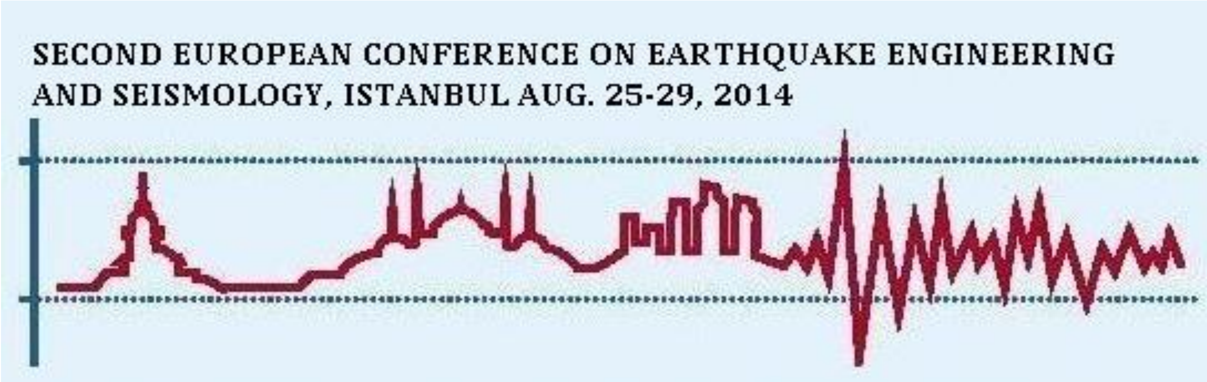

ASSIGNING MACROSEISMIC INTENSITIES OF HISTORICAL EARTHQUAKES FROM LATE 19TH CENTURY IN SW PELOPONNESE (GREECE)

Nikos SAKELLARIOU[1] and Vassiliki KOUSKOUNA[2]

ABSTRACT

The seismic activity of Greece has always been present in the country's history. Numerous earthquakes have occurred in the area of SW Peloponnese, which includes the seismically active faults of Kalamata, Pamisos and Messinian gulf, as well as the subduction zone of the Hellenic arc. In the present paper macroseismic information was collected from contemporary and recent earthquake studies and the local press for three significant earthquakes of this area, i.e. Messini (1885), Filiatra (1886) and Kyparissia (1899). These earthquakes are presented in detail, as far as the flow of information, damage reports, seismological compilations and intensity assignment and distribution are concerned, from which macroseismic parameters (i.e. epicentre, magnitude) were assessed. The macroseismic datapoints of the studied earthquakes were introduced to a database, containing the event dates (OS/NS), source of information and date, the digitized original texts containing all sorts of macroseismic information and, finally, the assigned intensities expressed in EMS98, which may also act as input to the Hellenic Macroseismic Database (http://macroseismology.geol.uoa.gr/).

INTRODUCTION

Throughout the ages earthquakes have been the most destructive of all natural hazards, having been associated with crises due to their effects in several aspects of human life. In historical times the damage and sudden crippling of the economy of an area led to population movements, emigration or desertification of villages, even small towns.

Since we are not able to foresee what will happen in the future, we have to find out what happened in the past and extrapolate to modern times. Previous research has uncovered evidence of destructive earthquakes in areas where only small earthquakes have been experienced within the last century or so. If we consider only information from the 20th century, during which earthquakes have been recorded by instruments, we would have no way of knowing whether an apparently seismically quiet area today is in fact at risk from a damaging earthquake in the future. Mallet tried to present the seismicity all over the world, before 1851, constructing a map where all the major fault systems could be seen. This map contained also the area of interest in this study (Mallet 1855). Furthermore, many others reported events from the study area, such as (in alphabetical order): Agamenone & Issel (1894), Ambraseys (1962, 2009), Ambraseys and Jackson (1990), Barrata (1901), Barbiani (1864), Cavasino A. (1931), De Giorgi (1898), Eginitis (1899b) (1901), Galanopoulos (1940, 1941, 1953, 1960, 1961), Karnik (1971), Mallet (1855), Mitsopoulos (1899, 1900), Michailovic (1951), Milne (1912),

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Montandon (1953), Morelli (1942), Papazachos and Papazachou (1989, 1997, 2003), Perrey (1848, 1870), Phillipson (1889), Shebalin (1974), Sieberg (1932a, 1932b) and Schmidt (1867, 1879), Vogt (1999), Von Hoff (1840,1841), etc. More specific, Julius Schmidt (1879) listed earthquakes in chronological order, while Mallet (1855), Von Hoff (1840,1841), Barbiani (1864), Papazachos and Papazachou (1989, 1997, 2003), Galanopoulos (1960, 1961), Karnik (1971) and Shebalin (1974) compiled parametric catalogs, providing information about the epicentre, the depth and the magnitude of the earthquakes. On the other hand Sieberg's (1932) classical compilations inform on earthquakes, description and distribution of their effects. Lampros (1910), Maravelakis (1938) and Shreiner (1975) compiled seismological studies, in which information about significant earthquakes was reported. Of special interest are she studies of Ambraseys and Finkel (1992), which is the output of collaboration between seismologists and historians and Ambraseys and Jackson (1990).

REGIONAL GEOLOGY – SEISMOTECTONIC SETTING

The geology of the study area (Fig. 1) is characterised by sedimentary rocks of alpine orogenesis. The nappe sequence consists of the Tripolis and Pindos units. The Tripolis unit is composed of neritic carbonates and flysch, outcropping mostly at the eastern part of Messinia. The Pindos unit occupies mainly the eastern part of Messinia, forming a classic nappe, which has overthrusted Tripolis from east to west. The whole formation is folded and faulted, forming thrusts of Mesozoic and early Cenozoic age, cut by neotectonic normal faults. The neotectonic formation of the area consists of horsts and grabens. Specifically, SW Peloponnese is formed by the Taygetos Mt horst, the Kalamata graben, the Kyparissia graben, the Kyparissia Mt horst, the Vlachopoulo graben and the Pylia Mt horst.

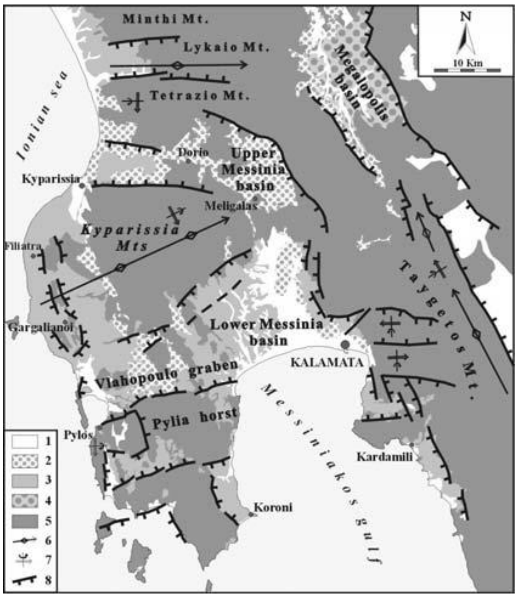

Figure 1. The Neotectonic macrostructure of SW Peloponnesus. 1: Holocene deposits, 2: Post-alpine continental deposits, 3: Post-alpine marine deposits, 4: Lacustine deposits, 5: Pre-neogene basement (Alpine units & Messinia conglomerates), 6: Macrofold axis, 7: Rotational axis, 8: Fault zones. (Ladas et al., 2004)

The recorded seismicity (Fig. 2) correlates well with several N-S oriented faults on and offshore. To the southwest, in the area of Pylos the onshore N-S oriented faults are very active. Events generated in this region indicate normal faulting (e.g Kalamata, 1986 event). Offshore seismicity is also significant mapping several active faults of N-S and NW-SE orientation, not all having been mapped. North of Kalamata, at the central part of the Meligalas basin, a NW-SE oriented fault is also very active. To the northeast, in the Megalopolis basin and its vicinity, the seismicity increases again. Two main fault systems of NW-SE and E-W orientation are relevant to the tectonic deformation of this region. To the west, in the Kyparissiakos Gulf, seismic activity is also high, coinciding with a major NW-SE oriented fault. Finally, the area is subject to seismicity due to the subduction taking place W and S of Messinia.

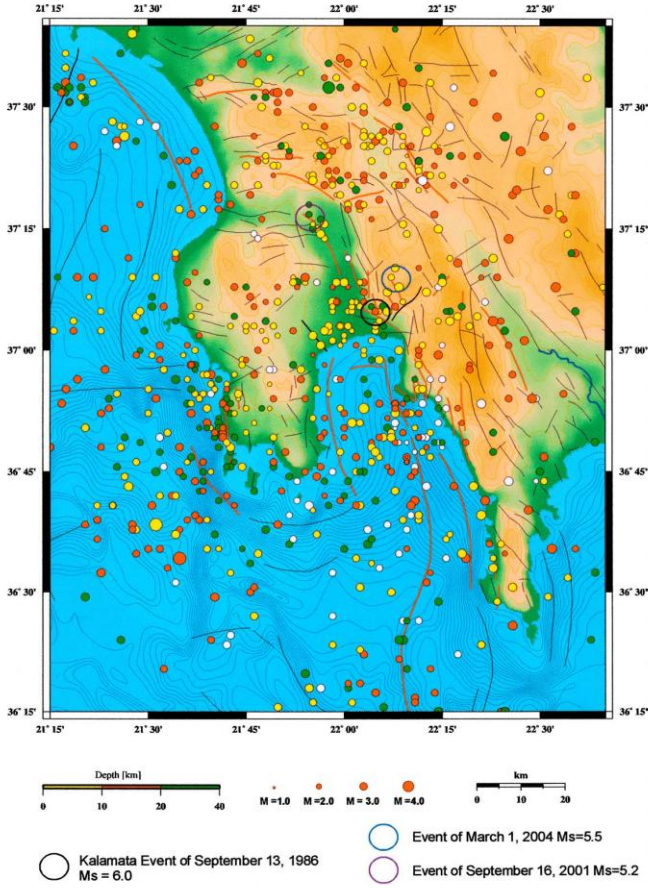

Figure 2. Seismicity distribution within the study area. Faults from the seismotectonic map of Greece published by IGME (1989) are shown. Active faults defined by the recorded seismicity are marked in red. The epicentres of the Kalamata 1986 event and those of September 2001 and March 2004 are plotted on the map (Papoulia and Makris 2004).

DATA COLLECTION AND PROCESS

The collection of Macroseismic data is the most important part of a Macroseismic study. There are two methods of collection.

The first is the direct merging of existing catalogs, without taking into account their primary data. In the second method, which is adopted in this study, the researcher traces the primary data set of each catalog and combines them with new ones, in order to create a general set of primary data. Then, the seismic parameters are determined and a new catalog is produced.

In the present study the first step of macroseismic investigation is the study of the parametric catalogs. The ones containing information on the area are: Galanopoulos (1960, 1961), Karnik (1971), Shebalin et al. (1973) and Papazachos and Papazachou (1989, 1997, 2003). Each earthquake in the catalogs has its own source or sources that justify the seismic event. The next step is the study of primary data and additional new sources, either historical or seismological.

For each of the three earthquakes a database with all the Macroseismic Intesnity Datapoints (MDPs) was compiled. This database contains information on the date (after convertion between Old Style (OS) and New Style (NS)), the locality, its coordinates, the digitized text, through which the intensity assessment was made, the total number of affected buildings and their vulnerability class, the damage degree, the total population and the number of human casualties. The final step is the intensity assessment, according to the European Macroseismic Scale (EMS-98). The earthquake parameters (epicentral coordinates, macroseismic magnitude) are then determined through the program MEEP v2.0 (Musson and Jimenez 2008). MEEP calculates the possible epicentres with four methods (centroid, MEEP, Bakun and Pairwise comparison). The macroseismic magnitude is determined through a general formula which takes into account the intensity (I) and the epicentral distance (R)

(1)

where a, b, c and d depend on the broader area of the earthquake. For Greece and for shallow events these constants are: a=0.62, b=2.035, c=0.002 and d=-0.96, respectively (Papazachos and Papazachou 2003).

EARTHQUAKE CASE STUDIES

1885 March 28, Messini

This earthquake caused local damage, mainly in the region of Kalamata, while it was felt as far as Athens, Mesolongi and Zakynthos. According to Galanopoulos (1953), severe damage was concentrated at four localities with maximum intensity I=9 (RF). 193 houses were destroyed or suffered severe damage. Galanopoulos (1940), presents a map with the suggested epicentre and the tectonic regime of the region (Fig. 3).

The available source of information on the earthquake effects is Galanopoulos (1953). The procedure described in the previous section led to 40 MDPs (identified localities, their coordinates and corresponding intensity). Maximum intensity Imax=9 was assessed for the localities Loi and Ano Karye. From the intensity distribution the isoseismal map was drawn, using the Krigging method (Fig. 3). In the same map, the four solutions for the earthquake epicenter are presented. In this study, the solution from the centroid method is adopted (black star), which is in agreement with the epicentre given by Galanopoulos (1940), probably associated to the N-S striking fault, which produced the 1986 Kalamata earthquake (Mw=6). The solutions for epicentre and magnitude are given in Tables.1 and 2, respectively.

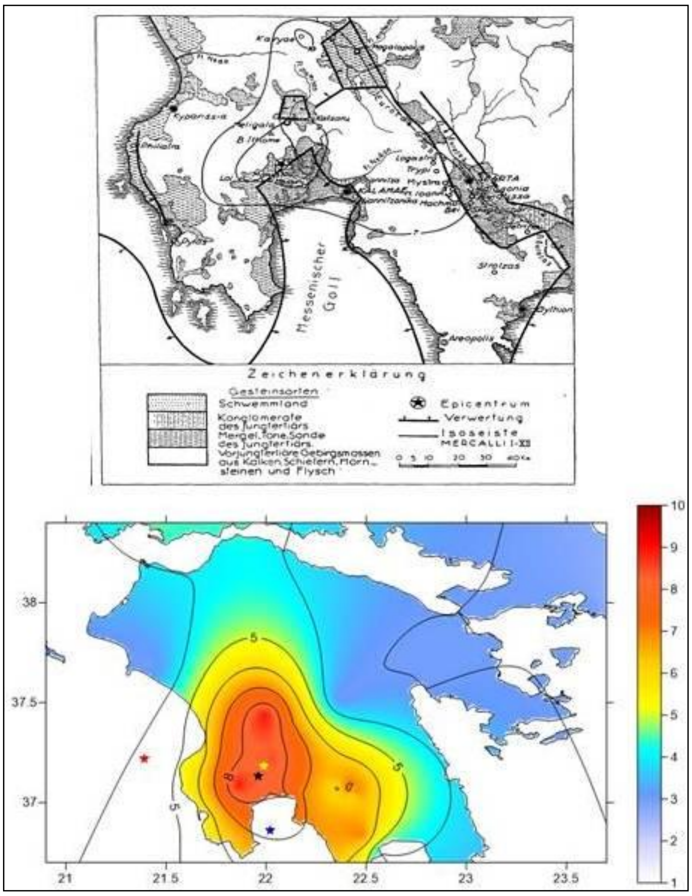

Figure 3. Map of the epicentre and the tectonic regime of the 1885 earthquake (Galanopoulos 1940) (top). Map of the isoseismals and the epicentres determined in this study (bottom).

1886 August 27, Filiatra

This large earthquake caused severe damage in a wide area of western Peloponnese. According to Galanopoulos (1953) many places were strongly affected, while the maximum intensity (10-11 in the RF scale) was observed mainly in the west coast of western Peloponnese. A total of 6000 houses were partly or totally destroyed. 334 people were killed, while 796 were injured (Fig. 4). It was felt as far as Chios and Smyrna to the east, Alexandria to the south, Northern Italy to the west and Albania to the north. The submarine cables, 30 miles away from Filiatra, were broken and a sea flood covered the coast at Agrilia (Ambraseys 2009).

Sieberg (1932) and Galanopoulos (1941a) draw the isoseismals of this earthquake, showing the intensity distribution all over the eastern and south-eastern Mediterranean (Fig. 5). Following the procedure for the 1885 earthquake, the present earthquake study used Galanopoulos (1941a, 1953), Ambraseys (2009), Ambraseys et al. (1994), Barrata (1901), De Giorgi 1898 and Mihailovic (1951). 344 MDPs were identified and the corresponding isoseismal map was drawn (Fig. 6). The adopted epicentre is offshore to the west, probably associated with the subduction zone and justifying the generation of a sea wave which struck the western coast of Peloponnese and flooded the beach at Agrilia (Ambraseys 2009). The solutions for epicentre and magnitude are given in Tables.1 and 2, respectively.

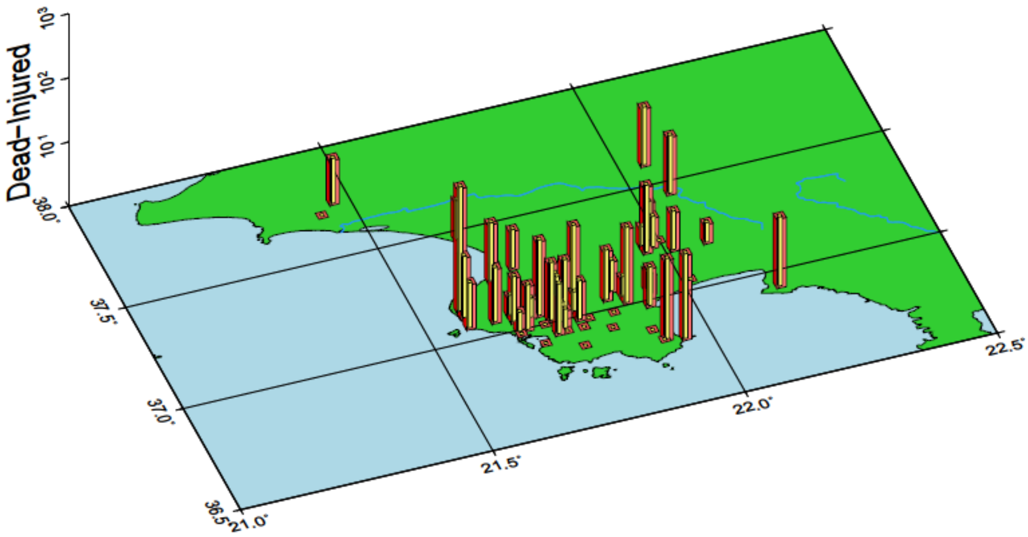

Figure 4. Distribution of numbers of dead (red bars) and injured (yellow bars) people, for 1886 earthquake

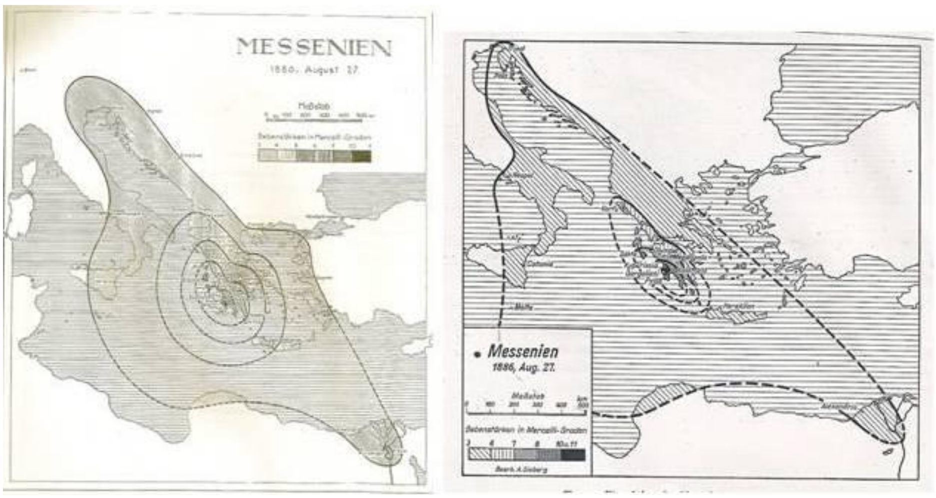

Figure 5. Intensity distribution and isoseismals for the 1886 earthquake (Sieberg 1932 and Galanopoulos 1941a).

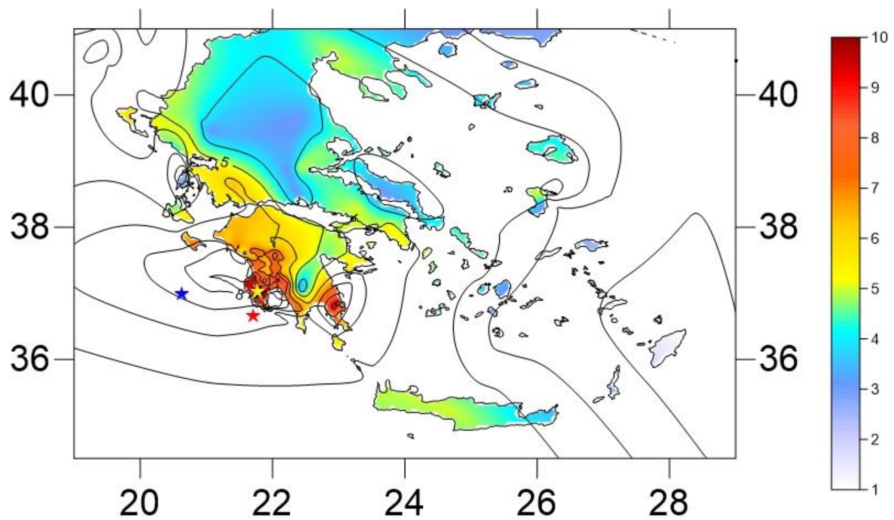

Figure 6. Intensity distribution and isoseismals for the 1886 earthquake, determined in this study.

1899 January 22, Kyparissia

This earthquake occurred in Messinia, SW Peloponnese and caused damage at several places. According to Galanopoulos (1941b), the most serious ones were observed in the village Khalazoni, where maximum intensity reached 9 (RF). The area had also suffered serious damage from the previous earthquakes of 1885 and 1886. In total 245 houses were destroyed and 275 became ruins. A sea wave (tsunami) was observed in Marathopolis and in Zante, where its height reached 0.40m. Minor damages were also observed in other places outside the meizoseismal area. The earthquake was felt all over Peloponnese and as far as Albania (Argyrokastro) and Sicily (Mineo and Catania).

Isoseismals for this earthquake are drawn by Galanopoulos (1941b). In the present study, 109 MDPs were identified and their intensity distribution is shown in Fig. 7. In the same map the epicenral solutions (Tables.1 and 2) are also presented adopting the solution for an offshore epicentre (red star), which justifies the sea wave observed in Marathopolis and Zante.

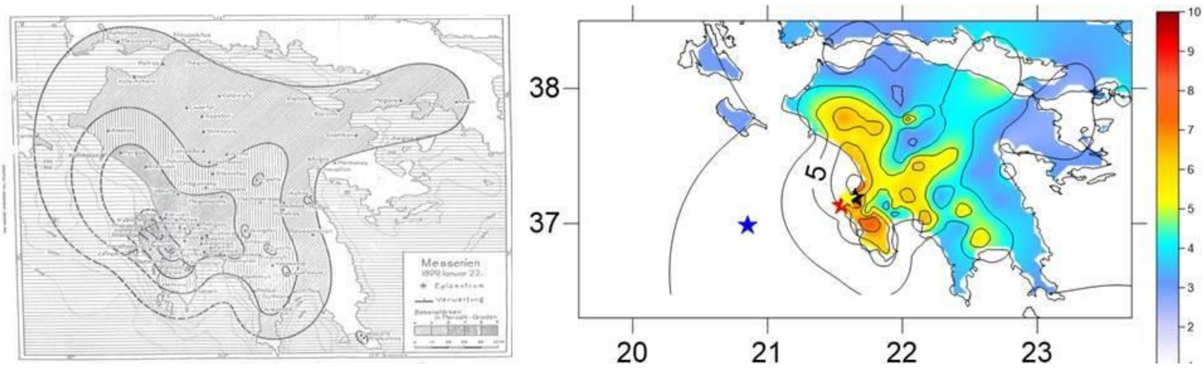

Figure 7. Map of intensity distribution and isoseismals for the earthquake of 1899.

CONCLUSIONS

Three strong earthquakes occurred in the vicinity of SW Peloponnese in a period time from 1885 to 1899. All three caused severe damage to many buildings and infrastructure and a lot of people lost their lives and many others were injured. Many villages were demolished, especially from the 1886 Filiatra earthquake. Some of the sources concerning the events of 1886 and 1899 report also the presence of sea wave (tsunami). In this study, we tried, through the investigation of various sources, to estimate the intensity of the affected places, present their distribution through isoseismal maps and, finally, to calculate the macroseismic epicentre coordinates and earthquake magnitude.

After the collection of all the available information, a database for each event was created. This database contained information on the date, locality, coordinates of each Intensity Datapoint, the digitized text, through which the assessment of intensity was performed, the total number of houses, the damage degree, the total population of the site and the number of casualties. Taking into account all the above information the estimation of intensity was made (EMS-98) and the determination of the macroseismic magnitude and the epicentre coordinates. In the following Tables 1 and 2, the macroseismic parameters of each earthquake are presented and compared to those of Papazachos and Papazachou 2003.

Table 1. Coordinates of the epicentres determined for each earthquake of this study

Earthquake	Papazachos & Papazachou 2003	This study
18850328	37.100 22.000	37.22 22.03
18860827	37.000 21.400	36.65 21.70
18990122	37.200 21.600	37.13 21.55

Table 2. Macroseismic magnitude determined for each earthquake of this study

Earthquake	Papazachos & Papazachou 2003	This study
18850328	6.0	5.7
18860827	7.3	7.3
18990122	6.5	6.5

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