

# The problem of seismic potential assessment: Case study of the unexpected earthquake of 7 September 1999 in Athens, Greece

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(Received April 10, 2000; Revised September 14, 2001; Accepted September 28, 2001)

Lessons learned from the disastrous earthquake ( $M_W = 5.9$ ) that hit the metropolitan area of Athens, Greece, on 7 September 1999, are examined particularly as for the seismic potential considered before the earthquake occurrence. A general belief was created in the past decades that the seismic potential in Athens was very low. Fault plane solutions of the 1999 shock indicate that it was associated with a normal fault trending WNW-ESE and dipping to SW. Field geological observations conducted after the event in the Fili neotectonic fault, situated at 15–20 km to the north of Athens, imply that it has possibly been the seismogenic structure of the main rupture, and that it reactivated in very recent geological times. Archaeoseismological observations performed in the ancient Fili Fort, revealed repaired structural damage that was very likely caused by an earthquake occurring in palaeochristianic or Byzantine times. From a new catalogue of historical earthquakes it results that the main events of 1705, 1805 and 1889 could be tentatively located within a distance of  $\sim 30$  km from Athens although the little macroseismic information available makes their locations quite uncertain. During the instrumental period of observation, only few small shocks were recorded in the Athens region. It is obvious that should a research effort had been undertaken before the 1999 earthquake, certainly it would be concluded that at least one strong earthquake took place in historical times in the broad region affected in 1999, and that the Fili fault is active and is capable to produce strong shocks in the future. However, such a study was never conducted by the scientific community beforehand.

## 1. Introduction

Earthquakes are major natural hazards in European regions like the Balkan Peninsula, Italy, parts of Russia, etc. Many cases of extensive loss of human life and injury as well as tangible and intangible social and economic losses have been reported (e.g. Shebalin *et al.*, 1974; Ganse and Nelson, 1979; Tiedemann, 1991). Dramatic conditions were created by catastrophic earthquakes in capital cities, like Bucharest in 1977, and Athens in 1981 and mainly in 1999. A comparison of earthquake economic losses with the gross national product (GNP) of the country shows that the 1977 Bucharest (Romania), 1980 Campania (Italy) and 1986 Kalamata (Greece) catastrophic earthquakes created material losses equal to 3.0%, 6.8% and 2.0% of the GNP of the respective countries (Coburn and Spence, 1992).

The reliable estimation of the seismic potential is a cornerstone for the seismic risk reduction in any earthquake-prone area. However, no single methodology has emerged for the seismic potential evaluation. In this paper several approaches developed worldwide are very briefly reviewed. Then, the earthquake ( $M_W = 5.9$ ) of 7 September 1999 that hit Athens, the capital city of Greece, is examined as a particular case of an unexpected disastrous event. This earthquake has been quite characteristic in that it occurred in a region traditionally considered as being of very low seismic potential.

Therefore, an effort was made to respond on three main questions: (1) Why the particular region of the 7 September 1999 earthquake was considered in the past as of very low seismic potential? (2) How new observations collected after the earthquake occurrence affect the seismic potential assessment? (3) What a research effort undertaken before the 1999 event would have revealed about the seismic potential?

## 2. Definitions of Seismic Potential: A Brief Review

The concept of seismic gap (Fedotov, 1965; Mogi, 1968; Kelleher *et al.*, 1973) has been among the very first ideas for the seismic potential assessment. Since that time the seismic gap hypothesis was further defended (e.g. McCann *et al.*, 1979; Nishenko and McCann, 1981; Nishenko, 1985, 1989, 1991; Nishenko and Sykes, 1993) or criticized (e.g. Kagan and Jackson, 1991). At the same time a variety of other approaches were also proposed including stochastic (e.g. Cornell, 1968; McGuire, 1978; Nishenko, 1989, 1991; see also Schenk, 1989 and McGuire, 1993 for reviews), deterministic (e.g. Iida, 1965; Slemmons, 1977; McCann *et al.*, 1979; Wyss, 1979) or both (e.g. Wesnousky *et al.*, 1984; Working Group on California Earthquake Probabilities, 1990). Wallace *et al.* (1984) suggested that the term earthquake potential can be expressed either numerically or verbally according to a variety of schemes. In fact, in seismogenic regions of the world a variety of methodological schemes have been tested including seismicity analysis,

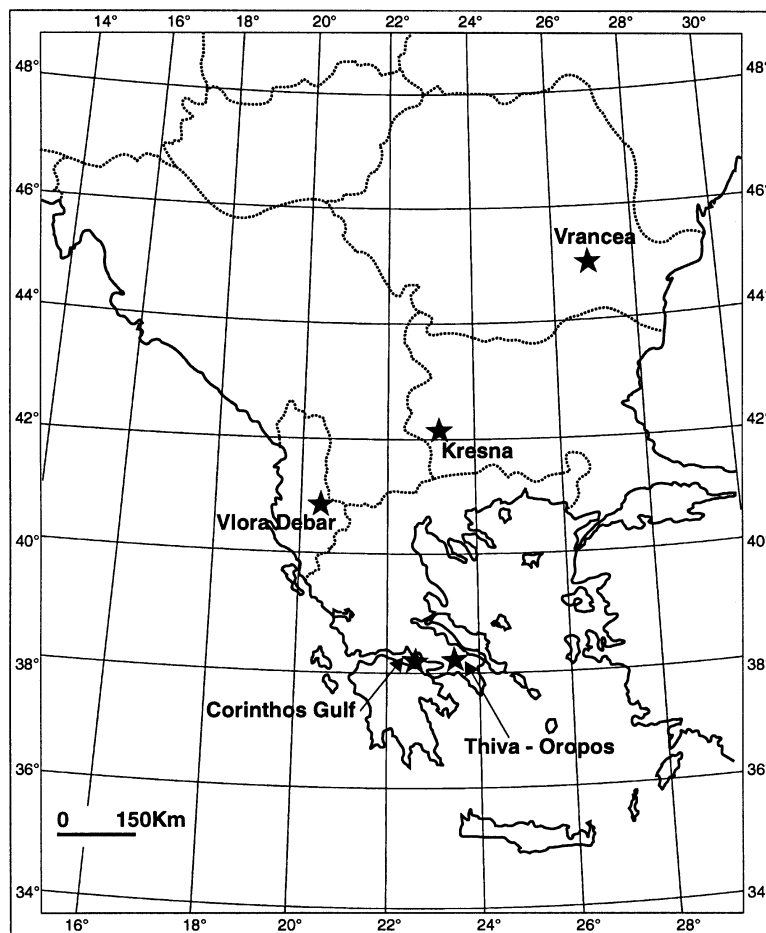


Fig. 1. The ASPELEA project test-sites of Thiva-Oropos and Corinthos Gulf (Greece), Vlorë-Debar (Albania), Kresna (Bulgaria) and Vrancea (Romania). The catastrophic earthquake of 7 September 1999 took place in the geographical area of the Thiva-Oropos active seismic zone (see Figs. 2 and 3 for details).

Table 1. Strong ( $M_s \geq 6.0$ ) instrumental shocks in the Thiva-Oropos seismic zone and adjacent regions. Parameters of the 1999 earthquake are included in Table 3. AJ97: Ambraseys and Jackson (1997), CP: Comninakis and Papazachos (1986).

Year	Month	Day	Hour	Min	Sec	Lat	Long	$h$ (km)	$M_s$	Ref
1914	10	17	6	22	32	38.3	23.4	$n$	6.0	CP
1928	04	22	20	13	46	37.9	23.0	$n$	6.3	CP
1938	07	20	00	23	35	38.3	23.8	$n$	6.0	CP
1981	02	24	20	53	37	38.1	22.8	12	6.7	AJ97
1981	02	25	02	35	54	38.1	23.1	8	6.4	AJ97
1981	03	4	21	58	07	38.2	23.2	7	6.2	AJ97

seismotectonics and palaeoseismology, gravity and geodetic measurements. The term “seismic potential,” however, has been used in a non-standard way by several investigators and different definitions or approaches were introduced by different authors in regions of different seismotectonic environments.

### 3. The Athens $M_{5.9}$ Earthquake of 7 September 1999

#### 3.1 Background information

The most seismically active fault zone in the broad area of Athens is that of Thiva-Oropos trending about W-E to the north of the metropolitan area of Athens (Figs. 1 and 2). Neotectonic fault scarps clearly indicate normal faulting with fault planes dipping to the north (e.g. Mettos *et al.*, 1986, 1992). Three strong earthquake sequences occurred

Table 2. Historical seismicity in the Thiva-Oropos seismic zone and the adjacent regions for the 18th and 19th centuries.

ID	YY	MM	DD	hh	mm	ss	Acc	Lat	Long	I	M	h	Region	Rel	Ref1	Ref2
1	1705	09	03				0Y	(38.0)	(23.7)	7(+)		n	Athens	4	AJ97, PP97, PAP	AF93, A94, AF99
2	1708	05(-)					?	38.5	23.6	7	6.0	n	Chalkis	3	AJ97	
3	1727	02	21(-)				?	37.9	23.0			n	Corinthos	3	AJ97, AF99	
4	1729	10	11(-)				?	38.5	23.6			n	Chalkis	3	AJ97, AF99	
5	1775	04	16				0	37.9	22.9	7.0	6.0	n	Corinthos	4	AJ97	
6	1785	06	24				0	38.3	23.6	7(+)	6.0	n	Oropos-Chalkis	4	A94, PP97, PAP	AF99
7	1805	10	17	night			1M	(38.0)	(23.7)	6?		n	Athens	4	SM75, A94, PAP	SM67, S32, M, G55, G60, K, UN, PC, PP, A94, PP97, SP
8	1853	08	18	08	30		20	38.3	23.2	8	6.5	n	Thiva	4	SM75, AJ97	SM67, SM76, M, MON, G55, G60, K, UN, G81, PC, PP, A94, MG, PP97, SP
9	1858	02	21	09	02		10	37.9	22.9	9	6.5	n	Corinthos	4	KS, SM67, SM75, AJ97, PP97	SM76, MI, S32, M, MON, G55, G60, K, UN, G81, PC, PP, TG, MG
10	1864	07	17	00			1	38.5	23.5	6(+)		n	Evria	4	SM75, G60	S32, K, UN
11	1868	12	28	09	28		1	38.5	23.5	6		n	Chalkis	4	SM75, G60	S32, G55, K, UN, A94
12	1874	01	17	01	46		30	38.25	23.75	6(-)		n	Athens	4	SM79, G60	SM76, MON, G60, K, UN, PP, PP97, SP
13	1874	03	18	03	08		30	38.4	23.9	7	6.0	n	Eretria	4	SM79, AJ97	G53, MG
14	1882	02	10	10	12		0.5	37.9	22.9	7		n	Corinthos	4	K	MI, MON, G60, K, UN, G81, PP, MG, PP97, SP
15	1887	10	03	22	53		15	38.1	22.9	8-9	6.4	n	Xilocastro-Kiato	4	G53, AJ97	
16	1889	01	22	04	15		30	38.25	23.75	6		n	Athens	3	G53, G60	A94
17	1893	05	23	20	04	45	60	38.3	23.25	8-9	6.0	10	Thiva	4	EG, AJ90	MON, G60, K, UN, G81, PP, AJ97, PP97, AJ97, SP
18	1893	11	14	08	39		30	38.0	23.5	7		n	Salamis	4	Aa, G60	K, UN
19	1902	04	11	18	37		2	38.5	23.5	6		n	Chalkis	4	Ab, G60, CP	
20	1902	05	01	11	08		20	38.5	23.5	6		n	Chalkis	4	Ab, G60	

ID: Code number, YY: year, MM: month, DD: day, hh: hour, mm: min., ss: sec., Acc: accuracy of time, Lat: geographic latitude, Long: geographic longitude, I: maximum intensity, M: Richter magnitude equivalent to surface-wave magnitude, *h*: focal depth in km, *n*: shallow shock, Rel: reliability of the event, Ref1: previous publication considered, Ref2: further reading, (+) means equal to or larger than, (-) means equal to or less than, Acc and Rel are explained in the text. Aa: Anonymous a, Ab: Anonymous b, A94: Ambraseys (1994), AF93: Ambraseys and Finkel (1993), AF99: Ambraseys and Finkel (1999), AJ90: Ambraseys and Jackson (1990), AJ97: Ambraseys and Jackson (1997), CP: Comninakis and Papazachos (1986), EG: Eginitis (1899), G53: Galanopoulos (1953), G55: Galanopoulos (1960), G60: Galanopoulos (1960), G81: Galanopoulos (1981), K: Karrik (1971), KS: Koustas (1858), M: Mourikis (1934), MG: Mougariis (1994), MI: Miline (1912), MON: Montadon (1953), PAP: this paper, PC: Papazachos and Comninakis (1982), PP: Papazachos and Papazachou (1989), PP97: Papazachos and Papazachou (1997), S32: Sieberg (1932), SM67: Schmidt (1867), SM75: Schmidt (1875), SM76: Schmidt (1876), SM79: Schmidt (1879), SP: Spyropoulos (1997), UN: Shebalin *et al.* (1974), TG: Tigarakis (1987).

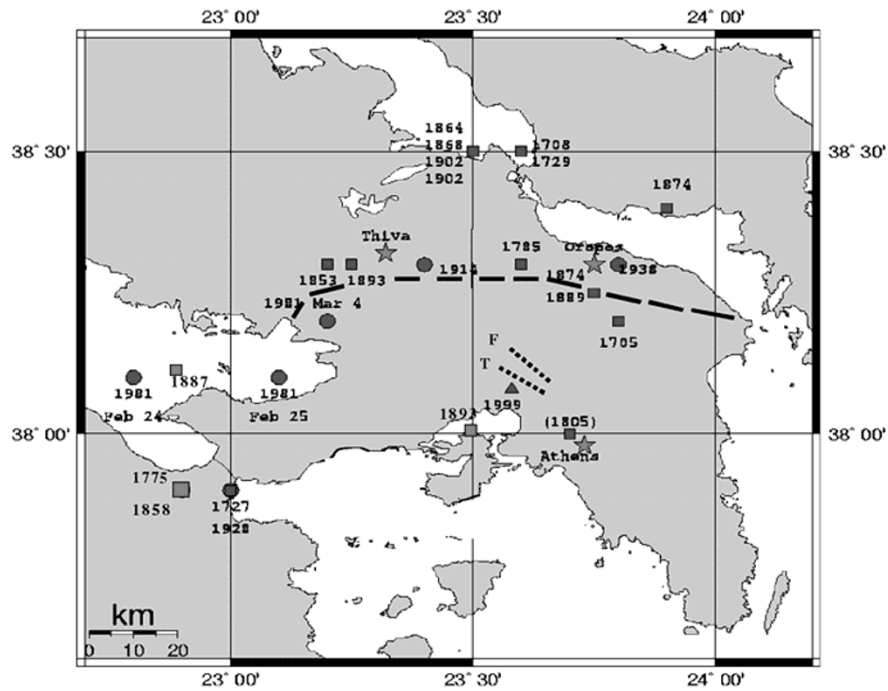


Fig. 2. The active tectonic zone of Thiva-Oropos (heavy line). Epicenters of strong shocks listed in Tables 1 and 2 are plotted. Circle: instrumental event (see Table 1), square: historical event (see Table 2), triangle: the 7 September 1999 shock (see Table 3). The 1805 event has been conventionally located at the historical centre of Athens for reasons explained in the text. F: Fili fault, T: Thriassion Pedion fault.

### Athens EQ Aftershocks 7-17/9

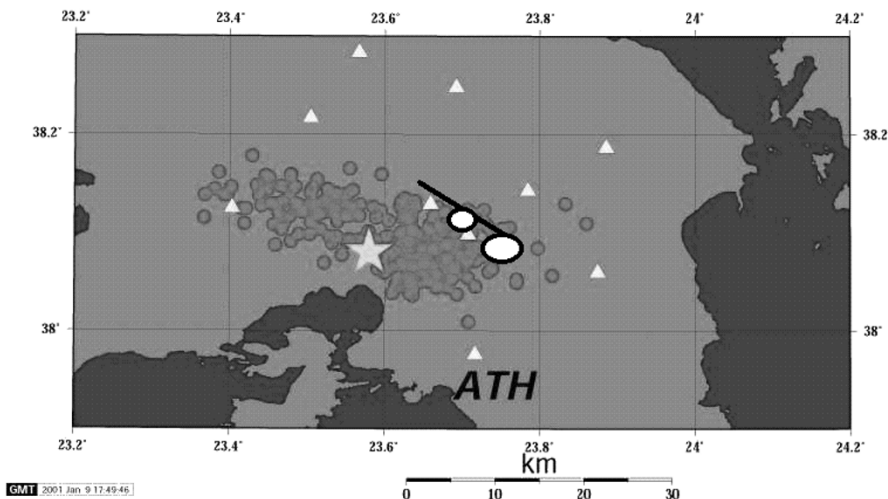


Fig. 3. Relocated epicentre of the 7 September 1999 main shock (star) and aftershocks (circles) for the period from 7 to 17 September 1999 (data from Papadopoulos *et al.*, 2000, 2001). Triangles: seismograph stations, straight line: Fili fault, ellipses: main damage zones of VIII-IX intensity degree. The Fili Fort is located very close to the NW part of the Fili fault.

in that area during the instrumental period of observation, namely in 1914, 1938 and 1981, while another set of six strong shocks were reported during the 18th and 19th centuries (Fig. 2; see for details and references in Tables 1 and 2). The event of 4 March 1981 ( $M_s = 6.2$ ) was one of the two very strong aftershocks of the large ( $M_s = 6.7$ ) main shock of 24 February 1981 (Table 1). The focal mechanism of the 4 March 1981 aftershock as determined by

Jackson *et al.* (1982), Papazachos *et al.* (1984) and Taymaz *et al.* (1991) is compatible with the geometry and kinematics of the neotectonic fault scarps in the Thiva-Oropos zone. Focal mechanisms of smaller magnitude earthquakes, however, are not available. Since the Thiva-Oropos seismic zone constitutes a great threat for the metropolitan area of Athens, it was selected as one of the test sites (Fig. 1) of the European project ASPELEA which stands as an acronym of

Table 3. Parameters of the earthquake of 7 September 1999 (last line) as well as of the small shocks that were recorded in 1965 and in 1997 within a distance  $D \leq 30$  km from the epicenter of that earthquake.  $\varphi_N^\circ$ : geographic latitude,  $\lambda_E^\circ$ : geographic longitude,  $h$ : focal depth,  $n$ : shallow shock,  $M_s$ : surface-wave magnitude.

Date	Time (UT)	$\varphi_N^\circ$	$\lambda_E^\circ$	$h$ (km)	$M_s$	$D$ (km)
1965 DEC 4	04 08 40.0	38.1	23.8	$n$	3.5	8
1997 NOV 4	10 30 32.9	38.14	23.39	24	4.4	20
	10 32 47.5	38.33	23.68	5	4.3	21
	10 43 45.9	38.12	23.71	34	3.3	9
	11 19 22.0	38.34	23.43	25	4.0	27
	13 31 38.2	38.23	23.60	20	3.8	9
	16 09 3.3	38.20	23.50	30	3.9	12
	NOV 5	10 27 54.0	38.24	23.52	26	4.5
	10 31 53.7	38.26	23.49	20	4.4	17
	10 35 22.9	38.17	23.58	25	4.2	4
	11 57 33.7	38.11	23.57	38	3.8	6
	14 11 36.4	38.28	23.45	5	3.5	21
	20 25 35.4	38.19	23.39	5	3.6	21
NOV 6	17 07 12.6	38.22	23.64	26	3.3	8
	17 47 15.1	38.18	23.50	22	3.8	11
1999 SEP 7	11 56 50.5	38.08	23.58	17	5.9	0

“Assessment of Seismic Potential in European Large Earthquake Areas.”

The moderate-to-strong ( $M_s = 5.9$ ) earthquake that hit the metropolitan area of Athens on 7 September 1999 was the most important, disastrous earthquake in modern history of Greece. Although the earthquake occurred geographically close to the well-known Thiva–Oropos seismic zone (Fig. 2), the 1999 earthquake seems to be related to another seismogenic structure, which probably is associated with a local fault segment of rather small length lying about 30 km to the south of that zone. The main shock ( $M_s = 5.9$ , NOAGI;  $M_w = 5.9$  and  $M_o = 7.8 \times 10^{17}$  Nm, USGS) took place at 11:56:50.5 GMT, at a distance of  $\sim 18$  km NW from the historical centre of Athens (Table 3) (Figs. 2 and 3). It was the first seismic event ever reported to have caused casualties within the Athens urban area. About 100 buildings were totally collapsed (see examples in Figs. 4 and 5) causing 143 casualties while another 800 injured. About 65,000 buildings suffered heavy or moderate damage. The first days after the shock about 100,000 people rendered homeless. The tangible loss caused exceeds 3b US\$, and from this point of view it was the worst natural disaster in modern history of Greece.

The main shock was preceded by four immediate foreshocks with  $M_L$  3.2, 2.5, 2.5 and 3.2 being recorded within 18 to 2 minutes before the main shock occurrence. More than 1,500 aftershocks were located from the recordings of a local array of portable instruments deployed in the earthquake area by the National Observatory of Athens, Institute of Geodynamics (NOAGI), immediately after the earthquake occurrence (Fig. 3).

### 3.2 The seismic potential in the Athens earthquake region

In this section instrumental and historical seismicity are examined to show why such a disastrous event, occurring only 18 km from the historical centre of Athens, was not expected even in the long-term sense. Then, we review new data collected after the Athens 1999 earthquake and examine how they can affect our consideration about the seismic potential of the particular region. For understanding why the seismic potential was considered to be very low before the Athens earthquake, two types of information should be taken into account; past seismicity and active tectonics.

#### 3.2.1 Past Seismicity

##### A. Instrumental earthquakes

During the instrumental observation era no considerable seismic activity was observed before the 1999 shock. Only small magnitude earthquakes were recorded from time to time like those of 3 April ( $M_s = 4.25$ ) and 4 December ( $M_s = 3.5$ ) 1965 and the cluster of fourteen earthquakes with  $M_s$  ranging from 3.8 to 4.5 that occurred in the 3-day interval of 4–6 November 1997 (Table 3). The strongest shocks ( $M_s = 6.0$ ) recorded in the Thiva–Oropos zone and its adjacent regions in the instrumental observation era are listed in Table 1 and plotted in Fig. 2.

##### B. Historical earthquakes

Studying historical seismicity is of importance for a reliable seismic potential assessment since it offers evidence for the long-term earthquake activity. Therefore, an effort was made to compile a new historical earthquake catalogue of the Thiva–Oropos seismic zone and its adjacent regions. Previous catalogues, scientific papers, reports, books and two unpublished earthquake archives of NOAGI, covering



Fig. 4. Collapse of a reinforced-concrete factory in the region of Aharnes (large ellipse in Fig. 3).



Fig. 5. Collapse of a reinforced-concrete factory located next to that shown in Fig. 4.

the time periods from 1893 to 1901 and from 1902 to 1915 inclusive, were used as data sources. For every strong earthquake event reported in the above mentioned sources, several parameters were estimated in the catalogue as shown in Table 2. As for the origin time, the epicentral coordinates, the maximum intensity reported and the estimated Richter magnitude, an evaluation was made based on the respective sets of parameters determined by previous authors. For each event the best set of parameters was chosen by combining the reports of more than one authors indicated by Ref1 in Table 2. The 1708 and 1727 events were reported only by Ambraseys and Jackson (1997) and Ambraseys and Finkel (1999) and, therefore, their determinations were adopted. The epicenters of the earthquakes listed in Table 2 are plotted in Fig. 2. The epicenter of the 1805 earthquake is tenta-

tively plotted in Athens where the earthquake was felt without any further indication about the possible earthquake epicenter.

In Table 2, two reliability parameters, Acc and Rel, are shown for each event. Acc indicates the accuracy of the origin time measured in units of the last entry of the time of occurrence. When the Acc indication is followed by Y or M, the accuracy unit is one year or one month, respectively. Rel measures the reliability of the earthquake occurrence itself. A scale ranging from 0 to 4 has been constructed to represent the reliability of an earthquake occurrence; 0 = very improbable earthquake, 1 = improbable earthquake, 2 = questionable earthquake, 3 = probable earthquake and 4 = definite earthquake.

Additional evidence for strong earthquake occurrences in



Fig. 6. Old reparation works in broken wall-stones in the Fili Fort. Reparation consists of bricks soldered by mortar.



Fig. 7. Polished surface of the Fili neotectonic fault.

the Thiva-Oropos zone comes from archaeological investigations. Excavations in a palatial workshop at Thiva indicated that an earthquake is the likely cause of the destruction that occurred in the 13th century B.C., that is in LH IIIB period, while another destruction, probably of seismic origin, occurred again in Thiva at the end of the 3rd millennium B.C. or EH period (Sampson, 1996).

One of the heavily damaged structures because of the 1999 catastrophic earthquake in Athens was the Fili Fort established in the 4th century B.C. The Fort, being located about 20 km to the north of the historical centre of Athens, is very close to the northern segment of the Fili fault (Fig. 3). This monument is structured by marble blocks of about 60 cm × 30 cm × 50 cm in dimension. Wall collapse as well as cracks, rotations and falls of structural elements were observed. Characteristic breaks and separation

of the broken parts occurred in several structural blocks. Of great interest is that reparation works were observed (Fig. 6) in similar, past breaks and separations in structural blocks, which may imply a damage from past earthquake(s). Reparation consists of bricks soldered by mortar. The bricks used probably represent palaeochristianic or Byzantine era. Further research deserves to be made to identify the earthquake event(s) that caused the repaired damage.

**3.2.2 Field observations and active tectonics** Field geological observations performed at the Fili normal fault after the earthquake of 7 September 1999 revealed the existence of steep scarps, indicating neotectonic and possibly active fault slips, and especially polished fault surfaces cutting mainly through basement crystalline limestone and occasionally through cemented limestone breccia. The polished surfaces, observed not only on the master neotectonic fault

(Fig. 7), but also on blocks separated from the fault surface because of the Athens earthquake, imply very young normal reactivation striking N110°–130° and dipping SW70°–80° (see also in Pavlides *et al.*, 1999). Teleseismic (USGS, Harvard, Caltech, Mednet, Papadimitriou *et al.*, 2000) and near-field (NOAGI) fault plane solutions of the main shock imply that it was associated with a normal faulting trending WNW-ESE and dipping about 56° to SSW (Papadopoulos *et al.*, 1999, 2000). This solution is consistent with the geometry of the aftershock area and implies that the Fili neotectonic fault (Figs. 2 and 7) possibly represents the surface expression of the seismogenic structure. In fact, downwards displacements of 1–6 cm of the hanging-wall, observed at three different positions of the Fili fault on the first day after the earthquake of 7 September 1999, indicate a marginal surface fault break associated with the main shock faulting. Moreover, the meizoseismal area of the earthquake (Fig. 3) is located in the hanging-wall domain of the Fili fault, and other important ground failures, like local landslides, block separations and rock falls, are concentrated along or very close to the Fili fault. Besides, the geometry of the fault is consistent with the geometry of the aftershock area and with the position of the relocated main shock focus which is placed at about 10 km to the southwest of the fault line with a focal depth of 17 km (Fig. 8).

The above observations make quite possible that the Fili fault constitutes the main seismogenic structure associated with the rupture of 7 September 1999. On the contrary, another fault in the aftershock area, that of Thriassion Pedion (Fig. 2), is not likely to be the source of the main rupture. Field inspection showed no evidence of surface displacements or other ground failures caused by the earthquake. Besides, the fault geometry does not fit the aftershock distribution and the relocated main shock focus.

From the previous analysis and the data listed in Table 2 it is evident that several strong, historical earthquake events were reported in the broad area of Athens, which could be

associated either with the Thiva-Oropos fault system or even with the Fili fault. For example, the events of 1705, 1805 and 1889 could be tentatively located at a distance of about 30 km from the center of Athens; however, the little macroseismic information available makes their epicentral locations very uncertain. The epicenter of 38.3°N, 24.0°E and the magnitude of  $M_s = 6.4$  suggested by Papazachos and Papazachou (1997) for the 1705 earthquake are not justified by the existing macroseismic data that include only one observation point in Athens (see Lambros, 1881 for original Greek text, and Ambraseys and Finkel, 1993 for an English version of it). On the other hand, field observations indicate that the Fili fault reactivated in very recent geological time, possibly within the historical period, but this fact revealed only after the occurrence of the Athens strong earthquake of 1999.

#### 4. Discussion and Conclusion

In view of seismic potential assessment some important lessons were learned from the catastrophic earthquake of Athens.

First, the 1999 earthquake was unexpected in the sense that it took place in a region traditionally believed to be of very low seismic potential. This belief was simply based on that past strong earthquakes were not documented to have ruptured the region. The scientific community, however, neglected to organize or at least to propose more systematic investigations regarding the seismic potential of the area situated only 20 km from the historical center of the capital city of a highly seismogenic country. The small magnitude earthquakes recorded from time to time did not attract the interest towards a more detailed examination of the seismicity of the area. Nor the active tectonics of the area was studied, the only “approach” being mapping of faults in geological maps of 1:50,000 scale. The geologically very young reactivations of the Fili neotectonic fault were revealed only after the 1999 earthquake occurrence. Therefore, the earthquake was generated from a previously unidentified seismogenic structure. Obviously this is a typical example of the classical way of seismologists’ thinking that only the high seismicity regions are of interest. The case of the Athens 1999 earthquake, however, indicates that the low rate of instrumental seismicity is not a safe criterion to evaluate the seismic potential. Other approaches, like tectonic analysis, historical seismicity, geodesy and gravimetry have proved to be of remarkable importance in studies of this type. Should a research effort had been undertaken before 1999, it certainly would have revealed that the neotectonic Fili fault is active, that at least one strong earthquake occurred on it in historical times and that strong shocks should be expected in the future.

Second, although the 1999 earthquake was of moderate-to-strong size, the occurrence of such an earthquake very close to a large urban area, like the metropolitan area of Athens, turned it to be a catastrophic shock. A few years ago, Papadopoulos and Arvanitides (1996) evaluated the earthquake risk in the several seismogenic segments of Greece, considering the risk as a convolution of seismic hazard, vulnerability and economic value exposed to the hazard. The result was rather impressive. The Athens region, in spite

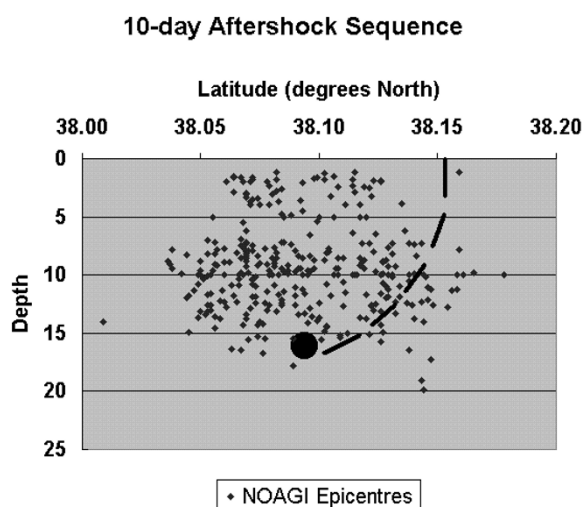


Fig. 8. Foci of the 10-day aftershocks plotted in Fig. 3 in a N-S section. Circle represents the relocated main shock while dashed line is a suggested illustration of the Fili fault. Horizontal scale doubles that of vertical scale.



of relatively low seismic hazard, was put at the top of the risk scale because of its very high value and vulnerability. The meaning is clear; even a moderate earthquake could produce extensive catastrophic consequences. This was exactly the case of the 1999 earthquake.

Third, there is no doubt that a systematic study is needed for all possible seismogenic structures in the Athens region. Earthquakes of a size comparable to that of 1999 could be generated in the future not only in the Thiva-Oropos zone but also in other seismogenic structures not yet identified. Now, the forthcoming Olympiad of 2004 makes one more important reason to drastically increase the scientific knowledge about the seismic phenomena in the metropolitan area of Athens.

**Acknowledgments.** This study has been performed within the frame of ASPELEA Research Project supported by EU-DGXII, Inco-Copernicus Program, contract no. IC-15CT-97-0200 and partly by the General Secretary of Research and Technology, Greece and the Earthquake Planning and Protection, Greece. We express our sincere thanks to two anonymous reviewers for their suggestions that helped to improve the original manuscript.

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