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Site effects during Andalusian earthquake (12/25/1884)

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ABSTRACT: The Andalusian earthquake (maximum intensity X in the MSK scale) has been the last biggest seismic event affecting the central southern part of the Iberian peninsula. Several available isoseismal maps allow an averaged interpretation of the relationships between the propagation of seismic energy and its amplification effects on the ground. In this research, we try to evaluate a new isoseismal map weighting the site effects. A new revision of historical data, yields new geotechnical information as well as geomorphological characteristics of the region under study. Our analysis on seismic hazards for the area provide new light on the general attenuation laws and the newly drawn isoseismal map is compared with former work to provide more accurate forecasting on seismic hazards and building damages for the future.

1 INTRODUCTION

The Andalusian earthquake of December 25, 1884, had been studied by some international research commissions (French, Italian and Spanish 1885) and by several authors (Orueta 1885, López Arroyo et al. 1980). All these researchers obtained the isoseismal maps as well. But only Orueta's work has tackled the problem of reflecting the local site effects.

Seismic hazard analysis requires adequate attenuation laws in order to get reliable results. Usually these laws are obtained from isoseismal maps that represent an averaged energy attenuation. However, real values on each point should be corrected for local site effects.

A different approach to obtain real intensity attenuation values at a point is presented in this paper. Direct macroseismic data from damages induced by the earthquake are included instead of the values gathered from the general attenuation laws.

Macroseismic data from several villages not included in previous works have beeen incorporated to the new isoseismal map taking and special attention has been paid to local ground effects observed during the 1884 earthquake.

This methodology provides advantages when seismic hazards predictions from expected intensities for the next 500 years are made and compared with those using standard attenuation laws.

2 SEISMOTECTONIC SETTING

The geology of the area is complex, with two different domains known as Internal and External Zones with different geological evolutions.

Three zones or subdomains (Nevado-Filábride, Alpujárride and Maláguide complex) constitute the Internal Zones. Palaeozoic and Triassic metamorphic rocks are the main constituent of the first two ones while Palaeozoic and Mesozoic sedimentary rocks are mainly found in the Maláguide complex. All these complexes are overthrusting the External Zones.

The External Zones are subdivided into two subdomains: Prebetic (to the North-East) and Subbetic (to the South-West). They are composed by Mesozoic and Tertiary sedimentary rocks.

Between the Internal and External Zones three domains are interposed: the Flysch Units, interpreted as sediments of a deep through; the Predorsal chain, wich partially represents the base of the Flysch or, according to some other authors, deep talus deposits; and the Dorsal chain, wich represents in part the transition to the Maláguide Unit. All these domains are formed by Mesozoic and Tertiary sediments also.

The Internal Zones derive from areas originally placed eastward of the present position. During their translation these zones ejected the domains of the Flysch, the Predorsal and the Dorsal, coming into lateral collision with the External Zones (Boccaletti 1987).

From the end of the Middle Miocene the Internal-External Zones contact was progresively sutured. It is in this period that the main actual fractures began.

After the orogenic pulse that placed the Internal Zones over the External ones there were distensive periods. The main consequence of them was the formation of intramountain basins (i.e., Neogene basins of Baza, Guadix, Granada and Ronda) filled by sediments of an age ranging from Middle Miocene (Serravallian-Burdigalian or Tortonian according to the area) to Quaternary.

Figure 1 show a schematic geological map of the area where the 1884 earthquake was felt.

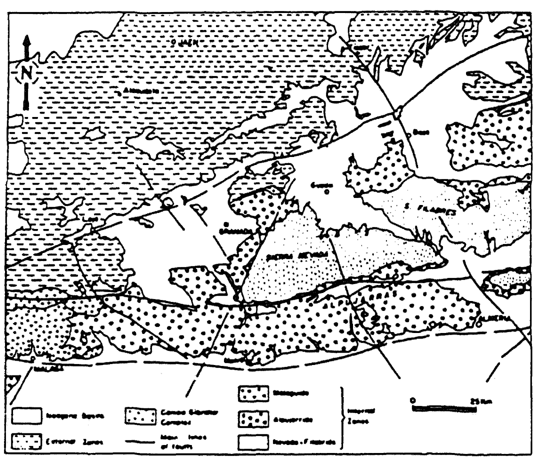

Figure 1: Schematic geological map of the Central sector of the Betic Belt (after Carreño et al. 1991).

Notice the three sets of faults in the Betic-Rifain area with direction N60 to E-W, NE-SW and SE-NW respectively (Sanz de Galdeano 1983).

The N60-90E set is approximately parallel to the Internal-External Zones contact. At the coast of Málaga and Granada and the Alpujarran Corridor these faults deviate slightly to an E-W direction. These faults present dextral strike-slip movements as well as other normal movements.

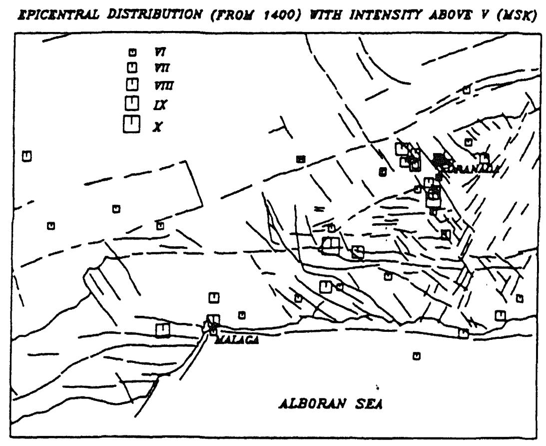

Figure 2: Spatial distribution of epicentres (I_0 > VI) versus main faults of the area.

Numerous faults are found along the NW-SE direction. The most prominent are those on the eastern edge of the Granada Basin. These faults moved as dextral strike-slip faults. They present important vertical movements also. Some of them seem to have moved as sinistral strike-slip faults during the Middle Miocene.

On the other hand the NE-SW faults trend is very well represented in the SE of Spain (Alicante, Murcia and Almería provinces), controlling the coastline of the area. They are sinistral strike-slip faults although they show significant vertical movements.

When the distribution of the faults is compared with the distribution of epicentres (I_0 > VI) one may observe a good correlation between both of them (see figure 2). The NW-SE faults in the Granada and Almería Sectors and the NE-SW in the Lorca-Murcia-Elche sector are well marked. It is also interesting to point out that there are maximums of earthquake concentration in the intersections of the fault sets (Sanz de Galdeano and López Casado 1988).

According to microseismic data (Carreño et al. 1991) the most actives fractures correspond to the NW-SE and the NE-SW sets although the 1884 earthquake has been also attributed to the Alpujarran Corridor fault system (E-W direction, Udías and Muñoz, 1980, Sanz de Galdeano, 1985) . This last fault system was responsible of the Sierra Tejeda and Sierra Almijara reliefs and allowed a continuous subsidence of the area (south boundary of the Granada Basin) during the Quaternary.

Also, from this microseismicity survey and from former existing analysis of focal depths, seismic activity into and around the epicentral area of 1884 earthquake seems to be only superficial.

3 ISOSEISMAL MAP

We have collected existing historical macroseismic data and studied old (Orueta 1885; Fernández Castro 1885; Macpherson 1885; Paso y Delgado 1885; Repullés y Vargas 1885) and recent (López Arroyo et al. 1980; García Maldonado 1985; Gómez Ruiz 1990) research works on the 1884 earthquake.

From the analysis of other isoseismal maps (Orueta, French Commission, Italian Commission, Spanish Commission, Steikhardt, Muñoz and Udías) we have obtained almost fifty new intensity data points and changed the as

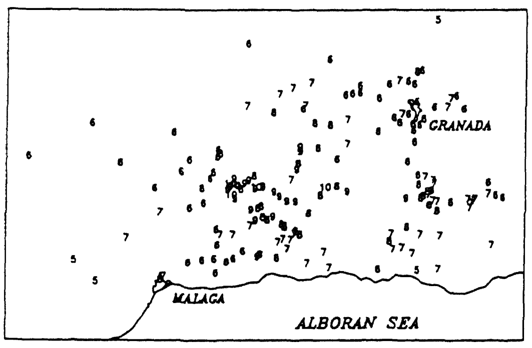

Figure 3: Asigned intensity values of Andalucía Earthquake 12/24/1884.

signed intensity of another twenty. Damages on buildings of A and B MKS types and ground geotechnical effects reported, were taken into account to perform this revision.

We show our results in two ways: figure 3 is a map of single intensity points. Figure 4 is a typical isoseismal map paying attention to local site effects.

Figure 4 and the tectonic map shown on figure 1 give us as the most likely location for the epicentre the junction of the two system SE-NW and E-W faults. The elongation of main iso seismal areas (IX, VIII and VII degrees) towards the E-W direction could

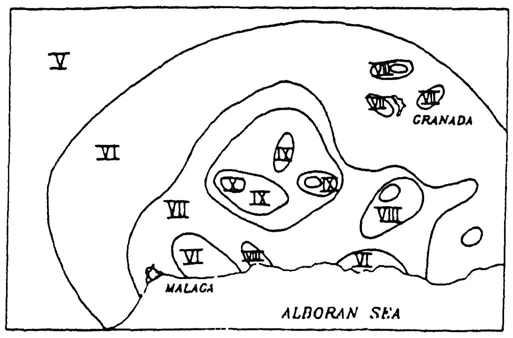

Figure 4: Isoseismal map of Andalucía Earthquake.

be due to amplification effects, not to source or directivity.

To study these amplification effects we have performed a nonlineal regression analisys between intensity and distance for three different kind of ground (Palaeozoic and Mesozoic, Tertiary and Quaternary sedimentary rocks). We have also calculated a general attenuation law using all points, independently of ground nature. The results are shown in figure 5. As it can be seen each fitted curve seems to be much alike each other but the data scattering is a clear proof of amplification effects.

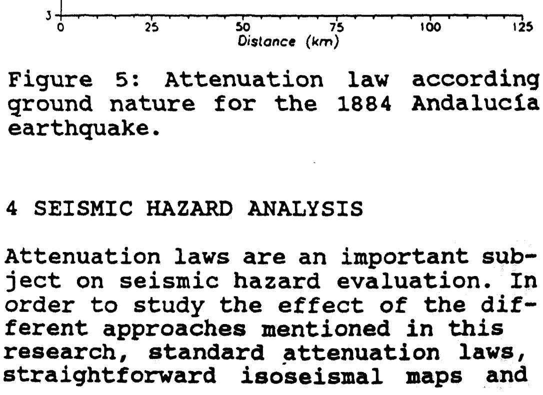

Figure 5: Attenuation law according ground nature for the 1884 Andalucía earthquake.

4 SEISMIC HAZARD ANALYSIS

Attenuation laws are an important subject on seismic hazard evaluation. In order to study the effect of the different approaches mentioned in this research, standard attenuation laws, straightforward isoseismal maps and real macroseismal intensity data, were used to evaluate a 500 years expected intensity map for the Granada province. For figure 6 we used the standard attenuation law given by Martín Martín (1984) comparing them with our set of single new and revised points. Figure 7 compares our results with Muñoz and Udías isoseismal map (1978).

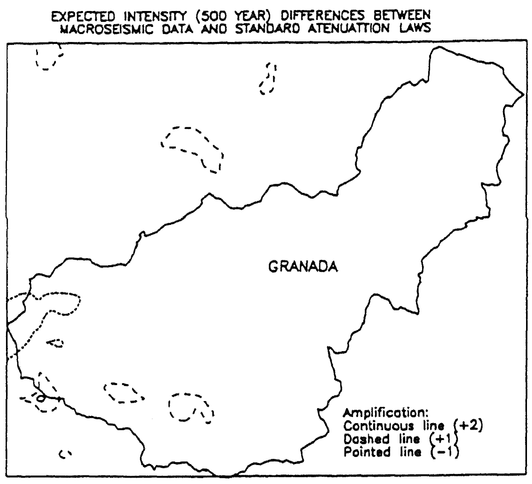

Figure 6: Differences between our revised and new set of single points and Martín Martín (1984) attenuation law results for expected intensities during the next 500 years.

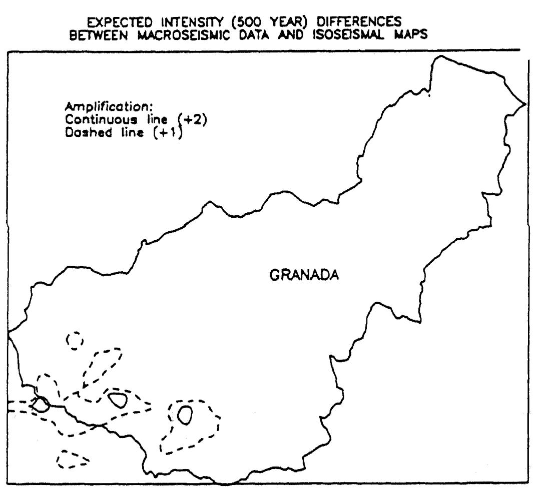

Figure 7: Differences between our revised and new set of single points and Muñoz and Udías (1984) isoseismal map for expected intensities during the next 500 years.

To remark the differences found in the last two maps we can look to two locations such as Albuñuelas and Güevéjar villages, most damaged with the the Andalusian earthquake. Figure 8 predict significant differences for Güevéjar village from the VII MSK intensity degree.

Figure 9 for Albuñuelas village show that with our method there could significant differences with other predictions as from VI MSK intensity degree. It is felt that a reason for this can come from adscribing a higher value for the intensity in our attenuation methodology than formerly thought.

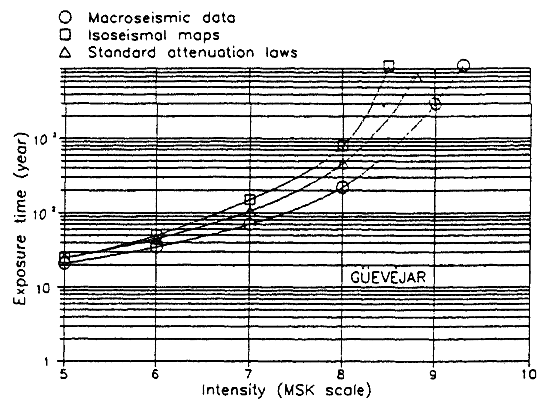

Figure 8: Expected 500 years intensity probability at Güevéjar.

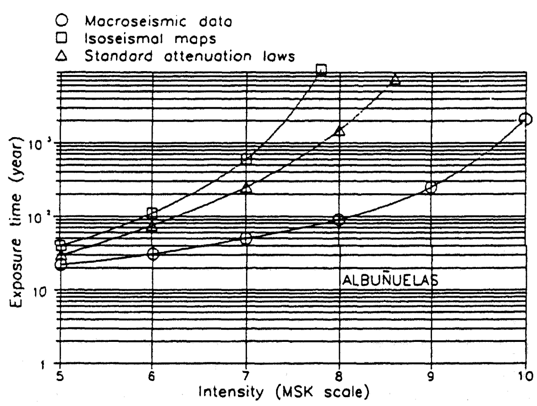

Figure 9: Expected 500 years intensity probability at Albuñuelas.

5 CONCLUSIONS

Fifty new intensity values for different geographical locations have been obtained through a new analysis of the 25 december 1884 earthquake. The analysis concentrated mainly in the ground effects and the reported damages to buildings paying special attention to indirect evidences such as landslides, rockfalls, ground failures, etc.

The new data allow us to redesign a new isoseismal map showing amplification effects which modify some of the results reported earlier by other authors.

Thus the new values of intensity provide new values of attenuation when forecastings on seismic hazards for the Granada region are made showing clear differences with other evaluations obtained using either standard attenuation laws or intensity data introduction as carried out by Muñoz and Udías (1980) isoseismal map. Differences of up to two MSK degrees inintensity are found for maps predicting seismic risks for the next 500 years.

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