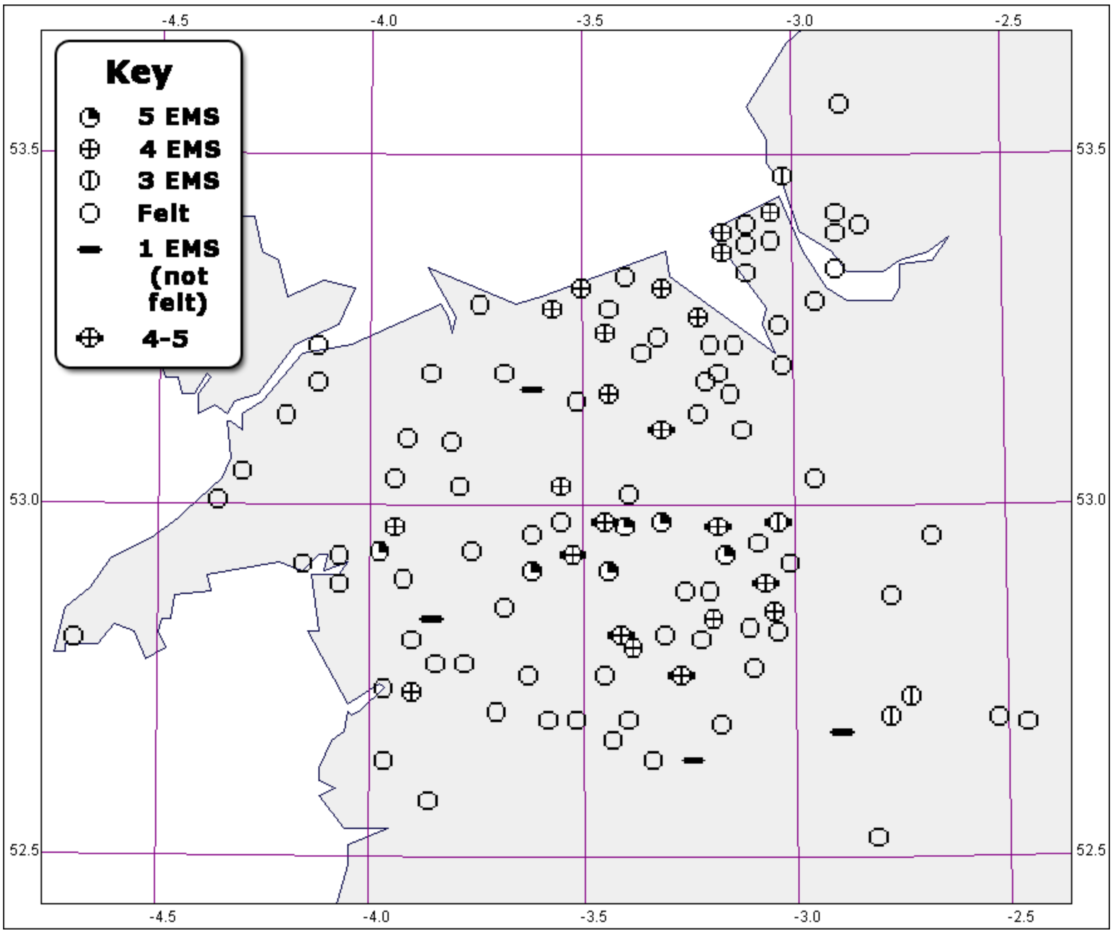

Figure 5

Intensity data points of the 23 January 1974 earthquake. Points are plotted using the international symbol set for intensity data. Circles with lugs either side indicate that the value is uncertain between that shown and the next highest.

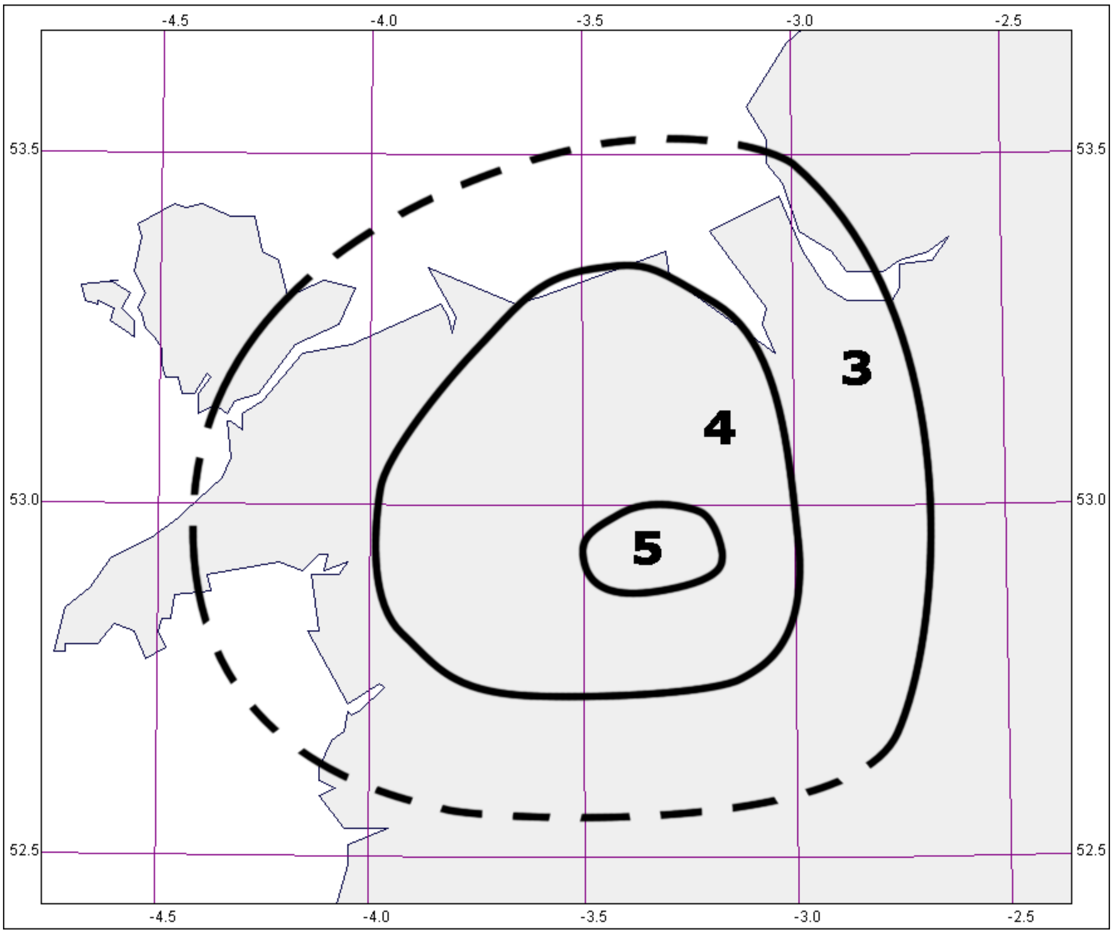

Figure 6

Isoseismal map (EMS intensities) for the 23 January 1974 earthquake.

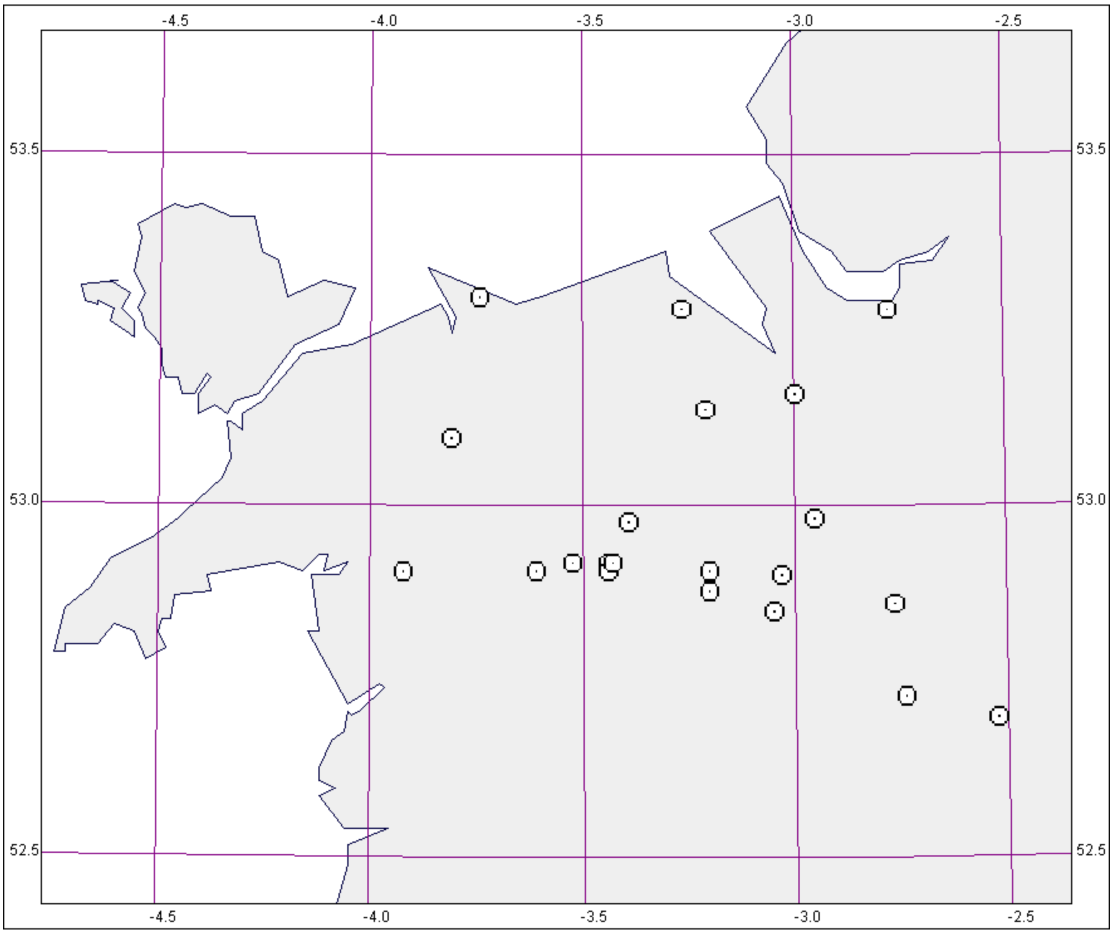

Figure 7

Location of places where the earthquake was felt and observers noted on the questionnaire that lights were seen around the same time.

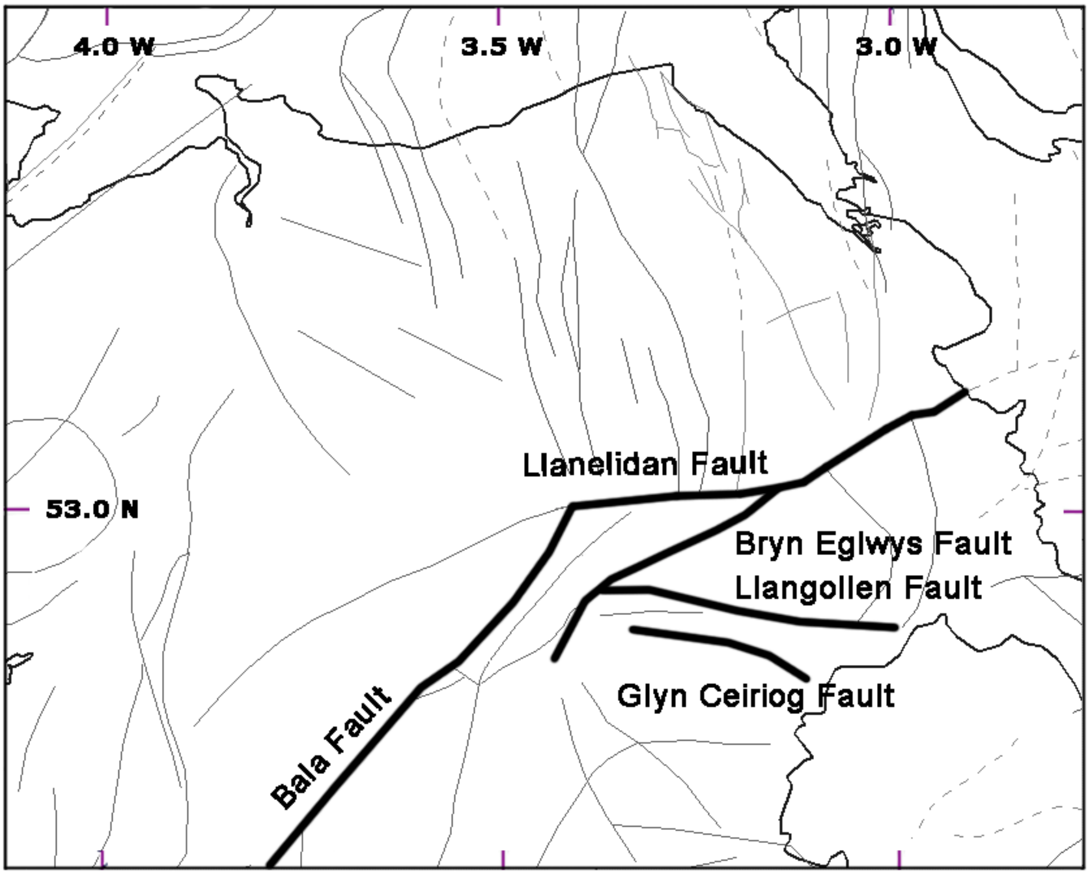

Figure 8

Location of faults discussed in the text (solid black lines). Also shown in fainter lines are other major faults in the region from the BGS fault database.

TABLES

	Burton and Neilson (1980)	Turbitt and Innes (1988)
Origin time	20h 38m 01.6s	20h 38m 00.9s
Epicentre	52.94 N 3.30 W	52.98 N 3.49 W
Depth	15 km	7.5 km
Magnitude	3.5 ML	3.5 ML
Epicentral error (1 s.d.)	Not determined	8.9 km
Depth error (1 s.d.)	Not determined	12.5 km

Table 1 – Instrumental parameters of the 23 January 1974 earthquake