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THE PYRGOS (MARCH 26, 1993; M_S = 5.2) EARTHQUAKE SEQUENCE AS IT WAS RECORDED BY THE PATRAS SEISMIC NETWORK

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ABSTRACT

The Pyrgos earthquake occurred on March 26, 1993 (M_S=5.2). The earthquake sequence devastated an area of about 15km around the city of Pyrgos. This study presents the earthquake sequence as it was recorded by the newly established permanent Patras Seismic Network, which is based at the University of Patras Seismological Centre. All events of magnitude greater than 2.8 ML are well-located and they are included in the present analysis. The main part of the seismic activity is observed East of the city of Pyrgos defining almost a N-S trend. A fault plane solution reported for the main event denotes sinistral strike-slip movement on a fault plane with a NW-SE trend. The epicentre location lies East of the Epitalio fault zone which is an extensional tectonic feature of similar trend.

ΣΥΝΟΨΗ

Ο σεισμός του Πύργου έλαβε χώρα στις 26 Μαρτίου 1993 (MS=5.2). Οι ζημιές επεκτάθηκαν σε μία περιοχή περίπου 15km γύρω από την πόλη του Πύργου. Η παρούσα μελέτη παρουσιάζει την σεισμική ακολουθία όπως καταγράφηκε από το πρόσφατα εγκατεστημένο μόνιμο σεισμικό δίκτυο του Πανεπιστημίου της Πάτρας, το οποίο έχει την βάση του στο Σεισμολογικό Κέντρο του Πανεπιστημίου Πάτρας. Όλοι οι σεισμοί με τοπικό μέγεθος μεγαλύτερο των 2.8 Ρίχτερ προσδιορίσθηκαν με μεγάλη ακρίβεια και συμπεριλαμβάνονται στην παρούσα ανάλυση. Το κύριο μέρος της σεισμικής δραστηριότητας παρατηρήθηκε στα Ανατολικά της πόλης του Πύργου, διαμορφώνοντας διεύθυνση περίπου Β-Ν. Η επίλυση εστιακού μηχανισμού που αναφέρεται για τον κυρίως σεισμό δεικνύει δεξιόστροφη οριζόντια κίνηση σε επίπεδο διάρρηξης με διεύθυνση ΒΔ-ΝΑ. Το επίκεντρο προσδιορίζεται Ανατολικά της ρηγματογενούς ζώνης του Επιταλίου, η οποία είναι κανονικού τεκτονικού χαρακτήρα με την ίδια διεύθυνση.

INTRODUCTION

On March 26, 1993 an earthquake sequence with main shock of magnitude 5.2 MS occurred towards the southeastern end of the city of Pyrgos (Fig 1). Prior to the main shock there were three foreshocks. The first with magnitude 4.9 M_S occurred 33min prior to the main shock and its location was north just outside the city. The second with magnitude 2.9 M_S occurred 1min prior to the main event and the third with magnitude 4.3 M_S occurred 2min prior to the main event and its location was at the northwestern end of the city.

In this paper, the time, magnitude and space distribution of the aftershock sequence is presented. Events with local magnitude greater than 2.8 M_L are

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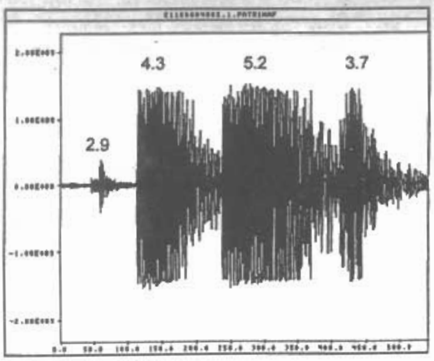


Fig. 1: The seismogram for the Pyrgos main shock, as it was recorded at the Nafpaktos (NAY1) outstation of the Patras Seismic Network. The numbers denote the M_S magnitudes of the events presented in this seismogram (two foreshocks, the main shock and one aftershock).

Σχ. 1: Το σεισμόγραμμα του σεισμού του Πύργου, όπως καταγράφηκε στον περιφερειακό σταθμό της Ναυπάκτου (NAY1). Τα νούμερα δείχνουν τα μεγέθη M_S των σεισμών που παρουσιάζονται στο σεισμόγραμμα (δύο προσεισμοί, ο κυρίως σεισμός και ένας μετασεισμός).

well-located and included in the analysis. These were recorded by the Patras Seismic Network which operates in the major region of western Greece.

THE PATRAS SEISMIC NETWORK

The 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 2). It consists of ten short period outstations, each with one vertical component (1Hz) seismometer operating at 60dB dynamic range and in a 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 STA/LTA technique is employed for event triggering. All events then are processed and located following the procedure which is described later on.

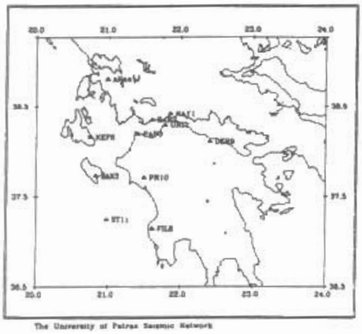


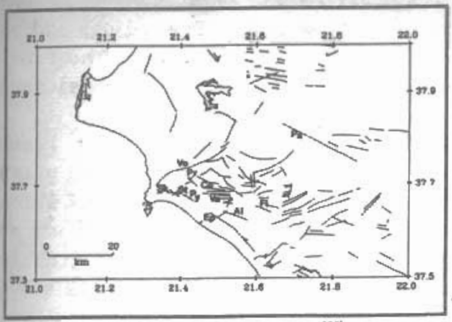
Fig. 2: The present station distribution of the Patras Seismic Network.

Σχ. 2: Η παρούσα διάταξη του μόνιμου Σεισμικού Δικτύου του Πανεπιστημίου της Πάτρας.

THE PYRGOS AREA

In the present study, as Pyrgos area is named the area including the city of Pyrgos, western Greece, and the adjacent area of a radius approximately 15km around the city. The neotectonics of this area are characterized by three main trends of normal faulting (Fig. 3) which started taking place in Middle-Upper Miocene (Lekkas et al. 1992). These have been taken from the neotectonic study of Lekkas et al. (1992) and can be classified as follows:

a) The NW-SE trend characterizes the faults in the localities of Epitalio (SSE of the city of Pyrgos), Alfeiousa (SE of the city), Flokas (E of the city)



Neotectonics of the Pyrgos area (after Lekkas et al. 1992)

Fig. 3: Neotectonics of the Pyrgos area (after Lekkas et al. 1992). Py: Pyrgos, Ep: Epitalio, Al: Alfeiousa, Fl: Flokas, Pr: Prasino, Va: Varvasaina, Co: Colirio, Sk: Skourochori, Vo: Vounargo, St: St John, Pa: Panopoulou.

Σχ. 3: Νεοτεκτονική της περιοχής του Πύργου (από τους Λέκκας και συνεργάτες 1992). Py: Πύργος, Ep: Επιτάλιο, Al: Αλφειούσα, Fl: Φλόκας, Pr: Πράσινο, Va: Βαρβάσαινα, Co: Κολίριο, Sk: Σκουροχώρι, Vo: Βούναργο, St: Αγιος Ιωάννης, Pa: Πανόπουλου.

and Prasino (N of the city). This main zone of NW-SE trend can be called the Epitalio fault zone, as the fault of the Epitalio locality is the greatest in length and dominates the neotectonics of this zone. This trend can also be taken as the dominant zone of faulting which exists at the city of Pyrgos. The Epitalio fault is also the SW bound of the major Pyrgos basin with the Panopoulou fault as the NE bound respectively.

b) The E-W trend characterizes the faults in the localities of Alfeiousa, Varvasaina and Colirio to the West and Skourochori to the East of the city of Pyrgos. This fault zone of E-W trend is called the Alfeios fault zone, because it is of the same direction as the Alfeios river to the South of the city of Pyrgos.

c) The NE-SW trend characterizes the faults in the localities of Vounargon and St.John, North of the city of Pyrgos, and is called the Vounargon fault zone, as the Vounargon fault dominates the entire zone and is the greatest in length fault.

It is important to note that these three major fault trends coexist at the city of Pyrgos, where they all seem to converge. It is also of a great importance that strike-slip movement on the NE-SW and NW-SE trending faults has not been reported. To the contrary, strike-slip movement has been reported on the E-W trend faulting which dominates the area East of the city of Pyrgos. It is also important to note that the NW-SE faults do cut the E-W faults and it is possible to consider also some small strike-slip component on them (Lekkas et al. 1992). This could be important in order to combining and linking these trends with the E-W trending normal faults to the west and east of the city.

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 5km on both epicentre and focal depth locations, and a RMS of travel time residuals less than 0.15.

To succeed these results on event locations, there was performed an exhaustive trial on various 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). These models were used with events with well known epicentre and focal depth, as they were reported by the USGS (taken from the monthly listing of NEIC) and the National Observatory of Athens (monthly Bulletins). In addition, these events were well recorded at all six operating

PATNET stations (note that during the Pyrgos earthquake sequence only the stations numbered 1 to 6 were fully operating), with a clear P-arrival and an accuracy (at the time of the earthquake) enough to measure S-arrival. The final velocity model used for the area of Pyrgos is shown in Table 1. This model gave the smallest RMS values on the events selected.

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

P-velocity	Depth
(km/sec)	(km)
5.7	0.0
6.0	5.0
6.4	17.0
7.9	40.0

Then, all the recorded events by at least five 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 and these location were finally accepted. Their epicentre distribution is shown in Fig 4.

The magnitude which is reported for all the events is the local magnitude M_L 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 procedure described in Melis et al. (1989) in order to define the constant parameters. Thus, the following equation derived was used:

$$M_L = 2.31 \, \mathrm{Log}(\mathbf{T}) + 0.0012 \, \mathbf{D} + \mathbf{c}$$

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 10 events which had been assigned local magnitude ML by the National Observatory of Athens. 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 Pyrgos area is similar to the Athens local magnitude.

THE PYRGOS EARTHQUAKE SEQUENCE

The epicentral distribution of events, which were recorded by PATNET (note that during the Pyrgos earthquake sequence only the stations numbered 1 to 6 were fully operating) and located following the above described procedure is shown in Fig 5. It can be seen that the area to the East of the city of Pyrgos is the area with the vast number of events occurred. Fig 6 shows the magnitude (Fig 6a) and depth (Fig 6b) distribution of the events located by PATNET versus time of occurrence. It is interesting to note that depth ranges from 0 to 20 km and that there was a range up to magnitude 4ML events occurring for over a two-weeks period following the occurrence of the main event.

A fault plane solution given for the main shock in the USGS preliminary

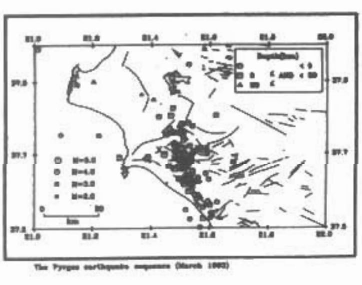


Fig. 4: The distribution of epicentres located in the area of Pyrgos from 25 March 1993 to 6 April 1993 inclusive. M denotes local magnitude. The neotectonic faults presented in this diagram are after Lekkas et al. (1992).

Σχ. 4: *Η κατανομή των επικέντρων στην περιοχή του Πύργου από 25 Μαρτίου 1993 έως 6 Απριλίου 1993. Μ είναι το τοπικό μέγεθος. Τα νεοτεκτονικά ρήγματα που παρουσιάζονται στο διάγραμμα είναι από τους Λέκκας και συνεργάτες (1992).*

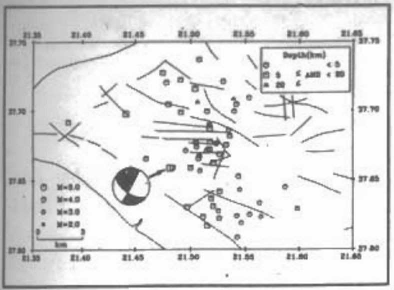


Fig. 5: The earthquake sequence at the Pyrgos area. The neotectonic faults presented in this diagram are after Lekkas et al. (1992). The fault plane solution of the main event is shown as taken from the USGS preliminary results (1993). M denotes local magnitude.

Σχ. 5: Η σεισμική ακολουθία στην περιοχή του Πύργου. Τα νεοτεκτονικά ρήγματα που παρουσιάζονται στο διάγραμμα είναι από τους Λέκκας και συνεργάτες (1992). Η επίλυση εστιακού μηχανισμού για τον κυρίως σεισμό είναι από το USGS πρώτα αποτελέσματα (1993). M είναι το τοπικό μέγεθος.

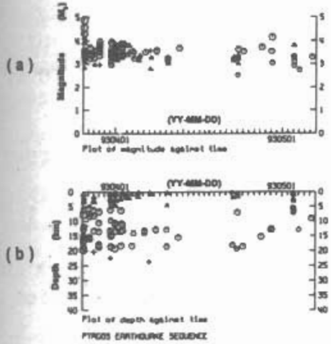


Fig. 6: The local magnitude distribution of the events considered in the present study versus their time of occurrence (a) and focal depth (b), respectively.

Σχ. 6: Η κατανομή του τοπικού μεγέθους των σεισμών που χρησιμοποιήθηκαν στην παρούσα εργασία συναρτήσει του χρόνου γένεσης (a) και του εστιακού βάθους (b), αντίστοιχα.

listings (March 1993), shows a fault-plane of NW-SE strike and sinistral strike-slip movement denoted (Fig 5). This can be well justified as the primary auxiliary plane of this fault plane solution, because the dominant trend of faulting in the epicentral area (SE of the city of Pyrgos) is the Epitalio fault zone. This is a NW-SE trending normal fault zone with the epicentre of the main shock occurred at the footwall East of the main escarpment. It is also important to note that faults of NNE-SSW strike, which is the trend of the secondary auxiliary plane of the fault plane solution, do not exist at the epicentral locality or the adjacent to it area.

Thus a NW-SE sinistral strike-slip movement can be sufficiently justified for the main shock.

It will be very interesting to see other fault plane solutions for the events occurred at all the described previously fault zones. This would be very useful in order to model the cross-cutting of these zones through the entire area. This kind of work will be performed using the data from a locally established microearthquake network, which operated by the Patras Seismological Centre in cooperation with the University of Leicester, during the aftershock sequence and for a period of one month after the occurrence of the main shock.

CONCLUSIONS

In the present study the events from the Pyrgos earthquake sequence, of magnitude greater than 2.8 MS are presented. The focal mechanism solution of the main shock denotes sinistral strike-slip movement on a NW-SE direction, which coincides with the trend of the Epitalio fault zone existing at the epicentral location of this event. However, strike-slip movement has been reported only on E-W trend faults (Lekkas et al. 1992).

Furthermore, the study of the aftershocks recorded by the locally established microearthquake network will investigate the possibility of strike-slip movements on both E-W and NW-SE trending faults.

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