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The macroseismic map of the 1992 Roermond earthquake, the Netherlands

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Abstract

Six countries contributed to a data base covering macroseismic observations from nine countries affected by the April 13, 1992 Roermond earthquake. Despite the diversity of data sources and variety of approaches by researchers in the countries involved, particularly concerning aspects of data acquisition and intensity assignment, a clear overall-picture of the macroseismic effects could be achieved. An acceptable estimate has been made of the following parameters: macroseismic focal depth h (= 18 km), intensity attenuation α (= 0.001), the 'theoretical' epicentral intensity I_0 (= 7.4) and the macroseismic local magnitude (= 5.6). For further study the complete macroseismic data base is available as an ASCII-file on diskette.

Introduction

The magnitude 5.8 M_L Roermond earthquake of April 13, 1992 at 01 h 20 m UT, with the epicentre (51.16° N – 5.95° E) located in the Province of Limburg in the south-eastern part of the Netherlands, was one of the larger seismic events this century in north-western Europe. It was experienced in wide parts of western and central Europe over an area of approximately 600 000 km^2.

Macroseismic effects of the Roermond earthquake were observed in the Netherlands, Germany, Belgium, Luxemburg, France, United Kingdom, Czech Republic and also in Switzerland and Austria.

The Roermond earthquake produced effects reaching a maximum intensity of I_{max} = VII MSK. Some pessimistic intensity assignments lead locally to a maximum intensity of VII–VIII. Substantial damage to buildings was reported in Roermond and Herkenbosch (the Netherlands), in Heinsberg (Germany) and in Maaseik (Belgium) (Bouwkamp 1994, Pappin et al. 1994). Also, some remarkable instances of ground deformation like sand boils and landslides generated by liquefaction were observed (Alkema et al. 1994, Davenport et al. 1994, Maurenbrecher et al. 1994, Nieuwenhuis 1994).

Since most people in the affected area were asleep at the time of the earthquake (03 h 20 m Central European Summer Time), circumstances were unfavourable for the reporting of low intensities and consequently for the determination of the area of perceptibility.

Immediately after the earthquake, acquisition of macroseismic data was initiated by various institutions in several countries. These efforts resulted in a voluminous and useful data base of macroseismic observations, ultimately providing the basis for the macroseismic map of the April 13, 1992 Roermond earthquake.

Construction of the macroseismic map

Data acquisition

As a first step in the construction of a macroseismic map, data gathering is a central issue. Data collection and subsequent analyses in the field of macroseismics is often done on an ad hoc basis. Hence, in the construction of the macroseismic map we were confronted with a variety of methods, questionnaires and data formats. This makes the construction of the map more complex and may even give rise to different estimates of intensities up to one intensity unit.

In general two methods of data acquisition have been used. The first method is based on personal reports. For example, in the United Kingdom people were invited to respond to a questionnaire form published in newspapers (Musson & Henni 1992). Also, individual telephone calls from the public were used. The number of reports that can be obtained in this way will depend strongly upon the population density in the region of interest. However, the reports received will be biased towards positive ones. It is, therefore, difficult to decide what percentage of the population felt the earthquake or reported a certain degree of damage.

The second method that is generally applied makes use of community reports. This was done, for example, in the Netherlands and Belgium. Questionnaire forms were sent to all municipalities. This method has two advantages. Firstly, there is a high degree of response even in the case where the earthquake was not felt by the population. Secondly, population density has less effects than in the previous method and there will be a more or less even spread of reports over a large area. The obvious drawback is that it remains uncertain on which information the completion of the questionnaire is based, whether only police reports were consulted or whether a fair assessment was made in a more general sense (e.g. concerning damage). This all adds to the varying quality of the primary data.

Intensity assignment

Qualified seismologists assigned intensities to the primary macroseismic reports or to groups of reports.

Table 1. Contributions to the 1992 Roermond earthquake macroseismic data base (the data for Austria, Luxembourg and Switzerland have been supplied by Belgian and German contributors)

Country	Number of data	Intensity scale used
Belgium	546	MSK-64 (Medvedev et al. 1965)
Czech Republic	9	MSK-64 (Medvedev et al. 1965)
France	1123	MSK-64 (Medvedev et al. 1965)
Germany	611	EMS-92 (Grünthal 1993)
Netherlands	487	MSK-64 (Medvedev et al. 1965)
United Kingdom	31	MSK-81 (Anonymous 1981)

Unfortunately, this process of intensity assignment remains subjective. This is mainly due to different approaches to describe the more or less gradual decrease of intensity away from the epicentral area. Some use half intensity units, others assign two intensities, for example VI–VII. This is concluded from the overlap of different intensity assignments. Furthermore, in north-western Europe there is little experience with higher intensities.

The degree of subjectivity generally increases for the lower intensities, since the distinction between intensity II and III is not clear in a number of cases. Besides, for a number of observations the fact that we are dealing with a ‘midnight earthquake’ has given rise to problems even in the distinction between III and IV. Moreover, the intensity III experienced from a large earthquake differs from the same intensity belonging to a small earthquake, because of the different frequency of the shaking.

The final result of the intensity assignment provides a file of geographical coordinates with appropriate intensities. A comment line in which the name of the locality can be included together with the postal code proved to be useful. For the Roermond earthquake the total file lists over 2800 entries. Contributions to the macroseismic data base are summarized in Table 1.

On the basis of this file we could unify all the data from the nine countries involved. Some of the available data were reassessed. Firstly, for the northern part of France the intensities required a revision, since the French intensity data were primarily overestimated. Secondly, the density of data points for Belgium was reduced without any loss of quality. Originally, each municipality in Belgium provided a manifold of almost identical intensity assignments, one for each of the villages within its territory. Within the scope of

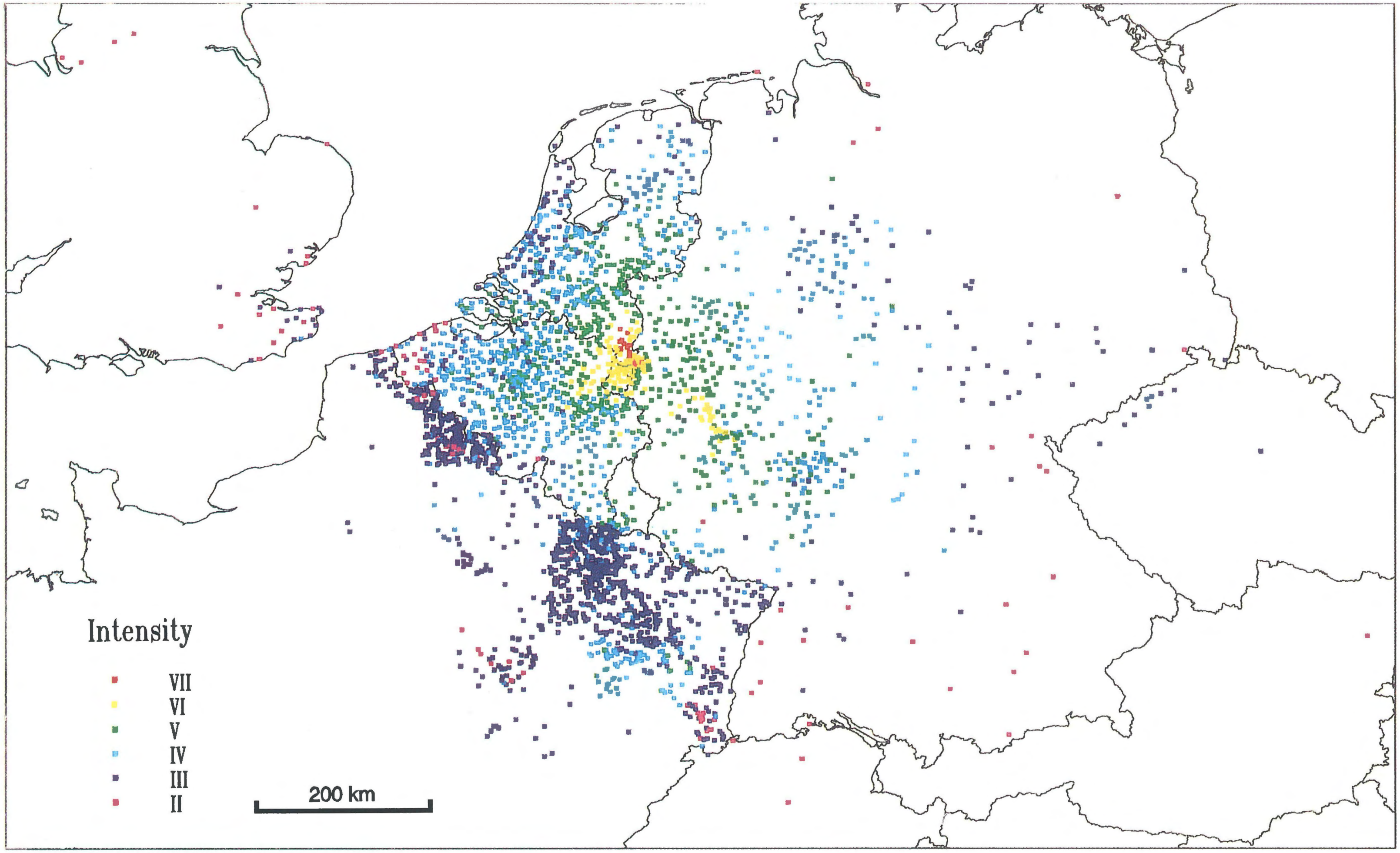

Fig. 1. Intensity map for the 1992 Roermond earthquake. Intensities are assigned according to the MSK-scale.

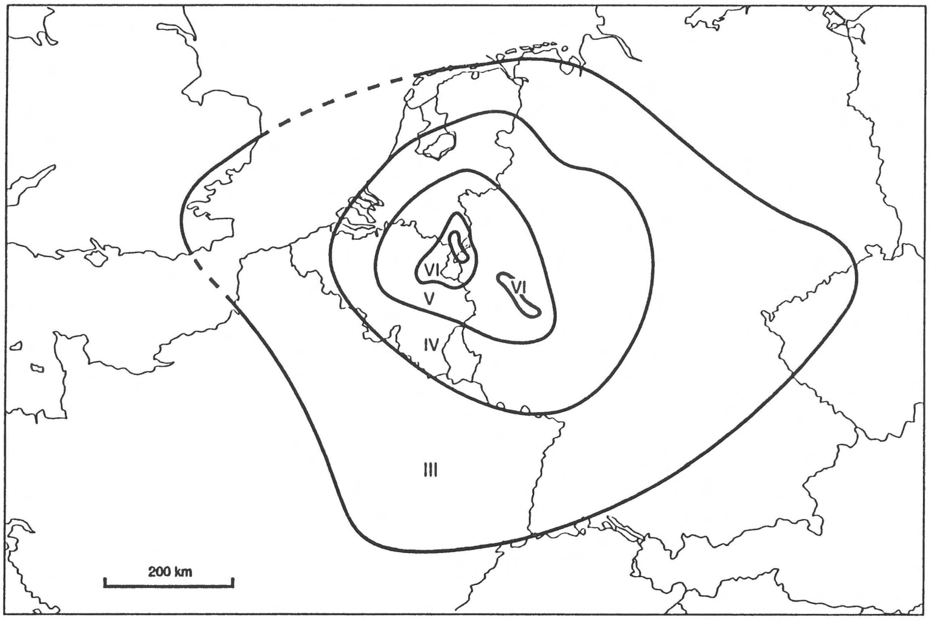

Fig. 2. Isoseismal map for the 1992 Roermond earthquake. Intensities are assigned according to the MSK-scale.

the overall Roermond map it was decided to allocate just one single intensity to a particular municipality. Thirdly, in the United Kingdom an 'F' (for 'felt') was assigned in a number of cases to felt reports with uncertain intensity. Such 'F' assignments probably represent intensities in the range II–III and have been marked as such in order to complete our macroseismic file. In our map all so-called 'in between' intensity assignments have been rounded to the next lower intensity. The resulting intensity map with all available observations is presented in Fig. 1.

Analyses

Isoseismals

The contouring of isoseismals remains subjective. In general we opted for smoothed isolines, keeping the number of 'islands' to a minimum. Nevertheless, for one area, i.e. the Middle Rhine Valley, an exception had to be made. The density distribution of data points, particularly towards the low intensity region, did not allow a more detailed approach, in order to achieve a fairly consistent map. Interpolation was needed for the intensity III isoline for areas such as the North Sea and the English Channel. Lack of adequate intensity II observations did not allow to draw the intensity II isoline. The resulting isoseismal map is shown in Fig. 2.

Estimation of macroseismic parameters

A plot can be made of the average isoseismal radii versus the intensity. Figure 3 shows the intensity attenuation curve together with the average isoseismal radii. The estimated error bars obtained from the degree of overlap between subsequent intensity values are indicated. The following average isoseismal radii have been estimated: $R_7 = 15$ km, $R_6 = 42$ km, $R_5 = 108$ km, $R_4 = 208$ km, $R_3 = 370$ km. Figure 3 is the basis for the Sponheuer method (Sponheuer 1960) to estimate the 'theoretical value' for the epicentral intensity I_0, the focal depth h and the attenuation parameter α (Meidow & Ahorner 1994). We found the following parameter values: 'theoretical' $I_0 = 7.4$, h = 18 km and $\alpha = 0.001$. For practical purposes the maximum observed intensity of I_{max} = VII in the epicentral area should also be used as epicentral intensity. The obtained focal depth is in good agreement with the instrumentally derived value of 17 km (Camelbeeck et al. 1994). The uncertainty in the macroseismic focal depth parameter is $\pm$ 2 km. Although there is in this region a fair amount of experience with this method for moderate and small earthquakes, the question arises whether in the case of

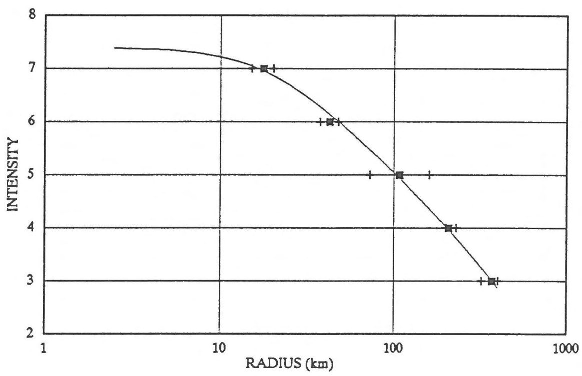

Fig. 3. Intensity attenuation and focal depth estimation for the 1992 Roermond mainshock. Solid squares indicate the average isoseismal radii, plusses indicate their error bars. The results obtained are: h = 18 km, $I_0 = 7.4$, $\alpha = 0.001$ km^{-1} (see Meidow & Ahorner 1994 for explanation of the parameters).

the Roermond earthquake the simple and robust Sponheuer method can be applied to the lowest isoseismals at large distances from the epicentre, since the effects of wave propagation with respect to frequency content and transmission path are not taken into account with this method. Besides, the response of the human receiver will certainly be highly variable depending on the frequency. Other parameters such as local geology, type of building, and state of perceptibility (e.g. asleep, awake at rest or awake and active) also play an important role.

The macroseismic local magnitude has been derived from an approximation for relating local magnitude (M_L) to the size of the isoseismal III, given by Musson (1994):

$$M_L = 1.03 \log A_3 - 0.19$$

where A_3 is the area in km^2 of isoseismal III MSK. An average radius of $R_3 = 370$ km then gives a macroseismic local magnitude of $M_L = 5.6$.

Conclusion

With the completion of the macroseismic map of the Roermond earthquake an inventory is presented of a unified data set of intensity measures and public response to this earthquake. For further study this data set will be available on floppy disk in an easy readable ASCII format.

As is the case for most macroseismic maps, the uncertainties of the Roermond map are hard to judge. This is partly due to the character of the macroseismic information itself. In the case of the Roermond map the different sources of the data are also playing a role. A truly unified approach is possible only if just one person is in charge of the interpretation and coordination of the data. It is therefore also recommended that for European use a unified and practical questionnaire should be developed, preferably in the context of the ESC Working Group on Macroseismic Scales. Such a questionnaire should be based on the updated MSK-scale and newly proposed European Macroseismic Scale (Grünthal 1993).

It remains a point of concern whether the Sponheuer model is the right tool for analysing macroseismic maps, since this model only accounts for the geometrical spreading in a homogeneous halfspace and attenuation. Nevertheless, using the Sponheuer method the macroseismic focal depth of the Roermond earthquake could be estimated at 18 km, in good agreement with instrumental determinations, and a 'theoretical value' of the epicentral intensity I_0 at 7.4.

The obtained macroseismic data base contains unique material for site-specific intensity correlation with ground motion data (Margottini et al. 1992) and comparison with historical macroseismic maps (Meidow 1994).

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