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A STUDY OF THE EARTHQUAKE OF NOVEMBER 6, 1992 IN IZMIR (TURKEY)

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ABSTRACT

On November 6, 1992, at 19:08 GMT, an earthquake occurred of surface wave magnitude Ms=6.0 and epicentral coordinates 38.19°N, 27.05°E. This event with epicenter at the Kusandasi Bay caused severe damage in the villages around the city of Izmir. The study of the aftershock distribution reveals a NNE-SSW delineation of the epicenters following the distribution of the major neotectonic faults in the area. Teleseismic waveform modeling revealed the focal parameters of the main shock with strike 239°, dip 81°, rake -165°, focal depth 9 km and seismic moment $0.96*10^{18}$ Ntm. This mechanism involves dextral strike-slip motion and it is possible strands of the North Anatolian Fault to extend southern and affect the tectonic regime of the area.

ΠΕΡΙΛΗΨΗ

Το Νοέμβριο του 1992, στις 19:08 GMT, έγινε σεισμός με μέγεθος 6.0 και συντεταγμένες 38.19°Β και 27.05°Α στον κόλπο του Κουσάντασι της Τουρκίας. Ο σεισμός, αν και μετρίου μεγέθους, εντούτοις προκάλεσε εκτεταμένες βλάβες στην ευρύτερη περιοχή της πόλης της Σμύρνης. Στην παρούσα εργασία μελετούνται οι μετασεισμοί του σεισμού του Νοεμβρίου καθώς και ο μηχανισμός γένεσης του κύριου σεισμού. Οι μετασεισμοί κατανέμονται σε διεύθυνση ΒΒΑ-ΝΝΔ, σε καλή συμφωνία με τα νεοτεκτονικά ρήγματα της περιοχής. Από τη μελέτη των κυματομορφών των P και SH κυμάτων, που καταγράφηκαν από σταθμούς σε αποστάσεις 30°-90°, με τη μέθοδο της αντιστροφής προέκυψε ότι ο κύριος σεισμός προκλήθηκε από τη μετατόπιση σε ένα ρήγμα οριζόντιας μετατόπισης, με παράταξη 239°, κλίση 81° και γωνία ολίσθησης -165°. Το βάθος της εστίας είναι 9 km και η σεισμική ροπή ειναι ιση με $0.96*10^{18}$ Ntm.

INTRODUCTION

On November 6, 1992 a moderate size earthquake (Ms=6.0) occurred at Kusadasi Bay, 60 km away from the city of Izmir at western Turkey and 45 km from Samos island. The earthquake was felt strongly along coastal Turkey as well at the islands of Samos and Chios in the Aegean Sea. Actually, this is the largest event since 1974 (Ms=5.5) to affect the city of Izmir. The earthquake did not produce any surface expression of the fault rupture.

Briefly, the occurrence of this shock is attributed to the westward movement of the Anatolian block relative to Eurasia (see fig.1). This escape of Anatolia is the result of the movement towards north of the African and Arabian plates relative to Eurasia (McKenzie 1978; Dewey et al., 1986; Kiratzi 1993, Papazachos et al., 1991, 1992; Kiratzi and Papazachos 1994). From plate motion models is estimated that

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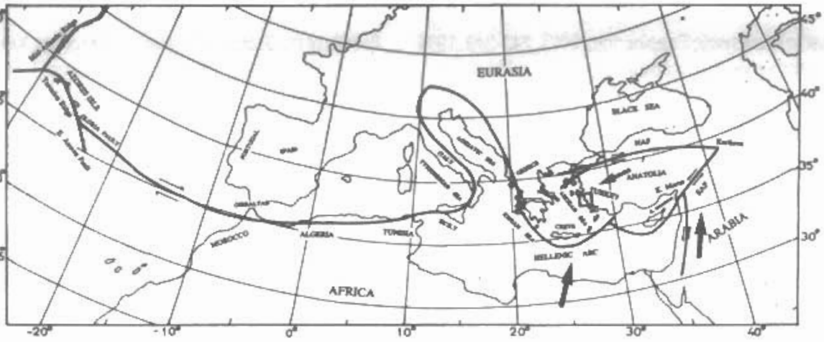

Fig. 1: The tectonic regime of the broader Aegean area showing the Anatolian block and the motion of Africa and Arabia towards north. (From Kiratzi and Papazachos, 1994).

Africa is approaching Eurasia at 10 mm/yr (Chase 1978, DeMets et al., 1990).

The earthquake of November 6, 1992 occurred near the city of Izmir which in deterministic terms belongs to the first degree hazard zone in the official Earthquake Hazard Regionalization Map of Turkey. Moreover, it occurred in an area where we have a lack of any large earthquake since 1964 when the WWSSN network was installed, thus, it is interesting to study the properties of the sequence. In the present paper we present an analysis of the aftershock distribution as well the focal mechanism of the mainshock.

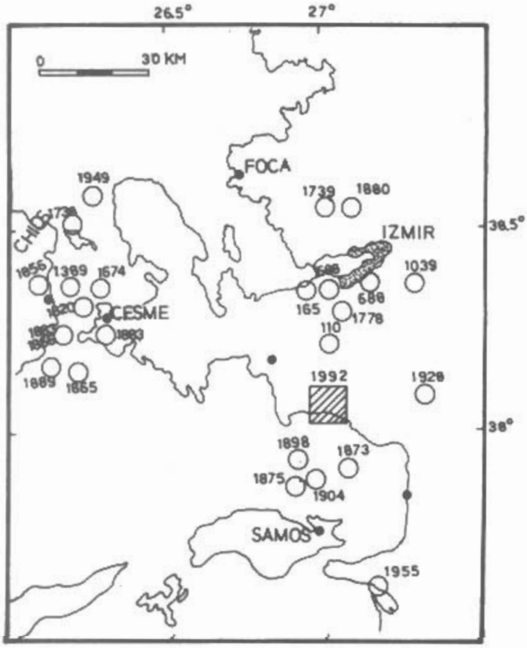

Fig.2: Distribution of the largest earthquakes with M>6.0 for the period 110 A.D - 1992 that occurred in the western coastal area of Turkey.

INFORMATION ON THE HISTORICAL SEISMICITY

There is a very good record of historical earthquakes that have affected the western coastal area of Turkey. Ambraseys (1988) and Papazachos and Papazachou (1989) cite that historical cities in the vicinity of the Izmir were destroyed in 17 A.D, 47, 105 and 178. Recent studies of earthquake hazard indicate expected peak ground acceleration of 0.5 and 0.6g for return periods of 225 and 475 years, respectively (Erdik et al., 1985).

Table 1 lists the largest earthquakes that have been reported to affect the broader epicentral area of the November 6, 1992 earthquake. The source of this catalogue is the work of Ambraseys (1988) and Papazachos and Papazachou (1989).

Figure (2) shows the distribution of the earthquakes with M>6.0 that are listed in Table 1.

LOCATION OF THE MAIN SHOCK AND SPATIAL DISTRIBUTION OF THE AFTERSHOCKS

In order to constrain the location of the mainshock and of the aftershocks

Table 1: Information on the historical and present century large earthquakes that occurred in the broader epicentral volume of the November 6, 1992 earthquake

Year	Date		φ°N	λ°E	Ms	Macroseismic Intensity	
110			38.2	27.0	6.8	IX	Ephesos
165			38.4	26.9	(6.5)	VIII	Izmir
688			38.4	27.2	(6.5)	IX	Izmir
1039	2/2		38.4	27.3	(6.8)	IX	Izmir
1389	20/3		38.4	26.3	(6.8)	IX	Chios
1674	23/1		38.4	26.4	(6.5)	VIII	Chios
1688	10/7	11:45	38.4	27.0	(6.8)	X	Izmir
1738	23/12	10:	38.5	26.3	(6.0)	VI	Chios
1739	4/4	Night	38.6	26.9	(6.6)	IX	Izmir
1778	16/6		38.3	27.0	(6.5)	IX	Izmir
1820	17/3		38.4	26.2	(6.0)	VII	Chios
1856	13/11		38.4	26.1	(6.6)	IX	Chios
1863	16/8		38.3	26.3	(6.2)	VIII	Chios
1865	11/10		37.7	27.1	(6.0)	VII	Samos
1865	11/11		38.2	26.2	(6.2)	VIII	Chios
1866	2/2		38.3	26.2	(6.3)	VIII	Chios
1868	3/5		37.8	27.0	(6.0)	VII	Samos
1873	31/1	23:13	37.8	27.1	(6.6)	VIII	Samos
1875	7/7		37.7	26.7	(6.3)	VIII	Samos
1877	13/10		37.7	27.0	(6.0)	VIII	Samos
1880	29/7	04:40	38.6	27.1	6.7	IX	Izmir
1881	3/4	11:40	38.2	26.1	6.4	XI	Chios
1883	15/10	15:30	38.3	26.4	6.5	IX	Tsesme
1893	12/3		37.9	26.9	6.6	VII	Samos
1904	11/8	06:08	37.7	26.9	6.8	VIII	Samos
1928	31/3	00:47	38.1	27.4	6.5	IX	Torbali
1941	13/7	15:39	38.1	26.2	6.0	V	Chios
1949	23/7	15:03	38.6	26.3	6.7	IX	Kardamyla
1953	2/5		38.6	26.6	5.6	V	Izmir
1955	16/7	07:07	37.6	27.2	6.9	VIII	Agathonisi
1969	6/4		38.4	26.4	5.8		Cesme
1974	1/2		38.5	27.2	5.5		Izmir

all the arrivals at the national network and at the stations of the neigbouring countries were collected and analysed using HYPO 71 software. A velocity model applicable to the area was used in the analysis (Panagiotopoulos, 1984). After a considerable number of trial runs the best constrained solution for the parameters of the main shock are: 38.19°N, 27.05°E, depth 10 km. This solution places the epicenter at the Menderes Massif, about 50 km NNE from the island of Samos.

In order to use the best of the available information concerning the location of the earthquake foci of the sequence we finally used the focal parameters of the events for which the standard error in the estimation of the epicenter (ERH), the standard error in the estimation of the focal depth (ERZ), the root mean square of the time residuals (RMS) and the number of station readings (N.O.) satisfied the following conditions: ERH≤3 Km, ERZ≤5 Km, RMS≤0.6 sec and N.O.≥6. The parameters of these earthquakes are listed in table 2.

Table 2: Information on the aftershocks recorded in the period November 6-February 28, 1993. The quality of the solution, is represented by N.O, RMS, ERH, ERZ and Q.

DATE		ORIGIN TIME	LAT.	LON.	D(km)	M_L	N.O	RMS	ERH	ERZ	Q
Nov	06	19: 8: 9.6	38.19	27.05	12.	5.7	70	0.7	2.1	2.7	C
"		20: 5:59.3	38.02	26.99	1.	4.7	35	0.4	1.2	2.8	C
"		22: 3:47.7	38.33	27.09	8.	3.8	28	0.4	1.7	2.7	C
"	07	3:25:44.1	38.17	27.00	5.	4.0	23	0.3	1.6	2.7	C
"		4:36:38.3	38.21	27.07	20.	3.8	24	0.6	2.8	2.9	B
"		4:41: 4.1	38.13	26.91	10.	3.7	12	0.2	2.0	1.8	C
"		9:30:21.2	38.04	27.03	14.	3.7	15	0.4	2.8	2.9	B
"		13:52: 4.7	38.01	27.04	7.	3.7	7	0.3	3.0	3.2	B
"		16:33:17.0	38.03	26.91	6.	3.7	13	0.4	2.5	3.3	C
"		20:53: 1.9	38.14	26.88	5.	3.6	26	0.5	2.1	2.7	B
"	08	9:32:38.2	38.05	26.95	7.	3.6	19	0.3	1.8	2.3	B
"		14:26:31.2	38.05	26.98	1.	4.0	18	0.5	3.0	3.1	B
"		18:21:21.7	38.17	26.97	15.	3.8	37	0.5	1.7	2.4	B
"		19:28:12.9	38.12	26.93	11.	4.0	30	0.5	1.8	2.7	B
"	10	15:52:15.9	38.03	27.00	11.	3.7	19	0.4	2.4	3.2	B
"	11	6:26: 3.2	38.05	26.97	1.	3.4	7	0.4	3.0	2.4	C
"	12	15:11:11.0	38.74	26.49	9.	4.6	62	0.6	1.6	2.3	C
"		15:19:12.1	38.71	26.52	15.	4.3	49	0.6	1.6	2.0	C
"		17:48:24.3	38.76	26.57	16.	3.8	28	0.6	2.4	2.5	C
"	15	19:17:24.3	38.06	26.86	0.	3.3	8	0.2	3.7	2.9	C
"	19	18: 7:52.8	38.07	26.88	5.	4.0	28	0.3	1.8	2.6	B
Dec	05	6:26:18.5	38.07	26.99	9.	4.1	29	0.3	1.5	2.1	B
"		6:35:37.5	38.22	27.20	2.	3.7	11	0.4	2.3	3.4	B
"	10	3: 2:53.2	38.02	26.85	1.	3.7	11	0.3	3.0	2.1	C
"		10:18: 0.6	38.02	26.88	3.	3.8	27	0.4	1.7	3.3	C
Jan	07	15:16:57.3	38.72	26.57	1.	3.5	14	0.4	2.5	2.6	C
"	20	4: 0:59.4	38.11	26.92	1.	3.9	22	0.4	2.8	3.9	C

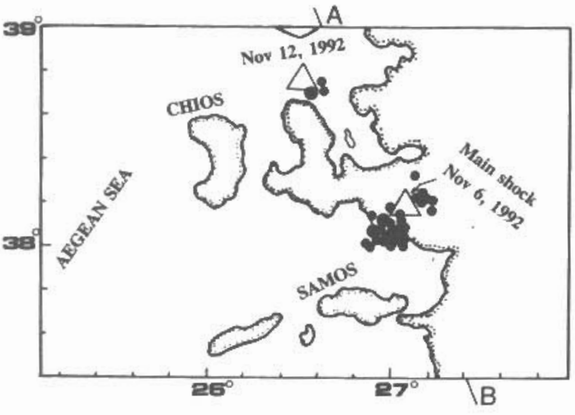

Fig. 3: Distribution of the earthquakes that occurred in the period November 6 - February 28, 1992 and are listed in Table 2.

Figure (3) shows the distribution of the best located earthquakes of the sequence. It is observed that the epicentres tend to delineate in a NNE-SSW line which is in fairly good agreement with the fault plane solution of the main shock and the distribution of major tectonic faults (Dewey and Sengor, 1979). It is interesting to see that there are two concentrations of aftershocks. On November 12, 1992 the seismic activity migrated to the north and two earthquakes with local magnitude 4.6 and 4.3 occurred in the epicentral area of the earthquake of 23 July 1949. In the same area, on May 24, 1994 another earthquake occurred with

M_L=5.7. These earthquakes and their aftershocks are located around 80 km away from the source region of the main shock. It is probable that the seismic activity of the Kusandasi Bay that started on November 6 triggered some distant faults.

The proposed formula between the length of the fault and the magnitude (Papazachos and Papazachou, 1989) predicts for an earthquake of Ms=6.0 a fault length equal to 16 Km, fault width equal to 10 km and displacement at the source equal to 17 cm. Actually, from the distribution of the aftershocks shown in figure (3) it is seen that the fault length is of the order of 20 km.

Figure (4) represents a vertical cross section along the line AB (shown in fig. 3). It is seen that the foci indicate a nearly vertical diping fault towards NNW with a mean dip of about 75°. The focus of the main shock is situated at a depth of about 10 Km at the center of the aftershock distribution. Most of the aftershock foci are distributed in the first 10 km of the crust.

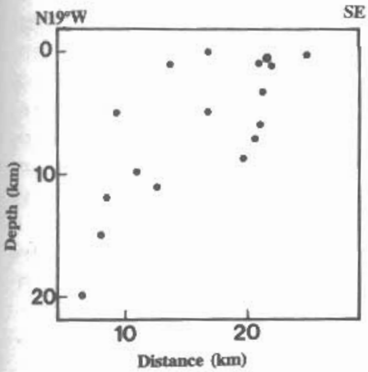

Fig. 4: Cross section along the line AB shown in fig.3. The distribution of the foci indicates a steeply dipping fault to NNW.

FOCAL MECHANISM OF THE MAIN SHOCK

Long period P and SH waves recorded at teleseismic distances by the World Wide Standard Seismograph Network (WWSSN) were inverted simultaneously in order to determine the centroid depth, the far-field source time function, the seismic moment and the source mechanism (strike, dip and rake) using the inversion procedure of Nabelek (1984). To avoid strong mantle and core interference we only used records from stations at distances between 30°-90° for P waves and 40°-70° for SH waves. At these distances body waves travel mostly in the lower mantle and the computation of synthetic seismograms is simpler. The magnitude of the earthquake was not large enough to produce good records at many stations resulting in a rather poor azimuthal coverage.

Seven P waveforms and 3 SH - waveforms were finally sellected for inversion. The records were digitized and interpolated at 4 and 2 samples per second for P and S waves, respectively. The seismograms are equalized to a common instrument magnification and epicentral distance. The crustal structure at the source is assumed to be a half-space with Vp=6.3, Vs=3.5 and density = 2.8 gr/cm^3.

The earthquake source parameters are estimated by mathcing the observed seismogams with the synthetic ones in a least square's sense. The final solution is presented in figure (5). The match is satisfactory at most of the stations even though most of them are near the nodal planes. The match is very good for the SH- waveforms. The waveforms are complicated at least for their later part and are typical of strike-slip earthquakes like the ones observed in the northern Aegean area (Kiratzi et al., 1991). The centroid depth is well contsrained (9±3 Km) and is in agreement with the estimation of the depth using the HYPO 71 program. The obtained solution (strike =239°±10, dip=81°±5 and rake=-165°±5), scalar seismic moment 0.96*10^{18}Nt.m, represents motion on a dextral strike-slip fault. The solution obtained here is in good agreement with the one proposed from the NEIS and HARVARD centers. From the distribution of the aftershocks we assume that from the two nodal planes the one that trends NE and dips to the NNW is the fault plane.

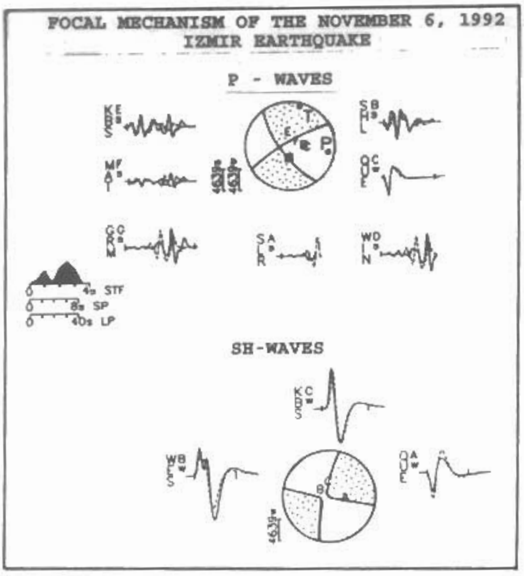

Fig. 5: Radiation pattern, observed waveforms and synthetic waveforms (dashed line) of the mainshock of November 6, 1992. Amplitudes are normalized to an instrument gain of 3000 at a distance of 40°. The station code is identified to the left of each waveform together with an upper case letter, which identifies the position in the focal sphere, and a lower case letter that indicates the type of the instrument (s= short-period, w=long period). The vertical bar near the focal sphere shows the scale in μm. The source time function is shown in the middle of the figure.

CONCLUSIONS

This paper presents an analysis of the properties of the November 6, 1992 sequence (M=6.0) that occurred at the Kusandasi Bay of Turkey. The distribution of the best located aftershocks shows that the main shock occurred in a fault that has a total length of about 16 Km dipping steeply to NNW. Most of the earthquake foci have focal depths that range from 5-13 Km. The main shock occurred at a depth of about 9 Km (determined from the inversion of body waves) and then the rupture propagated towards NNE. The fact that most of the damage was reported to occur in the villages to the south-west of the city of Izmir (Kandili Observatory report 1993), strongly supports this assumption.

The best double couple mechanism calculated for the main shock, from the inversion of long and short period P and SH waves corresponds to two nodal planes with strike= 146°, dip=74°, rake=351 the first and strike 239°, dip 81° and rake -165°, the second, focal depth h=9 Km, and seismic moment equal to $0.96*10^{18}$ Ntm. From the distribution of the aftershocks we assume that the second plane that dips steeply to the NNW is the fault plane.

The most important of the present paper is the fact that it involves dextral strike-slip motion in an area that we had little information from recent large earthquakes. This motion indicates that probably, there are strands of the North Anatolian Fault Zone that probably extend southern and affect the tectonic regime of that area.

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