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RECENT MICRO-EARTHQUAKE ACTIVITY AT NORTHERN EVOIKOS GULF, CENTRAL GREECE

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ABSTRACT

During the last 4 months of 1999, the Institute of Geodynamics, of the National Observatory of Athens, deployed in the area of north Evoikos gulf, a local seismic network of 5 digital stations equipped with sensitive 3-components seismometers. The recorded micro-earthquakes, located in the upper part of the crust, show that there is significant seismic activity in the area of northern Evoikos gulf. This activity could be correlated not only with the main faults of the area, which are the Atalanti fault and the fault running parallel to the coasts of Evia island but also with other faults which are assumed to be, till now, less active or not so important.

KEY WORDS: Microearthqakes, Seismotectonics, north Evoikos gulf, Atalanti fault.

1. INTRODUCTION

The northern Evoikos Gulf, Central Greece, a NW-SE trending graben separating North Evia island from Central Greece, is one of the most active tectonic areas of continental Greece. Several major normal faults bound the high relief along both coasts. Concerning the seismic activity, it is also intense, since ancient times.

Although its interesting tectonic and seismic features this area didn't receive the scientific attention as other neighbouring areas, the Gulf of Corinth for example. Recently, the new concepts of the prolongation of the Anatolia fault system into the Aegean Sea and its connection with the big tectonic grabens of continental Greece, like the north Aegean trough, the Evoikos and the Corinth gulfs, (Armijo et al. 1996), have triggered several studies for detailed fault mapping, monitoring of micro-earthquake activity, determining deformation rates, etc.

Following these ideas the Institute of Geodynamics of the Observatory of Athens (IG-NOA), performed a seismic experiment in the area by deploying a sensitive temporary seismic network of 5 digital, 3-components stations, in order to monitor and study the microearthquake activity at northern Evoikos gulf and to correlate it with the existing faults of the area. This network was operated for the period of the last 4 months of 1999.

In the present paper results are presented of the spatial distribution of the recorded microearthquakes and the focal mechanisms of some of them. Focal mechanisms of some older large earthquakes are also plotted. Finally, all the observations are combined, in order to obtain a better understanding of the regional tectonics and its seismic activity.

2. TECTONICS AND SEISMICITY OF THE AREA

The northern Evoikos Gulf, a 100km long, NW-SE trending graben separating North Evia island from Central Greece, is one of the most active tectonic areas of continental Greece. Various scientists have studied the geology and the morphotectonic-neotectonic characteristics of the area in the past (Philip 1974; Lemeille 1977; Rondoyianni 1984; Mercier et al. 1989; Roberts and Jackson 1991; Collier et al. 1994; Eliet and Gawthorpe 1995; Ganas 1997). Several major normal fault zones, in a step-like arrangement, bound the high relief along the southern coast striking WNW-ESE and dipping to the north (Fig.1). These fault zones are the Sperchios and Thermopylae on the north-west, the Kammena Vourla–Agios Konstantinos-Arkitsa at the center and the Atalanti on the south-east. At the easternmost end of this fault system, the Malesina fault is located, which has a NE-SW direction and dips towards NW. Inland, towards the west there are other normal fault zones, the most important being those of Parnassos and Kallidromo. On the northern side, the situation is simpler. There exists a major antithetic normal fault zone, running almost off-shore, parallel to the coast of the Evia, dipping to the south. These large normal faults cut and displace not only rocks of Mesozoic and Tertiary age but also younger sediments of Plio-Pleistocene age.

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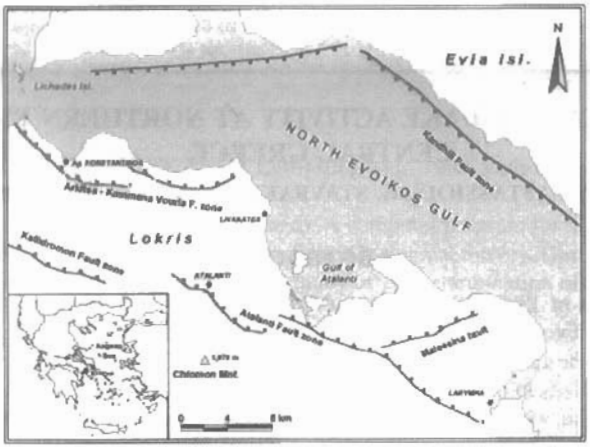

Figure 1. Simplified tectonic map of the area.

Morphotectonic investigations showed that the coastal environment has undergone significant changes which can be recognized in the form of raised terraces, raised or submerged beachrocks and marine notches, while on the lowlands tsunami deposits are found as well as alternations of marine and terrestrial sediments (Cundy et al. 2000; Papanastassiou et al. 2000).

Historical sources and archaeological findings prove, that this area has been affected by a number of catastrophic earthquakes since ancient times, the most important of them being those of 426BC, 105AD, 551, 20 and 27 of April 1894 (Oldfather 1916; Galanopoulos 1960; Karnik 1971; Bousquet and Pechoux 1977; Ambraseys and Jackson 1990; Guidoboni 1994; Papazachos and Papazachou 1997). The last two shocks affected the area from Agios Konstantinos to the northwest till Larymna to the southeast. For these events there are several reports for the causalities and the consequences to the natural environment and the tsunami wave that inundated the coastal areas (Skouphos 1894; Mitsopoulos 1895; Papavasiliou 1894a, b). From these reports it is concluded that the Atalanti fault was the causative one, although there were different views about the length of the rupture and the vertical displacement. Recent work, re-evaluating these earthquakes (Pantosti et al. 2001),

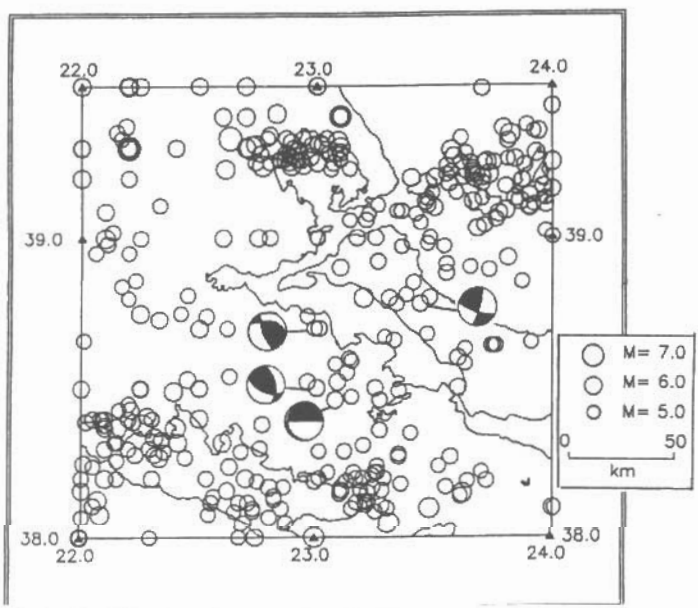

Figure 2. Background seismicity of the broader area of north Evoikos gulf, for the period 1900-2000. The fault plane solutions for the strong past earthquakes computed in this study are also plotted.

showed that the first event of the 20th of April could be caused by the activation of the Malesina fault, which in turns activated the Atalanti fault during the second earthquake of 27th of April.

According to recent work (Papanastassiou et al. 2001), which recompiled the seismological archives of the IG-NOA, other information (Makropoulos et al. 1989) and local seismicity studies (Lagios et al. 1985; Burton et al. 1995) it is shown that the instrumental seismicity of the northen Evoikos gulf is not as high as in other nearby areas like the Gulf of Corinth or the Sporades basin. This area seems to be almost free of seismicity (Fig. 2).

The few seismic studies, as well as the low level of seismicity in this area, also result to a lack of available focal mechanisms for strong earthquakes. In order to overcome this need, the bulletins of the International Seismological Centre (ISC) were checked to find past strong earthquakes with sufficient P-wave polarities. By this search, 4 new mechanisms, for earthquakes located in the broader area of northern Evoikos gulf, were plotted. Their parameters are given in Table 1. The focal mechanisms correspond not only to normal faulting, which is in agreement with the local tectonics, but also to reverse faulting.

TABLE 1

DATE	ORIGIN TIME	LAT N	LON E	DPT Km	MAG	PLANE 1			PLANE 2		
						AZM	DIP	RAKE	AZM	DIP	RAKE
1974 NOV 14	13:22	38.50	23.08	27	5.0	110	55	50	345	51	132
1974 NOV 14	15:29	38.50	23.15	35	5.0	160	15	-20	269	84	-104
1986 JUN 6	15:34	38.70	22.99	32	4.0	160	65	120	286	38	43
1988 JUL 12	02:26	38.75	23.45	18	4.7	115	65	10	20	80	154

3. MICROEARTHQUAKE ACTIVITY

IG-NOA, in order to record the microearthquake activity deployed a portable seismic network, composed of 5 Reftek digital stations equipped with 3-components Lenartz seismometers. The instruments were installed at Kammena Vourla, Atalanti and Malesina at Central Greece, Aidipsos and Limni at Evia. The microseismic activity was continuously monitored, from the beginning of September 1999 through the end of December 1999, and several hundreds of events of $M_L >> 1.0$ were recorded.

The network provided a satisfactory coverage of the area of north Evoikos Gulf and allowed for well resolved hypocenters. Although in the recordings there was a noise from the numerous aftershocks of the 7th September 1999, Parnitha earthquake, more than 500 events, having at least four (4) P-wave and three (3) S-wave readings, were selected. The events were located by using a velocity model based on local studies (Makris et al. 2000) and is given in Table 3. The Vp/Vs ratio was estimated from Wadati diagrams and was found to be $1.78 \pm\pm 0.02$. The HYPOCENTER, (Lienert 1994) computer program was used to locate the events, which are plotted in figure 3. The obtained solutions had standard errors less than 0.3sec for RMS, 1.5km and 2Km for the horizontal direction (ERH) and depth (ERZ) respectively.

The earthquakes in the study area are located at depths shallower than 15km. Their spatial distribution shows that are not regularly located in the area of north Evoikos gulf. Two clusters of activity are clearly observed, one at the southern end of the gulf, area of Skorponeri bay and the other one, north of Malesina peninsula. The southern cluster is denser, well defined and occupies a bigger area while the northern one shows a diffused spatial distribution. Diffuse seismicity is also observed at the northern part of Evia island. Is pointed out that, as the Scorponeri cluster is located outside the area covered by the local network, these events could be a little bit misplaced. However, the small values of the locations errors permit to conclude, that the distribution given in figure 3, is not far from the actual one.

Polarities of P-waves and the program FPFIT (Reasenberg and Oppenheimer 1985) were also used to plot focal mechanisms for some of the recorded earthquakes (Fig. 3). Their parameters are listed in Table 2, showing normal faulting, in accordance with the local tectonic regime.

TABLE 2

No	DATE	ORIGIN TIME	LAT N	LON E	DPT Km	MAG	PLANE 1 AZM	PLANE 1 DIP	PLANE 1 RAKE	PLANE 2 AZM	PLANE 2 DIP	PLANE 2 RAKE
1	1999 NOV 2	03:50	38.92	23.10	7.3	1.6	315	60	-120	184	41	-49
2	1999 NOV 7	07:21	38.73	23.12	7.6	1.3	30	40	-120	247	56	-67
3	1999 NOV 30	00:03	38.61	23.22	10.3	1.4	85	40	-70	290	52	-106
4	1999 NOV 30	22:00	38.71	22.84	6.4	1.5	265	45	-110	57	48	-71
5	1999 DEC 12	23:55	38.72	23.37	3.5	1.0	145	45	-100	310	45	-80

TABLE 3

LAYER WIDTH (km)	Vp (km/sec)
0 - 4	4.8
4 - 7	5.4
7 - 10	5.8
10 - 15	6.3
15 - 30	6.5
> 30	7.0

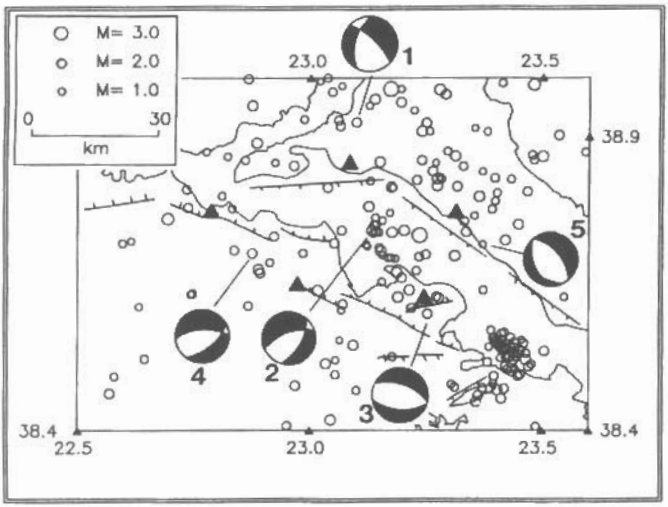

Figure 3. Map view of the well-located microearthquakes. The determined fault plane solutions are also shown. Their focal parameters are given in Table 2. Filled triangles give the position of the stations of the local seismological network. The main faults are also shown.

4. DISCUSSION – CONCLUTIONS

Main target of this work was to examine the seismic activity of the faults existing in the area of north Evoikos gulf. So, its of great importance to correlate and find any relation between the spatial distribution of the located microearthquakes with the morphological surface traces of the faults of the area.

The spatial distribution of the located microearthquakes shows that are not regularly located in the area of north Evoikos gulf, as two clusters of activity could be clearly observed. The first one is located at the southern end of the gulf, area of Skorponeri bay and the other one, north of Malesina peninsula.

Scorponeri bay, is the southern-east end of the Atalanti fault. The southern cluster is located north of the fault trace, on the hanging wall of the Atalanti fault. At this area, besides this fault there are also the Paralimni and the Pavlos fault zones, having a WSW-ENE direction and a dip towards SE being almost perpendicular to Atalanti fault, which are possible control the termination of it. So this cluster is located in the junction of these fault zones and could n[illegible] Malesina could not clearly be

correlated with one of the faults of the area, the Atalanti, the Malesina or the fault that bounds the coasts of Evia island. However the number 2 plotted focal mechanism of a microearthquake belonging to this cluster, could be easily correlated with the Malesina fault. However this is not enough to draw accurate conclusions about the seismic activity of this fault. The focal mechanisms no 3,4 and 5 could be related with the main fault zones of central Greece and the coast of Evia island respectively.

Furthermore the plotted focal mechanisms of the past strong earthquakes of the area, table 1, didn't give any help to distinguish the active faults. Unlikely some of them show reverse faulting and as their depths are not so shallow these could be related with structures located at depth.

Recently Makris et al. (2000) conducted in the same area deep seismic sounding, and operated a large local network consisting of 24 stations for a period of 50 days. They also recorded significant microearthquake activity in this area of northern Evoikos gul.

The results of these independent works show that in this area seismic stress is released not with strong quakes but with intense microearthquake activity, which is not recorded by the operating seismic networks.

It is important to add that usually the seismicity recorded by a local network operated for a short time period, does not reflect the permanent characteristics of the area. However, in the case of north Evoikos the similar results of the two aforementioned networks, prove the rightness of the results.

Continuous monitoring of the micro-seismicity of the area with a dense local array and precise deformation measurements by GPS are needed. The obtained results will permit to understand the seismicity pattern, the activity of the faults, the distribution of strain, the way that the energy is released and how the motion from Anatolia is transferred to this area and to other areas of the Greek mainland.

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