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Macroseismic data: present limits and future possibilities

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Abstract
The earthquake of 23 November 1980 was a clear example for the Italian public opinion of how a natural event may disrupt the social organization of whole communities and have economic consequences for the whole country. The media have played a major role in the growth of a public awareness of seismic risk, so defence against earthquakes and the issue of necessary financial resources to obtain such a goal have been, and still are, a highly relevant topic. Italian scientists, who were at the time of the earthquake involved with the Progetto Finalizzato Geodinamica (P.F.G., Geodynamical Oriented Project) that was approaching its term, hastened to draw up seismic-hazard maps of the Italian territory. In doing so, they became aware that potentialities of scientific research had not been exploited to the full. In particular, they saw that a reconstruction of the seismic history of the territory offered good possibilities of future developments in the light of new research methods based on a multidisciplinary approach. In fact, only a very small part of the potentially available material had been found and utilized, its interpretation being made according to monodisciplinary research criteria that were essentially connected with investigation conducted in the field of seismology.
From the still incomplete data that are available at the present time one can see that the seismicity of Southern Italy, here taken as an example, does not appear to be homogeneous, being characterized by different models of release and transmission of energy. We think that current research that makes use of methods designed considerably to narrow the margins of error within which the severity of shaking is normally defined will make it possible to gain an insight into the matter. One of the problems that is increasingly gaining momentum is represented by the self-evident inadequacies of interpretations only made in terms of macroseismic intensity, which indeed appears to be a rather poorly discriminating factor in comparison with the wealth of available data.

1. Introduction

Over the past two decades there has been a considerable increase in the number of studies aimed at the definition of seismic hazard of the Italian territory. In this respect, strong pressure has been exerted by public opinion following the last two great events, the Friuli earthquake of 1976 and, even more, the Irpinia one of 1980, which millions of televiewers were able to watch live. As a result, the issue of safety has gained momentum, becoming gradually more complex. It is reasonable to surmise that the demand for safety will in time cease being all-inclusive and, getting more uniform, will involve the assessment of vulnerability thresholds of specific subsystems, as happened in other countries faced with similar problems.

Italian scientific community is therefore committed to putting forward larger-scale solutions that, while involving more detailed information, are expected to be able to select the best response of each one of the subsystems to seismic events. At the moment macroseismic information is playing a major role in the definition of the seismic characteristics of the Italian territory. Since the recurrence of moderate- and large-energy events in the same area is rather rare, checks supported by instrumental data alone are not possible. On the other hand, the processing of macroseismic information, drawing on the contribution of related disciplines, has lately improved its capability of finding solutions. As opposed to that type of data, the traditional synthesis parameter, intensity, is still in use today in spite of its inadequacy to give a complete picture of the complex character of experimental situations.

Think for instance about the possibility of distinguishing damage sustained by different parts of a built-up area going as far as locating single damaged buildings and how difficult it is to express all that in terms of intensity. It is to intensity, however, that one currently refers to describe the characteristics of a historic seismic event or, as generally happens in the field of engineering, in process calculations.

The present paper will deal with both the advantages involved in directly utilizing experimental macroseismic data instead of those extrapolated for assessing hazard and the possibility of finding out, within areas judged to be homogeneous, differences in the store, release and transmission of seismic energy. For this purpose, some examples calibrated on data available for Southern Italy are shown. One can see two typical fields produced by high-intensity Apenninic earthquakes in the area concerned. They appear markedly different on account of both the size of the areas affected by high intensities and the different attenuation as a function of distance. Another example concerns the different attenuation patterns of intensity in directions perpendicular and parallel to the axis of the Chain, which were determined by directly utilizing experimental data instead of equal-effects areas, as is the rule. Finally, as concerns the same area and the drawing up of sensitivity maps, differences between a synthesis resulting from the simple use of catalogue data and that associated with the direct use of experimental data are shown.

Such characteristics, centered on Southern Apennines, set the stage for a greater-scale regionalization of the area even though still utilizing only a small part of the existing capability to discriminate effects caused by seismic events.

2. Two classes of earthquakes

Figure 1 shows the decay of intensity with

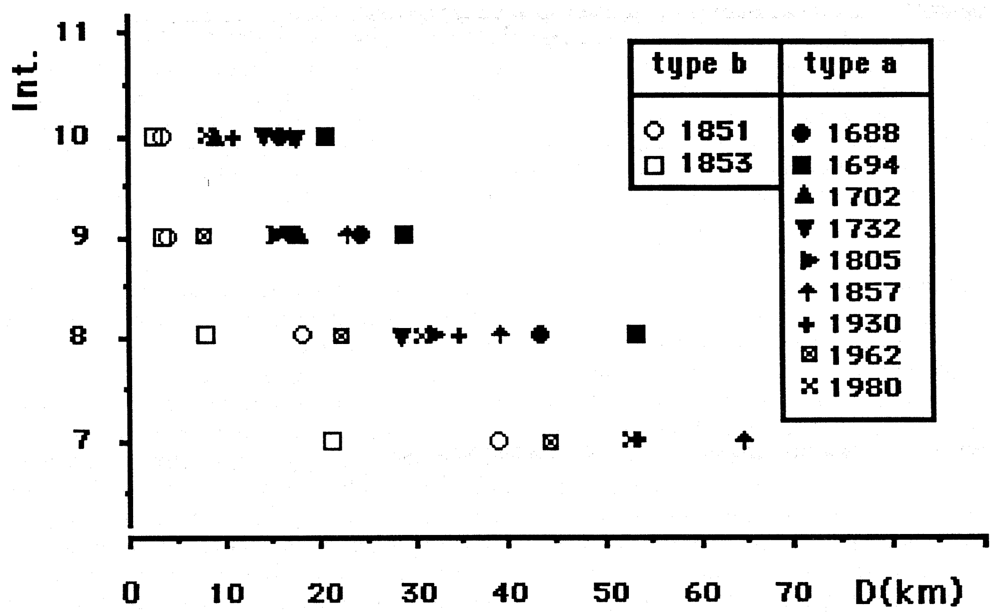

Fig. 1. High-intensity earthquakes in the last three centuries in Southern Italy. Average intensities *versus* distance. «Type-a)» events are characterized by similar decay of energy with distance in comparison with «type-b)» ones in which decay is very strong.

distance for events of the Southern Apennines that reached at least the X degree at the epicentre. The mean-epicentral distance associated with each macroseismic degree was utilized. The events are all associated with high-epicentral intensities and are characterized by two different models of energy propagation. It is possible to group most of them under one head (type a). Although they can be distinguished according to the released energy, the events display a similar intensity trend with distance. In fact, if lower-energy events are translated to the right, their curves tend to overlap those of the higher-energy events. The event of 23 November 1980 in the lower part of the representation can be used as a reference for energies. Two events can at least be assigned to the second class (type b): the Vulture one of 14 August 1851 and the Caposele one of 9 April 1853. The two earthquakes show, in very limited areas, a high epicentral intensity that decays to non-destructive values within few kilometres. Such peculiarities decrease the chance of retrieving older historic evidence of type-b events and that may well be the reason for the small number of events that can be assigned to that class. In fact, it is not so much the epicentral intensity as the size of the area affected by high intensities, together with the number and importance of built-up areas, that constitutes a factor directly proportional to the likelihood of retrieving evidence of an event. And this is all the more true the further back in time one goes. On the other hand, such earthquakes are among the disastrous ones and deserve our full attention also because of their greater frequency which cannot be tested experimentally on the basis of our current knowledge. Besides, if the events are not carefully selected, one risks either underestimating their maximum effects, if their magnitude is correctly assessed, or overestimating their magnitude if their maximum effects are utilized. To this end, all experimental points available for each earthquake were utilized in order to avoid any error that could be made because of the use of equivalent radius associated with isoseismic areas. The method proposed by Chandra (1979) was utilized, each experimental point being associated with intensity and epicentral distance.

Assuming a constant epicentral depth of 10 km for earthquakes with epicentral intensity I_0 and intensity I at a distance R and an equation such as

$$I(R) - I_0 = a + b\,R + c\,\log R$$

the following two attenuation relations were obtained:

type a: $I_0 - I = -0.9\ (\pm 0.6) + 0.05\ (\pm 0.01)\,R + {} + 0.9\ (\pm 0.6)\log(R{+}10)\quad r = 0.94$

type b: $I_0 - I = -7\ (\pm 1) + 0.04\ (\pm 0.03)\,R + {} + 7\ (\pm 1)\log(R{+}10)\quad r = 0.97$

Figure 2 shows the relations and, for the sake of comparison, the law of intensity attenuation with the distance used for shakeability maps of the Italian territory (Petrini *et al.*, 1979). The considerations above and the differences observed between type-a and type-b patterns strongly suggest that one must proceed with caution when utilizing macroseismic data for correlations with current seismic parameters or for working out regional characterizations (magnitude values obtained from epicentral intensity, recurrence period, etc.)

3. Intensity attenuation and Apenninic trend

Isoseismals of earthquakes of Southern Italy have been utilized in the drawing up of seismotectonic maps (Branno *et al.*, 1986; Patacca and Scandone, 1986), in determining source characteristics and in studies concerning hazard. That has been done to obtain numerical data directly or compare forms and sizes of isoseismals with field characteristics obtained through different procedures. With the use of the same isoseismals, for instance, discrete seismic sources were proposed with roughly Apenninic trends in order to account for fast attenuation patterns toward the Tyrrhenian or the Adriatic in contrast to a better propagation in the Apenninic direction. This was made both for single events and the synthesizing of regional patterns.

Whether it was due to arbitrary plotting of isoseismals or to the areal distribution of experimental points has often been a matter of discussion. In order to ascertain such an in-

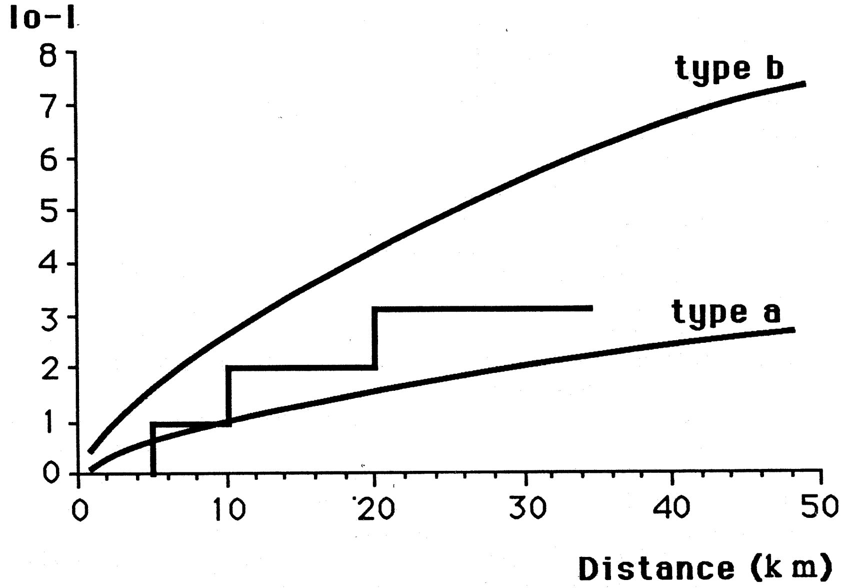

Fig. 2. Attenuation intensities relations for «type-a» and «type-b» events (see text) in comparison with the law (stepwise line) utilized by the national shakeability map (Petrini *et al.*, 1979). Note the different energy decay for the same epicentral intensities (see also fig. 1) and the implications for hazard and related parameters.

fluence, type-a earthquakes, as defined in the previous paragraph, were utilized for the Apenninic area that stretches from the Matese mountains to the Ionian Sea. In this configuration two quadrants contain the Apenninic direction. To each experimental point, so subdivided, were associated the corresponding intensity and epicentral distance and then mean distances for each class of intensity were computed. The result is shown in fig. 3a),b), where an Apenninic trend is clearly seen.

Figure 3a) shows computed mean values of epicentral distances while fig. 3b) shows percentage differences between Apenninic trend values minus the anti-Apenninic values on the Apenninic values. In fig. 3b) one must note, in particular, the strikingly high value that corresponds to intensity *I*=IX. Such a characteristic is all the more significant if one takes into account the fact that the longitudinal dimensions of the area located on the field by such an intensity pattern come closest to the dimensions of the source zone which can be determined by other means and for earthquakes comparable in energy with those concerned.

4. Distribution of the effects

Maximum-experienced-damage maps are one of those products which mostly suffer from both the ambiguities of seismic catalogues and the difficulty in representing an earthquake by a few symbols. Such maps represent the maximum intensity experienced by an area in a given period of time; from them derive the maps that subdivide areas according to the number of times a given threshold has been crossed over a time-span and so on according to more and more specific requirements. The maps are generally made from catalogue data, in particular epicentral intensity values, and from attenuation laws through which it is possible to compute the value expected on the site. In order to highlight the utilization of experimental data and urge to reduce the use of extrapolated values as much as possible, two types of print-outs were produced and compared: one utilizing experimental data directly, the other only epicentral intensity and attenuation law. The first print-out was made on the basis of earthquakes having their epicentres in Southern Italy with *I*=IX and the sites were selected which

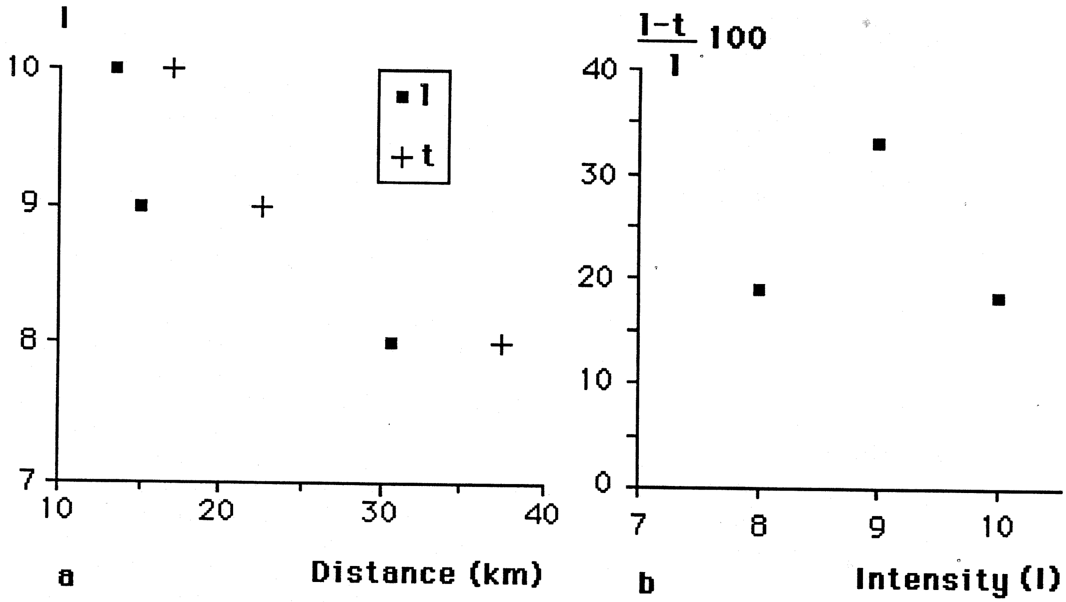

Fig. 3. Apenninic trend of the «type-a» events. All the experimental points for every event have been divided in quadrants, two by two, containing the direction of (l) and perpendicular (t) to the Apennine Chain. a) Average distance for *I*=8,9,10; b) per cent difference between the longitudinal (l) and perpendicular (t) to Apennine Chain average distance for *I*=8,9,10. Note the high value for *I*=9.

experienced effects of the IX degree at least once (fig. 4a)). The result was compared with that obtained from epicentral data of the Italian seismic catalogue (Postpischl, 1985) and the attenuation relation utilized for the Shaheability Map of the Italian Territory (Petrini *et al.*, 1979). Like fig. 4a),b), figure 4c) shows a comparison between experimental data of sites that at least once reached the VIII degree (black dots) and data obtained by the method above over the same time-span and for the same events. The comparison suggests that simple attenuation laws, if more tentative, fail to effectively render the effects produced by historic seismic events and how necessary it is to refer to actual reconstructions as much as possible in order to get an exhaustive representation.

5. Effects

Macroseismic intensity is the parameter utilized for a synthesis of the effects of earthquakes as recorded by the environment, natural or man-made. Its utilization has experienced changing fortunes since the latter half of the 19th Century when it began to be used in Europe, expressed in degrees organically arranged in macroseismic scales. Subsequent revisions to which such scales have since been subject reveal the experimental, empirical character of their origin. It is this very approach that for a certain period set a limit to their utilization whereas our century has witnessed an increasing use of instrumental recordings which are able to give more reliable measurements of events. On the other hand, a deeper knowledge of physical phenomena associated with the release and propagation of seismic energy has entailed a necessity for getting data on historic earthquakes as homogeneous as possible with our current standard. A comparison between the systems is in itself impossible, since the two methods of measurement have nothing in common. What is more, macroseismic data imply the use of recording instruments (buildings, bells, trees, ponds) that change according to place and time. Thus intensity seems to constitute a separate universe, susceptible of

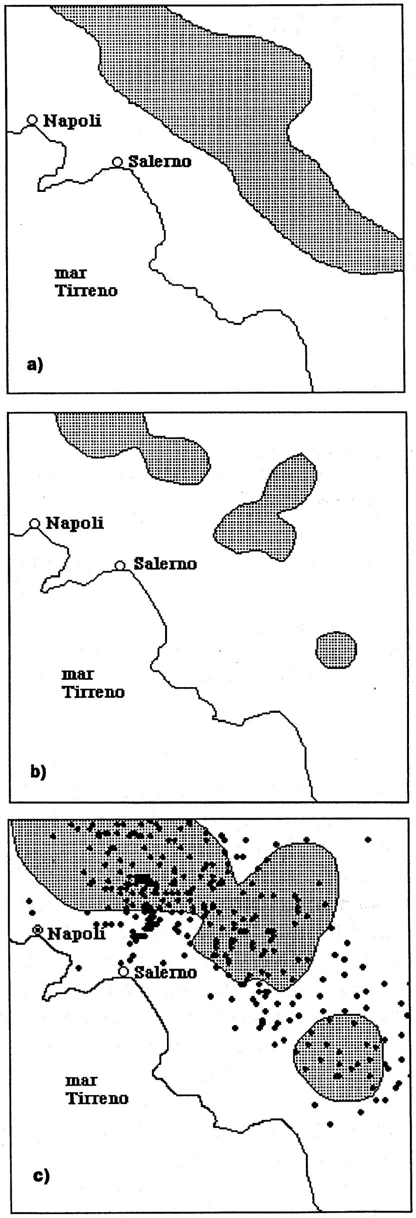

Fig. 4. Historical suffered effects since 1456. a) The shadowed area has at last once experienced IX degree effects; b) expected IX degree effects by utilizing Italian catalogue and intensities attenuation law(see text). Compare fig. 4a) and 4b); c) the same with fig. 4a), b) to compare localities that experienced the VIII degree (black points) and expected area (shadowed).

improvement but set apart. However, since it was necessary to draw up new outlines of the earthquakes of the past and get rid of inaccuracies in calculations, seismologists, who were at first the only ones to be concerned with the reconstruction of historic events, were joined by other experts with the aim of finding, analyzing and criticizing sources, reconstructing political, religious, architectural and urban backgrounds associated with the events.

This new interdisciplinary method of dealing with earthquakes has produced two immediate results: abundance and extreme accuracy of data. Such a scientific contribution is not yet perceptible because the new stage is just under way and has only partially appeared in a few published works; we think, however, that the potentialities of such team-work have not been fully grasped yet. Effects, which are the direct concern of seismologists, are only a part of the whole picture associated with a big earthquake. Its consequences go well beyond the damage suffered by buildings or human reactions; if one wants to get all relevant information, one has to sift the response of the establishment, the behaviour of people or the course of action taken by the scientific community. The new frontier is therefore the best possible utilization of data made available by researchers. One of the immediate developments lies in the determination of the object that recorded the event and in a study of its response. Thus the single effect associated with the recording object would yield the gravity of the event.

6. Conclusions

We think that one of the most positive results achieved by the Italian scientists who are concerned with seismic events is, besides the improved organization of the surveillance network, the correct inclusion of seismic events in all fields with which they interact. The Irpinia earthquake of 23 November 1980 can be considered a watershed between the old and the new ways in which earthquake experts and the external world cooperate. Researchers' activity has increased and so have available data and related problems. Those who are more specifically concerned with hazard have to take account of the necessity of both synthesizing data in a model as well as reducing the margin of error involved in the evaluation of the phenomenon. Hence they know very well the importance of a correct interpretation of basic data and the path they follow from the beginning up to the final illustration resulting from the various processing stages.

In this paper we have proposed some criteria for the seismic characterization of the Southern Apennines, pointing out the extent to which a direct utilization of basic data may be preferable to an extrapolation through the use of simple empirical relations. Moreover, we have brought into focus the problems that begin to appear just when available data offer more research courses than we are able to pursue. It seems that the priority must be given to the quantitative expression of the importance of effects. The coupling of the effect to the recording object seems to be the path that could be taken straightaway. This would, among other things, make it unnecessary to involve more effects in defining a degree as is the case with current macroseismic scales.

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