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In this issue

The Macroseismic Survey of the 27 February 2008 Market Rasen Earthquake

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Immediately following the occurrence of the Market Rasen earthquake on 27 February 2008 (5.2 ML, 4.5 Mw), an online questionnaire was opened on the BGS web site to collect felt reports. In addition, questionnaire data were collected automatically by USGS as part of the "Did You Feel It?" (DYFI) programme (Wald et al. 1999), and also by EMSC as part of its European monitoring. Some additional data were also gathered by agencies on the fringe of the felt area, notably ROB in Brussels, and DIAS in Dublin. This report summarises the findings.

The total number of usable data collected were as given in Table 1.

Each agency initially processed its own data according to its own procedures. The map produced by USGS was based on its principle of "community intensity", in which each questionnaire was assigned a score based on several indices, and a Modified Mercalli intensity value assigned to the average score for a particular place, based on a correlation between such scores and assigned intensities for the 1994 Northridge earthquake (Wald et al. 1999). The BGS data was assessed for EMS-98 intensities according to a procedure described by Musson (2006). The data were aggregated by squares 5x5 km in size, and an intensity assigned to each square according to the proportion of reports of various different effects. The EMSC data was processed by town or city, but the intensity assessment procedure was one based closely on Musson (2006), as described in Gilles (2008). A difference between the BGS and EMSC procedures is that the former only attempts to assign intensity given at least five responses, otherwise it is only noted as "felt". Both USGS and EMSC attempt to assign intensity values to a place even if there is only one observation.

It should be noted that none of these are intensity assessments as they might have been made twenty years ago, by a seismologist comparing data to the text of the intensity scale. The DYFI process never really assigns intensity at all; it is based on a correlation between a set of scores and a training data set. The Musson (2006) procedure is intended to mimic the mental processes of a seismologist assigning intensity, but in the end,

Agency	Number of responses
BGS	19,927
USGS	10,794
EMSC	596
Others	31
Total	31,348

Table 1. Data received, by agency

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SECED member awarded 2007 EERI Innovation Prize

Dr Rui Pinho, a SECED member since 1996, was the recipient of the 2007 edition of the prestigious EERI Innovation Prize (Earthquake Engineering Research Institute, California, USA) in recognition of his "exceptional leadership qualities, problem-solving capabilities, and entrepreneurship in defining and executing major programs leading to the reduction of earthquake risk".

Dr Pinho, a past lecturer at Imperial College, now based at the University of Pavia, was awarded for his major role in the development of the Centre for Post-Graduate Training and Research in Earthquake Engineering and Engineering Seismology (the ROSE School), which is widely recognized as a leading international training center in the field.

Pinho's role as deputy coordinator of the LESSLOSS project, involving nearly 50 European partners focused on risk mitigation for earthquakes and landslides was also recognised, as was his position as co-founder and technical director of SeismoSoft, an enterprise that develops and distributes a free collection of structural analysis and signal processing programs that have been accessed by users in over 100 countries.

The Shah Family Innovation Prize is a cash award granted to younger professionals and academics, currently in its tenth edition. For further information, visit http://www.eeri.org/home/honors_shah_innovation.html.

Seismic design of masonry structures

Evening Technical Meeting, Thursday 18 September 2008 at 6pm, Institution of Structural Engineers, London, presented by Prof A. Plumier and Prof H. Degée.

This meeting will focus on the seismic design of masonry structures in moderate seismicity regions. Presentations will be made by Professors André Plumier and Hervé Degée from the University of Liège, and will address key technical issues related to the assessment and design of masonry construction. The meeting is complementary to the short course *Seismic Design to Eurocode 8* (see p. 8). Attendance at the presentation is free, and reservation can be made for the dinner held after the meeting at a cost. Further information regarding the event and the venue will be available at the website of the Institution of Structural Engineers (http://www.istructe.org.uk).

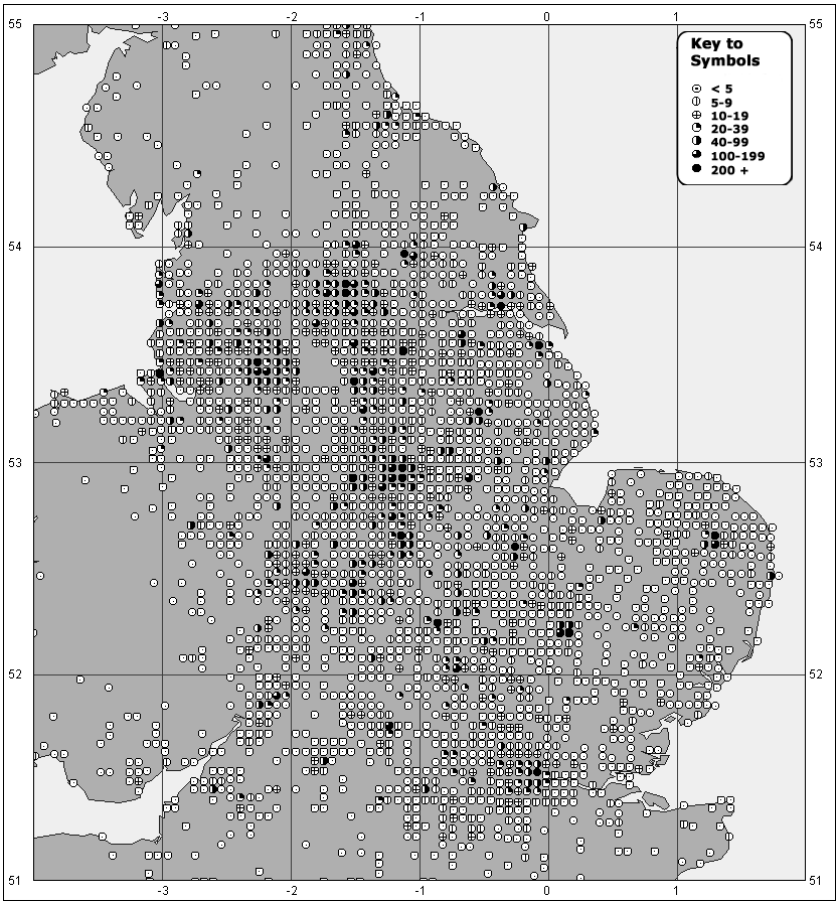

Figure 4. Number of reports per place on which intensity values are based, for the area shown in Figure 1b

that can be discerned just by walking round the streets looking at the outside of houses. Ultimately, however, it can be stated that in the context of this study, intensity 6 is defined according to whether the data received passes or fails certain tests laid down in the intensity-assessing algorithm. This process is entirely transparent and objective, and consistent from earthquake to earthquake.

The earthquake was felt very widely over an area bounded by the Lancashire coast, York, Norwich, London, and Birmingham, and additionally in two pockets around the mouths of the rivers Tyne and Tees. Over this area the intensity was a mixture of 4 and 5 mingled and almost undifferentiated by distance; south of Bedford there are signs that the intensity was reducing, but the shaking seems to have been quite marked in London. The isoseismal 5 has been drawn to enclose the area where the intensity was predominantly 5 EMS. Isoseismal 4 is open to some interpretation; it is clear that the intensity dropped sharply west of Birmingham, but the northern part of the contour is partly shaped by population distribution. Figure 4 is also useful; it shows the number of reports received from each location, and confirms, for instance, that the intensity values around Norwich were assigned on large samples, and not just a few questionnaires.

The course of the isoseismal 3 is also somewhat subjective, given that data beyond the area of intensity 4 are mostly too sporadic for good intensity assessments. The course of the isoseismal 3 in such cases is often influenced chiefly by a decrease in the density of observations.

The earthquake was definitely felt in Aberdeen at very low intensity, and there are a few isolated reports from the countryside north of Aberdeen. A very small number of people felt the earthquake in Ireland, France, Belgium and the Netherlands. The most distant report was from Liege, just off the east of Figure 1a.

Processing the isoseismals to yield macroseismic parameters for the earthquake (Musson 1996) gives a magnitude of 5.2 ML and a depth of 25-30 km. The magnitude is in very good agreement with the instrumental data; the instrumental depth is not well constrained but the event is clearly deep and at least 20 km. Not surprisingly, given the absence of high intensities in the epicentral area, the macroseismic epicentre is not well determined. Using a method based on the attenuation method proposed by Peruzza (1992) but better known in its development by Bakun and Wentworth (1997) gives a solution at 53.20 -0.82 (39 km from instrumental location). The Boxer solution (Gasperini et al. 1999) is better, at 53.43 0.69 (24 km from instrumental location).

The Market Rasen earthquake was not only the largest earthquake in Britain since 1984, it is looking like being one of the most expensive, with the total cost to insured property likely to be in the low tens of millions of pounds, according to the Association of British Insurers. Thanks to internet technology, it has been possible to gather and process a huge macroseismic dataset in a very short amount of time.

Acknowledgements

I would like to record my thanks to Dave Scott, BGS, Dave Wald and Vince Quitoriano, USGS, Sébastien Gilles, EMSC, Thierry Camelbeeck, ROB, and Tom Blake, DIAS for their assistance. This paper is published with the permission of the Director of BGS (NERC).

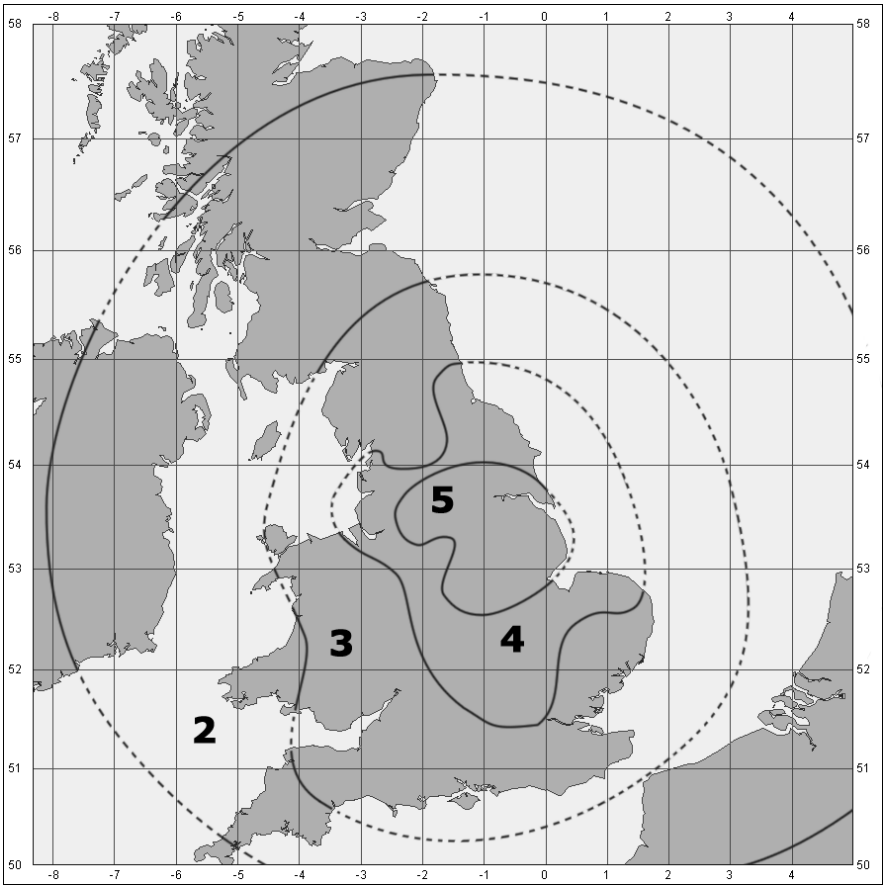

Figure 2. Isoseismal map based on Figure 1

Figure 3. Street scene in Gainsborough on the day of the earthquake, showing an instance of chimney damage (BGS photo by SL Sargeant)

number of respondents to the BGS survey who reported some kind of damage to property was 7%. The figure for the USGS data set was 7%. The figure for the EMSC data set was also 7%. A comparison was also made on the issue of the overthrow of objects. The BGS/EMSC questionnaire asks two questions: were any small objects moved or knocked down, and were stable objects like books moved or knocked down. The USGS questionnaire asks only about objects on shelves, and offers the responses of a few things fell down, many fell down, or everything fell down. Probably the answers to the USGS question are better compared to "stable objects" in the BGS questionnaire. The percentage of the entire USGS data set reporting at least a few objects thrown down was 10%. The percentage of the entire BGS data set reporting objects like books shifted or fell was 10% (the equivalent EMSC value was higher: 31%, but the EMSC data is more biased towards the near-field of the epicentral area).

The results show isolated values of 6 EMS at 59 locations, widely scattered over England in an area roughly between York and Nottingham, and east of Manchester. In no part of this area was the density of such observations sufficient to draw an isoseismal 6. It was a very noticeable characteristic of the earthquake that damage was reported in isolated cases over a very wide area; much greater than is normal in comparable earthquakes, and probably related to depth. The 1984 earthquake, which also had a depth of around 20 km, caused damage as far away as Liverpool. Examination of the area around the epicentre on the day of the earthquake did not suggest intensity 6; the isolated damaged chimneys were in almost all cases in very poor condition anyway (Figure 3 and Sargeant 2008, pers. comm.). This may well be true of more distant chimney damage. Five of the intensity 6 locations were assessed on the minimum of five responses to assess intensity; however, fifteen were based on twenty or more responses, and two on more than 100 responses.

Since the questionnaire respondents are self-selecting, there is likely to be an inherent bias towards stronger effects, which may lead to assessments of intensity 6 where this was actually observed only very locally, or even not at all, compared to what would be obtained from an exhaustive survey based on random selection. On the other hand, field investigation tends to neglect interior damage and non-damaging effects, which also contribute to intensity 6 assessments. One should beware, in assigning intensity, of becoming fixated on a few damage diagnostics, especially those

the intensity values are assessed according to a set of rules (detailed in Musson 2006) rather than the wording of EMS-98 (Grünthal 1998). In both cases, the procedures are totally objective.

Following the web publication of the immediate results of the three macroseismic surveys, the three data sets (the raw data, not the intensity values) were combined. In the case of the EMSC data, this was easy, since the EMSC questionnaire is based on the BGS one. For the USGS data this is much more of a challenge, since the USGS does not collect data on some common macroseismic diagnostics. For instance, one of the key differences between intensity 3 and 4 EMS is that at intensity 4, the shaking is strong enough to rattle doors, windows, crockery, etc. This information is missing from the USGS data and has to be recorded as "no answer" in the final data set.

The final data set of 31,348 responses is the largest macroseismic data set ever assembled for a UK earthquake. The previous record was held by the 19 July 1984 Lleyn peninsula earthquake, for which about 12,000 paper questionnaires were collected (and not all of which were ever processed because of the magnitude of the task; Musson 1992). Values were assigned to a total of 2,763 places, including those where only "felt" or "not felt" is given.

The data points are shown in Figure 1. Figure 2 provides an isoseismal map. The results are heavily dominated by the BGS data set, because of the superior geo-coding used, by which each questionnaire response can be located to 1 km. The USGS data, when converted to the 5 km grid system, give only 390 points. Thus 85% of the locations in Figure 1 do not include USGS data. However, many of the locations in the far-field are based purely on USGS data.

Nevertheless, aside from the issues of diagnostics missing from the USGS data, the different data sets are overall rather compatible. Of the total collection of questionnaires, the

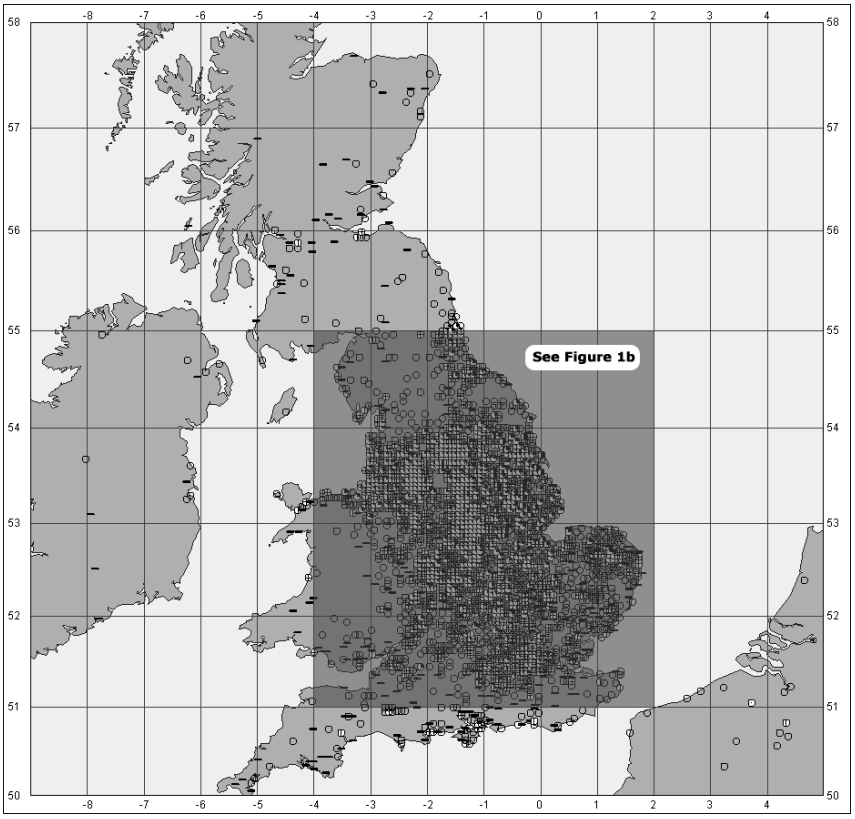

Figure 1a. Intensity point map for the 2008 Market Rasen earthquake

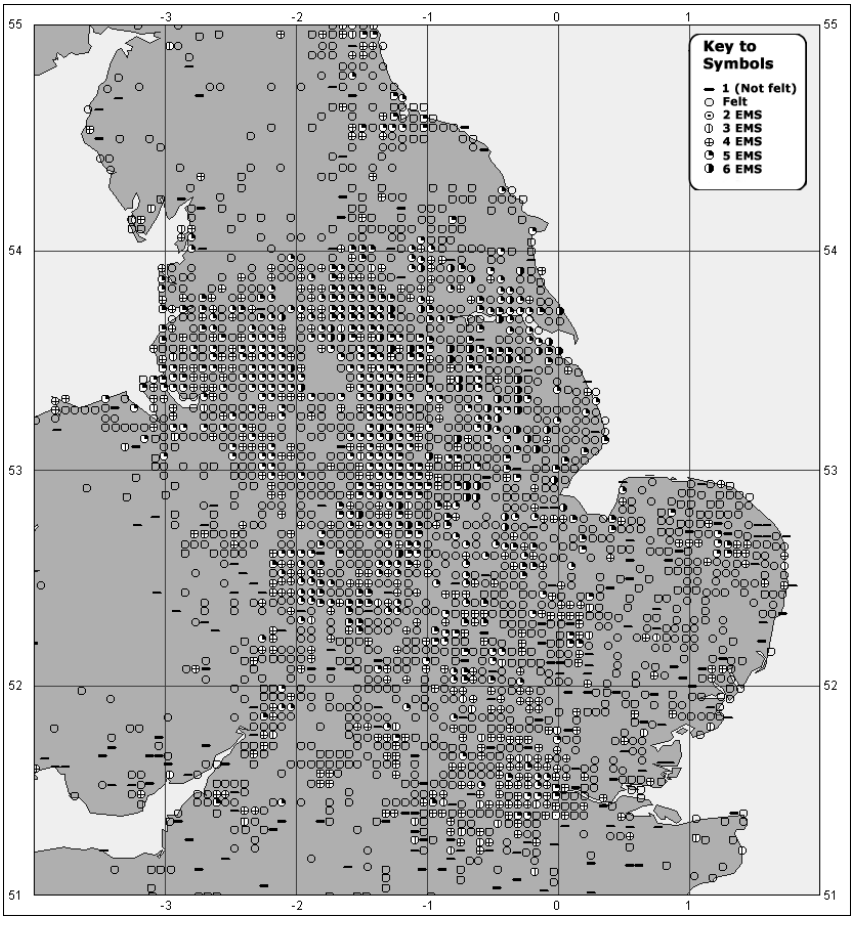

Figure 1b. Detail for inset area in Figure 1a