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THE PATRAS (JULY 14, 1993; M_s= 5.4) EARTHQUAKE SEQUENCE

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ABSTRACT

The Patras earthquake occurred on July 14, 1993 (M_S=5.4). The entire earthquake sequence is presented in this study as it was recorded by the newly established Patras Seismic Network, which is based at the University of Patras Seismological Centre. The hypocentre spatial distribution of the earthquake sequence for a period of 20 days, can be divided into three characteristic areas. The first lies at the city of Patras and surroundings indicating dispersed seismic activity of focal depths ranging from 3km to 15km. The second defines a NW-SE trend starting NW offshore from the city of Patras, and is almost forming a flat, as the focal depth of the events in this area is ranging from 22km to 30km along a line of approximately 35km long. The third starts SE of Trikhonis Lake and continues a few kilometres to the North of the Lake, with the main characteristic the dispersed seismicity with focal depths ranging from 3km to 20km.

ΣΥΝΟΨΗ

Ο σεισμός της Πάτρας έλαβε χώρα στις 14 Ιουλίου 1993 (M_S=5.4). Στήν παρούσα μελέτη παρουσιάζεται η σεισμική ακολουθία όπως καταγράφηκε από το πρόσφατα εγκατεστημένο μόνιμο σεισμικό δίκτυο του Πανεπιστημίου της Πάτρας. Η κατανομή των υποκέντρων της σεισμικής ακολουθίας σε διάρκεια 20 ημερών χωρίζεται σε τρεις χαρακτηριστικές περιοχές. Η πρώτη ευρίσκεται στην περιοχή της πόλης της Πάτρας μετά των περιχώρων της, και υποδεικνύει διάσπαρτη σεισμική δραστηριότητα με εστιακό βάθος από 3km έως 15km. Η δεύτερη, καθορίζει μία γραμμή διεύθυνσης ΒΔ-ΝΑ, που αρχίζει ΒΔ της πόλης της Πάτρας και σχηματίζει ένα επίπεδο, καθώς το εστιακό βάθος των σεισμών στην περιοχή κυμαίνεται από 22km έως 30km, κατά μήκος μίας γραμμής μήκους περίπου 35km. Η τρίτη αρχίζει ΝΑ της Λίμνης Τριχωνίδας και συνεχίζεται μερικά χιλιόμετρα Βόρεια της Λίμνης, με κύριο χαρακτηριστικό την διάσπαρτη σεισμικότητα, με εστιακά βάθη να κυμαίνονται από 3km έως 20km.

INTRODUCTION

On July 14, 1993 an earthquake sequence with a main shock of magnitude 5.4 MS occurred 7km south of the city of Patras. It devastated an area of about 20km within and around the city and in particular the villages of Saravali, Krini, Mintilogli and the areas of Kato Agyia, the old city of Patras and Rio. All the old and under preservation buildings in the city of Patras suffered greatly and even some newly built structures were left in need of reinforcement after the earthquake.

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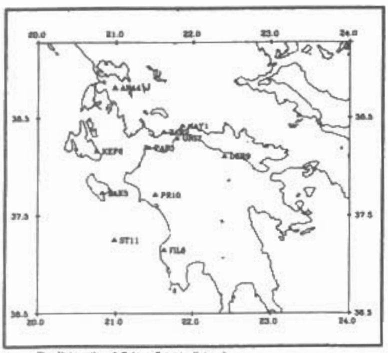
The study presents the whole earthquake sequence as it was recorded by the University of Patras Seismic Network. The data cover the time period from July 8, 1993, six days prior to the main event, to July 27, 1993, fourteen days after the main shock. Spatial, magnitude and time distribution of the entire sequence is presented. Over 500 well-located events are used in the analysis of this study.

THE PATRAS SEISMIC NETWORK

The University of Patras Seismic Network (hereafter PATNET) is a microearthquake network based at the University of Patras Seismological Centre. PATNET is covering at the moment the whole area of Western Greece with the Akarnanika station to the furthest north point, the Filiatra station to the furthest south, the Zakynthos station to the furthest west and the Derveni station to the furthest east (Fig 1). It consists of ten short period outstations, each with one vertical component (1Hz) seismometer operating at 60dB dynamic range and in low noise environment. The signals are radiolinked via FM subcarriers to the central recording site at the University of Patras, where a three component (one vertical and two horizontal on E-W and N-S directions (1Hz) seismometers) station exists. There, each channel signal is antialias filtered with a 30Hz Butterworth low-pass filter, sampled at 100Hz and converted to digital form with a resolution of 32bits.



The University of Patras Seismic Network

Fig. 1: The present station distribution of the Patras Seismic Network.

Σχ. 1: Η παρούσα διάταξη του μόνιμου Σεισμικού Δικτύου του Πανεπιστημίου της Πάτρας.

The STA/LTA technique is employed for event triggering. In addition, the option for continuous recording is also available, and in the case of the present study it was used during the first three days of the aftershock sequence. All events then are processed and located following the procedure which is described later on.

THE PATRAS AREA

In the present study, as Patras area is defined informally the area covering the Gulf of Patras and the adjacent area as well as the area South of Trikhonis Lake to the North (Fig 2). As discussed by Brooks et al. (1988) and Melis et al. (1989), the Patras area is a complex area in terms of seismotectonics. It lies at the junction of two different structural trends within the current neotectonic extensional regime of an approximately AND - S direction (Fig 2). The first is the WNW - ESE zone of extension defined by the Gulf of Corinth graben (Brooks & Ferentinos 1984), which possibly extends northwestward to Trikhonis Lake (Melis 1986, Melis et al. 1989); the second is the NE - SW faulting associated with the Rio graben (Kontopoulos & Doutsos 1985) which has been interpreted as a transfer (transtensional) fault zone linking the Gulf of Patras graben in the southwest with the Corinth - Trikhonis zone of extension in the northeast (Melis 1986, Brooks et al. 1988, Melis et al. 1989).

Several studies have been conducted on this graben system (Fig 3). Tselentis and Makropoulos (1986) investigated the crustal deformation rate of the entire

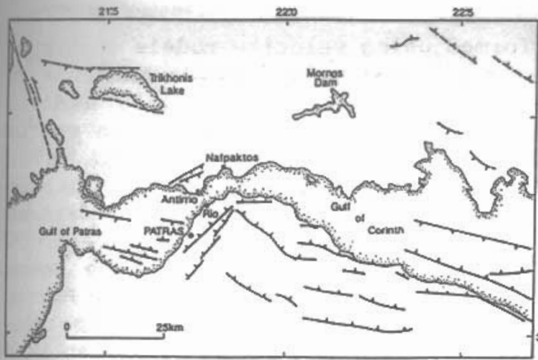


Fig. 2: Regional tectonics of Patras (after Ferentinos et al. 1985, Brooks et al. 1988, Melis et al. 1989).

Σχ. 2: Τεκτονική στην ευρύτερη περιοχή της Πάτρας (κατά τους Ferentinos et al. 1985, Brooks et al. 1988, Melis et al. 1989).

graben system. Ferentinos et al. (1985) studied the Patras graben offshore and showed that the seabed is affected by synsedimentary faulting with the same WNW - ESE trend. A follow-up study by Chronis et al. (1991) shows the same pattern of active faulting. Zelilidis et al. (1987) described a tectonic regime with a similar WNW - ESE trend onshore immediately to east of the eastern end of the Patras graben. This coexists with a NE - SW fault regime defining the Rio graben, which was studied onshore by Kontopoulos & Doutsos (1985) mainly to the north at the Antirio locality, and to the South by Doutsos et al. (1989). Offshore studies in the immediate vicinity show the existence of a complicated system of active faults with several trends, of which NE - SW and NW - SE appear to be the most dominant (Perisoratis et al. 1986, Chronis et al. 1987).

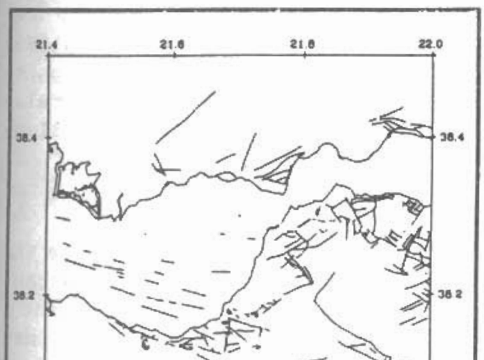


Fig. 3: Neotectonics of the Patras area (after Ferentinos et al. 1985, Kontopoulos & Doutsos 1985, Doutsos et al. 1989, Chronis et al. 1991).

Σχ. 3: Νεοτεκτονική της περιοχής της Πάτρας (από τους Ferentinos et al. 1985, Kontopoulos & Doutsos 1985, Δούτσος και συνεργάτες 1989, Chronis et al. 1991).

It has been suggested that the Rio graben developed earlier than the Corinth graben (Doutsos et al. 1989). Thus, as it is an extensional tectonic feature of NE - SW trend, it could well develop right - lateral strike slip motion if reactivated by the current regionally dominant N - S extensional regime forming the Corinth, Patras and Trikhonis grabens (Fig 2). Brooks et al. (1988) and Melis et al. (1989), in their seismotectonic model for the region based on local microseismicity data (Melis 1986), suggested that Rio - Antirio may behave as a transtensional fault zone linking the Corinth - Trikhonis graben system with the Patras graben (Fig 3).

EVENT LOCATION PROCEDURE

For the event location and magnitude calculation the HYPO71PC (Lee and Lahr 1975; Lee and Valdes 1985) computer program was used. The locations accepted were allowed an error less than 3km on both epicentre and focal depth locations, and a RMS of travel time residuals less than 0.10.

In order to constrain our dataset to follow the above mentioned error allowances, a large number of trial runs

Table 1: The P-velocity model used for final event location .

P-velocity (km/sec)	Depth (km)
5.7	0.0
6.0	5.0
6.4	18.0
7.9	39.0

was performed using velocity models suggested by other microearthquake studies in the area and adjacent regions (e.g. Melis 1986, Pedotti 1988) in cooperation with well known models for the Aegean area (e.g. Makris 1977, Panagiotopoulos and Papazachos 1985). The best velocity model was obtained using a dataset of twenty events which were well-recorded (clear P and S arrivals) by all the seven stations of PATNET (note that during the Patras earthquake sequence only the stations numbered 1 to 7 were fully operating) and had local magnitude greater than 3ML. The final velocity model used for the area of Patras is shown in Table 1.

Then, all the recorded events by at least six of the PATNET stations were located using this velocity model. The station delays which were suggested by this run, were incorporated to a final run for all the events recorded at least at four stations. All the events then were located and these location were finally accepted. Their epicentre distribution is shown in Fig 4.

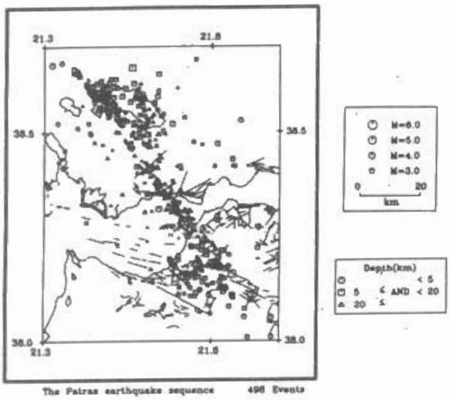


Fig. 4: The Patras earthquake sequence. The neotectonic faults presented in this diagram are taken as in Fig 3. M denotes local magnitude.

Σχ. 4: Η σεισμική ακολουθία της Πάτρας. Τα νεοτεκτονικά ρήγματα που παρουσιάζονται στο διάγραμμα είναι από το Σχήμα 3. Μ είναι το τοπικό μέγεθος.

The magnitude which is reported for all the events is the local magnitude ML calculated from total signal duration. The computation was also done by HYPO71PC using the formula defined by Lee et al. (1972) in conjunction with the one described in Kiratzi & Papazachos (1985) and Melis et al. (1989), thus setting the constant parameters describing the relationship for PATNET stations. The following equation was used:

$$M_L = 2.32 \, Log(T) + 0.0013 \, D + c$$

where T is the signal duration, D is the epicentral distance in km and c a constant different for each station. The constant c was calculated in a least squares sense using 15 events which had been assigned local magnitude ML by the National Observatory of Athens (1994). Thus, the above equation was calibrated at all PATNET stations for the local magnitude reported by the National Observatory of Athens. The result is that the local magnitude calculated for the events recorded in the Patras area is similar to Athens local magnitude.

THE PATRAS EARTHQUAKE SEQUENCE

The Patras earthquake sequence was well recorded by the Patras Seismic Network. The STA/LTA triggering technique was used in conjunction with continuous recording, enabling the recording of very small events down to magnitude 0.5 M_L.

The epicentral distribution of events recorded in the Patras area during 20 days after the main event is shown in Fig 5. Three main areas can be

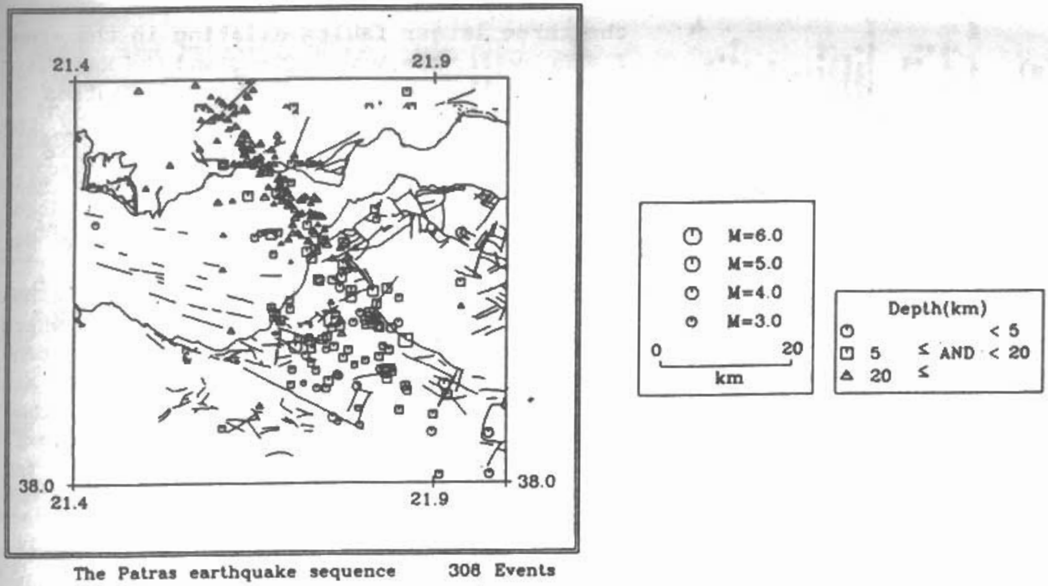


Fig. 5: The distribution of epicentres located in the area of Patras. M denotes local magnitude. The neotectonic faults presented in this diagram are taken as in Fig 3.

Σχ. 5: Η κατανομή των επικέντρων στην περιοχή της Πάτρας. M είναι το τοπικό μέγεθος. Τα νεοτεκτονικά ρήγματα που παρουσιάζονται στο διάγραμμα είναι από το Σχήμα 3.

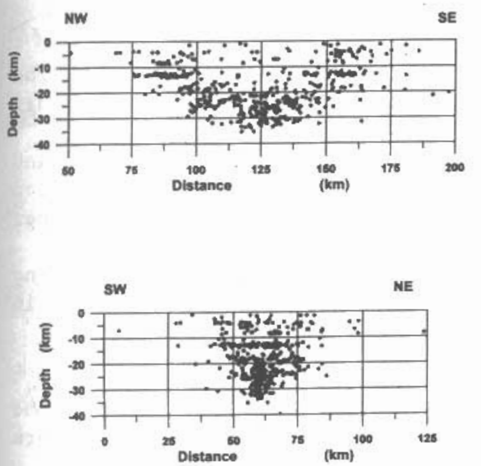


Fig. 6: Depth cross-section of hypocentres projected on a NW-SE line (a) and SW-NE (b), respectively.

Σχ. 6: Τομή ως προς το εστιακό βάθος των υποκέντρων προβαλόμενων πάνω σε διεύθυνση ΒΔ-ΝΑ (a) και ΝΔ-ΒΑ (b), αντίστοιχα.

identified. The first, is characterized by dispersed seismicity, which occurred onshore at the city of Patras area and adjacent localities. The second, is characterized by a concentration of seismicity forming almost a single line. This feature is extended from NW of the city of Patras towards the Trikhonis Lake in a NW-SE direction with events occurring at 22km to 30km focal depth, defining almost a flat zone at that depth and of a length of approximately 35km. Finally, the third area starts at the northwestern end of the flat zone dispersing at the location of Trikhonis Lake with shallower focal depths appearing.

Fig 6a demonstrates the focal depth distribution of the hypocentres projected on a NW-SE line and in Fig 6b projected perpendicular on a SW-NE line. Thus, the NW-SE trending feature is followed and analyzed in space.

The first area of dispersed seismicity at the city of Patras and surroundings is related to the numerous small neotectonic faults of NE-SW direction and

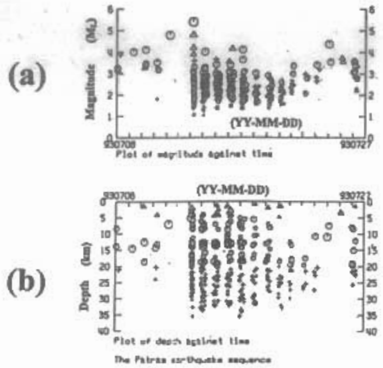


Fig. 7: The local magnitude distribution of the events in the present study versus their time of occurrence (a) and focal depth (b), respectively.

Σχ. 7: Η κατανομή του τοπικού μεγέθους των σεισμών της παρούσης εργασίας συναρτήσει του χρόνου γέννεσης (a) και του εστιακού βάθους (b), αντίστοιχα.

the three larger faults existing in the area. The Saravali, the Achaia Claus and the Kastritsi faults, all of NE-SW direction (Doutsos et al. 1989). These are cross-cutted by the Leontio basin of main direction WNW-ESE to the East. The majority of these events with shallow focal depth occurred at the Rio graben, and hence the damages to the villages described earlier on.

In the second area, the feature with a NW-SE trend direction lies at the junction where the Rio graben meets with the Patras graben. It is interesting that the focal depths are concentrated at the range of 22 to 30 kilometres, forming almost a flat line approximately 35km long. This is a new feature for the particular area and needs further detailed investigation.

The third area with the dispersed seismicity covers the Trikhonis Lake and surroundings. Here, focal depths range from 3 to 20 kilometres. This is also seen in other microearthquake studies in the area, observing deeper focal depths (Pedotti 1988, Melis 1992).

Finally, Fig 7a,b depicts the time distribution of the event magnitude and focal depth.

CONCLUSIONS

The Patras earthquake sequence revealed a new feature in the area. The flat at about 25km depth with a NW-SE trend at the northern end of the Gulf of Patras towards the Trikhonis Lake.

It was also observed the dispersed seismicity in the city of Patras and surroundings, where small faults are active. Similar observation was also made in the area of Trikhonis Lake, but with focal depths ranging deeper down to 20km.

Finally, it will be interesting to investigate the entire sequence using focal mechanism solutions and relate the new feature to the neotectonics in the area.

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