Evaluation of 1947-1993 macroseismic information in Portugal using the EMS-92 scale

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Abstract
In the present work macroseismic information of the earthquakes felt in Continental Portugal from 1947 to 1993 was evaluated using the EMS-92 intensity scale. Press information, and data in the seismological questionnaires used in this period of time, were used as prime information. Prior intensity assignments were also used in the analysis. Two methodologies – A and B – were followed, according to the type of information available: A) whenever seismological questionnaires or descriptions of effects are accessed this information was analysed leading to an intensity value and to an intensity quality factor; this methodology includes a standardisation of questionnaire evaluation, through the use of conversion keys; B) if only an intensity assignment, in any known scale, existed, then a conversion of intensities was made. The results of these two methodologies are compared and discussed. Based on the above mentioned information a database with 1947-1993 Portuguese seismic information was built up, and a few features of its contents were discussed.

Key words *intensities – EMS-92 scale – questionnaires*

1. Introduction

The Institute of Meteorology (IM), founded in 1946 as National Meteorological Service, is the Portuguese institution responsible for seismic surveillance in Portugal. Since 1947, this entity has collected macroseismic information whenever an earthquake was felt in the country, and presents annually, in the Seismic Annuary of Portugal, the intensity values at the different sites where information is available. The criteria for the evaluation of intensity have varied throughout the years, because of the change in personnel responsible for the task, and because of the different macroseismic intensity scales used: from 1947 to 1960, 1917 Mercalli-Cancani-Sieberg scale (MCS-17 scale); from 1961 to 1975, 1931 Wood-Neumann scale (WN-31 scale); and from 1976 till present, 1956 Modified Mercalli scale (MM-56 scale). These three scales are named «starting scales» in the present work.

An evaluation or re-evaluation of macroseismic information based on well determined rules and on a single intensity scale is desirable in order to minimise the related subjectivity and to increase the reliability of subsequent studies. In this paper that task was accomplished for the period 1947-1993.

The EMS-92 intensity scale was considered the most appropriate for the purpose, mainly because it includes a user's guide, and was therefore adopted.

In this study the information evaluated consists not only of the data collected and/or treated by the IM, but also of some material published in the press and collected by the authors in libraries.

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2. Existing information

Two classes of information were considered in this analysis: *information describing effects* and *intensity values assigned by IM.* The data of each pair (felt earthquake; site with macroseismic effects) is of one or both classes.

In the *information describing effects* class, four types of data are considered:

1) specialised publications;

2) information circulated by press and radio;

3) information received at the IM or at meteorological stations, from people that felt the seism;

4) information in IM seismological questionnaires.

In relation to the specialised publications, they only refer to the most significantly felt earthquakes, namely the February 28, 1969 event. The least significant group of data is the second.

Most of the information comes in seismological questionnaires. Three main types of questionnaires were found. One of them (type 1) requires extensive answers describing macroseismic effects, allowing a satisfactory EMS-92 intensity evaluation, when carefully answered. It was only used for very few pairs (seism; site), in the years of 1948 and 1951.

The other two types of questionnaire are inappropriate to EMS-92 intensity assignment. The second type of questionnaire (type 2), used in the large majority of situations, includes, besides other items not directly connected to intensity determination, the following questions (*), which are to be answered on a *Yes* or *No* basis.

1) Was it felt only by persons under particularly favourable circumstances?
2) Was it felt only by some people at rest, especially by those at the top floors of the buildings?
3) Were there any observations of suspended objects swinging?
4) Was it felt indoors, mainly at the buildings top floors, but many people didn't recognise it as an earthquake?
5) Did parked vehicles shake slightly?
6) Was there a shaking similar to that of a truck passing by?
7) In daytime, was it felt by many people indoors but by only a few outdoors?
8) At night, did a few people wake up?
9) Did china, windows or doors rattle?
10) Were sound cracks from the walls heard?
11) Did parked vehicles shake significantly?
12) Was it felt by almost everybody?
13) Did many people wake up?
14) Did china, glass windows, etc., break?
15) Did any stucco crack?
16) Were precariously supported objects overturned?
17) Did trees, posts or other high objects move?
18) Did the pendulum clocks stop?
19) Was it felt by everybody?
20) And did many frightened people get out?
21) Did heavy furniture move?
22) Did plaster or stucco fall from walls or ceilings?
23) Were there any damaged chimneys?
24) Did everyone get out?
25) Were there slight damages in the well built houses?
26) Were there significant damages in the poorly built houses?
27) Were there any fallen/destroyed chimneys?
28) Was it felt by persons driving vehicles?
29) Were there significant damages in buildings, some of them being partially destroyed?
30) Did chimneys, columns, walls or monuments fall?
31) Were there any car accidents?
32) Was there partial destruction of solidly built buildings?
33) Did any buildings move from their foundations?
34) Were there any cracks in the ground?
35) Did most of the stone or wooden buildings get destroyed from the foundations upwards?
36) Did the ground get generally cracked?
37) Were there significant landslides in steep slopes?
38) Did only few buildings keep standing?
39) Were there large and deep cracks in the ground?
40) Were there landslides?
41) Were there rockfalls?
42) Did everything get completely destroyed?
43) Were there huge changes in the ground surface?

(*) The translation intends to follow the Portuguese version as closely as possible.

The third type of questionnaire (type 3) includes a set of items similar to the above questions No. 4, 6, 7, 9, 10, 12, 16 and 19. Thus, it does not cover scenarios corresponding to the upper grades of the intensity scales.

The way questionnaires were filled in is not standardised. Some questionnaires were returned from entities such as City Halls and Community Councils; the others were filled in by IM staff during *in situ* inquiries. In both cases, most of the times, there is no information on the representativity of the answers.

The *intensity values assigned by IM* class of information consists of the (earthquake; site) intensity values, in scales other than EMS-92, as presented in the Seismological Annuary of Portugal.

3. Data evaluation

Two methodologies, A and B, were considered for data evaluation. For each pair (earthquake; site), according to the available information, one or both of them were followed.

3.1. *Methodology A*

Methodology A was used whenever there was any description of the earthquake effects for the pair (earthquake; site). If that is so, two determinations were made:

1) determination of EMS-92 Macroseismic Intensity following EMS-92 guidelines;

2) determination of a *Quality Factor of Intensity* developed in this paper to qualify the data and the subjectivity of the intensity evaluations. It is classified as *Good*, *Medium* or *Doubtful*, as follows:

– *Good* (*G*): the information is precise and complete enough; the intensity is evaluated by means of a single grade and there is no subjectivity in this determination.

– *Medium* (*M*): the information is not precise or complete enough. There is subjectivity in the determination of intensity.

– *Doubtful* (*D*): the information is contradictory or very incomplete. There is subjectivity in the determination of intensity.

According to the meaning of EMS-92 intensity intervals – *i.e.*, an intensity interval includes two or more grades which are compatible with the macroseismic data of the site; therefore, it is assigned when the information is not good enough to determine a single intensity grade – these intervals have necessarily an *M* or *D* quality factor.

EMS-92 guidelines and recommendations minimise the subjectivity of intensity determination but do not eliminate it completely. Therefore, when the data are in seismological questionnaires, as it is the case with much of the present information, questionnaires with analogous answers can be associated to different values of intensity and intensity quality factor. To eliminate this situation, a standardisation of questionnaire evaluation was made in the present work, using *conversion keys*.

A conversion key is a correspondence established between a set of answers to questions – in the type 2 questionnaire – and an EMS-92 intensity and a quality factor. In order to illustrate the meaning of conversion key and its notation – a condensed notation is used – an example, key 267, is presented below:

Key 267: 9Y, 13Y, 15Y → V *Medium*

This means that the key applies to questionnaires such that:

– questions 9, 13 and 15 are answered *Yes*;

– the last affirmative answer is to question 15; from question 16 onwards, questions are answered *No* or are not answered;

– questions 10 to 12, and 14, have the answer *No* or are not answered;

– questions from 1 to 8 may have any answer (*Yes*, *No*, no answer, no standardised answer).

For these scenarios the evaluation established is EMS intensity V, with quality factor *Medium*.

For the most common type of questionnaire (type 2), 619 conversion keys – representing far more sequences of answers – were created. Some of these, with minor changes, were applied, when needed, to type 3 questionnaire.

These keys do not cover all possible scenarios, but only those found in the data.

Due to the fact that these questionnaires were not formulated according to the EMS-92 scale, two types of difficulties arose in the determination of the conversion keys:

– the representativity of each macroseismic effect (number of occurrences) is not well accessed;

– the questionnaires do not mention EMS vulnerability classes and damage grades, and are vague about the highest intensities.

The first situation was faced very frequently; as the large majority of events were not strongly felt, the latter item was not as important as it might have been. Because of both these handicaps, 29.6% of the conversion keys lead to intensity intervals instead of single grades and among these, for high intensities, 5 keys have intensity intervals including three possible values (VI-VIII and VII-IX). Moreover, there are 5.3% of cases with quality factor *Doubtful*; only 32.3% of the keys have quality factor *Good*, and all these cases refer to intensities below VI. Table I shows the number of conversion keys per intensity value and per quality factor. These quantities illustrate the difficulties, and inevitable subjectivity, in assigning intensity by means of the type 2 questionnaire.

Table I. Number of conversion keys per EMS-92 intensity value and per intensity quality factor.

	Good	Medium	Doubtful	Total
II	1	1	–	2
II-III	–	9	–	9
III	28	14	–	42
III-IV	–	31	9	40
IV	99	43	5	147
IV-V	–	54	2	56
V	72	86	6	164
V-VI	–	45	5	50
VI	–	72	3	75
VI-VII	–	19	1	20
VI-VIII	–	4	–	4
VII	–	3	1	4
VII-VIII	–	3	–	3
VII-IX	–	–	1	1
VIII	–	2	–	2
Total	200	386	33	619

Many of the indications in the EMS-92 guide were useful, and some definitions, guidelines and examples were particularly helpful for the present study, namely those in section 2.2 («Assigning intensity»), in section 2.2.5 («Reliability and uncertainty»), in Annexe A («Examples illustrating classifications of vulnerability and damage used in the scale») and in Annexe D («Examples of intensity assignment»).

Some of the most experimental aspects of EMS-92 scale, those connected to engineered buildings, were not used because the vulnerability classes found in the data were only of types A, B and C. Damage grade classification was mostly needed for the February 28, 1969 event – the only one with significant damage to buildings.

Perhaps due to the questionnaire structure, there were situations that hardly fit the EMS-92 scale, namely the scenarios – occurring in large numbers in the data – such as: *«the earthquake was felt by many people or almost everybody, even outdoors, causing many people to get frightened and run out»*, and with only one of questions No. 14, 16, 18 and 28 answered *Yes*. In these cases it was decided to attribute an intensity IV-V, with – exceptionally for intensity intervals – the intensity quality factor *Good*.

It should be noted that the item *«woodwork creaks in a few cases»*, which takes part in the EMS-92 definition of intensity IV and may be accessed by the answers to question No. 10 of the previously shown type 2 questionnaire, was never found – in the present study – for the scenarios evaluated with intensity IV. One possible reason for this may be that this item is not well positioned in the definition of grade IV. Even if this effect starts to occur at intensity IV, it may not correspond to the lower threshold of this grade. In that case – since the definition of a grade has the meaning of the lower threshold of the corresponding intensity – the item should not be explicitly mentioned.

The present work also tackled the known fact that the effects caused by an earthquake on people and objects may be quite different if observed at a ground floor or at upper floors. Some doubts occurred in some of these cases. For instance, what intensity is to be assigned in a situation where no one at the ground floor and first floors of the buildings of a certain area noticed the event, whereas it was felt by some in the floors above? And what is the intensity when the typical scenario at the ground and lower floors is III and at upper floors – but not higher than the fifth floor – is IV? EMS-92 user's guide recommends to discount all reports from observers located higher than the fifth floor when assigning intensity, but this guideline does not seem precise enough to the determination, at least for cases of low intensity, such as the previous two.

3.2. *Methodology B*

Methodology B was used for all pairs (earthquake; site) that have an intensity value attributed in Seismological Annuary of Portugal. It consists in converting this intensity value – in the starting scale – to EMS-92 scale, by means of *conversion tables*. The procedure leads only to an intensity value. No intensity quality factor was assigned.

In order to obtain the conversion tables two different procedures were used.

One of them, referred as conversion 1, is a two-stage conversion process. It is based on tables, obtained by Levret, 1982 («Les caracteristiques des seismes pour le choix des sites des centrales nucleaires», unpublished notes) comparing different intensity scales with the MSK-64 scale, and on a subsequent comparison of MSK-64 and EMS-92 scales. The latter confrontation led to the conclusion that, in spite of their differences, there is a correspondence between MSK-64 and EMS-92 intensity grades of equal order. A handicap of conversion 1 is the fact that Levret's results are prior to the EMS-92 user's guide.

The other procedure, named conversion 2, consists in the direct evaluation of which EMS-92 intensity grade – or grades – corresponds to each intensity grade of the starting scale. This method was used whenever the text of the starting scale was available.

Because of practical aspects, the conversion tables used in this work – presented in table II – include single grades and intervals of consecutive intensity grades. The intensity intervals of the starting scales were considered to mean intermediate intensity grades – «half-grades». Those of the EMS-92 mean that, considering a value of the starting scale – grade or grade interval – its lower intensity scenarios correspond to the first grade of the EMS interval, whilst its upper level scenarios correspond to the second grade of that interval.

As far as conversion 1 is concerned and due to the already mentioned equivalence between MSK-64 and EMS-92 scales, conversion 1 tables reproduce Levret's conclusions.

With regard to conversion 2, some of the differences – between starting and EMS-92 scales – observed in the range I to IV-V of the starting scales, are due to the interpretation, used in the present work, of the quantities of the effects on people; on the other hand, the use of one of EMS-92 guidelines, namely that the definition of each EMS-92 grade should be viewed as the lower threshold of that grade, justifies the remaining differences. The results of conversion 2 for intensities connected with damage to buildings, especially WN-31 VII to VIII-IX levels and MM-56 VII to IX values, should be considered to have some uncertainty, because grade definitions of the starting scales are not complete enough for damage representativity, types of damage, and also, as far as WN-31 scale is concerned, building types. The absence of a sole item – mentioning damage to buildings – in MM-56 definition of intensity V led, by conversion 2, to a IV-V EMS-92 intensity value, instead of V. The grades at the top of the starting scales – IX to XII in the case of WN-31 scale and X to XII in the case of the MM-56 scale – are defined by items quite different from those of the EMS-92 scale. Therefore, conversion 2 results for these grades were based on common sense.

Table II. Conversion tables used in the present study.

MCS-17 → EMS-92 (conversion 1)		WN-31 → EMS-92 (conversion 1)		WN-31 → EMS-92 (conversion 2)		MM-56 → EMS-92 (conversion 1)		MM-56 → EMS-92 (conversion 2)	
I	I	I	I	I	II	I	I	I	I
I-II	II	I-II	II	I-II	II	I-II	I	I-II	II
II	II	II	II	II	II-III	II	II	II	II-III
II-III	II	II-III	II	II-III	III	II-III	II	II-III	III
III	III	III	III	III	III	III	III	III	III
III-IV	III	III-IV	III	III-IV	III	III-IV	III	III-IV	III
IV	IV	IV	IV	IV	IV	IV	IV	IV	IV
IV-V	IV	IV-V	IV	IV-V	IV	IV-V	IV	IV-V	IV
V	V	V	V	V	V	V	V	V	IV-V
V-VI	V	V-VI	V	V-VI	V-VI	V-VI	V	V-VI	V
VI	V	VI	VI	VI	VI	VI	VI	VI	V-VI
VI-VII	V	VI-VII	VI	VI-VII	VI	VI-VII	VI	VI-VII	VI
VII	VI	VII	VII	VII	VI-VII	VII	VII	VII	VI-VII
VII-VIII	VI	VII-VIII	VII-VIII	VII-VIII	VII	VII-VIII	VII	VII-VIII	VII
VIII	VII	VIII	VIII	VIII	VIII-IX	VIII	VIII	VIII	VIII
VIII-IX	VII	VIII-IX	VIII-IX	VIII-IX	IX	VIII-IX	VIII	VIII-IX	VIII
IX	VIII	IX	IX	IX	IX	IX	IX	IX	IX
IX-X	VIII	IX-X	IX	IX-X	X	IX-X	IX	IX-X	X
X	IX	X	X	X	X	X	X	X	X-XI
X-XI	IX-X	X-XI	X	X-XI	X-XI	X-XI	X	X-XI	XI
XI	X	XI	XI	XI	XI	XI	XI	XI	XI
XI-XII	XI	XI-XII	XI	XI-XII	XI	XI-XII	XI	XI-XII	XI
XII	XI-XII	XII	XII	XII	XII	XII	XII	XII	XII

The absence of a quality factor associated with each value of intensity makes the distinction between the results of this methodology and those of methodology A. In order to emphasise this difference, a new value of intensity quality factor, such as for example VD – that stands for «very doubtful» – or the indication T – for «table» – for instance, are proposed to accompany the evaluations of intensity obtained by means of conversion tables.

4. Database

A database including the Portuguese 1947-1993 seismic information is being built. For each earthquake it includes:

1) *Earthquake identification*:
   - 1.1 - Date
   - 1.2 - Time
   - 1.3 - Xep, Yep – epicentral location, in military coordinates (km) (*)
   - 1.4 - Inf-epi
   - 1.5 - Focal depth
   - 1.6 - Inf-h
   - 1.7 - Magnitudes

(*) Site locations in military local coordinates were already available in the «Reportório Toponímico de Portugal», and may be directly used to compute distances.

2) *References*

3) *For each site with macroseismic information:*
   - 3.1 - X, Y – site military coordinates (km)
   - 3.2 - Certloc – quality factor for site
   - 3.3 - Soil – site soil type
   - 3.4 - MCS17 int – MCS-17 intensity value
   - 3.5 - MCS17 conv1 – EMS-92 intensity value obtained through MCS-17 conversion 1
   - 3.6 - WN31 int – WN-31 intensity value
   - 3.7 - WN31 conv1 – EMS-92 intensity value obtained through MCS-17 conversion 1
   - 3.8 - WN31 conv2 – EMS-92 intensity value obtained through MCS-17 conversion 2
   - 3.9 - MM56 int – MM-56 intensity value
   - 3.10 - MM56 conv1 – EMS-92 intensity value obtained through MCS-17 conversion 1
   - 3.11 - MM56 conv2 – EMS-92 intensity value obtained through MCS-17 conversion 2
   - 3.12 - EMS-92 int – EMS-92 intensity value obtained by direct evaluation
   - 3.13 - Int QF – intensity quality factor
   - 3.14 - Key – number of conversion key applied

Any one of these parameters may be blank.

– Epicentral location is a value chosen among the three or fewer points accessed: the epicentres referred in each one of the two studies «Seismological Annuary of Portugal» and Sousa *et al.* (1992), and the medium point of those two previous locations. The decision is based on the inspection of the geographical distribution of macroseismic data and of the possible epicentre locations, which may determine which position is the most compatible and if it is reasonable to chose any. Inf-epi is a parameter informing on the epicentral choice, if any.

– Focal depth is a value chosen among, at the most, three possibilities, which are the values referred in the two above mentioned studies, and their average. The choice – if any – takes into account the previous epicentre decision, and the difference between the two original values of depth. Inf-h is the parameter that informs on this determination.

– In the database there are five fields for magnitude – local magnitude, *P* wave magnitude, surface wave magnitude, magnitude of undetermined type, and magnitude determined by IM (the procedure used by IM to determine magnitude has varied through time: macroseismic magnitude and duration magnitude were the types considered during the 1947-1993 period).

– Certloc is a parameter allowing two values, 0 if there is no certitude on site location and 1 in the opposite case.

– Soil type may be 0, 1 or 2 meaning hard, intermediate and soft ground respectively. Soil determination was made through inspection of the Geological Chart of Continental Portugal (1:500000 scale). Soil 0 includes eruptive rocks, metamorphic rocks, all soils from Mesozoic and Palaeozoic Eras, the soils from the Precambrian Period, the Palaeogene-Miocene soils and those from the Palaeogene. Soil 1 includes the Pliocene soils, the undifferentiated Mio-pliocene soils and the Miocene marine and continental *facies*. Soil 2 includes all Antropozoic soils and the undifferentiated Plio-placencian soils.

5. Discussion

The 1947-1993 macroseismic information, in a total of 3255 pairs (earthquake; site), refers to 297 earthquakes. With the exception of the February 28, 1969 earthquake, this period of time is characterised by slightly or moderately felt earthquakes. Most of them did not cause damage to buildings. About 78% of the analysed earthquakes have maximum EMS-92 intensity below or equal to IV; in approximately 2% of the events maximum intensity is IV-V, and in about 9% it is V. Close to 3% of the seisms have maximum intensity V-VI, nearly 1% have VI and about 1% have VI-VII. In one case maximum intensity VII-VIII was attained and in another case VIII-IX (VIII being more likely) was obtained. In all the other cases intensity assignment was vague, corresponding to intervals with ranges of more than two grades. The years with the largest numbers of felt earthquakes were 1969 (23 events) and 1986 (15 events); in 1984 no seisms were felt. Figure 1 shows the evolution of these occurrences in time.

From these 297 events a data selection with 99 events was made, based on the value of

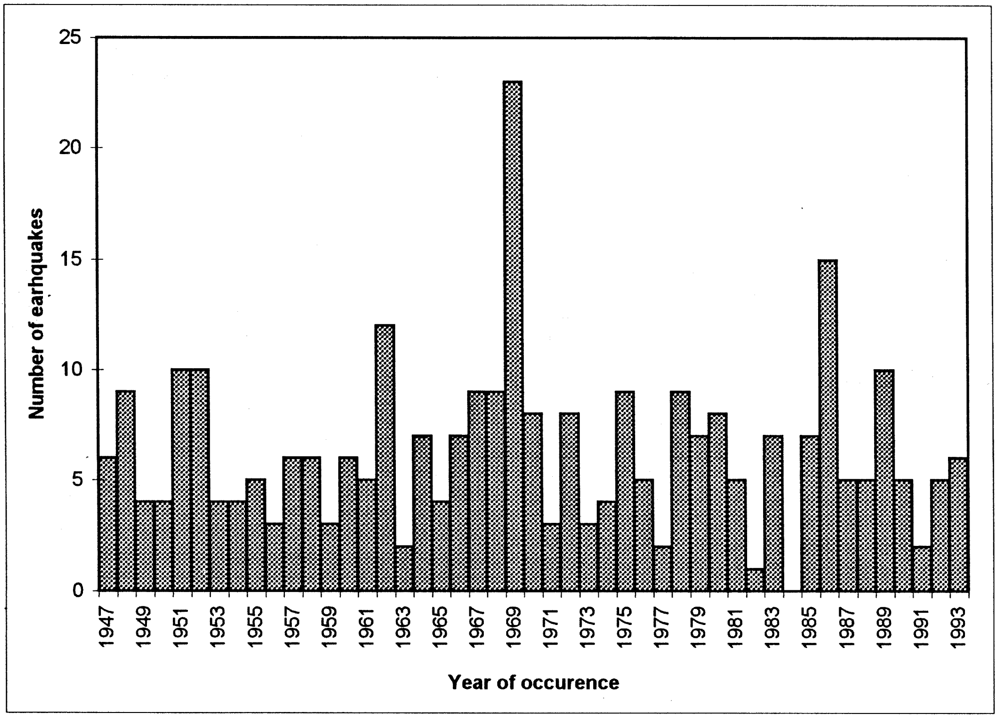

Fig. 1. Number of occurrences per year in the period 1947-1993.

Inf-epi and on the magnitude information. These earthquakes are the ones whose epicentral locations are known – without too much contradictory information – and simultaneously whose local magnitudes are available. 78 of them have some information on focal depth. The information on these 99 earthquakes was the first to be included in the database and is already available. From here on, the text refers only to this set of data, presenting the results of intensity evaluations and discussing some of its features. As a notation in graphic presentations, intensity intervals are represented by half integer values.

Continental Portugal is located in the Eurasian Plate, in the crossing region between its N-S continental border and a E-W frontier between Eurasian and African Plates, both of these geological structures being situated in the Atlantic. Besides these tectonic features, there are also active faults in Portuguese territory. Two main seismic mechanisms are responsible for the earthquakes felt in Continental Portugal: interplate earthquakes are caused by the movements at Eurasian and African plate borders, and intraplate earthquakes are generated at Eurasian active faults in the Portuguese territory.

Figure 2 presents the 99 epicentres and corresponding local magnitude (M_l) classes. It should be noted that major magnitude values are mostly associated with sea-epicentre earthquakes – the weaker sea events are not felt in Portuguese territory – whereas there are large numbers of on land-epicentre earthquakes with local magnitude in the (3.0, 4.0) class. As a first approach, sea-epicentre seisms may globally be considered interplate earthquakes and on land-epicentre events correspond to intraplate seismicity.

Figure 3 shows the evolution in time of maximum intensities per event (I_{max}), deter-

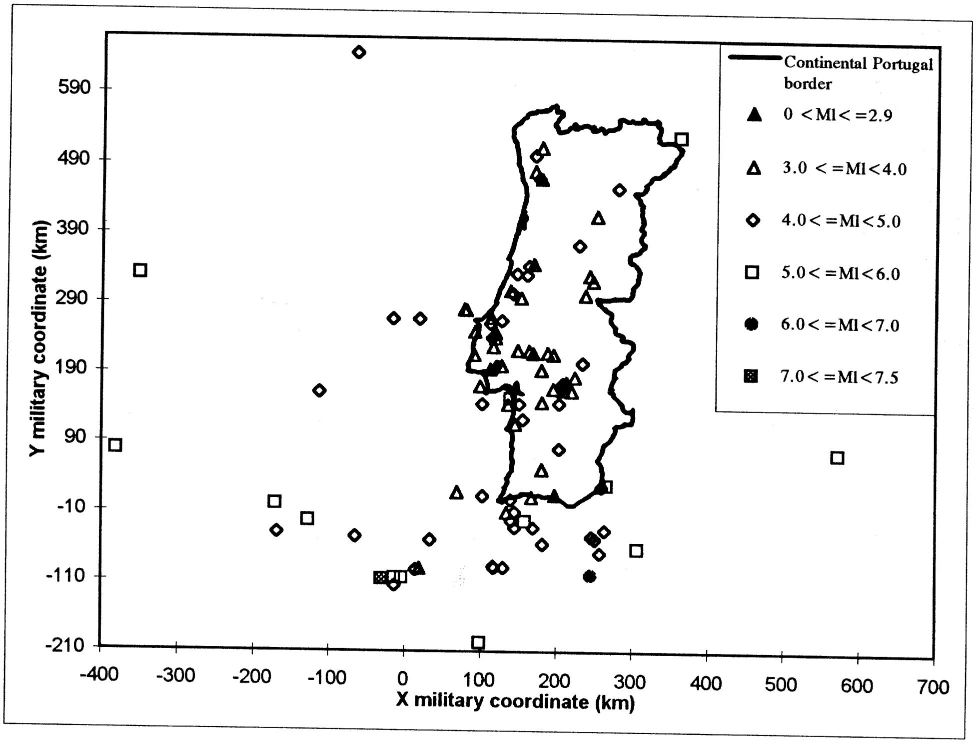

Fig. 2. Map of epicentres with local magnitude classes.

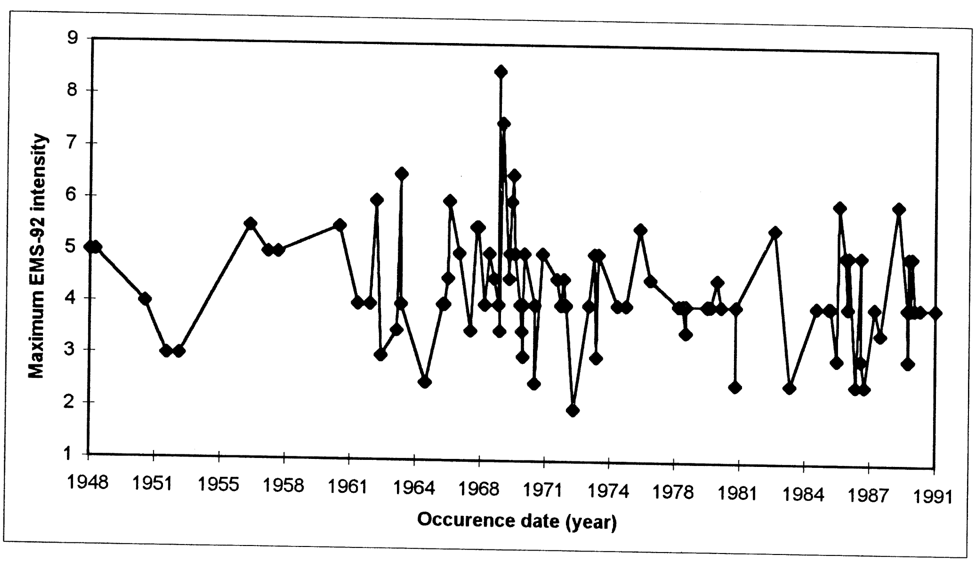

Fig. 3. Evolution of maximum EMS-92 intensity per event, in time.

mined through methodology A. For each earthquake, maximum intensity was frequently observed at a few sites. Maximum intensity is typically in the range (3.0, 6.0). Both for local magnitude and for maximum intensity per event, maximum values were attained in 1969.

A linear relation between local magnitude and maximum intensity, for earthquakes with on land-epicentre, was obtained through data fitting, using the minimum squares method. The group of data considered in this procedure consisted of the 71 events with on land-epicentre, from the previous set of 99 earthquakes; and, for each intensity interval in the data, the value considered for the fit was the average of the extremes, in spite of the real meaning of the interval. The result

$$M_l = 2.75 + 0.26\, I_{max}$$

has residual standard deviation 0.56, and coefficient of simple determination (R^2) 0.15; it satisfies t and F statistical tests with an α risk of 0.05. This expression, together with the corresponding data, are graphically presented in fig. 4. Data scatter is quite large, and the degree of linear statistical relation between M_l and I_{max} is small. Some reasons to explain the scatter are: 1) the influence of focal depth and of the prop-

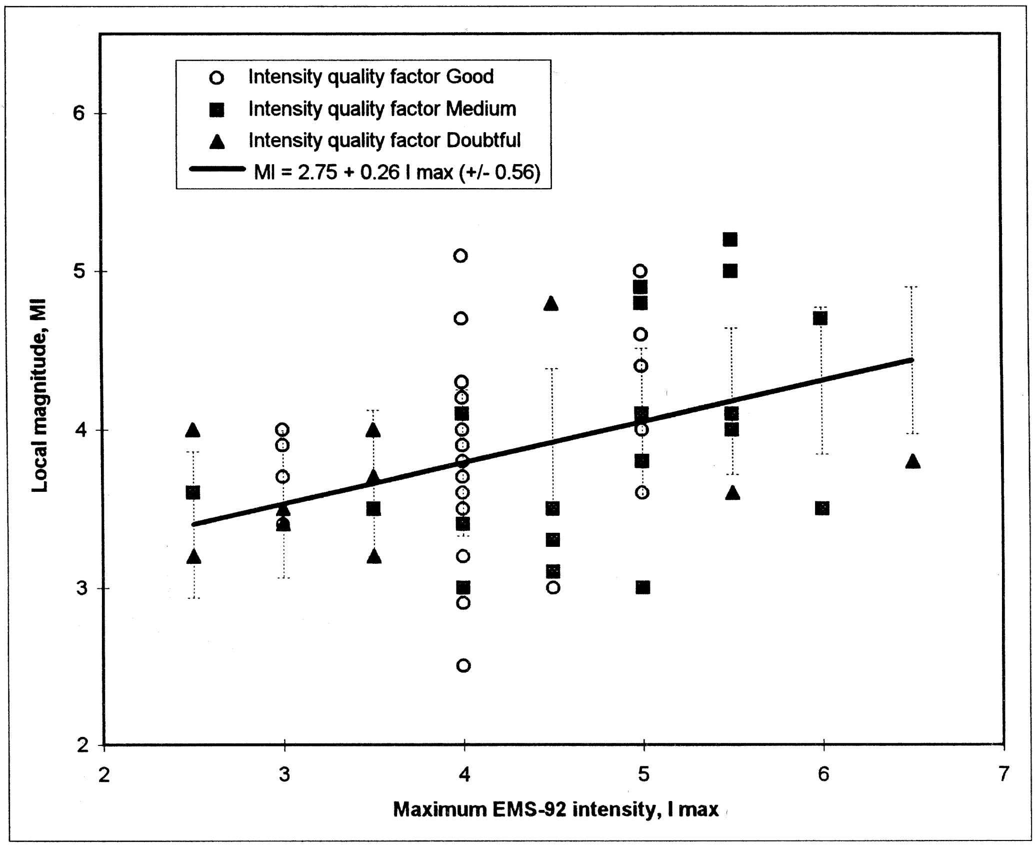

Fig. 4. Local magnitude *vs.* maximum EMS-92 intensity per event, for earthquakes with on land epicentre: data and empirical fitting.

agation path; 2) the uncertainty in M_l values and 3) the uncertainty in I_{max} values. In order to take into account item (1), data fitting of a relation including, besides the previously considered terms, a term proportional to the logarithm of focal depth was accomplished; however its results failed a t statistical test. Since the values of errors of determination of the local magnitude were not available, the influence of item (2) on data scatter was not studied. To minimise the effect of subjectivity of intensity assignment – item (3) – expressions of the two forms already mentioned were obtained considering, separately, first the data with *Good* or *Medium* intensity quality factor, and next only the information with *Good* quality factor. The residual standard deviation and the coefficient of simple determination of the results obtained were, in both cases, worse than in the previous case.

Further analysis of the results of EMS-92 intensity evaluation contained in database are the subject of the next section.

5.1. *Comparison of methodologies A and B*

Table III presents the number of pairs (earthquake; site) associated with each intensity grade, obtained through methodology A; for the same set of pairs, the corresponding results of conversion through methodology B are also presented.

It is commonly agreed that methodology A is the most reliable, and should be used whenever possible, and that the use of conversion tables leads to error propagation. Even the use of «perfect» conversion tables leads to a transcription of the errors made in direct intensity evaluation – which might have occurred systematically, from the EMS point of view, especially if this direct evaluation is prior to EMS intensity assessment guidelines.

Nevertheless, in some situations methodology B is the only possible process to assign intensity, and should therefore be calibrated.

In the present study the sets of pairs (seism; site) to which the two methodologies can be applied do not coincide. Table IV presents a comparison, for the pairs in common. The differences in assignment, in this table, were computed considering intensity intervals as half integer values. The two methodologies lead to quite different results reaching a maximum difference of 3.5 degrees in the case of two pairs in the WN-31 conversion 1 *vs.* methodology A comparison and in one of the WN-31 conversion 2 *vs.* methodology A comparison. Such extreme values, however, are probably a consequence of the evaluation of different and contradictory sets of data. Differences of one degree are quite common, around 30% of all cases, for conversion comparisons shown in table IV. Despite these differences, the correlations between the evaluations using methodologies A and B are quite large, as expected since the sets of intensity values resulting from both methodologies – as they come from the same field of macroseismic descriptions – are not independent.

As far as WN-31 and MM-56 intensity comparisons are concerned, in spite of the fact that type 1 conversions – *i.e.*, the two-stage conversion – have a slightly higher correlation, it is shown in table IV that type 2 conversions – *i.e.*, the direct conversions – lead to a better fit at least for the intensity range of the present data. Conversion 2 tables should thus be used in case of further methodology B determinations.

The best fit of conversion 2 to methodology A is possibly due to two reasons. The first is that the criteria followed by Levret, when comparing the scales, are not known, but probably are not equal to those recommended in the EMS-92 scale; the second reason is the fact that, since intensity evaluation both via methodology A and by conversion 2 was made by the same authors, the interpretation followed, of EMS-92 scale and of its guidelines, was the same in the two procedures. In spite of the second item, the results point out the need to follow standardised and known procedures of intensity evaluation.

6. Final considerations

The purpose of the present work was to obtain, and make available, macroseismic intensity assignments as reliable as possible, from

Table III. Results of methodologies A and B.

Methodology A

EMS-92 Int.	No. of pairs	Percentage	Int. quality factor	No. of pairs	Percentage
I-II	3	0.14%	G	881	40.25%
II	62	2.83%	M	1117	51.03%
II-III	263	12.01%	D	191	8.73%
III	422	19.28%			
III-IV	128	5.85%			
IV	739	33.76%			
IV-V	108	4.93%			
V	211	9.64%			
V-VI	69	3.15%			
VI	102	4.66%			
VI-VII	50	2.28%			
VII	14	0.64%			
VII-VIII	13	0.59%			
VIII	4	0.18%			
VIII-IX	1	0.05%			
EMS total	2189	100.00%	Int. QF total	2189	100.00%

Methodology B

MCS-17 → EMS-92 conversion 1		
EMS-92 Int.	No. of pairs	Percentage
II	8	9.52%
III	23	27.38%
IV	45	53.57%
V	8	9.52%
MCS total	84	100.00%

WN-31 → EMS-92 conversion 1			WN-31 → EMS-92 conversion 2		
EMS-92 Int.	No. of pairs	Percentage	EMS-92 Int.	No. of pairs	Percentage
I	2	0.22%	II	68	7.34%
II	148	15.98%	III	435	46.98%
III	353	38.12%	IV	196	21.17%
IV	196	21.17%	V	54	5.83%
V	97	10.48%	V-VI	43	4.64%
VI	84	9.07%	VI	84	9.07%
VII	34	3.67%	VI-VII	34	3.67%
VII-VIII	8	0.86%	VII	8	0.86%
VIII	4	0.43%	VII-VIII	4	0.43%
WN total	926	100.00%	WN total	926	100.00%

MM-56 → EMS-92 conversion 1			MM-56 → EMS-92 conversion 2		
EMS-92 Int.	No. of pairs	Percentage	EMS-92 Int.	No. of pairs	Percentage
II	277	36.88%	II-III	175	23.33%
III	283	37.68%	III	385	51.33%
IV	149	19.84%	IV	149	19.87%
V	41	5.46%	IV-V	35	4.67%
VI	1	0.13%	V	6	0.80%
			V-VI	1	0.13%
MM total	751	100.00%	MM total	751	100.00%

Table IV. Comparison of methodologies A and B.

Correlation	EMS-92 (method A)
EMS-92 (MCS-17 conversion 1)	0.777
EMS-92 (WN-31 conversion 1)	0.869
EMS-92 (WN-31 conversion 2)	0.858
EMS-92 (MM-56 conversion 1)	0.787
EMS-92 (MM-56 conversion 2)	0.721

| EMS (method A) - EMS (MCS conversion 1) |*	No. of pairs	Percentage
0	37	44.05%
0.5	24	28.57%
1	23	27.38%

| EMS (method A) - EMS (WN conversion 1) |*	No. of pairs	Percentage
0	302	32.61%
0.5	205	22.14%
1	362	39.09%
1.5	21	2.27%
2	28	3.02%
2.5	6	0.65%
3.5	2	0.22%

| EMS (method A) - EMS (WN conversion 2) |*	No. of pairs	Percentage
0	351	37.90%
0.5	223	24.08%
1	312	33.69%
1.5	13	1.40%
2	22	2.38%
2.5	4	0.43%
3.5	1	0.11%

| EMS (method A) - EMS (MM conversion 1) |*	No. of pairs	Percentage
0	251	33.42%
0.5	204	27.16%
1	275	36.62%
1.5	12	1.60%
2	9	1.20%

| EMS (method A) - EMS (MM conversion 2) |*	No. of pairs	Percentage
0	391	52.06%
0.5	177	23.57%
1	172	22.90%
1.5	6	0.80%
2	5	0.67%

* Absolute value of the differences.

data collected in events occurring in the last 50 years. Improvement of quality of this kind of data is important since the results produced are to be used in different developments, such as the determination of seismic parameters – epicentre, focal depth and magnitude, for events without any or enough instrumental information – and attenuation studies – isoseismal maps and attenuation laws for macroseismic intensity – with further use in seismic risk analysis. The methodologies developed here may be transposed to other places with similar seismic activity and data types.

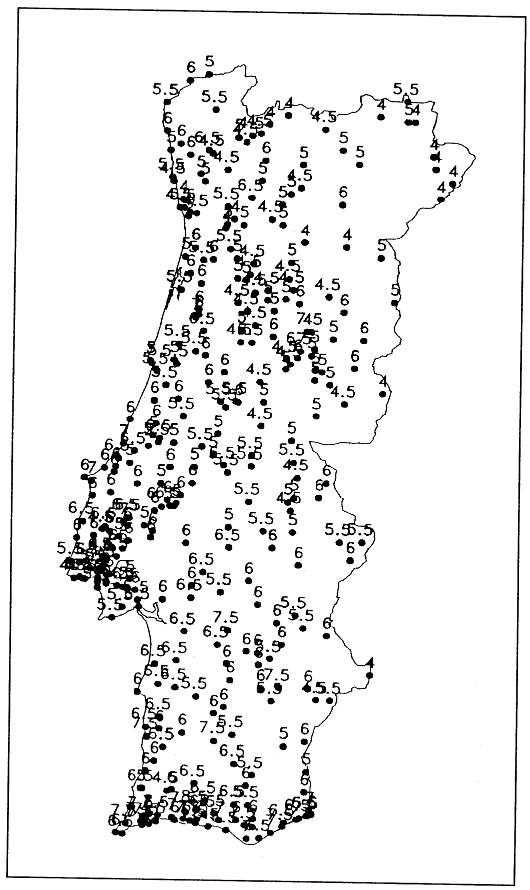

Fig. 5. EMS-92 intensity (obtained by methodology A) at the observation sites, for the February 28, 1969 earthquake.

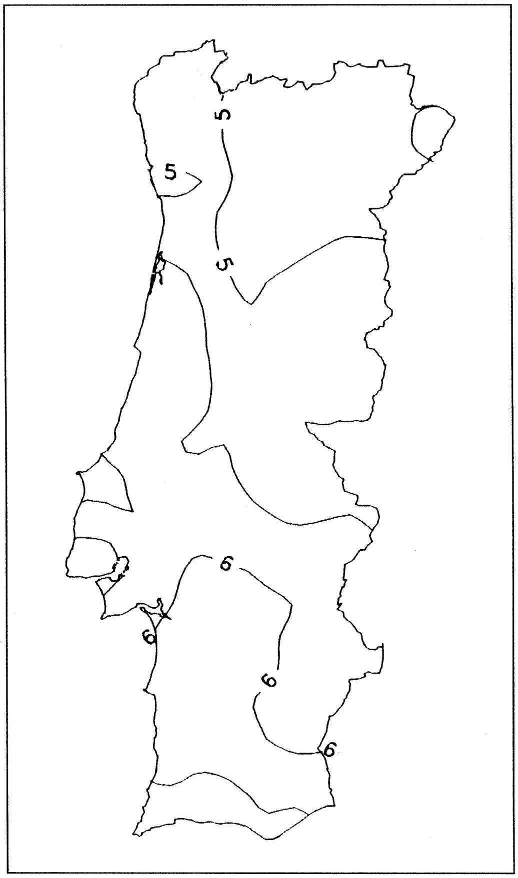

Fig. 6. Isoseismal map for the February 28, 1969 earthquake.

The EMS-92 scale was selected as the working scale in this paper. Taking into account the results obtained, some considerations on intensity assignment may be pointed out:

– The EMS-92 user's guide significantly contributes to the minimisation of subjectivity in intensity determination. EMS-92 scale, is clear in relation to intensity assessment as far as the range of intensity, types of buildings and grades of damage of the data studied are concerned.

– In spite of the efforts made, using EMS guidelines and the quality factor, differences of one grade in intensity may occur if other authors evaluate the information of some of the pairs (earthquake; site) studied, especially in the case of data available only in questionnaires.

– To reduce this uncertainty, the development of a new questionnaire, adapted to the EMS-92 scale, would be of great help. A first draft of a new questionnaire has already been obtained (Paula and Oliveira, «Avaliação de informação macrossísmica de Portugal Continental. Estudos de atenuação», in preparation). Subsequently an expert algorithm capable of treating the data automatically should be obtained.

– The re-interpretation of data sources (methodology A) is the most reliable method for assessing intensity evaluations. Methodology A should be extended, in the case of Portugal, to other periods of time prior to 1947 for which information exists in questionnaires and especially in widespread publications.

– The use of conversion tables in intensity assignment should be avoided; in case no other alternative is available, care should be exercised to choose the most adequate conversion table.

Besides the intensity quality factor, information on the error in the determinations of other quantities in the database, such as epicentral coordinates, focal depth and magnitudes, are required and deserve further attention. This was evidenced with an example in section 5, when referring the relation between local magnitude and maximum intensity.

Attenuation studies, considering all the available information evaluated, are now in progress. In these studies, data filtering, taking into consideration the intensity quality factor and the values of the parameters Certloc, Inf-epi and Inf-h, of the database, is considered. Some of these studies refer to isolated events, such as the February 28, 1969 earthquake. The effects of this event are described in several newspapers and in specialised publication such us Marecos and Castanheta (1970) and Mendes (1974). This earthquake is the best documented example for the EMS-92 intensity distribution. Figure 5 presents all data points obtained for this event with methodology A, and fig. 6 the corresponding isoseismal map. Other attenuation studies consider different sets of earthquakes, such as the on land-epicentre earthquakes and the sea-epicentre earthquakes, with magnitudes in different ranges. These studies plan to check the influence of source and path on attenuation laws. The effects of local soil type are also being considered.

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