

THE 1992, NOVEMBER 18 GALAXIDI EARTHQUAKE, AN AFTERSHOCK STUDY

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A B S T R A C T

On 1992, November 18 an earthquake of $M_s=5.9$ occurred in the central part of the Gulf of Corinth near Galaxidi. No surface ruptures were observed on either side of the Gulf and the larger amount of the aftershocks were located offshore. The aftershock sequence was unusually short in time and defined a zone 25 km long and 15 km wide dipping northwards. The dip of this seismic zone seems to be steeper in the South and shallower in the North. The prolongation to the surface of the fault plane determined by the aftershocks corresponds to the well known normal fault of Aegion which is one of the main features that have created the Gulf.

Ο ΣΕΙΣΜΟΣ ΤΟΥ ΓΑΛΑΞΕΙΔΙΟΥ ΣΤΙΣ 18 ΝΟΕΜΒΡΙΟΥ 1992,
ΜΕΛΕΤΗ ΤΩΝ ΜΕΤΑΣΕΙΣΜΩΝ

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Π Ε Ρ Ι Λ Η Ψ Η

Στις 18 Νοεμβρίου 1992 ένας σεισμός μεγέθους $M_s=5.9$ συνέβει στο κεντρικό τμήμα του κόλπου της Κορίνθου, κοντά στο Γαλαξείδι. Επιφανειακές ρωγμές δεν παρατηρήθηκαν σε καμία πλευρά του κόλπου και οι περισσότεροι μετασεισμοί εντοπίζονται μέσα στον κόλπο. Η μετασεισμική ακολουθία είναι ασυνήθιστα μικρής χρονικής διάρκειας και σχηματίζει μιά ζώνη μήκους 25 Km και πλάτους 15 Km βυθιζόμενη προς τον βορά. Η κλίση αυτής της ζώνης είναι μεγαλύτερη νότια και γίνεται μικρότερη προς τον βορά. Η επέκταση στην επιφάνεια του επιπέδου του ρήγματος, που καθορίζεται με την βοήθεια των μετασεισμών, αντιστοιχεί στο γνωστό ρήγμα του Αιγίου το οποίο είναι ένα από τα κύρια ρήγματα που δημιούργησαν τον Κορινθιακό κόλπο.

INTRODUCTION

The Gulf of Corinth is an asymmetric graben formed by normal en echelon faults located at the southern part of the Gulf and dipping north and by some antithetic faults located on the northern part. The extension rate across the Gulf is estimated to be 4.73-10.5 mm/yr (Billiris et al., 1991; Rigo et al., 1993; Papazachos and Kiratzi, 1992)

The most known earthquakes of this region are: the 1928 Corinth earthquake ($M_s=6.3$, Sieberg, 1929), the 1965 Aetolia earthquake ($M_s=6.7$, Ambraseys and Jackson, 1990; Ambraseys, 1967), the 1965 Eratini earthquake ($M_s=6.4$, Ambraseys and Jackson, 1990), the 1970 Antikyra earthquake ($M_s=6.2$, Liotier, 1989) and the 1981 Corinth sequences ($M=6.7, 6.4, 6.3$, King et al., 1985; Jackson et al., 1982). The mechanisms of these earthquakes show fault planes striking E-W and they are consistent with the active N-S extensional regime of the Gulf.

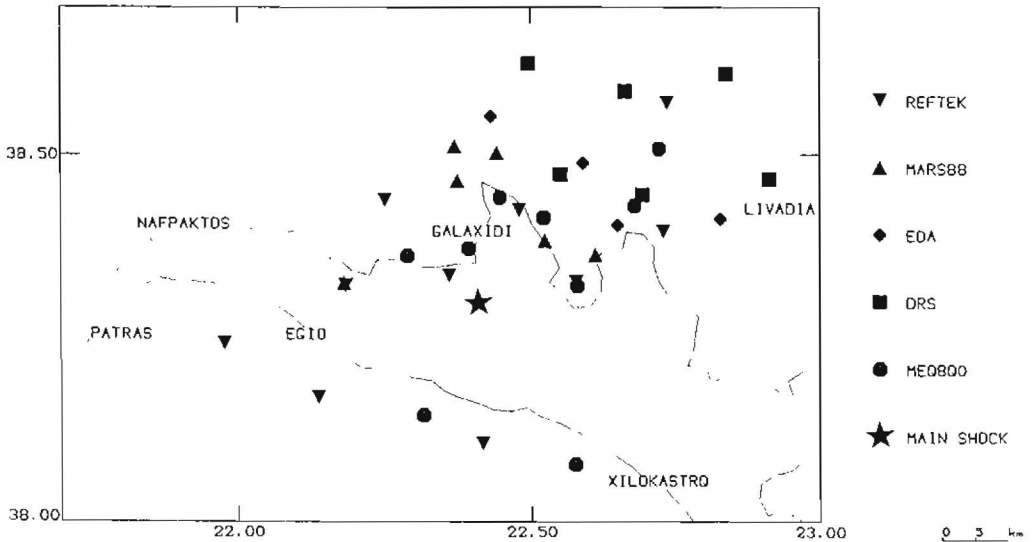


Fig.1. Location map of the station network. Most of the stations were installed in the northern part of the Gulf where the strongest intensity was felt and only 5 of them were installed in Peloponnesus. The star is the location of the main shock computed by the Geophysical Laboratory of the University of Thessaloniki.

The region has also been studied with two microearthquake surveys. The first one conducted during the summer of 1986 in the Peloponnesus and surrounding areas (Hatzfeld et al., 1990) and the second one (Rigo et al., 1993) during the summer of 1991 at the northern part of Peloponnesus. The results of these studies show N-S extension for the Gulf of Corinth with fault planes

trending E-W and dipping north which are in agreement with the results deduced from the study of the strong earthquakes.

On 1992 November 18, an earthquake of $M_s=5.9$ occurred in the central part of the Gulf of Corinth near Galaxidi. In order to study the aftershock sequence a network of 35 portable stations was installed in the area for about 10 days. Here we present the results obtained from the study of these aftershocks.

DATA

We started installing the first instruments on November 22 and by November 25 a network of 35 portable stations was fully operational in the area. Different instruments have been used. Among them 9 MEQ analog recorders, 4 EDA 1-D digital recorders, 6 DRS 1-D digital recorders, 6 MARS88 3-D digital recorders and 10 REFTEK 6-channels (seismometers and strong motion) recorders (fig. 1).

Because most of the damages were reported at the northern part of the Gulf and no surface ruptures were visible, we installed most of the instruments north and only 5 instruments in Peloponnesus. At the same time geodetic measurements were carried out in the area. The results of the geodetic data are discussed in an other paper by Briole et al. (1993). The network remained operational until December 4 when we considered that we would not learn much more by maintaining longer the instruments. At that time all the instruments were moved out except 3 strong motion ones which were left there for several months.

During this period (November 25-December 4) 255 events were recorded. We know from the permanent Greek network that no events with magnitude greater than 4.0 have occurred after the main shock. According to a statistic study of Papazachos and Papazachou (1989) for the area of Greece, an earthquake of magnitude 6.0 is normally followed by about 25 aftershocks with magnitude equal or greater than 4.0.

All the data has been grouped and located using the HYPO71 location program (Lee et Lahr, 1975). The velocity structure that we have used is available from a microearthquake study conducted in Epire. In total we have located 255 events from which we have chosen the 195 located using more than 6 P and S readings, $RMS < 0.5s$ and location error both in epicenter and in depth smaller than 5 km. In this paper we examine about 60 events located within the region of interest.

AFTERSHOCK LOCATIONS

The locations of all the events are shown in fig. 2. The total seismicity recorded during this experiment is spread between Patras and Xylokaastro. It is therefore possible that it corresponds to the normal seismic activity of the Gulf of Patras and not to a specific aftershock sequence. We choose the cluster located around the epicentral zone of the main shock as the one which most probably corresponds to aftershocks.

This cluster is of about 60 events and defines an area 25 km long and 15 km wide trending SSW-NNE. For an earthquake of

magnitude $M_s=6.0$ we expect a fault area of about 240 km^2 (Aki, 1967) and therefore the aftershock sequence is a little larger than expected.

A cross section (fig. 4) trending perpendicularly to the Aegion fault shows clearly a deepening of the aftershocks towards the North. We notice also that the dip of the seismic zone is more important in the South than in the North, as a listric fault. This is in agreement with other studies conducted in this region (King et al., 1985). The prolongation to the surface of this zone corresponds to the well known Aegion fault which is one of the main features that have created the Gulf.

In order to investigate some systematic bias due to the projection we computed two other cross sections:

1) One perpendicular to the strike of the fault plane as defined by the main shock (Briole et al., 1993) (fig. 5). This cross section also confirms that earthquake hypocenters become deeper northwards and cannot be associated with an antithetic fault dipping South.

2) A second one, identical to the one computed by Rigo et al. (1993) for the microearthquake data of the summer of 1991 (fig. 6). We cannot really find a consistency between these two sections but this is probably due to the fact that this region is outside of our network and then the location of our events is not as well constrained.

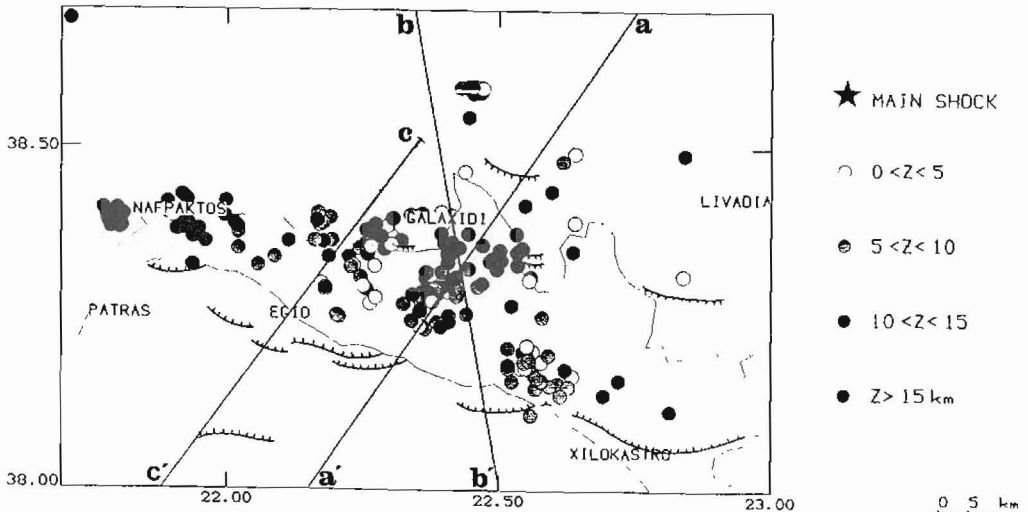


Fig.2. Location of 193 events recorded from November 22 to December 3. These events are located using more than 6 P and S-wave arrivals, $RMS < 0.5$ and the location error both in epicenter and depth is smaller than 3 km. The epicenters are spread over a wider zone than the surface fault inferred from the main shock. The locations of the sections in Figs 4, 5 and 6 are shown. Surface faults are also represented.

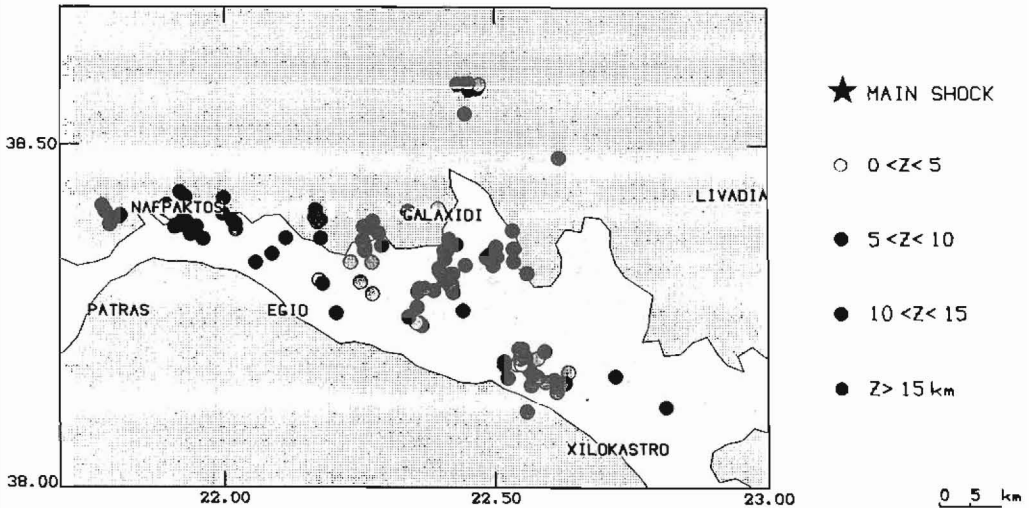


Fig.3. Location of 119 events located with more than 5 P- and 3 S-wave arrivals, $RMS < 0.3$ and location error smaller than 3 km in epicenter and in depth. We notice the same aftershock cluster around the epicentral area.

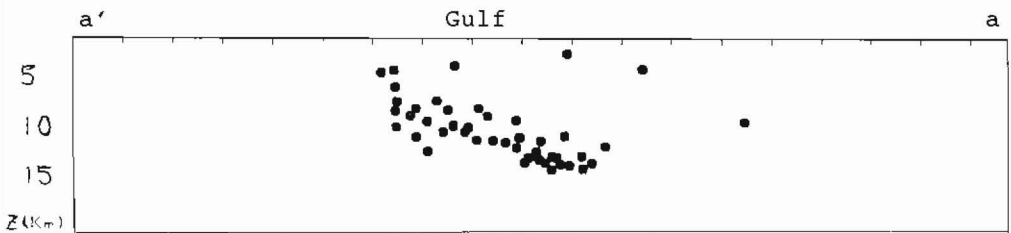


Fig.4. Cross section perpendicular to the surface fault of Egion. The arrows are the coast while is the Aegion fault. We notice that the hypocenters of the earthquakes are getting deeper to the North and that the prolongation of the aftershock zone at the surface corresponds to the fault of Aegion.

AFTERSHOCK FAULT PLANE SOLUTIONS

We computed the fault plane solutions for 8 events located around the epicentral area. Lower focal sphere projection with polarity readings are shown in fig.7 while their geographical distribution is shown in fig. 8.

Normal faulting is indicated by 5 fault plane solutions (#58,121,217,224,226) located within the Gulf, west of the epicentral area. The fault plane solutions for the #121,224 and 226 events are very well constrained, showing planes trending ESE-WNW and dipping north. The events #58,217 are less

constrained and they also show fault planes oriented ESE-WNW. The T-axes for these events are trending NE-SW which is consistent with the ones computed for larger events.

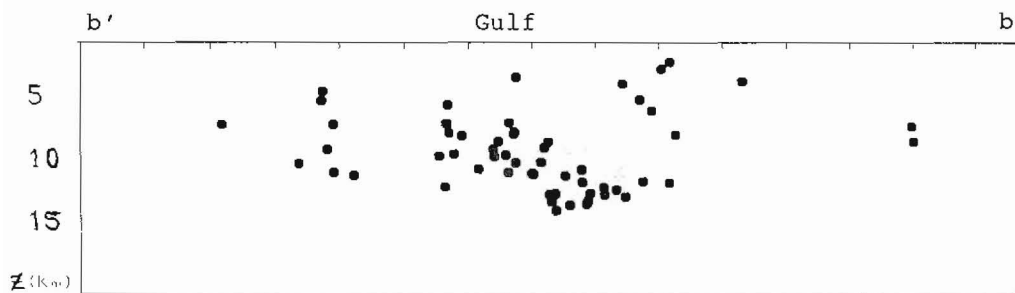


Fig.5. Cross section perpendicular to the fault plane defined by the main shock (Briole et al., 1993). This cross section also shows a deepening of the hypocenters towards the North.

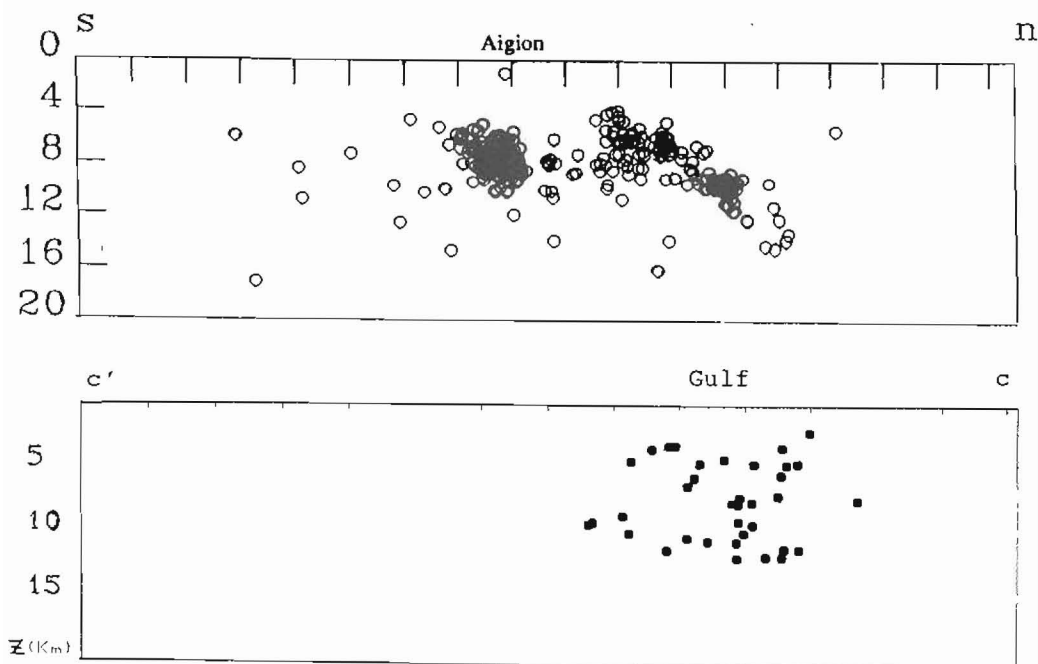


Fig.6. Cross section located near Aegion as for the micro-earthquake survey of 1991 (Rigo et al., 1993). a) The 1991 earthquakes b) The Galaxidi earthquakes.

There are also 2 fault plane solutions showing strike slip faulting (#179,227). These events are located at the edges of the

main fault surface and they are well constrained. The mechanism #227 shows dextral strike slip motion if we assume a NE-SW trending plane. This motion is consistent with the main fault being normal and dipping North.

At the northern part of the aftershock area, we find also a mechanism (#104) showing NE-SW compression. This reverse mechanism could be due to the shortening located behind the main normal fault.

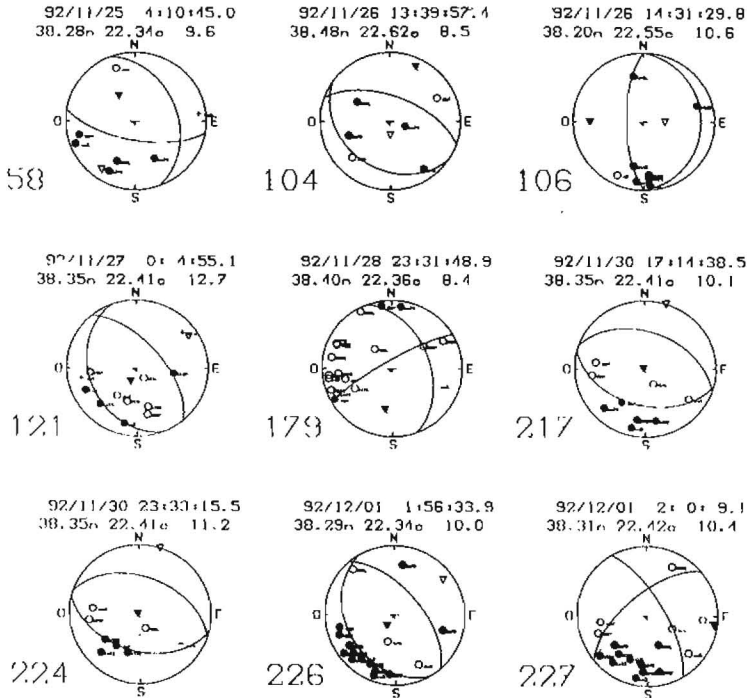


Fig.7. Lower hemisphere focal spheres of 9 events. Black and empty dots are reliable compressional and dilational first motions, + and - are uncertain.

CONCLUSIONS

The Galaxidi earthquake occurred in the central part of the Gulf of Corinth a region dominated by active extensional tectonics. The main shock was located offshore and no surface ruptures were reported on either side of the Gulf. The aftershock sequence was quite short in time and no strong aftershocks ($m_b > 4.0$) were reported after the main shock. The discrimination between the aftershock sequence and the normal microearthquake activity is therefore uncertain. We assume that the cluster of earthquakes located around the main shock corresponds to the aftershock activity.

The aftershock cluster is 25km long and 15 km wide which presents a surface a little larger than the one for a main shock

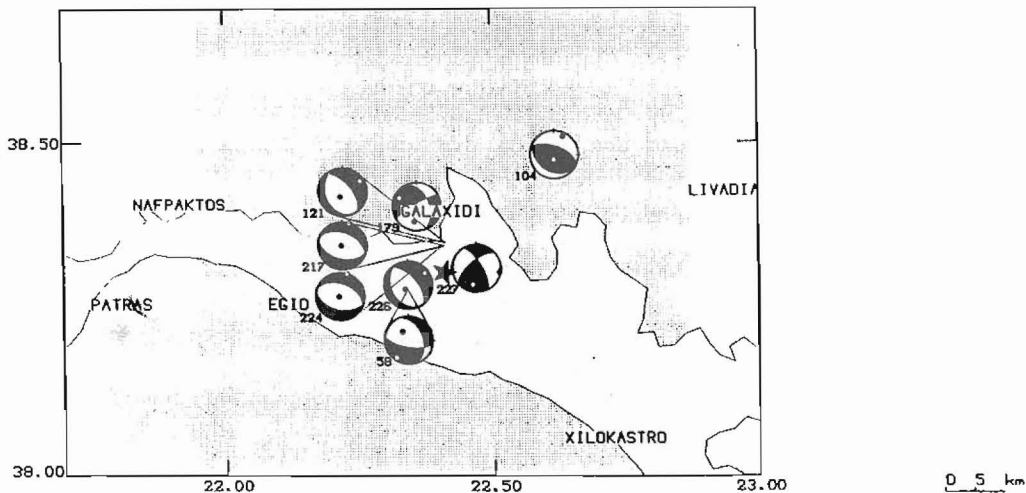


Fig.8. Map location of the 8 fault plane solutions. We observe normal faulting around the epicentral area, 2 strike slip faults at the edges of the aftershock cluster and one reverse fault behind the main seismic region. A south dipping normal fault is therefore very unlikely.

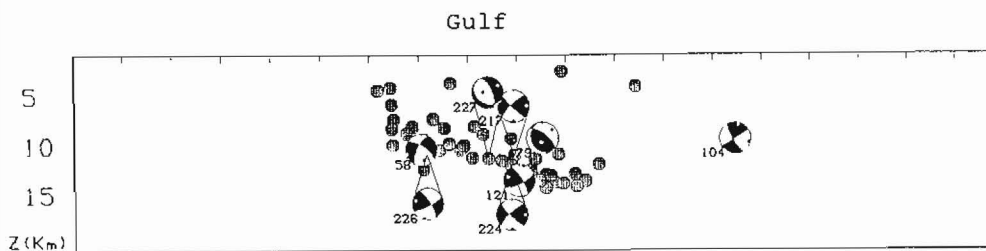


Fig.9. Cross section identical as 4 but with focal mechanisms back projected.

of $M_s=5.9$. The depth of the aftershocks is between 2-5 km in the South and it becomes more important (10-15 km) to the North suggesting a north dipping fault. The dip of this zone seems to be shallower to the North, suggesting a listric fault which is in agreement with other studies conducted in this region (Jackson et al., 1982).

The fault plane solutions show normal faulting around the epicentral area with planes trending ESE-WNW, strike slip faulting at the edges of the aftershock area and reverse faulting behind the main normal fault. The prolongation at the surface of the fault plane determined by the aftershocks corresponds to the Aegion fault.

The evidence presented here suggests that the November 18 shock occurred on a major north-dipping fault, most probably the fault of Aegion.

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