Present seismic activity of Sparta fault (Peloponnesus, southern Greece) and its implications

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Introduction

Sparta fault is an imposing landform, located along the eastern front of Taygetos mountain, southern Greece. Taygetos has a prominent relief ranging between 300 and 2400 m. Its eastern front represents one of the most impressive normal fault systems in Greece. It has a length of 60 km, trending NNW–SSE and dipping to the east. It consists of several segments, the southern one being the Sparta fault, a normal pure dip-slip fault (Fig. 1) with a direction of N30°W, a length of more than 22 km and a dip of 40° towards the east. Sparta fault is composed of two successive segments having a step like geometry, with surface lengths of 14.5 and 7.5 km, north and south, respectively. This morphotectonically significant area has been studied in detail by several researchers (Dufaure, 1975; Armijo et al., 1991; Maroukian et al., 1999). They suggested that this fault should be active at least since the early Quaternary.

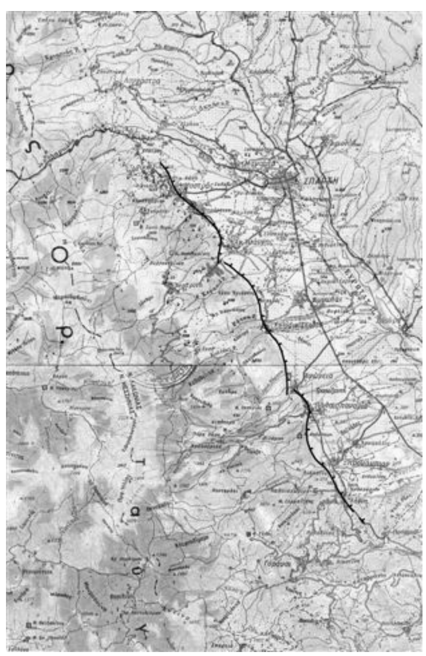

Figure 1. Topographic map of the area of Sparta fault, shown with a black line

The existence of important ancient settlements and other archaeological sites in this area (Ancient Sparta, Byzantine Mystras) provides information on the seismological history of the area. During the 6th and 5th centuries B.C., a series of disastrous earthquakes are reported (550, 496, 464 and 412 BC) (Papazachos and Papazachou, 2002). Among them, that of 464 BC was the most destructive and devastated the ancient city of Sparta, killing more than 20,000 people and causing great social upheaval, as many historians testify (Thucidides, Pausanias, Ephoras, Diodoros of Sicily, Cicero, Strabo, Pliny the Elder, Ploutarch and Aristophanes). After a detailed morphotectonic study of the eastern Taygetos front Armijo et al. (1991) attributed this earthquake to a reactivation of the Sparta fault.

In the last decade several independent works have been presented for the area of the Sparta fault studying several subjects, like indentifying periods of extensive sediment supply corresponding to phases that increased the size of the alluvial fans (Pope and Millington, 2000, 2002; Pope et al., 2003), assessing the earthquake slip history on different locations along the Sparta fault by determining ^{36}Cl exposure ages as a function of height on the scarp (Benedetti et al., 2002), performing palaeoseismological trenching and dating destruction layers in archaeological excavations in the city of Sparta (Papanastassiou et al., 2002).

The compilation of these works permitted to draw conclusions on the seismic history of the fault as well as its segments and to estimate the magnitude of the individual palaeoearthquakes (Papanastassiou et al., 2005). They confirm the existence not only of the 464 BC earthquake but also of several more that occurred at ca. 3900 BC, 2500 BC and 2000 BC, 550 AD and 1000 AD. The events that occurred in 2500 and 464 BC should correspond to major events of magnitude of the order of 7, which ruptured the entire length of the fault, while those of 3900 BC, 2000 BC, 550 AD and 1000 AD, to smaller events of magnitude 6–6.5. The first three events seem that they have ruptured the northern segment of the fault while the fourth one the southern segment. The return period of strong earthquakes along the Sparta fault is estimated to be around 2000 years, but within these periods events of smaller magnitude that ruptured segments of the fault have also occurred that makes this return period not fixed.

On the other hand, following our recent seismological knowledge, this region is characterized by low seismicity. In this work we evaluate the current seismicity recorded by the Seismological Network of the Institute of Geodymanics as well as those by local networks, in order to examine, by using different seismicity patters, whether this low seismicity is a precursor of a coming major earthquake.

The Method

The existing instrumental earthquake catalogues (Papanastassiou et al., 2001; monthly Bulletins of the Institute of Geodynamics of Athens), depict that the seismicity of the area is low and compared to other places of Peloponnesus, is quite negligible. Figure 2 illustrates very clearly the lack of seismicity in the area of Sparta while in the neighboring areas there are many earthquakes.

It is also impressing that during two independent seismological experiments that operated local networks in the area, a quite small number of microearthquakes were also recorded. In more detail, figure 3a shows the spatial distribution of the microearthquakes recorded by a local network of 6 analogue stations complemented with 2 digital, 3-component, permanent stations of the Institute of Geodynamics which operated from August through October, 1996. (Papanastassiou 1999), while in figure 3b the distribution of the recorded events from the local network of 5 digital, 3 component stations accompanied by 5 digital permanent stations of the Institute of Geodynamics that worked from July till the end of October 2007, is exposed (Karastathis, 2007).

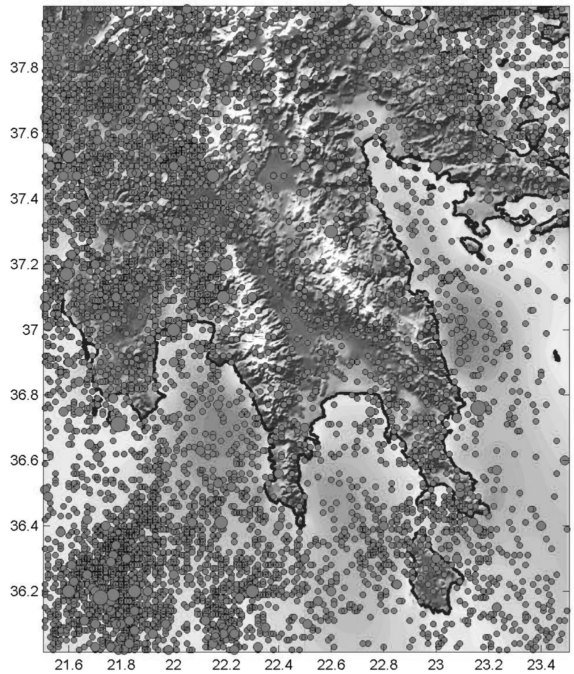

Figure 2. The seismicity of the broader area of the Sparta fault during the period 1900-2007.

Trying to distinguish whether the recorded earthquakes in the vicinity of Sparta fault by the seismological network of the Institute of Geodynamics is a precursor of a coming strong event, we applied some techniques to this group of earthquakes, which contains less than two hundred earthquakes (Figure 2).

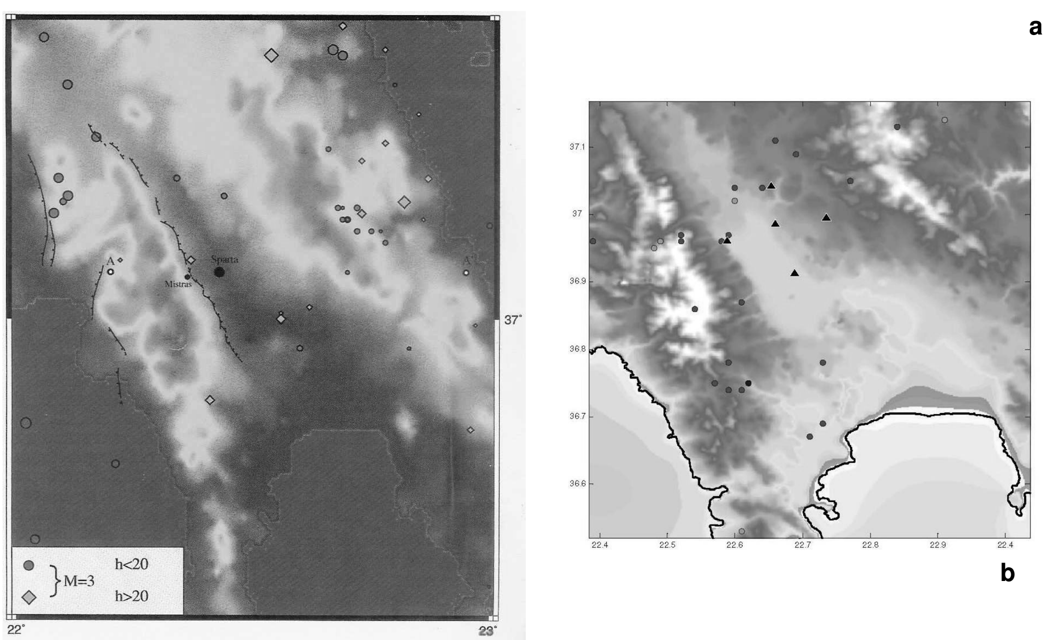

Figure 3. The spatial distribution of the microearthquakes recorded a) during 1999 (Papanast-tassiou 1999) and b) during 2007 (Karastathis et al., 2007)

Figure 4 is a spatial-time plot of the recorded earthquakes located near to the fault, in a N-S and E-W direction. This plot could provide evidence of a change in the rate of the recorded seismicity. It is obvious that, since 1985 there is a change in the seismicity, with an increase in the number of events. However this change is owed to the upgrading of the seismological network and is not a result of the modification of the seismicity state. From this plot it is also deduced that the recorded earthquakes are occurring along the whole length and width of the fault, without showing a preferable concentration at a specific part of it.

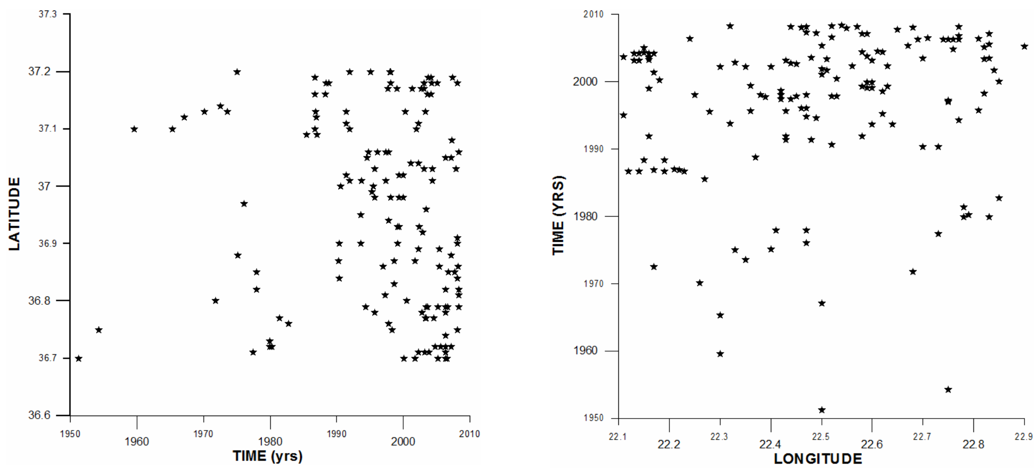

Figure 4. Spatial – time distribution of the earthquakes recorded at the vicinity of Sparta fault.

The b value was next calculated (Fig. 5) in order to examine whether or not there is a temporary change in the seismicity. It is known that this parameter is related with the stresses and the mechanical properties of the seismogenic layer, which are related to the tectonic history of the area. It was found to have the value of 1.4, a value which is quite frequent in areas of active tectonism. However the small number of the earthquakes comprising the examined group did not permit the examination of any change of this parameter with time.

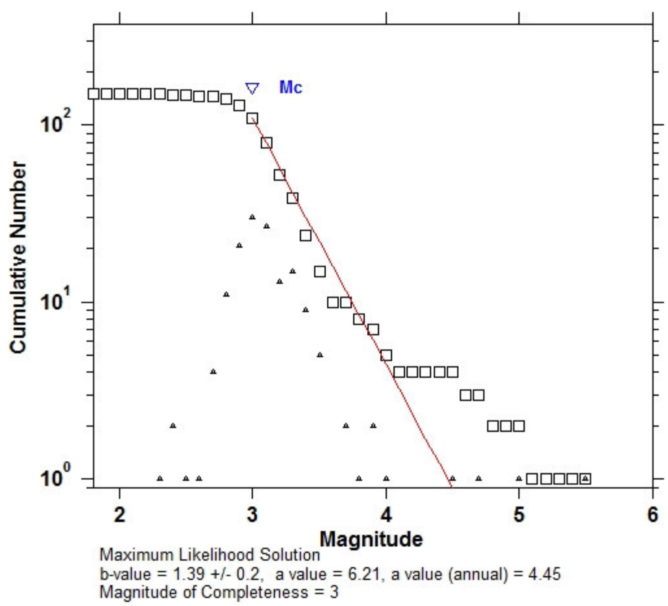

Figure 5. Plot of cumulative frequency of earthquakes versus magnitude.

Three kinds of sequence patterns, namely, successive, periodical, and random, can be found in most earthquake catalogues, and may reflect the relationship between the tectonic stresses and stress releases during earthquakes. In view of earthquake prediction, Matsumura (1984) developed a method for describing seismicity patterns in the space and time domain, and proposed a parameter, the 'v-value', which is closely related to the apparent interaction between two successive earthquakes. This parameter is derived on the basis of the Weibull distribution and the values characterize the earthquake sequence as being periodical ($v > 0.7$), clustered ($v < 0.3$), or random ($v = 0.4$-0.6).

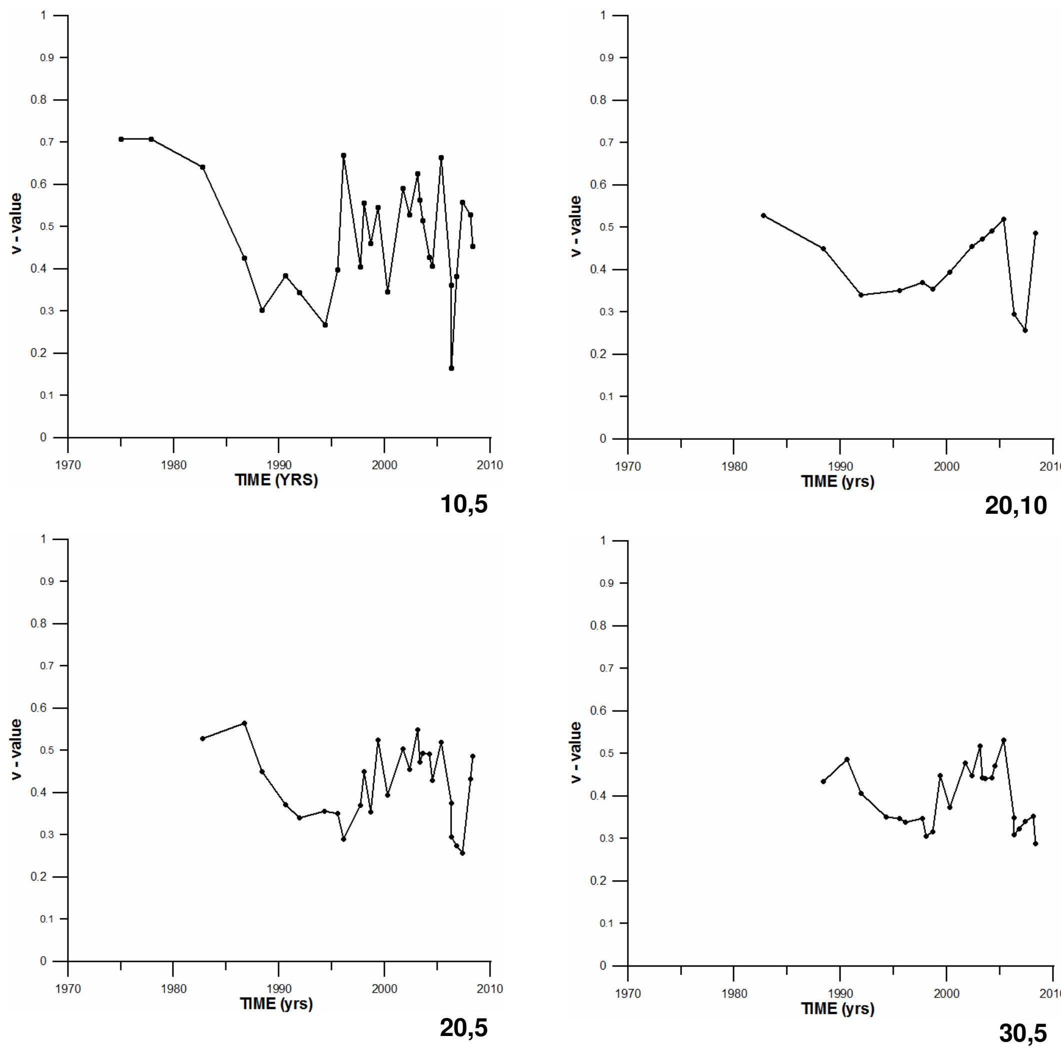

Figure 6. Plots showing changes of v-value. Numbers at the right lower corner of the plots indicate the group of successive shocks and the moving window that was used to calculate the v-values

v-value, is defined by $(\text{mean } T)^2 / \text{mean } (T^2)$, where T is the time interval between two adjacent earthquakes and indicates the pattern of time sequences of earthquakes and has been computed on the basis of a number of successive earthquakes comprising a certain group. This group is successively moved by a window of events until the end of the data set. The retrospective analysis of several earthquake sequences that happened in Greece, revealed that low v-values preceded the occurrence of relatively large earthquakes (Papanastassiou et al., 1989 a, b). This technique has been applied in our data set in an attempt to discover temporal changes in seismicity. The v-value from all the plots is between 0.6 and 0.3, which characterizes the recorded seismicity as being random.

Results and Discussion

In this study, all the available data, recorded earthquakes, b values and v-values were not enough to permit us to evaluate the current state of seismicity in the Sparta area and especially whether or not there is a sign of an eminent strong event.

It is evident that the seismicity is low. In the vicinity of the Sparta fault in the last 50 years there have been recorded less than two hundred events, a very small number comparing to neighbouring areas. This situation prevented us to examine variations in the b value. However the v-value method which was applied indicates that these events are randomly occurring without having any connection between them.

Kato et al., (1997), demonstrated that the regional stress relaxation tends to lower the seismic activity, leading to the appearance of precursory seismic quiescence.

Given that the preseismic deformation is not localized near the fault but is spread over a big area, in order to monitor the behaviour of the Sparta fault a dense permanent network of seismological stations is required distributed over a broader area of the fault accompanied with a network of GPS measurements. Possibly such networks will permit us to elucidate the seismic and dynamic conditions of this area.

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