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# Towards uniform earthquake hazard assessment in Europe

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**Abstract**
A summary of the state of the art in seismic hazard assessment in Europe is presented. We cover the evolution of presently used methodologies in seismic hazard practice, the availability of data and structured data bases at regional scale and the results of recent experiments in regional seismic hazard assessment. We present a strategy for the implementation of the GSHAP regionalized approach and the identification of geophysical institutions to act as Regional Centres and of test-areas of significant seismotectonic importance.

## 1. Introduction

Catastrophic earthquakes in Europe are mainly occurring in the Mediterranean area. In this context also the North-African coast has been frequently hit by disastrous earthquakes. Therefore, most casualties in history are reported for the denser populated areas around the Mediterranean, especially where the quality of buildings is not adequate to the high seismic hazard.

However, some areas in central and northern Europe with comparatively smaller earthquake activity reveal also high seismic risk, taking into account the concentration and vulnerability of industrial facilities. Here the major part of possible economic losses is rather associated with medium sized earthquakes due to the relatively high frequency of occurrence compared to large earthquakes. The aspect of loss of life may be of lesser importance than in the Mediterranean.

Figure 1 shows a rough sketch with the distributions of large earthquakes and important economic centres. One of the seismically pronounced risk-axes, counting economic and human losses, is clearly extending from North to South, including the Rhinegraben Riftzone, Switzerland and the entire Italian Peninsula. Apart from this zone other Mega-Cities around the Mediterranean share a high seismic risk, *e.g.* Barcelona, Lisbon, Alger, Cairo, Istanbul and Athens.

Seismologists in the European area have collected rich archives of information on effects of historical earthquakes, dating back to medieval time. The European Seismological Commission has therefore initiated the issue of a map of maximum observed intensities (ESC 1983). Figure 2 shows a simplified version of this map for the Mediterranean. It proves, in a more quantitative sense, the high seismic hazard existing in the Mediterranean area. It must be mentioned that – due to different national procedures in data acquisition and evaluation – this map is not homogeneous. It can be shown, *e.g.*, that the maximum intensities for Greece are clearly underestimated in comparison to Italy.

## 2. Availability of data

For practically all countries in Europe and North Africa earthquake data have been compiled into catalogues by seismologists and other interested parties. However, the standards

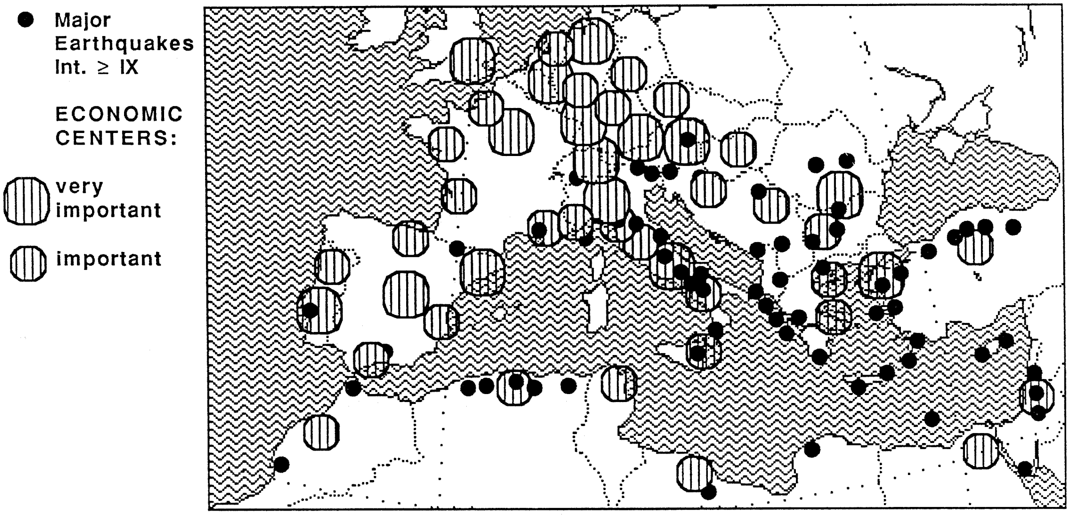


**Fig. 1.** Major earthquakes and economic centres in the European-Mediterranean area. The figure is simplified and not complete.

and formats on which these catalogues are based, are not always the same.

Figure 3a) and b) show graphically the contents of 13 national catalogues, which were available to the scientific community in the mid 80's. The most striking problem in these catalogues concerns the estimation of magnitudes and intensities. This is not a critical issue, if no attempt is made to compare these data collections. Many scientists in Europe agree that most of these catalogues have to be modified in order to fit into what could be called a «Homogeneous European Data Base», useful for supra-national comparison and hazard assessment.

## 3. Methods

During the last two decades in many countries in Europe projects have been launched, to assess earthquake hazard on a nation-wide basis. As demonstrated in a recent joint project by ESC and IASPEI (McGuire *et al.*, 1993), most of these projects employ preferably probabilistic methods. Figure 4 shows the elements of the hazard assessment procedure.

First a number of independent data sets have to be compiled which then serve as a basis for the next steps. Compilations of complete and accurate epicentre data are most essential for the procedure. Since this requirement is practically nowhere fulfilled, elaborate statistical methods have to be introduced to take this incompleteness into account. Isoseismal maps and other macroseismic data serve as input for the investigation of regional attenuation relationships.

The basic data must be transformed into distributions in space, time and size to be used as input for modern computer programs. Most of these programs require knowledge of seismogenetic zones in form of area sources and/or faults. At this point the knowledge of tectonic features in the region is relevant to give the calculated results a predictive character. Without this information only the behaviour of the past is calculated.

In practically all methods still professional judgement is involved. Especially when the maximum possible earthquake («upper bound»), the lower threshold of the complete data set, or the accuracy and scatter of the data have to be estimated. Experience has shown that maximum value statistics using Gumbel-

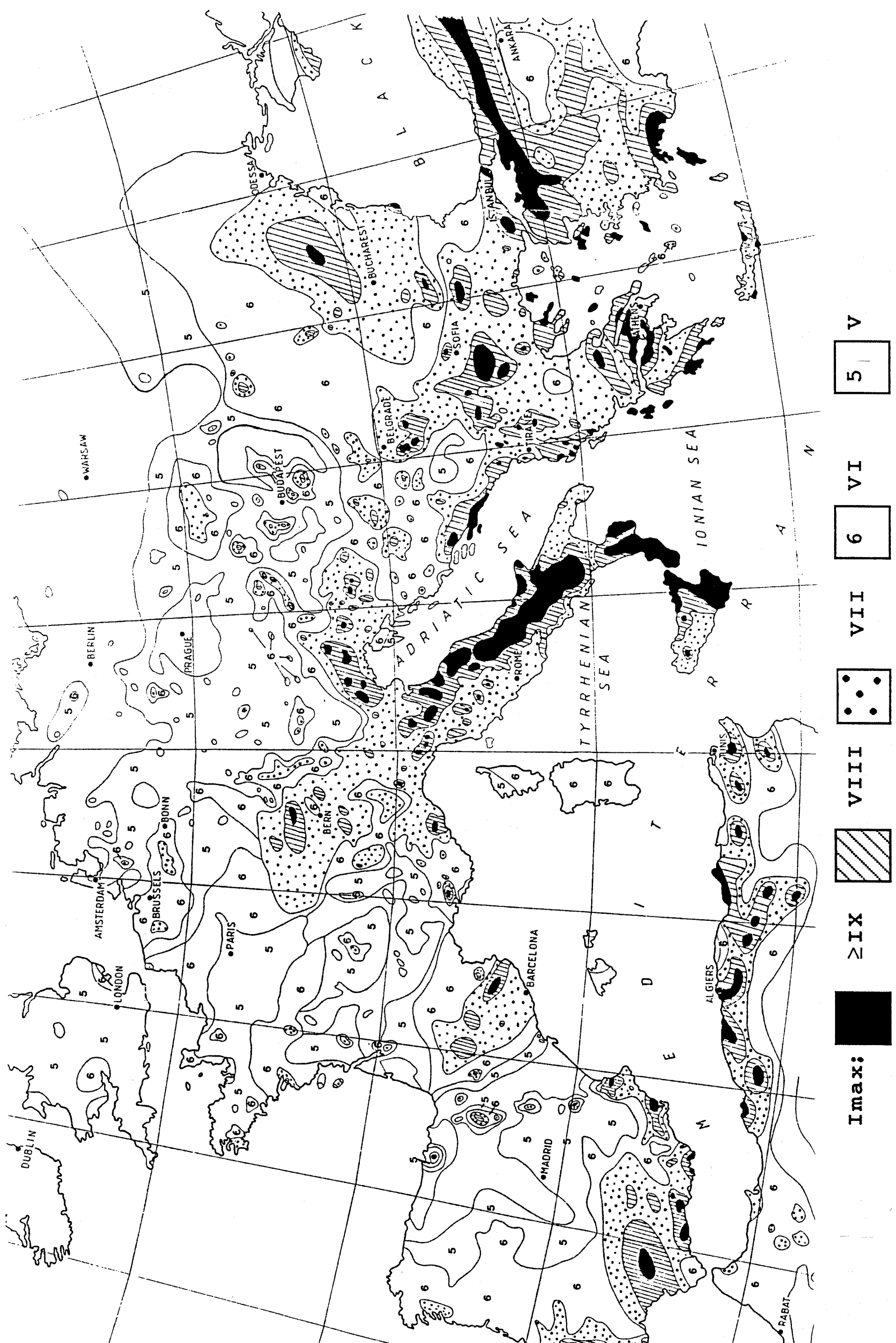


**Fig. 2.** Maximum observed intensities in Europe. Source: ESC 1983.

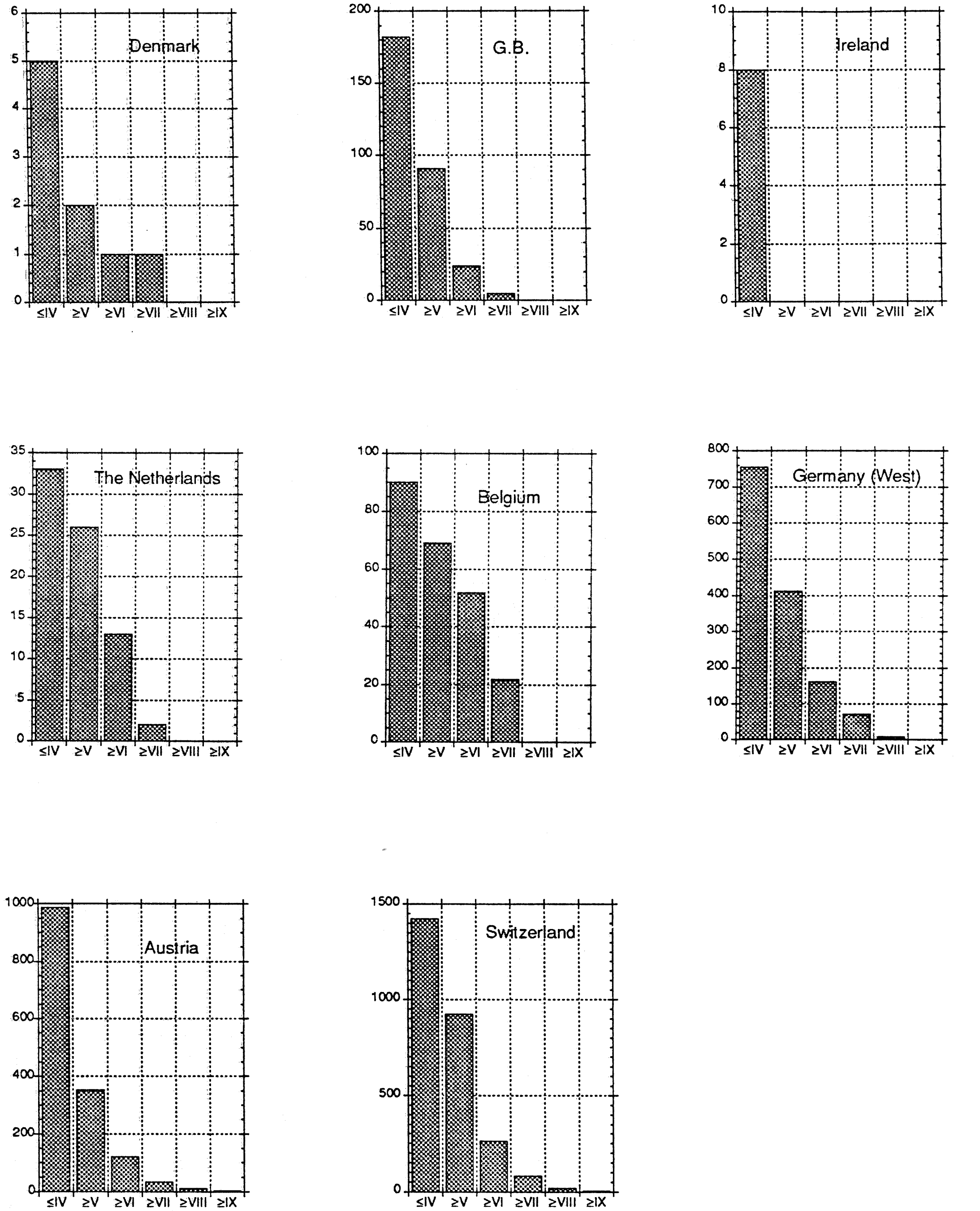


**Fig. 3a).** Number of earthquakes by intensity class for selected Northern and Central European countries. Source: national catalogues as available in 1985.

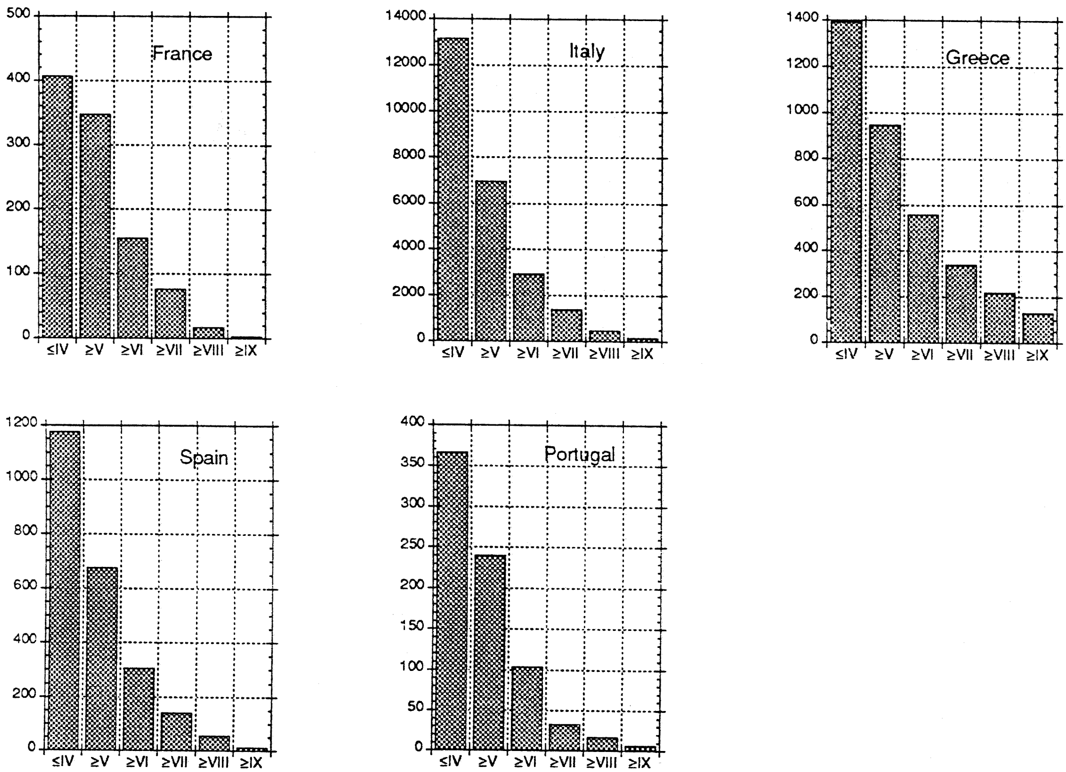


**Fig. 3b).** Number of earthquakes by intensity class for selected Southern European countries. Source: national catalogues as available in 1985.

distributions are not very successful to determine the maximum earthquake in an area.

The mapping of the results is usually done by calculating the probability distribution of the occurrence of ground motion values for a regular grid of sites. This is followed by contouring the results for fixed values of ground motion or probabilities. Figure 5 illustrates, as an example, the results of such procedure for Switzerland. The probabilities of occurrence are mapped in relative values, taking the central part of Switzerland (Zurich) as a reference. The isolines can also be given certain absolute values for given intensity- or probability-levels.

Figure 6 shows typical frequency of occurrence distributions over epicentre intensities. For better comparison, the numbers of earthquakes in each region are normalized. The gradients of the linear fits to the individual data vary between 0.45 and 0.70. The quality of the fit is good within the intensity range V to XI. It therefore can be concluded that the data sets of the illustrated countries are relatively complete. It must be explained that for Algeria only the central part, and for Belgium only the southern (seismically active) part of the country were considered. A rather «untypical» behaviour can be seen for Switzerland, where low intensity data (V,VI) are more dominating than in the other countries.

In most countries in Europe up to now mainly macroseismic data are used to derive the typical attenuation relationships of ground motion. This has three reasons: 1) historical earthquakes are dominating in the catalogues;

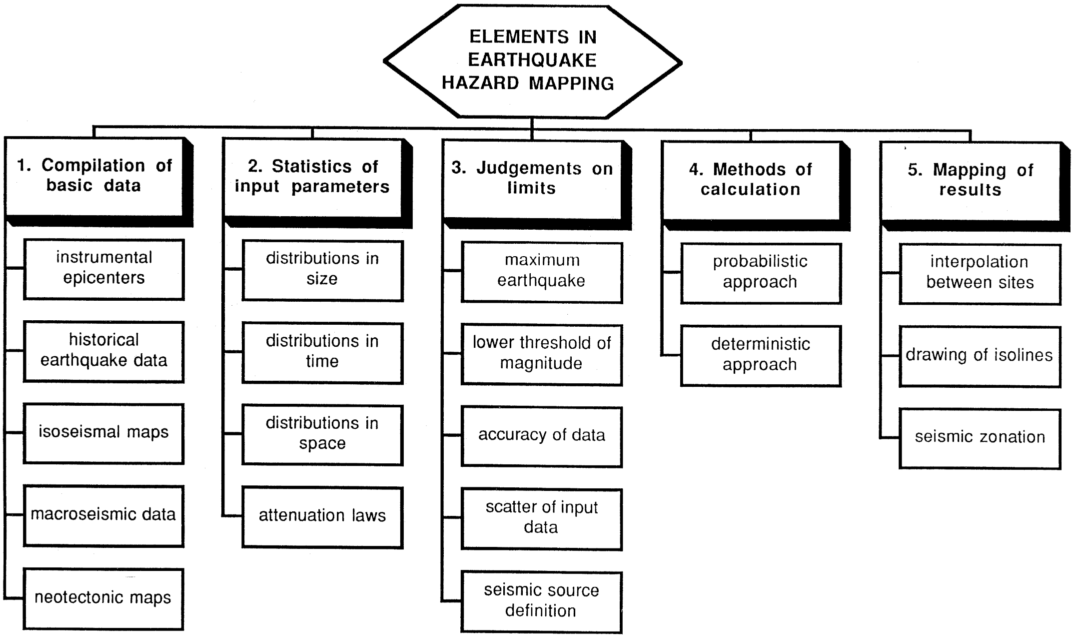


**Fig. 4.** Elements in earthquake hazard mapping, as used in many European countries.

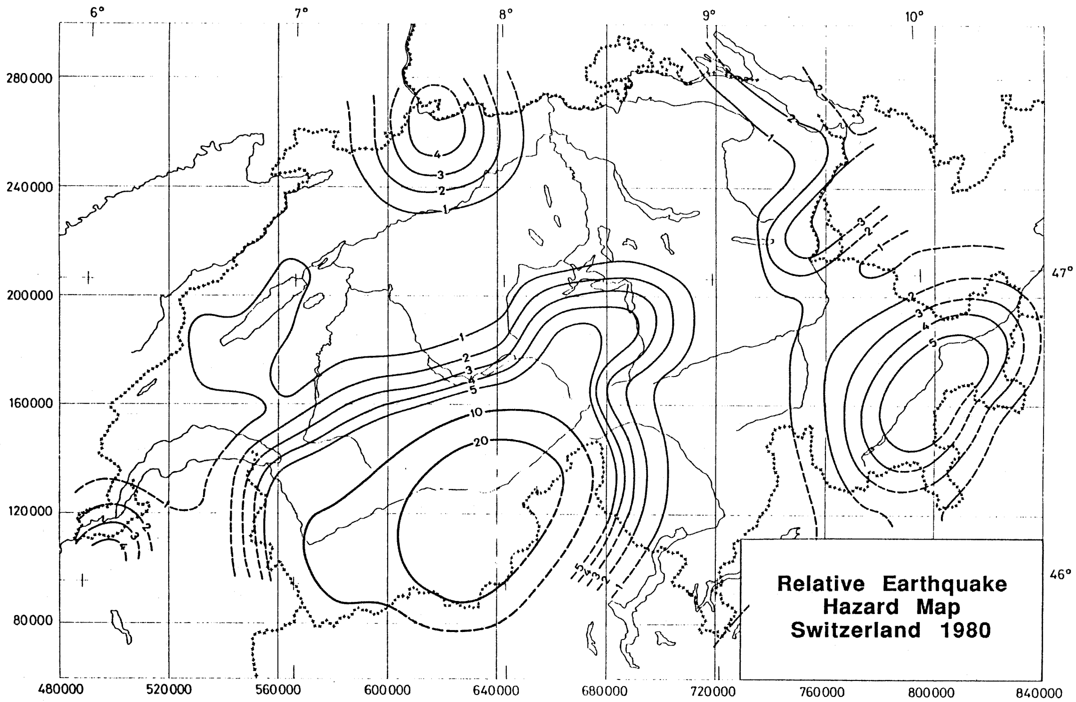


**Fig. 5.** Example of an earthquake hazard map using probabilistic methods as described in the text. The numbers indicate relative figures compared to Zurich as a reference.

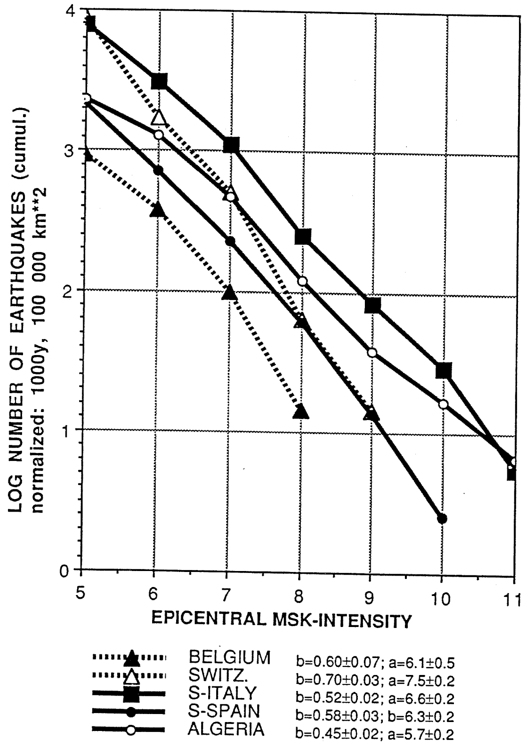


**Fig. 6.** Typical frequency distributions for five selected European regions. For comparison, all figures are normalized to a period of 1000 years and an area of 100 000 km**2.

2) strong motion records are not (yet) available in sufficient quantity; 3) if acceleration records are available, the peak – acceleration is not accepted as representative for the severity of ground motion.

All authors in the TERESA workshops are fully aware about the limited accuracy and meaningfulness of intensity data. In some regions a clear azimuth – dependence of attenuation is observed, at least with macroseismic data. In fig. 7 this fact is shown by the two curves S-Italy // and S-Italy -/, representing the two main directions parallel and perpendicular to the strike of the Apennines, respectively. Considering the considerable scatter of the data, the differences between most of the curves are less significant than it seems. This scatter must be taken into account when using distributions in the calculations. Usually 0.5 to 1.0 sigma-values in the intensity attenuation curves are taken for a conservative calculation.

The most underestimated fact in the quantitative assessment of the seismic activity in a region is the variation with time. In fig. 8 this behaviour is demonstrated for the data set of Southern Italy. A clear trend of decreasing activity must be assumed after 1910. On the other side, the lower activity in earlier centuries can partly be explained by the increasing incompleteness of the catalogue. It is also noteworthy that a quite similar behaviour is found in the data set of Switzerland. If the calculations of earthquake hazard should have a predictive quality, at least for the coming decade, these trends have to be considered accordingly.

## 4. Planning for GSHAP

During the technical planning meeting for GSHAP in Rome on 1-3 June 1992, the following guidelines have been developed by a working group, which consisted of representative scientists of European and African countries.

### 4.1. *Regional boundaries*

For planning and data – managing purposes, the «European – African Block» should be subdivided into several working areas (the list is not complete and should mainly demonstrate the general philosophy):

*Northern Europe*: Finland, Iceland, Norway, Sweden.

*Central-Eastern Europe*: Austria, Belgium, Bulgaria, Czech Republic, France, Germany, Hungary, Luxembourg, Netherlands, Poland, Romania, Slovakia, Switzerland, U.K., W-Russia.

*Western Mediterranean*: Algeria, Italy, Malta, Morocco, Portugal/Azores, Spain, Tunisia.

*Eastern Mediterranean*: Albania, Cyprus, Egypt, Greece, Israel, Jordan, Croatia, Leba-

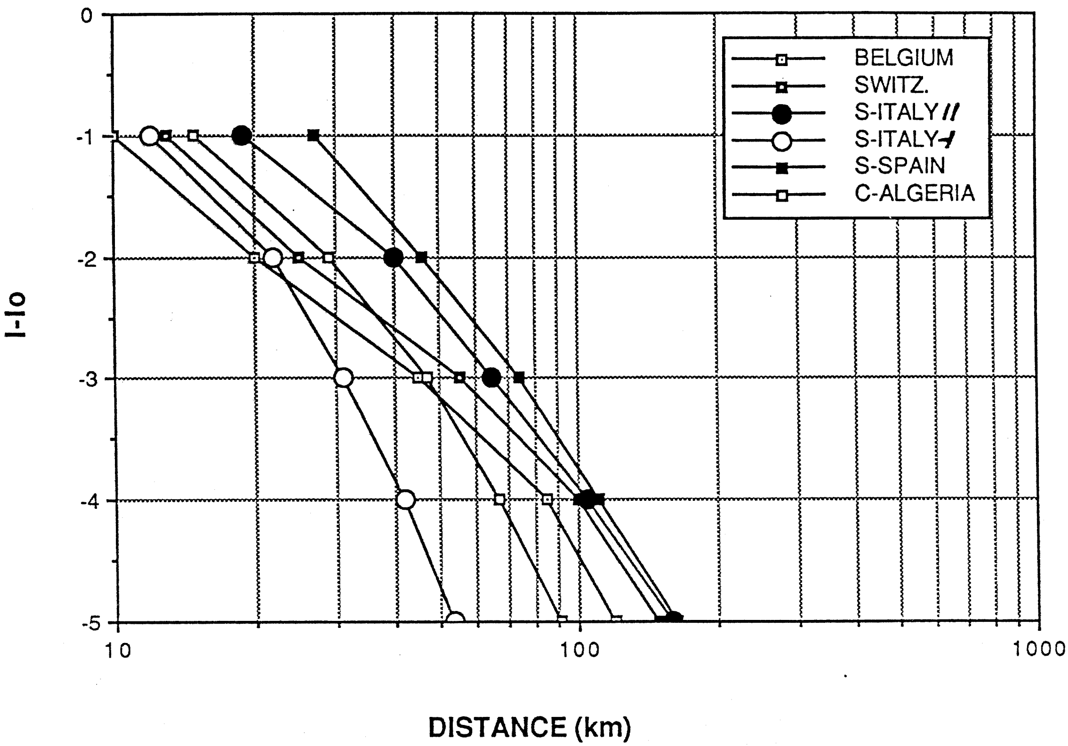


**Fig. 7.** Examples of intensity attenuation with distance in Europe. Source: ESC-TERESA- project 1989.

non, Libya, Macedonia, Serbia, Slovenia, Turkey.

*Central- and Eastern Africa*: Ethiopia, Kenya, Mozambique, Tanzania, Uganda, Rwanda, Sudan, Tanzania, Zaire, Zimbabwe.

*Southern Africa*: Rep. of South Africa.

*Western Africa*: Guinea.

## 4.2. *Regional centres*

For the European and Mediterranean area the following institutions may be chosen as co-ordinating regional centres:

a) Centre Seismologique Europe-Mediterranéen (CSEM) in Strasbourg, France, generally for data collection and homogenization in the ESC-area;

b) GeoForschungsZentrum in Potsdam, Germany, for Northern and Central Europe;

c) Seismological Institute Rabat, Morocco, for Western and Eastern Mediterranean;

d) Geological Survey, Nairobi, Kenya, for Africa.

The following general considerations have been applied for the association of regions to the different regional centres:

– most countries listed under the above sub regions N. Europe, C.- E. Europe, W. Mediterranean and E. Mediterranean adhere to the European Seismological Commission (total 36 member countries) and are already collaborating with CSEM;

– national boundaries are the main guidelines for subdivisions to obtain homogeneous national data sets in the first part of the project. Nevertheless, it is recommended to keep the countries in the two Mediterranean sub regions finally in one working unit;

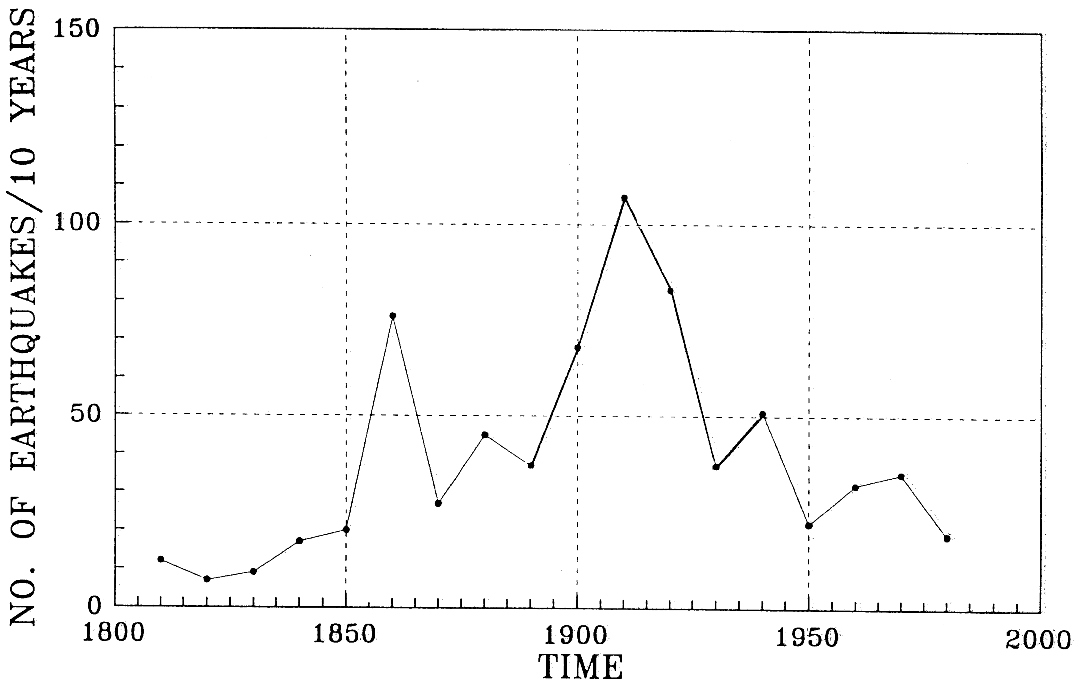


**Fig. 8.** Time variation of earthquake activity in Southern Italy (number of earthquakes with $I \geq 5$ in ten-year windows). Source: ESC-TERESA-project 1989.

– the regional centres in the European – African block co-ordinate their efforts specifically concerning areas of common interest in overlapping data-zones (*e.g.* Rhinegraben, Alps, Balkans);

– the Mid Atlantic Ridge (Azores Islands, Iceland) deserves special attention in this context.

### 4.3. *Pilot study areas*

a) The Maghreb area (Radius of about 200 km around Gibraltar) was agreed to be a suitable test area in the European - African block for the following reasons:

– common African and European ground

– existing good data base

– regional centre Rabat is situated in the area.

b) East African Rift Zone (3S -7N / 28E - 38E):

– high seismic activity

– regional centre Nairobi is situated in the area.

### 4.4. *Already existing organizations and structures*

– European-Mediterranean Seismological Centre (CSEM), Strasbourg, France for data collection.

– European Seismological Commission's working group on seismic hazard for task groups.

– Open Partial Agreement of the Council of Europe, Strasbourg, for co-ordination.

### 4.5. *Already existing data bases and related projects*

– MEDEA: seismological data bank, CSEM Strasbourg

– European Geotraverse, ESF
– National catalogues and maps in each ESC-country
– SEISMED: seismicity in the Mediterranean, UNDRO
– Balkan project, UNESCO
– TERESA project, ESC
– Projects on historical earthquakes, CEC Brussels
– PAMERAR project, UNESCO
– Maghreb earthquake catalogue, IGN Madrid
– Kenya-Germany co-operative project
– SADEC co-operative project Africa-Nordic countries
– Strong motion data bank, Imperial College London
– Strong motion data bank, Italian N.E.C. Rome
– Strong motion data bank, IZIIS Skopje.

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