



**British  
Geological Survey**  
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# The macroseismic survey of the 27 February 2008 Market Rasen earthquake

Earth Hazards and Systems Programme

Internal Report OR/08/029





BRITISH GEOLOGICAL SURVEY

EARTH HAZARDS AND SYSTEMS PROGRAMME

INTERNAL REPORT OR/08/029

# The macroseismic survey of the 27 February 2008 Market Rasen earthquake

RMW Musson

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## *Keywords*

Earthquakes, Britain, intensity, magnitude, macroseismic, questionnaire, survey.

## *Front cover*

Earthquake damage in Gainsborough; photo taken on 27 February 2008 by SL Sargeant.

## *Bibliographical reference*

MUSSON, RMW. 2011. The macroseismic survey of the 27 February 2008 Market Rasen earthquake. *British Geological Survey Internal Report*, OR/08/029. 14pp.

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Maps and diagrams in this book use topography based on Ordnance Survey mapping.

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## Foreword

This report is the published product of a study by the British Geological Survey (BGS) into the effects of the 27 February 2008 Market Rasen (or Lincoln) earthquake, magnitude 5.2 ML, 4.5 Mw. In contrast to former BGS practice (since 1974), in the last few years macroseismic data (i.e. reports on earthquake effects) have been collected over the internet through a page on the BGS web site (<http://www.earthquakes.bgs.ac.uk/index.html>). Formerly, questionnaires were published in local newspapers, and the task of sifting and interpreting the replies was immense. Data of this sort is also gathered routinely by USGS as part of their “Did You Feel It?” programme, and also by EMSC. Data from all three agencies, plus data from local agencies in Belgium and Ireland, have been merged in this study.

## Acknowledgements

I would like to record my thanks to Dave Scott, BGS, who developed and maintains the BGS internet questionnaire system, and to Dave Wald and Vince Quitarano, USGS, Sébastien Gilles, EMSC, Thierry Camelbeeck, ROB, and Tom Blake, DIAS for providing data, advice and assistance.

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# 1 Introduction

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 was also gathered by agencies on the fringe of the felt area, notably ROB in Brussels, and DIAS in Dublin. No data were received by BCSF in France. This report summarises the findings of the survey.

## 2 Data and interpretation

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

<i>Agency</i>	<i>Number of responses</i>
BGS	19,927
USGS	10,794
EMSC	596
Others	31
<b>Total</b>	<b>31,348</b>

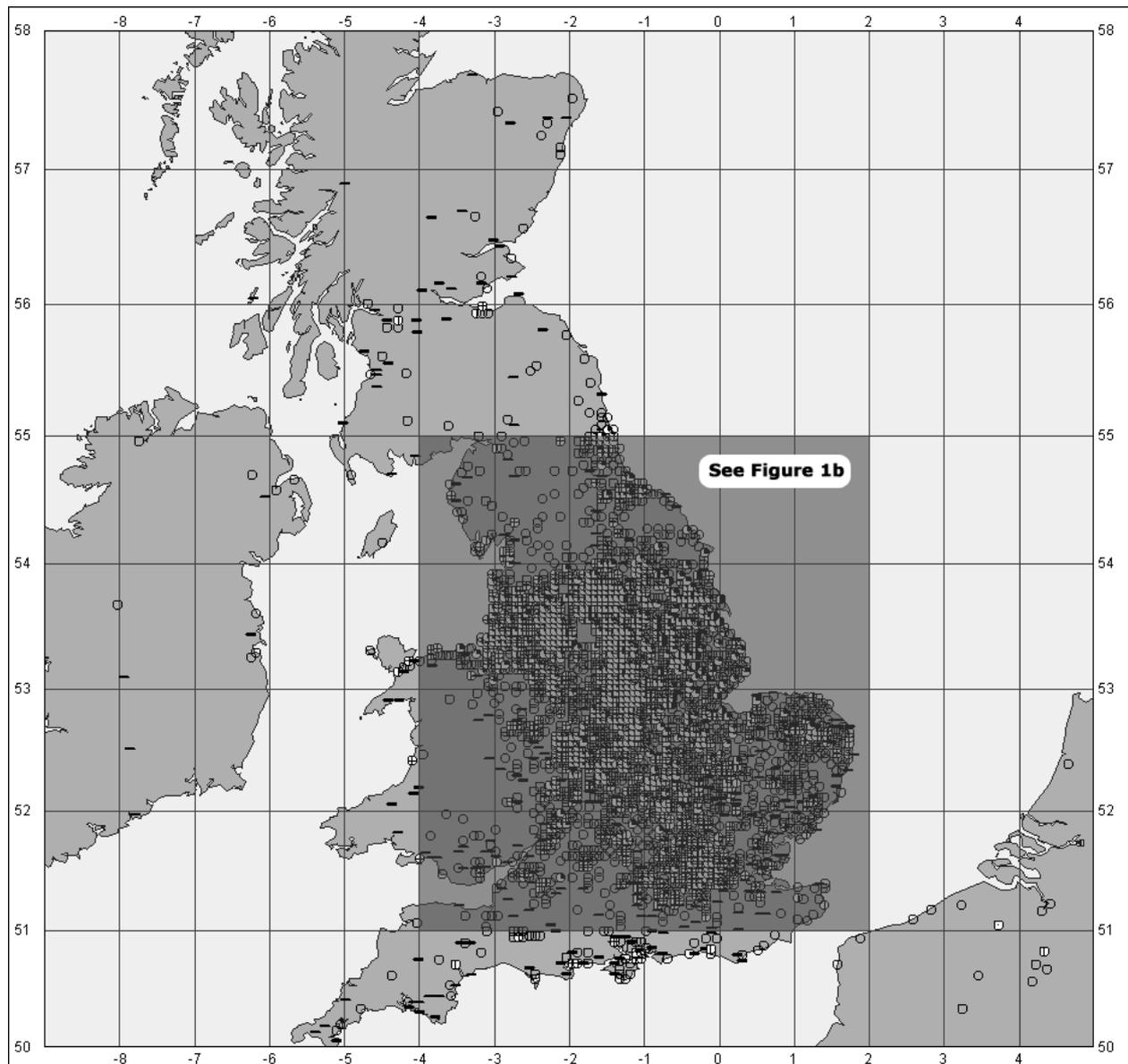
**Table 1 - Data received, by agency**

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, 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.



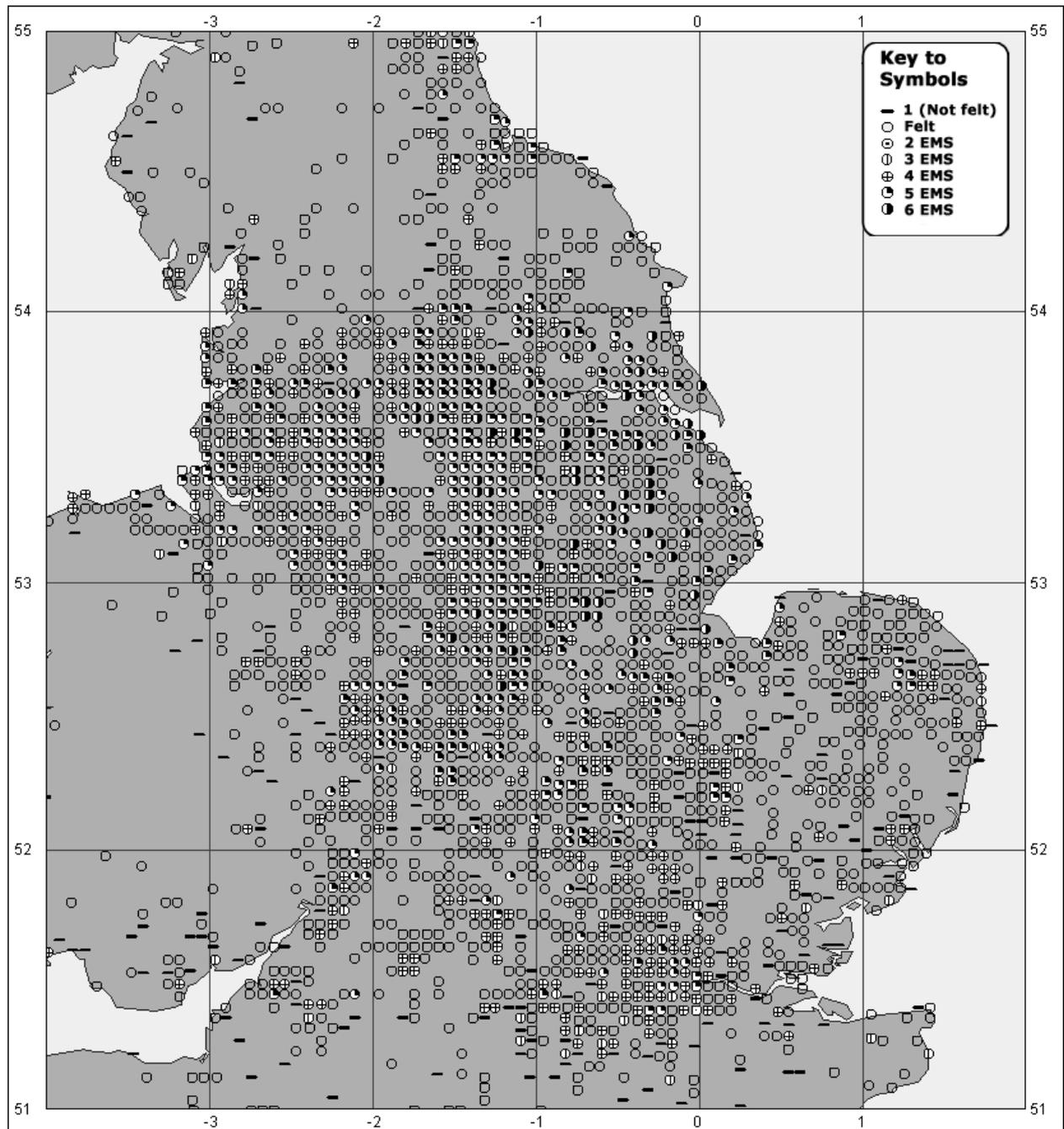
**Figure 1a - Intensity point map for the 2008 Market Rasen earthquake (see Figure 1b for key to symbols).**

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 Llyn 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 number of

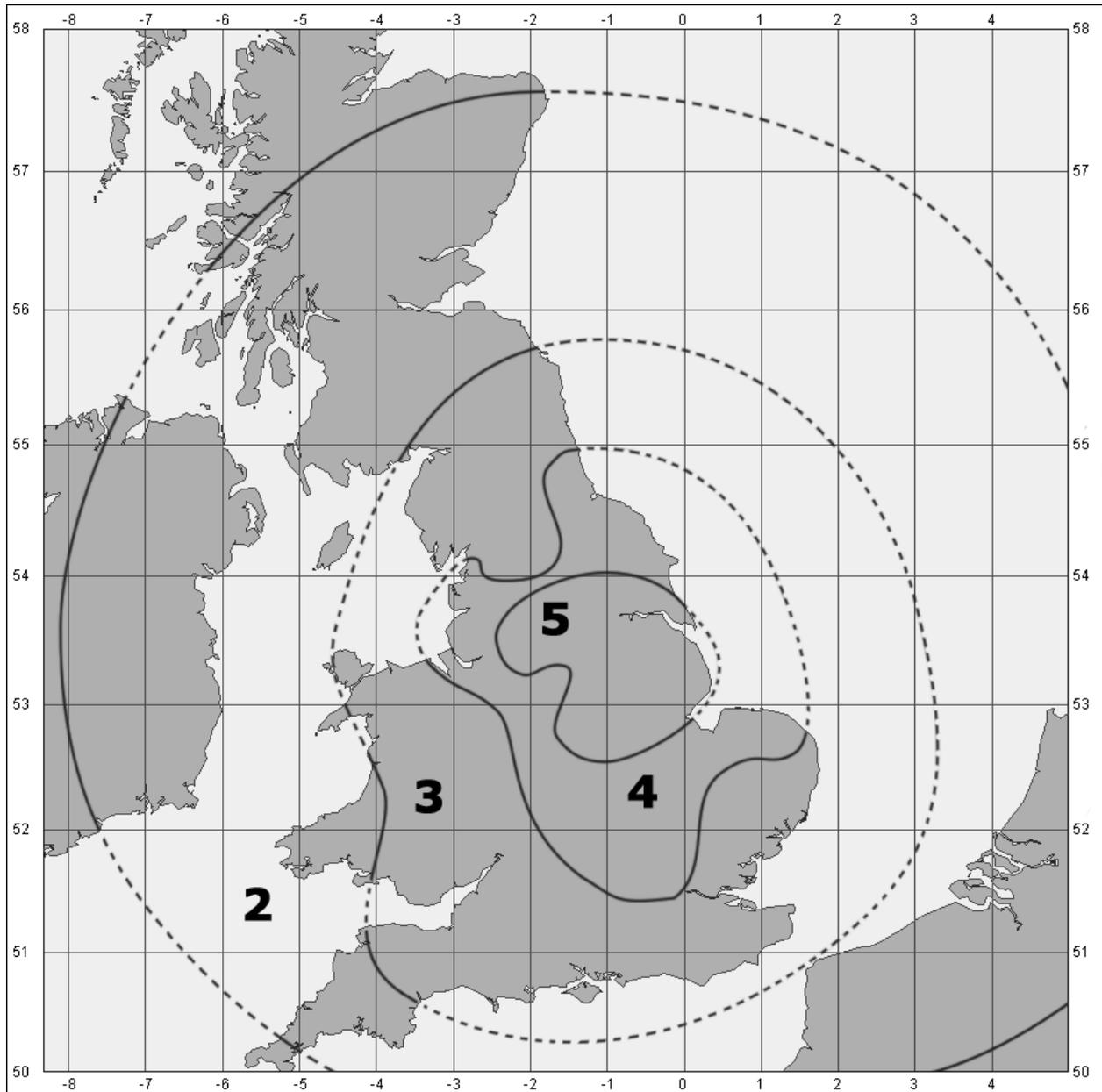
respondents to the BGS survey who reported some kind of damage to property was 7%. The figure for the USGS data set was 7%. The figure for the EMSC data set was also 7%. A comparison was also made on the issue of the overthrow of objects. The BGS/EMSC questionnaire asks two questions: were any small 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).



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

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.



**Figure 2 - Isoseismal map based on Figure 1.**

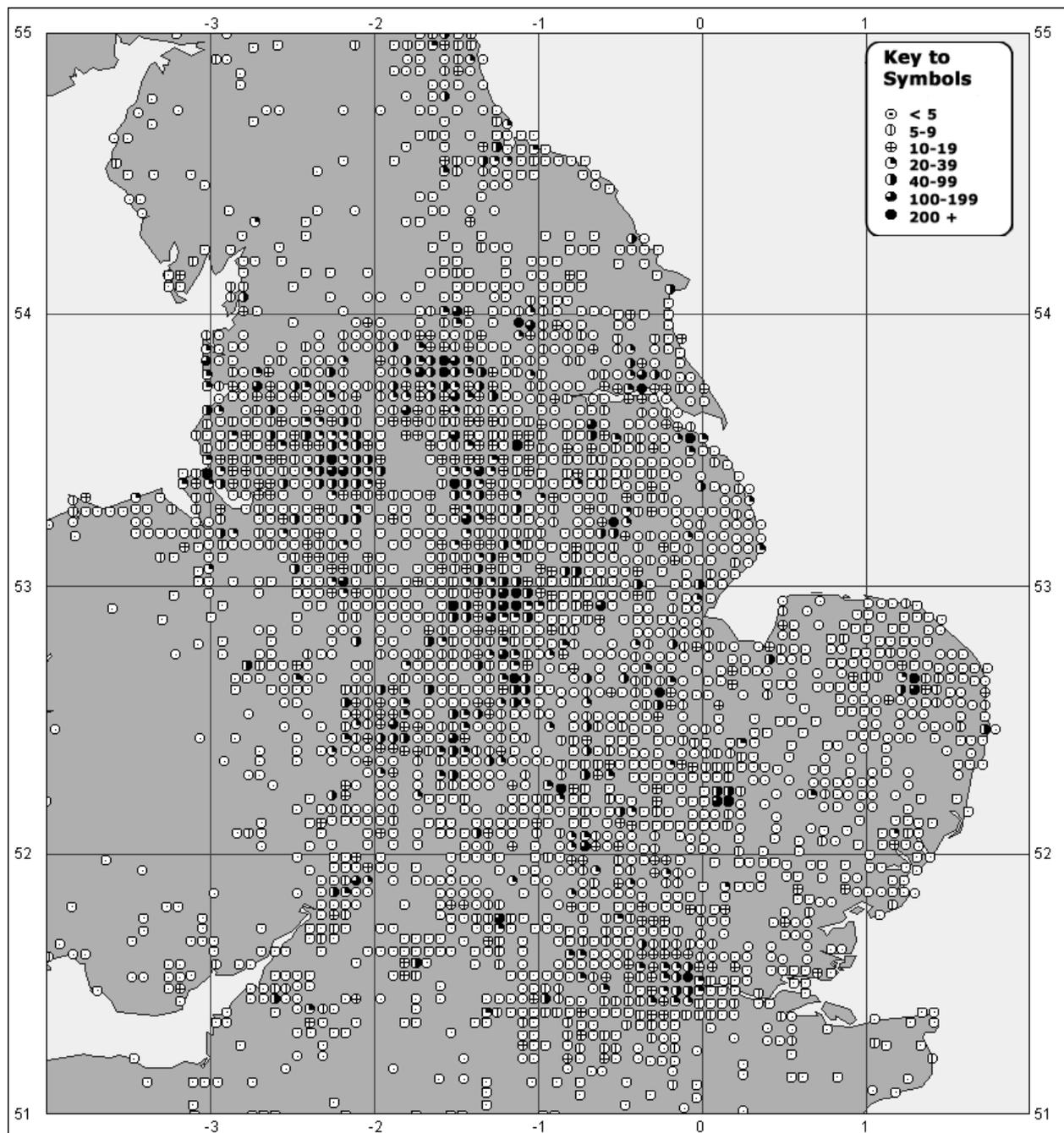
Since the questionnaire respondents are self-selecting, there is likely to be an inherent bias towards stronger effects, which may lead to assessments of intensity 6 where this was actually observed only very locally, or even not at all, compared to what would be obtained from an exhaustive survey based 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 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.



**Figure 3 - Street scene in Gainsborough on the day of the earthquake, showing an instance of chimney damage (BGS photo by SL Sargeant; see also cover picture).**

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.



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

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.

### 3 Macroseismic parameters

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 (Gasparini et al. 1999) is better, at 53.43 -0.69 (24 km from instrumental location).

### 4 Conclusions

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 dataset in a very short amount of time.

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