Critical considerations on the evaluation of macroseismic effects

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Abstract

The definition of some of the standards used for evaluating local effects and optimizing the relative macroseismic procedures are critically considered, also from the different interpretative points of view to have come out of the « Earthquake Catalogue » work group of the Italian Geodynamics Projetc (PFG). Particular stress has been laid on the significance and reliability of the main macroseismic parameters which depend most directly on the investigative criteria used and on their ability to characterize efficiently the interaction of earthquakes and environment.

Essentially, the analysis is of critical considerations and field-observations, the fruit of macroseismic investigations carried out prevalently in the Calabro-Peloritan Arc region. The seismic intensity, the use of macroseismic scales, the investigatory criteria, the macroseismic field and its

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anomalies are the topics chosen for a study which — even if limited from certain aspects — it is hoped will stimulate further thought and evaluations.

Riassunto

La definizione di alcuni standard operativi per la valutazione degli effetti locali e l'ottimizzazione delle relative procedure macrosismiche sono criticamente considerate anche in relazione alle differenti interpretazioni emerse nell'ambito del Gruppo di Lavoro « Catalogo dei Terremoti » del PF « Geodinamica ». Particolare enfasi è posta sul significato e l'affidabilità dei principali parametri macrosismici più direttamente dipendenti dai criteri dell'indagine e sulla validità di quest'ultima a caratterizzare efficacemente l'interazione terremoto-ambiente.

L'analisi si compendia essenzialmente in considerazioni critiche ed osservazioni di campagna maturate nel corso di indagini macrosismiche svolte prevalentemente nella regione dell'Arco Calabro - Peloritano. L'intensità sismica, l'uso delle scale macrosismiche, i criteri d'indagine, il campo macrosismico e le sue anomalie sono gli argomenti scelti per una trattazione che — pur se limitata ad alcuni aspetti — vuole essere di stimolo per ulteriori riflessioni e valutazioni.

Introduction

To characterize the seismicity of a region basically involves a good knowledge of its geology, tectonics and seismic phenomenology. In recent years after a period of inactivity that can only in part be explained by the War, there has been in our country an increasing interest shown in the macroseismic study of historic and recent earthquakes. Stimulating factors have on the one hand been the occurence of earthquakes in areas recognized as being seismic but, despite that, little known, or in areas wrongly considered as being of low seismic risk; on the other hand, the need of facing up to the difficulties caused by the lack of an earthquake catalogue that is satisfactory from the point of view of its homogeneity and completeness. Some of the problems connected with this lack have been the subject of analyses carried out in the Italian Geodynamics Project. In the course of discussion on the best way to catalogue the earthquakes in Italy —

one of the priority tasks of the Project — differences of opinion emerged on the setting up and carrying out of macroseismic investigations. The problems involved are complex but often the difficulty occurs on account of different ways of « measuring » the effects and/or of « evaluating » the local conditions.

The aim of this work is to stress our point of view on the investigatory criteria and the analysis methodology and data interpretation. What follows is the result both of numerous macroseismic surveys made since 1975, mainly in the Calabro-Peloritan Arc, and of analyses of studies and literature reports of historical earthquakes. In particular, attention has been paid to certain of the most important « points » which are often differently evaluated, such as: the reliability of the macroseismic intensity value, the definition of the intensity degree, the correct use of the macroseismic scales and the isoseismal outlines used to characterize the regional macroseismic field.

Seismic Intensity

Even when the seismic intensity is evaluated on the basis of empirical data resulting directly from macroseismic investigations, there is no reason for considering it less reliable than quantities such as the displacement and acceleration caused by seismic waves. The opposite concept is far from rare and is supported by the circumstance that macroseismic intensity is not definible as are the quantities which can be measured by instruments.

The seismic intensity at a site depends both on essentially continuous physical factors such as the propagation of elastic energy associated with the various types of seismic waves, and on other discontinuous ones such as the elastic parameters of the rocks, the resonance periods of the buildings and the ground-building interaction. Despite the different « contribution » of the listed factors, the seismic intensity may be considered a continuous quantity. That is correct outside the near field, (Chandra, 1979) since the effects of the source are negligible and the inten-

sity is controlled mainly by the propagation of the transverse and surface waves. Generally, however, the discontinuity caused by the factors mentioned is of a size such as to be lost with the integration inherent in the « measuring method ».

What can give rise to ambiguity or confusion in the correct use of the intensity is the fact that various parameters — the lithological properties of the ground, different types of building styles, the focal depth, source mechanisms, etc. — can lead to evaluations of equal intensity being reached even when the energy released at the source is different or vice versa. Nuttli (1976) has clearly shown how little the energy is suitable for « measuring » the earthquake intensity.

The investigation becomes reliable and the attribution of the intensity degree correct at a site when there is careful observation followed by critical analysis of the effects of the earthquake on people and their environment, the buildings and ground.

The justification for empirically characterizing the intensity lies essentially in the following considerations: one of a scientific nature (i) and the other historico-social (ii).

(i) The macroseismic intensity offers information about an area that it is not easy to replace with instrumental observation data. In fact, it is out of the question that a vast number of instruments should be set up which might supply the same abundance and variety of data that can be obtained from a macroseismic investigation. Moreover, instrumental data, apart from being unable to supply a measurement of the earthquake-environment interaction, considered case by case is of far more limited significance than macroseismic data. In fact, instrumental data characterize a single point — the observation station — whereas macroseismic data characterize an area. To this should be added the fact that the numerous attempts to correlate intensity with measurable physical quantities, and particularly with acceleration, have on the whole produced unsatisfactory results (Bolton et al., 1976).

(ii) From the historico-social point of view, the validity of this fundamental macroseismic parameter is particularly seen in that it is the source of most of the information and knowledge

we have of the historical earthquakes, as well as allowing the degree of damage to be evaluated at individual sites. Instrumental monitoring in the modern sense of the term of earthquakes began only at the start of this century, whereas there is a considerable amount of documents and chronicles of earthquakes in the past, particularly from the 15th Century on (ENEL, 1977).

The work of Medvedev (1968, 1977), Sponheuer and Karnik should be understood in this spirit: in the task they were assigned by the European Seismological Commission, they did not work out a completely new intensity scale (MSK) but redescribed and redefined the MCS scale in a more technical and modern way. In particular, in the MSK scale the quantization has been improved of the « permanent » effects of the earthquake by means of classifying the type of damage and expressing as a percentage the damage encountered in the various types of building works. Despite this, we are of the opinion that there are still limitations, in that in their scale the occurrence of specific phenomena is defined (for instance, the swinging of hanging lamps, the moving and/or falling of objects, etc.) and the percentages are expressed in pre-established fixed values rather than in ranges of percent values.

Macroseismic scales and investigation criteria

The scale of intensity, which ever one it may be — but here we shall refer more specifically to the MCS and MSK scales mentioned above — shows intervals (degrees of intensity) that are nor fully definable in extent nor comparable one with another on account of the heterogenous nature of the classification factors (*indices*). These limits are not, however, so much inherent in the intensity as an *index* of the strength of the earthquake as in the real difficulties of « measuring » it. In our opinion, subjectivity — often attributed to the intensity — is not due so much to the classification criteria on which a given scale is based as to the person who observes. In any case, this subjectivity can be overcome by optimizing the investigation method, introducing a more detailed classification of the effects and finally

by developing suitable analytical procedures (Sponheuer, 1960; Shebalin, 1974a; Riznichenko, 1975; Bottari et al., 1979).

The investigation criteria are different and directly connected with the *indices* of the scale. In the middle and low degrees the *indices* consist of people's physical sensations and of the temporary and/or permanent effect on objects. For the former category, in particular, a large sample is needed to lend it any statistical significance for evaluations. Only in this way will the perceptive limits (in sitting standing up, moving, lying half-asleep or sleeping) lose their subjective nature. One of the criteria we have experimented in macroseismic observation, valid for all degrees but in particular for the low and middle ones, is that of making an exhaustive investigation in the small — or medium-sized built — up areas by collecting statistically significant samples (e.g. the inhabitants of a whole building and sampling all the characteristic parts of the center itself). In rural areas the sampling is necessarily more spread-out, but wherever possible uniformly distributed in order to verify that the result obtained for the built-up center is closely correlated with the regional trend of the macroseismic field or else that it is rather a local anomaly, the extent of which can therefore be defined.

The study of temporary and permanent effects on objects is where possible completed by tracing the size, the direction of movement and the mechanical characteristics of the object. One can thereby easily have a large number of acceleration estimates to compare with the instrumental data which will clearly be less numerous.

Our thesis is supported by historical data and data from investigations carried out in recent years. The following points may be mentioned:

— During the earthquake of 25th January 1968 (Valle del Belice, Sicily) there were no cases of human perception in Messina in the MCS-II area; heavy candelabras hanging particularly low down in the churches were seen to swing slightly in correspondance with the passing of the long-period waves. That shows that here, as in other cases too, the intensity evaluation must be made using the scale very critically.

At Norcia (in Umbria) as a consequence of the earthquake of 19th September 1979 amongts other things a pinnacle on the facade of St. Benedict's Church was seen to have been twisted anticlockwise (Fig. 1; Favali et al., 1980).

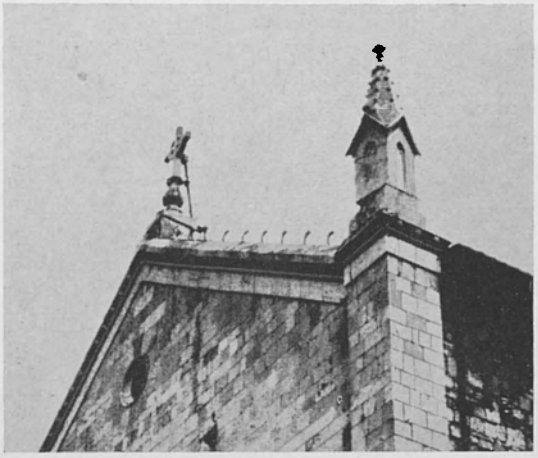

Fig. 1 - Anticlockwise twisting of the pinnacle of St Benedict's Church in Norcia, Umbria (earthquake of 19th September 1979).

— During the earthquake in the Gulf of Patti of 15th April 1978 (Barbano et alt., 1979) in the southern part of the island of Vulcano, (over a radius of 1500 m) the statues of the Church of Piano, the patio columns of the houses (Fig. 2) and the Gelso Lighthouse)Fig. 3) — which was broken two-thirds the way up without falling — were all seen to have rotated in the same direction.

Another *index* is the damage to building works which becomes more serious from degree-VI upwards. For a correct assesment of the local situations, analysis of the damage should be made according to the type of work and the prevailing geological and geomorphological conditions. Table I shows in synthetic form the percent distribution of damage according to the five

degrees of damage and the type of building work, following the MSK scale. In MSK scale, as has already been pointed out above, intensity is expressed by a single percent value and not by a range; moreover, the percentages proposed (5% individual; 50% many; 75% most) are not enough even for a qualitative distinction. It

Fig. 2 - A patio column broken and twisted in an anticlockwise direction at Vulcano Piano (the island of Vulcano, Aeolian Islands; earthquake of 15th April 1978).

can be seen that when there is a precise percentage for the degree of damage according to the type of work, it becomes difficult and even contradictory to use the scheme. That is mainly due to the difficulty of finding a satisfactory correspondence

Fig. 3 - The Gelso Lighthouse (the Island of Vulcano, Aeolian Islands) with the tower broken and twisted anticlockwise two-thirds the way up (earthquake of 15 th April 1978).

between the real values observed in the investigation and those indicated in the MSK scale. Hence, by quantitatively interpreting some other terms used in the MSK-scale, it was proposed to introduce a more numerous set of quantitative definitions, as follows (in italics the new terms proposed): 5% individual; 25% *some*; 50% many; 75% most; 95% *nearly all*. It can also be seen that for each type of building work Table I is lacking in a complete, 100% distribution of the percent damage. For example, in degree VIII we find 50% of 3rd-degree damage and 5% of 4th--degree damage in building-type B. But it is not specified where the remaining 45% is distributed.

Finally the *index* « effects-on-the-ground » (part of « Natural Phenomena ») is undoubtedly complex and for its use requires more specifically a knowledge of geomorphology and structural geology. It is widely held that effects on the ground are observable only in the highest degrees and even the MSK scale does not sufficiently clear up this problem. It is very likely that the effects on the ground are connected with the depth and source mechanisms and only secondarily with the reaction beaviour of geological formations and foundation grounds.

TABLE 1

Percentages of the building works damaged broken down, according to the type of work, into groups A, B and C together with the classification of damage (from 1st to 5th degree).

Classe of damage	Percentage of damage														
	VI			VII			VIII			IX			X		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
1 st	50	5				50									
2 nd	5				50				50						
3 rd				50				*95*	5			*95*			
4 th				5			*95*	5			*95*	5			*95*
5 th							5			50	5		75	50	5

NOTE: This scheme is elaborated by present authors from MSK-76 scale.

In cases where the hypocenter is so superficial that the focal volume is nearly at the surface, ground deformation can be seen accompanied by and/or preceded by seismic shocks even many hours before. In such cases an intensity scale, based essentially on the effects of the shock following on the passing of seismic waves, cannot be acritically applied. Furthermore, it must be

considered, rather, that in the corresponding mesoseismic area the ground deformations, prevalently inelastic ones, may even be on a large scale.

Recently an example of this type was observed on Etna in connection with the Mascalucia earthquake of 23rd August 1980: superficial fractures (Figs 4 and 5) opened up for about nine hours along a line (NNW-SSE) running for 1 kilometer or so from downslope to upslope; this preceded seismic shocks, the main one of which was accompanied by fracturing of the second order in the upper part of the lineament.

Among the many problems inherent in ground analyses, one should remember the none too simple distinction between surface faulting (Bosi and Carraro, 1979), as a tectonic movement connected with a stress field, and the trigger effect caused by shaking on tectonic and geo-morphological structures in conditions of precarious stability.

Also the MSK scale, where these trigger effects are concerned,

Fig. 4 - A fracture in the ground (Tremestieri, Mt. Etna), with a vertical displacement of 1 cm and a horizontal clockwise one of 1.5 cm, that preceded the Mascalucia earthquake of 23rd August 1980.

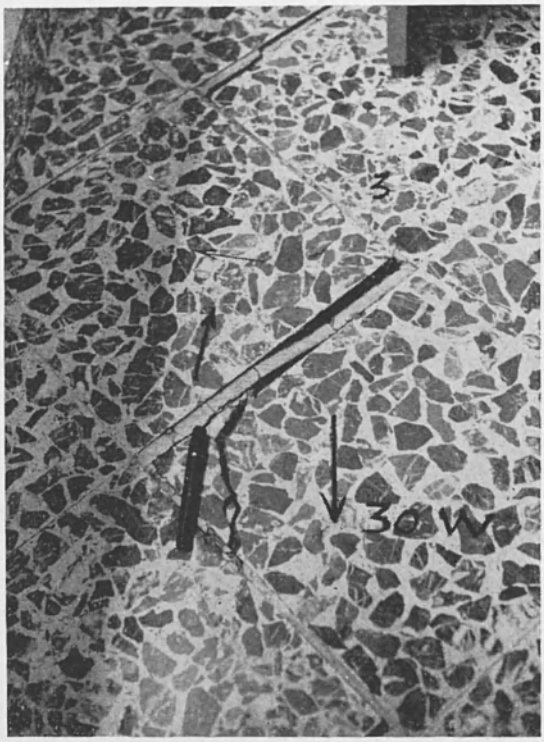

Fig. 5 - A fracture inside a house in Tremestieri (Mt. Etna) along the same alignment as that of Fig. 4 (NNW-SSE) with the displacement prevalently horizontal and clockwise. The cement joint in the floor tiles was made after a previous fracture (about 20 years ago) occurring with the same amount of displacement and analogous phenomenology.

is generally not so easily applied. For example, the various types of landslide that can be caused by the earthquake are not all to be found in the same degree of the scale. In fact, none of the following appear to be equivalent: the generation of a landslide, the formation of a new crown upslope with respect to an already existent main one, the reactivation or at any rate the trigger of an already existent landslide, the formation of a new crown downslope from the main one in the already existent displaced material, etc.

THE MACROSEISMIC FIELD

A reasoned analysis of the survey data allows the « control point field » to be defined by attributing the degree of intensity to the individual sites. In this phase it is as well to assign the weight for each control point so as to achieve a more correct isoseismal outlining. As has already been pointed out above, the definition of degree in the MSK scale is not expressed by a range of index values but by a single value; it follows that in the isoseismal outlining these values can be taken as the lower, average or upper limits of the grade itself.

The second criterion is the one we have chosen whereby the isoseismal outlining follows intermediate values which, where specifically surveyed in the investigation, are indicated as half degrees on the control point field. That, besides, is consistent with the use that the authors themselves make of the scale (Prochazkova, Karnik, 1978). While maintaining the control points as the basic data set, one tries to show the regional macroseismic field when doing the isoseismal outlining. That is to say by not considering those points with the lowest statistical weight (or isolating them, within a contour line if they are over a sufficiently wide area) we smooth the isoseismals in order to characterize the regional trend. The anisotropy of this trend is essentially connected with the geological structural characteristics controlling the propagation of the seismic waves (Nuttli, 1976).

The following step is immediate: the parameter characterization of the « normal » macroseismic field corresponding with the observed regional field (Shebalin, 1972; 1974). The results obtained from analyses of various historical and recent events, following the method of Bottari et al. (1979), confirm that Blake's (1941) model is adaptable for the macroseismic fields of the Calabro-Peloritan Arc.

Outlining the regional field brings out, besides, the macroseismic anomalies which are basically subdivided, according to their extent, into limited, local and regional. Here we do not consider the limited anomalies; these are more easily identifiable in medium and high-intensity areas, and, their being small, it

is more right to analyse them in the microzoning phase. The regional anomalies which appear as anisotropy of the trend, are in all probability connected to the geological and structural framework.

The local anomalies are more extensive than the limited ones, often being more complex and showing a greater weight than them in conditioning the isoseismal outlining. They are more frequently caused by unfavorable geomorphological and/or hydrogeological conditions such as those encountered in the Ferruzzano earthquake of 11th March 1978 (Bottari et al., 1981) causing an increase in intensity at four different sites (from degree VII to VIII) of the mesoseismic area. Geomorphologically unstable areas are characterized by the repeatability of the anomalies. What has been observed in the Ferruzzano earthquake, for example, substantially reproposes the observations of Sabatini on the 1907 Ferruzzano earthquake (Sabatini, 1908). Another example (Fig. 6) of an increase in intensity (by about 1 degree) was observed at Bagnara Calabra during the Reggio Calabria earthquake of the 16th January 1975 (Bottari and Lo Giudice, 1975), which was then repeated (Fig. 8) during the Gulf of Patti earthquake of 15th April 1978 (Barbano et al., 1979). For the first of these earthquakes, during which in the Bagnara area there was the same intensity as in the mesoseismic area, a trigger phenomenon was proposed as an alternative, given the particular structural conditions (Bottari and Lo Giudice, 1975). The same phenomenon, or alternatively the channeling of energy, was proposed to explain the vast area of higher-degree anomaly in the Iblean Mountains during the Gulf of Patti earthquake (Barbano et al., 1979). However, as is repeatedly found in the earthquakes mentioned, the lithological-technical characteristics of the formations and their structural relationships are generally the most common causes of more or less extensive local anomalies.

Other local anomalies, often only apparent ones, are due to the difficulty of defining the low degrees (a statistically insufficient sample, the unavailability of people in suitable conditions, etc.) and to the lack in the middle degrees of certain types of building in which, and only in which does the damage allow the degree to be defined (Fig. 6).

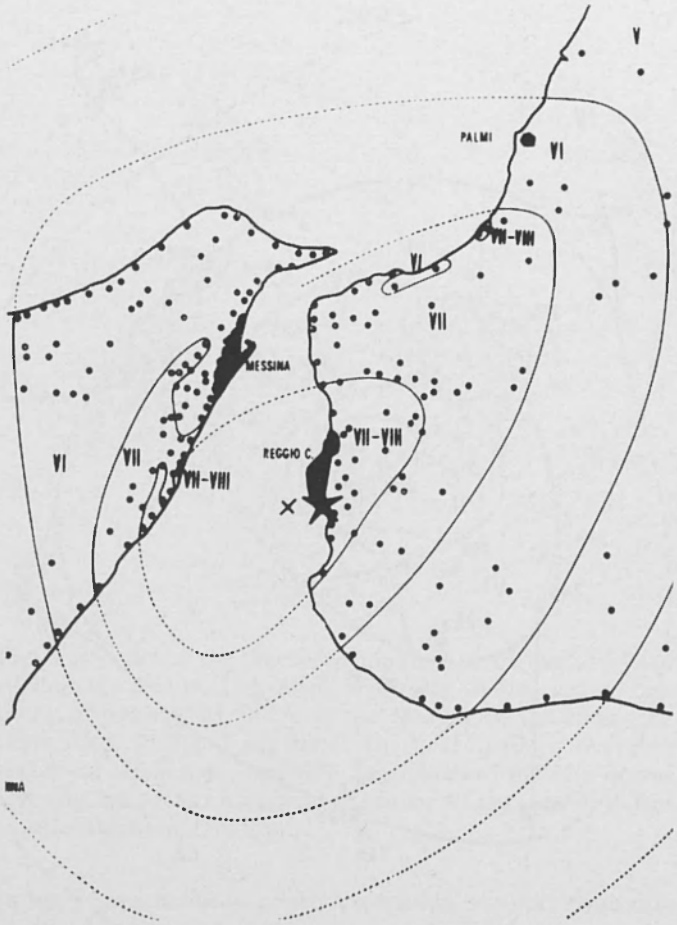

Fig. 6 - A part of the macroseismic field of the Reggio Calabria earthquake of 15th January 1975. Two local anomalies can be seen: the lower-degree one along the Messina coast in the VII-degree area is attributable to the absence of particular types of buildings and can be considered apparent The higher-degree anomaly at Bagnara Calabra, although small in extension, is of equal intensity to that in the mesoseismic area.

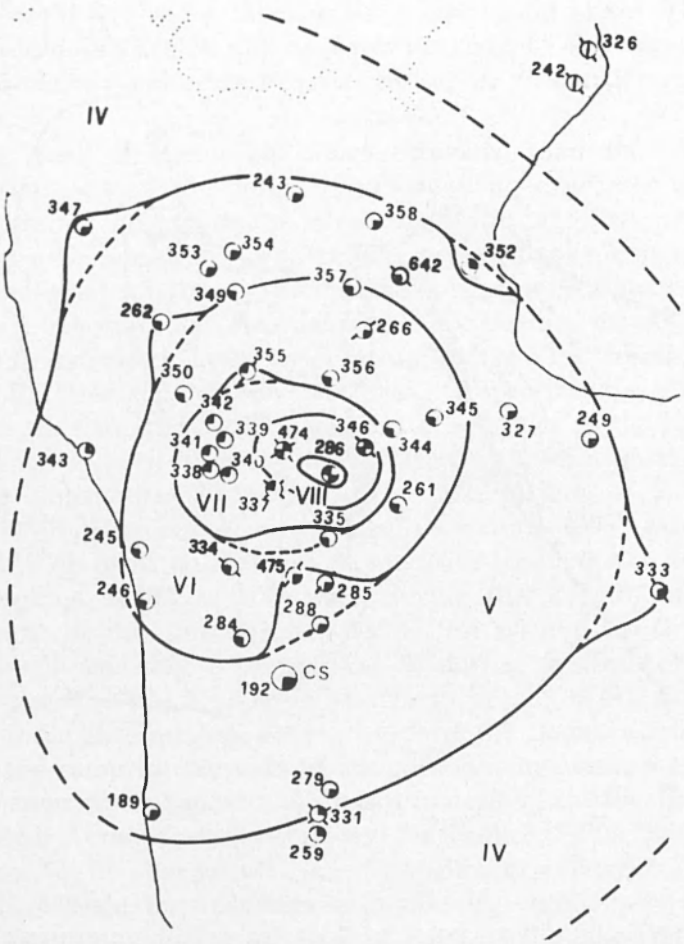

Fig. 7 - A part of the macroseismic field of the Bisignano earthquake (3rd December 1887, Calabria). The isoseismal from degree VII to degree V of the MSK scale shown, through the dashed line parts, the trend of regional field. The alignment of lobes along the NW directional trend can be interpreted as an anomaly of a regional nature. The key to the symbols used and the numbering of the control points mentioned is given in an open-file report (Bottari and Lo Giudice, in press).

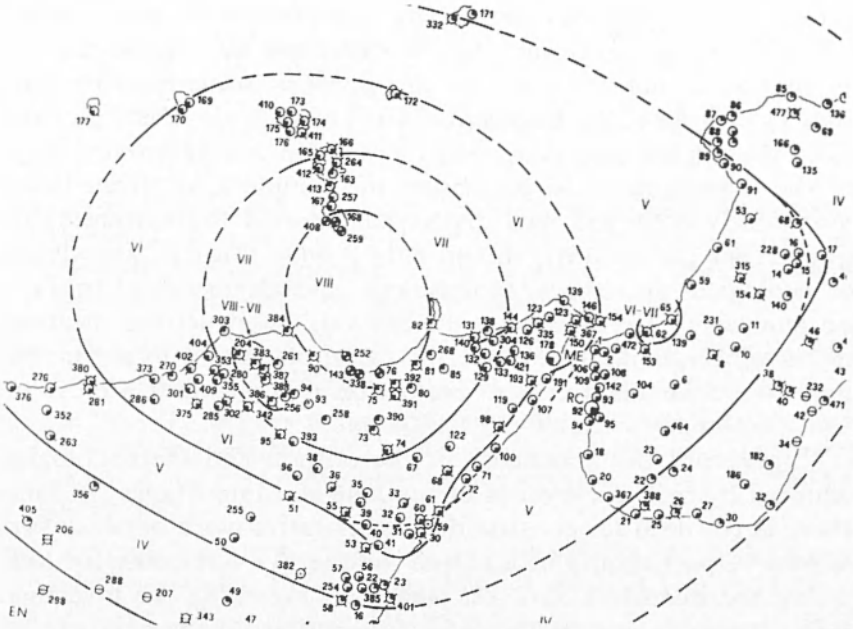

Fig. 8 - A part of the macroseismic field of the Gulf of Patti earthquake (Sicily; 15th April 1978). For the isoseismal outlining of degrees VI and V of the MSK scale the considerations made in Fig. 7 are valid. The field displays two positive local anomalies: one well contained within the degree VII area (the Naso zone) and the other in the degree V area (inside Bagnara Calabra).

Figures 7 and 8 show some examples of macroseismic fields where, following the type of outlining described, both the regional trend of the field and the local and regional anomalies are evidenced separately. The generally satisfactory agreement between isoseismal patterns « smoothed » in this way and Blake's model (1941) supports the validity of the procedure adopted.

Concluding remarks

From a critical consideration of the criteria at the basis of an evaluation of the effects of an earthquake on people and their environment, it can be seen that apart from the difficulties and

limitations inherent in macroseismic methodologies, some causes of error and/or ambiguity can be overcome by a judicious use of the MSK intensity scale. To this purpose, some macroseismic indices correlated to the degrees of the MSK scale muste be carefully considered and statistically evaluated in the survey stage of the investigation. In particular, the sample apart from being sufficiently wide and well distributed around the epicenter, requires that the surveyor should have a wide range of knowledge of geological structures, morphology and engineering. In fact, an analysis of the effects on the ground, the structural meaning of certain regional anomalies, the cause of certain local anomalies, etc., demands a critical evaluation that excludes a more or less « automatic » use of the MSK scale.

Therefore the knowledge of the criteria and methodologies adopted by each surveyor is of fundamental importance. In fact, there is the need for constructive comparative work between surveyors — particularly at a nation-wide level — not only for analysing the historical data, but above all regarding the investigation criteria to use in the field. Given that observation of the effects of earthquakes is of ancient origin whereas a macroseismic methodology in the modern sense of the term is fairly recent, this comparative work should lead towards:

— the giving up of a collection of concepts and commonplaces that are scientifically out of date and have negative consequences on the objectivity and validity of the data;

— encouraging everyone to cooperate so that with the meeting of different experience and knowledge a more organic definition of the subject may be reached.

To this purpose, we consider the solving of the following problems to be of the utmost importance:

i) an improved quantization of the international MSK scale « definitions »;

ii) the regionalizing of the MSK scale according to the different types of building found in the various areas of Italy, as Medvedev himself (1968) wished to be done;

iii) homogeneity at a national level of the methods of mapping of the macroseismic field.

REFERENCES

BARBANO M. S., BOTTARI A., CARVENI P., COSENTINO M., FEDERICO B., FONTE G., LO GIUDICE E., LOMBARDO G., PATANÉ G., 1979 - *Macroseismic study of the Gulf of Patti earthquake in the geostructural frame of North-Eastern Sicily.* « Boll. Soc. Geol. Ital. », 98, pp. 155-174.

BLAKE A., 1941 - *On the estimation of focal depth from macroseismic data.* « Bull. Seism. Soc. America », 31, 3.

BOLTON SEED H., MURARKA R., LYSMER J., IDRISS J. M., 1976 - *Relationship of maximum accelerations, maximum velocity, distance from source and local site conditions for moderately strong earthquakes.* « BSSA », 66, pp. 1323.

BOSI C., CARRARO F., 1979 - *Considerazioni terminologiche in campo sismotettonico.* « Geogr. Fis. e Dinam. Quat. », 2, pp. 21-28.

BOTTARI A., LO GIUDICE E., 1975 - *Studio macrosismico del terremoto di Reggio Calabria del* 16 *Gennaio* 1975. « Annali di Geofisica », XXVIII, pp. 151-176.

BOTTARI A., LO GIUDICE E., - *Rappresentazione dei campi macrosismici.* Open file report. - Ist. Geof. Messina - 1st. Int. Vulcanol. Catania (in press.).

BOTTARI A., FEDERICO B., LO GIUDICE E., 1979 - *Methodological considerations regarding the determination of some macroseismic field parameters. Application to earthquakes in the Calabro-Peloritan Arc.* « Boll. Geof. Teorica ed Applic. », 21, pp. 197-225.

BOTTARI A., LO GIUDICE E., NICOLETTI P. G., SORRISO-VALVO M., 1981 - *The Ferruzzano earthquake of* 1978: *macroseismic effects and slope-stability conditions in southern Calabria* (*Italy*). « Rev. Geol. Dynam. Geogr. Phys. », 23, pp. 73-84.

CHANDRA, U., 1979 - *Attenuations of intensity in United States.* « BSSA », 69, 2003-2010.

E.N.E.L., 1977 - *Catalogo dei terremoti avvenuti in Italia dall'anno* 1000 *al* 1975. Geotecneco S.p.A., San Lorenzo in Campo.

FAVALI P., GIOVANI L., SPADEA M. C., VECCHI M., 1980 - *Il terremoto della Valnerina del* 19 *settembre* 1979, (*The Valnerina earthquake of* 19*th September* 1979). « Annali di Geofisica », XXXIII, volume unico.

MEDVEDEV S. V., 1968 - *Seismic zoning of the USSR, Israel Program for Scientific Translations*, Jerusalem 1976.

MEDVEDEV S. V., 1977 - *Seismic intensity scale MSK-76.* « Pub. Inst. Geophys. Pol. Acad. Sc. », A-6 (117), 95-102.

MEDVEDEV S. V., SPONHEUER W., KARNIK V., 1967 - *Seismic Intensity Scale Version MSK* 1964. Pub. N. 48 of the Institut fur Geodynamik, 69 Jena (DDR).

NUTTLI O. W., 1976 - *Comments on seismic intensity, size of earthquake and related parameters.* « BSSA », 66.

PROCHAZKOVA D., KARNIK V., *Atlas of isoseismal maps. Central and Eastern Europe.* Geophysical Institute of the Czechoslovak Academy of Sciences, Prague.

SABATINI V., 1908 - *Appunti sul terremoto calabrese del* 23 *ottobre* 1907. « Boll. Comit. Geol. d'Italia », serie IV, 9, pp. 28-36.

SHEBALIN N. V., 1972 - *Macroseismic data as information on source parameters of large earthquakes.* « Phys. Earth. Planet. Interior », 6, pp. 316-323.

SHEBALIN N. V., 1974a - *Foci of the strong earthquakes in the USSR.* « USSR Academy of Sciences », Moscow (in Russian).

SHEBALIN N. V., 1974b - *Principles and Procedures of Cataloguing of Earthquakes in Balcans Region.* UNESCO - Skopje.

SPONHEUER A., 1960 - *Methoden zur Herdtiefenbestimmung in der Makroseismik.* Freiberger Forschungshefte C. 88 Geophysik, Berlin.