A PRELIMINARY REPORT ON SULTANDAĞI-AFYON EARTHQUAKE OF FEBRUARY 3, 2002*

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February 7, 2002

**This report based on the preliminary earthquake prepared by the author on February 4,2002 in Turkish together with new inputs from Halil Kumsar of Pamukkale University and new data.*

1 INTRODUCTION

An earthquake with a magnitude of 6.2 on Richter scale occurred near the town of Sultandağı of Afyon Province of Turkey at 9:11 AM (7:11 GMT) on Turkish Standard Time. This earthquake will be named as Sultandağı-Afyon earhquake in this report. According to preliminary reports, the heavy damage occurred in the towns of Sultandağı and Çay. It has been also reported that some fault breaks observed in the villages of Kırca, Dörtköy, Yakasenek and Gedil. The magnitude of earthquake differ between 5.6 and 6.7 according to various magnitude scales. The official reports indicated that dead toll was 45. Most of the people were killed by the collapse of walls of buildings.

2 THE LOCATION OF EARTHQUAKE AND ITS MAGNITUDE

The coordinates of the hypo-center and magnitude of the earthquake is given in Table 1. Figure 1 and Figure 2 show the epicenter location of the earthquake according to the Earthquake Engineering Department of Turkey and USGS. The heavy damage occurred in the towns of Sultandağı and Çay. Figure 3 shows a LANDSAT view of the earthquake region

Table 1 The hpocenter parameters and magnitude of the earthquake

Institute	Latitude (E)	Longitude (N)	H (km)	M_L	M_S	M_w	M_b
DAD	38.460	31.300	11.0	6.1			
Kandilli	38.581	31.248	5.0	6.0			
USGS	38.557	31.116	10.0	6.2	6.5	6.3	5.7
ETHZ	38.520	31.160	24.0		6.2	6.7	
HARVARD	38.630	31.120	15.0		6.5	6.5	

3 THE SEISMICITY AND TECTONICS OF THE REGION

The earthquake region is just on the boundary of 1st and 2nd degree of earthquake risk map for Turkey prepared by the Earthquake Research Department (DAD-ERD) of Turkey. The last largest earthquake in the region occurred in Dinar on October 1, 1995. The known active faults in the region are Sultandağı Fault, Tatarlı Fault and Kumdanlı Fault as shown in Figure 4 according to MTA. Sultandağı fault is a dextral fault, which had a thrust type deformation sense initially and then its deformation sense become normal at later stages. Tatarlı fault and Kumdanlı fault are sinistral oblique faults. The region seismically become very active following the seismic activity in Denizli region (Figues 5 and 6). An earthquake with a magnitude of 5.9 occurred at Eber Lake in 2001. The faulting was due to mainly normal faulting and its strike was almost parallel to that of Sultandağı Fault. Figure 7 shows the faulting mechanisms in the region and its vicinity according to USGS. As seen from the figure, the normal faulting is the dominant mechanism in the region. Earthquakes occur along the faults with strikes NW and NE due to normal faulting.

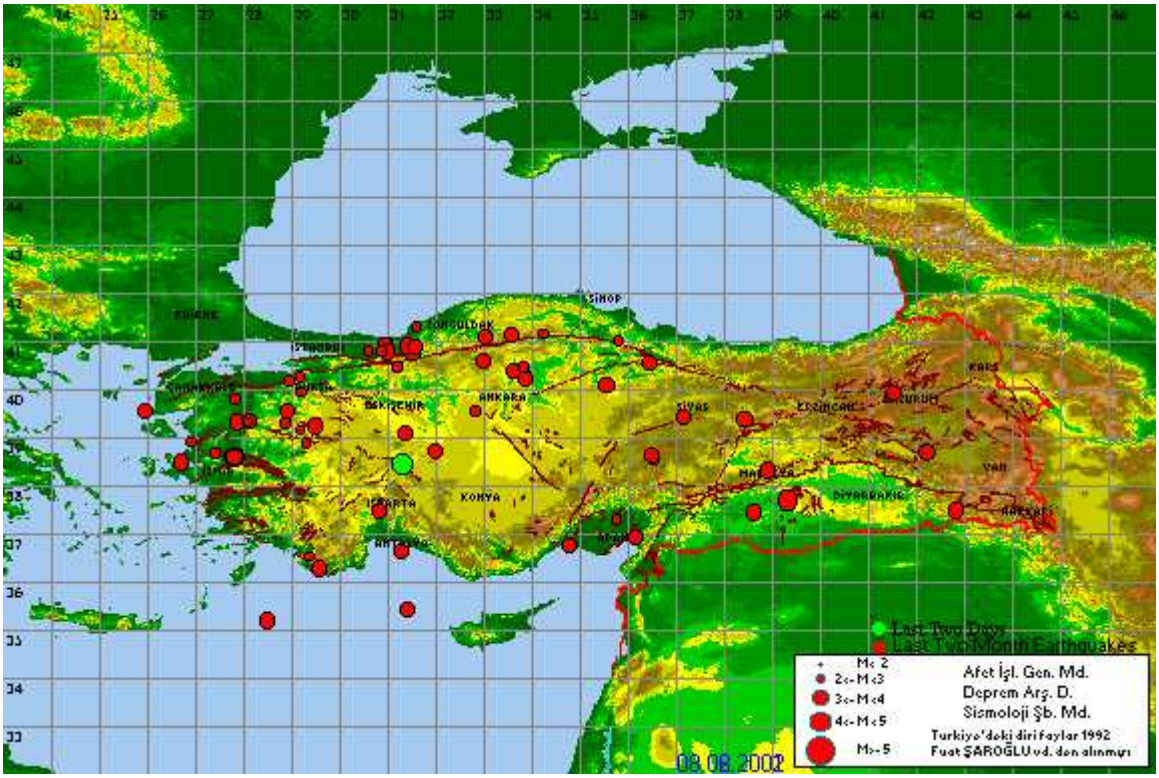


Figure 1 The location of earthquake by the Earthquake Research Department of Turkey

AFYON PROVINCE, TURKEY

2002 02 03 07:11:29 UTC 38.56N 31.11E Depth: 10.0 km, Magnitude: 6.2

USGS National Earthquake Information Center 02/02/03 16:13:21 UTC

Figure 2 The earthquake location according to USGS

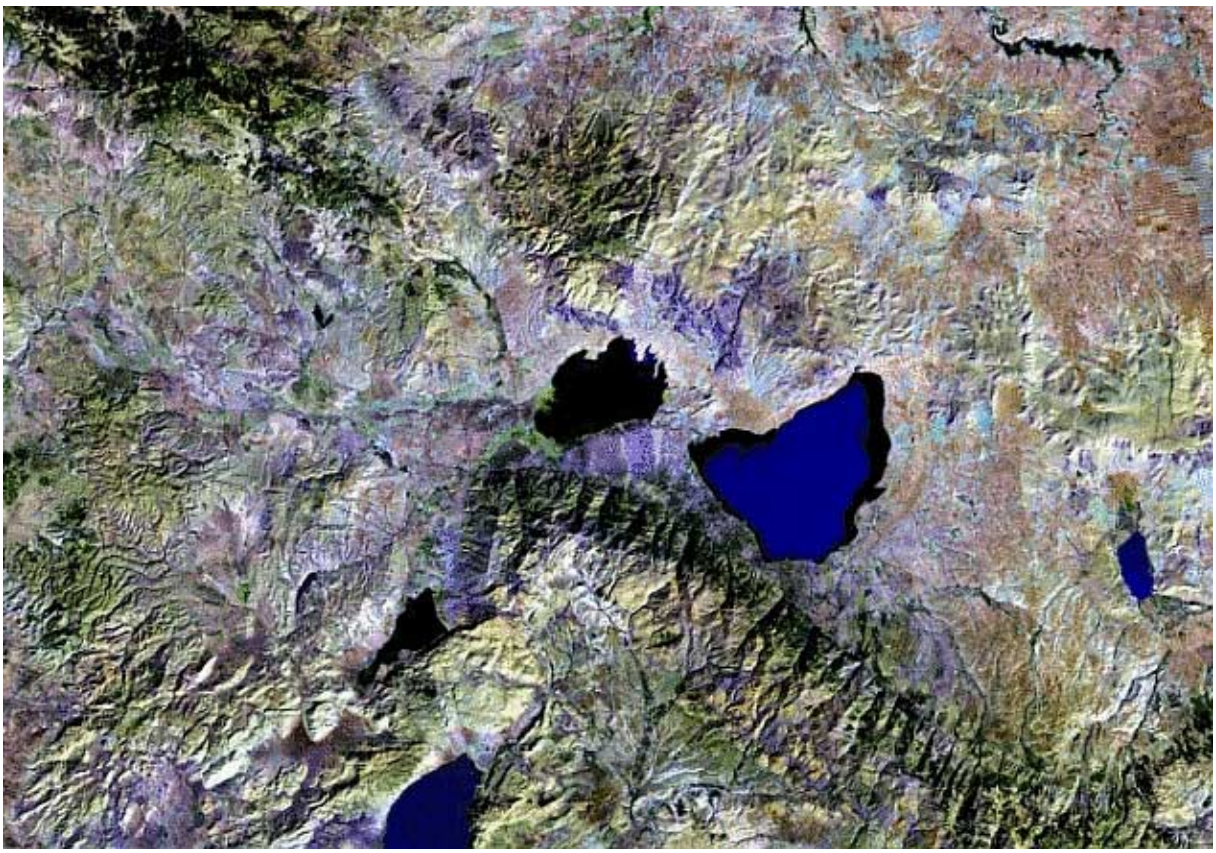


Figure 3 A LANDSAT view of the region (after MTA)

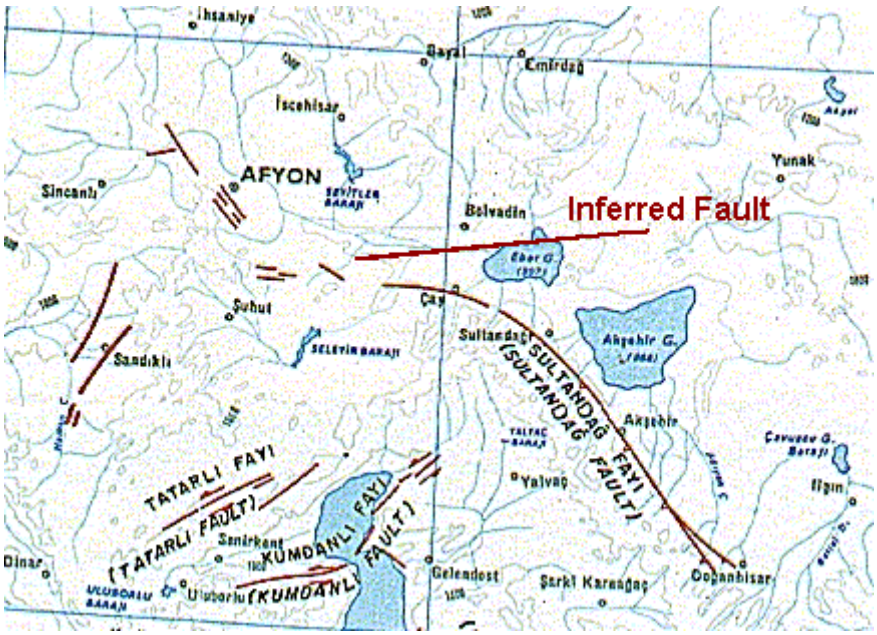


Figure 4 Active faults and the surface projection of the inferred fault in the region (Active fault map by MTA)

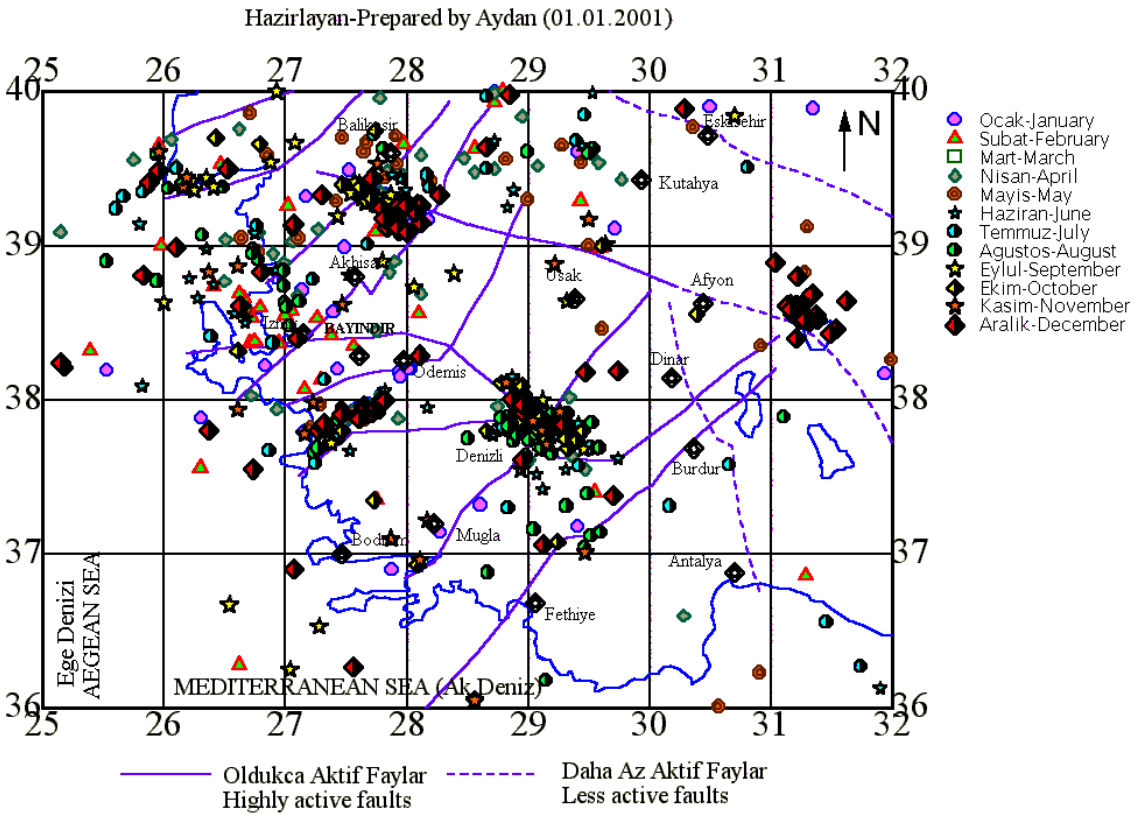


Figure 5 Seismic activity of the Western Anatolia in 2000

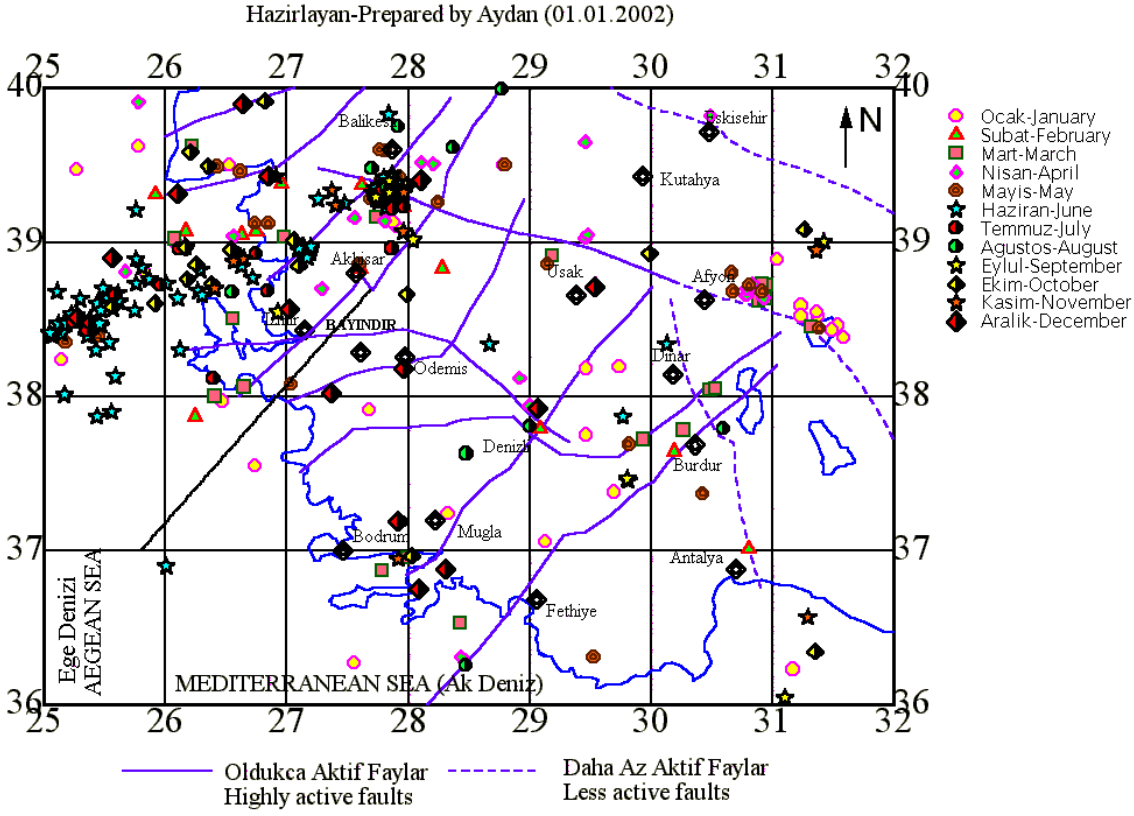


Figure 6 Seismic activity of the Western Anatolia in 2001

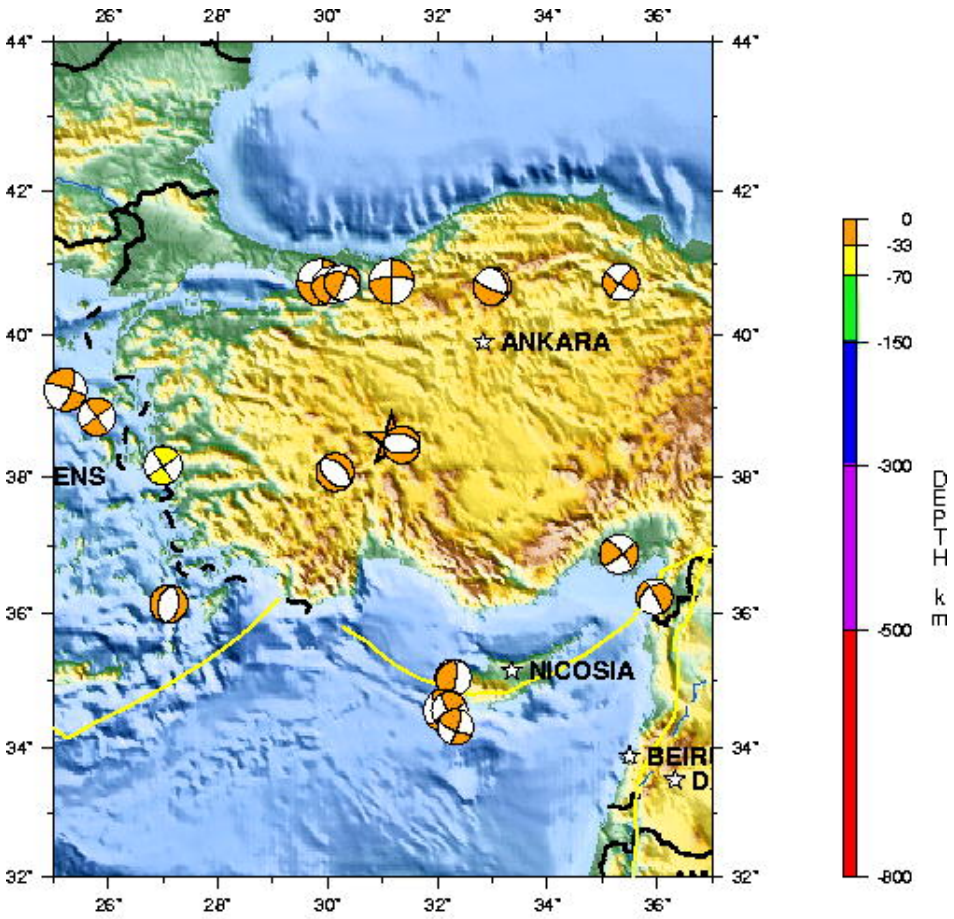


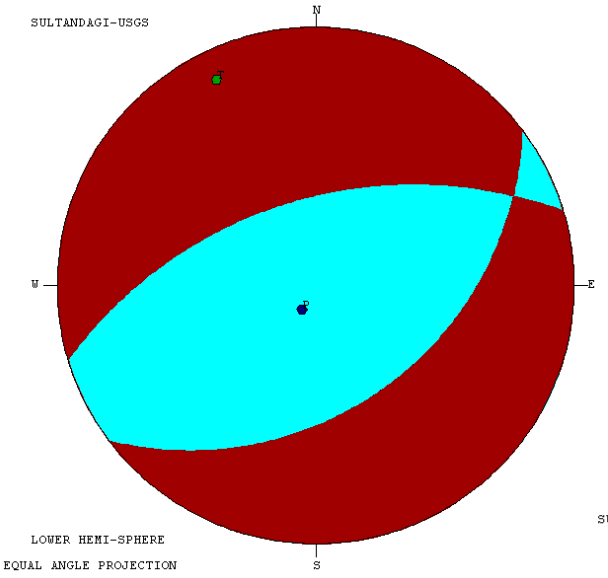
Figure 7 Faulting mechanisms in the region and its vicinity according to USGS

4 FAULTING MECHANISM

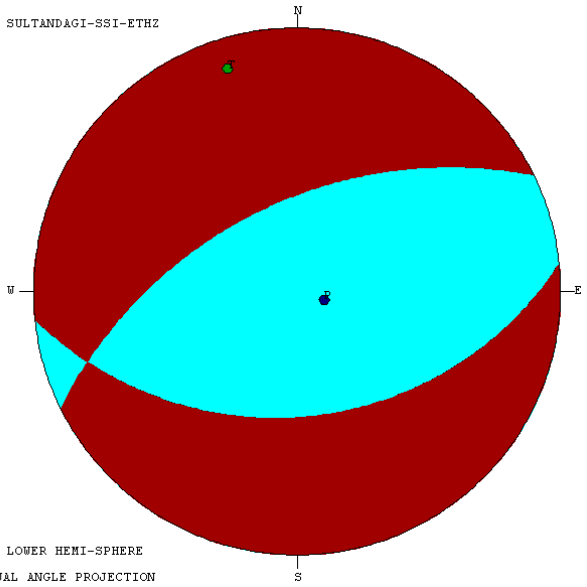
USGS, HARVARD and Swiss Seismological Institute obtained focal plane solutions. Their preliminary solutions have been revised and the revised solutions are shown in Figure 8. All solutions indicated that the main mechanism of the earthquake fundamentally is normal faulting. Nevertheless, a small component of lateral deformation exists. While USGS and HARVARD solutions indicate the lateral component is dextral, the solution by Swiss Seismological Institute (ETHZ) has a sinistral component. Table 2 gives the parameters of focal plane solutions. Figure 9 gives the observed and fitted waveforms for solving the faulting mechanism. According to the field investigation reports, some ground breaks occurred in the villages of Kırca, Dörtköy, Yakasenek and Gedil. It has been also reported that some ground breaks occurred at Maltepe village of Çal town. Figure 10 shows some pictures of ground breaks reported by H. Kumsar of Pamukkale University. The strike of the earthquake fault might be extensions or splays of Tatarlı fault in the region. Kumsar of Pamukkale University (Denizli-Turkey) pointed that Hoyran fault may be activated during this earthquake as shown in Figure 11.

Table 2 Focal plane solution parameters

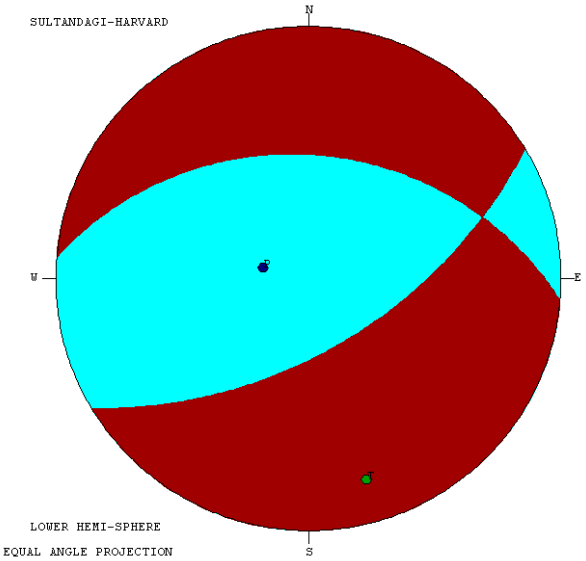
Institute	NP1			NP2		
	Strike	Dip	Rake Angle	Strike	Dip	Rake Angle
USGS	53	39	-106	254	53	-78
ETHZ	84	39	-74	244	53	-102
HARVARD	59	58	-111	275	38	-60



(a) Focal plane solution by USGS



(b) Focal plane solution by ETHZ



(c) Focal plane solution by HARVARD

Figure 8 Focal plane solutions by different institutes (re-drawn by Aydan)

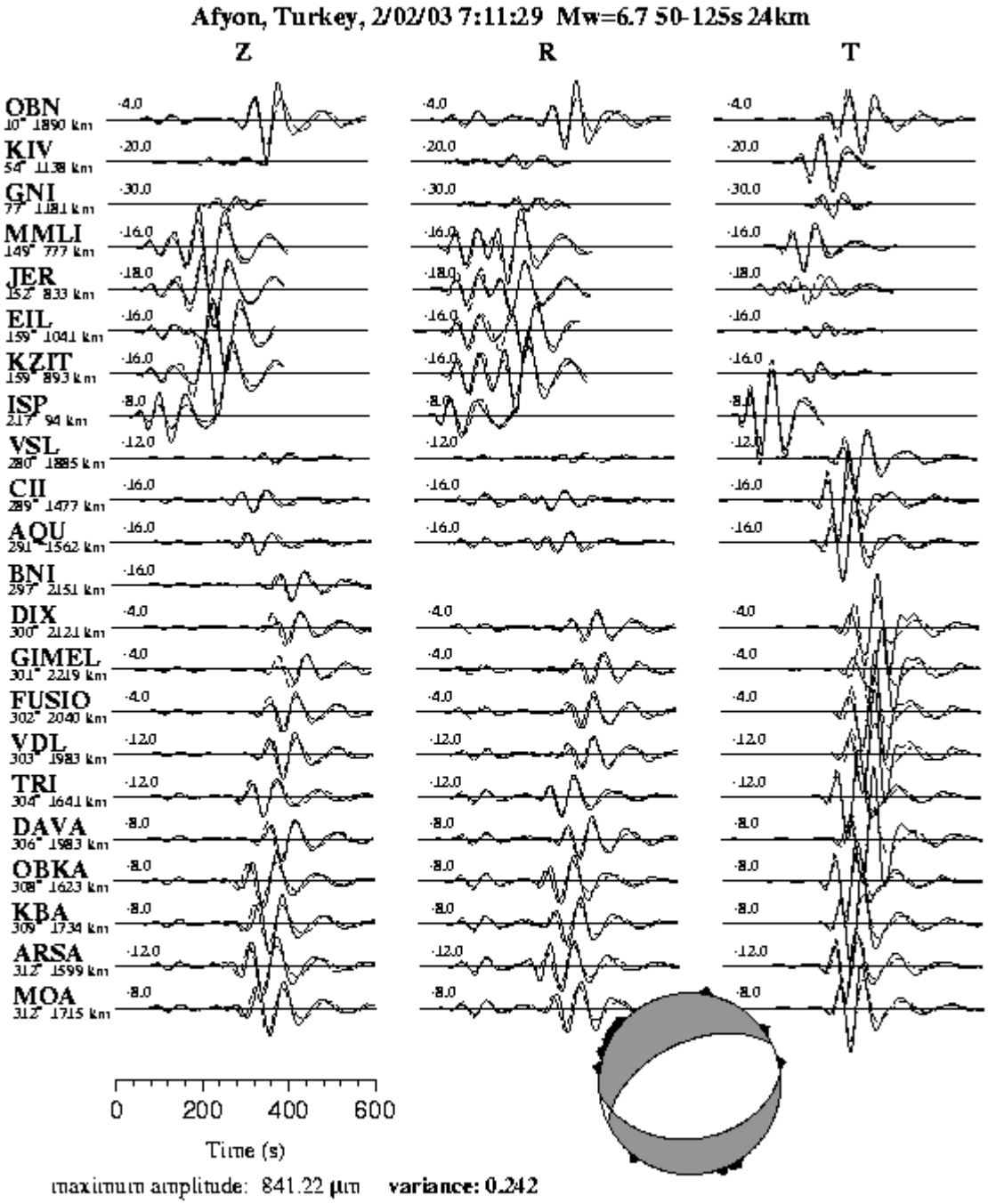


Figure 9 Observed and fitted waveforms for solving the faulting mechanism by Swiss Seismological Institute at ETHZ

Figure 10 Ground breaks observed at Maltepe (pictures by H. Kumsar of Pamukkale University)

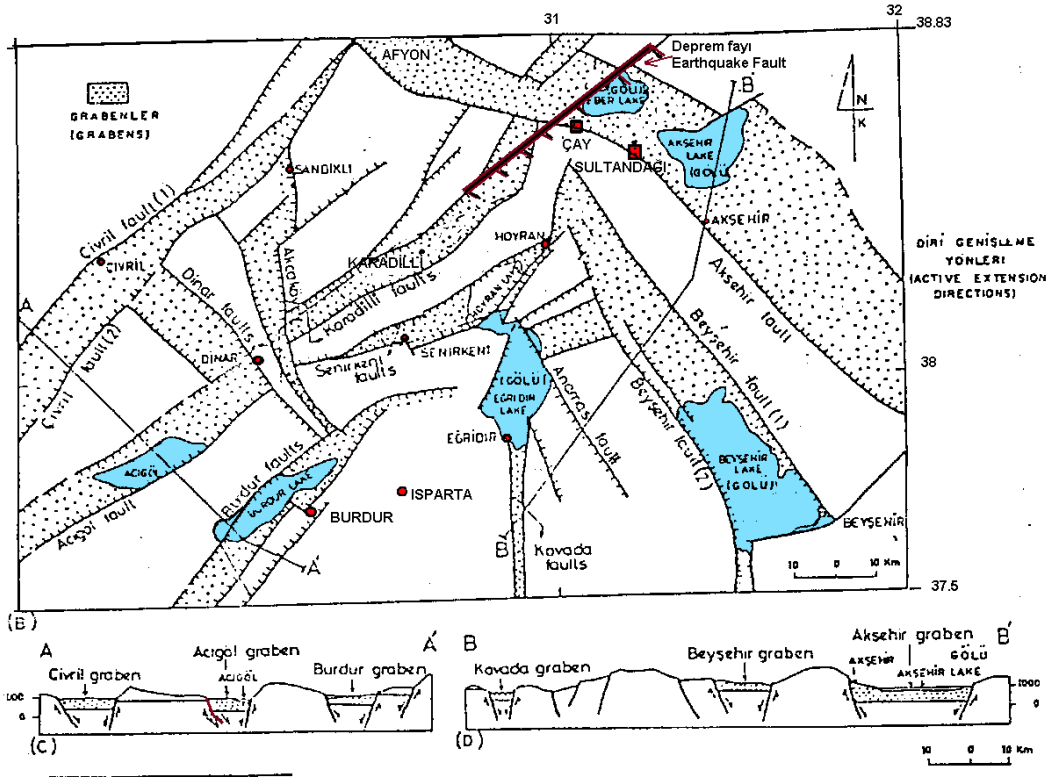


Figure 11 Tectonics of the earthquake region (modified after Koçyiğit-1984)

The author initially thought that the Sultandağı earthquake was caused by a fault plane dipping to north on the basis of focal plane solutions by USGS and SSE, earlier aftershock data and LANDSAT view of the earthquake region on the February 4, 2002 report. Since the main shock, 79 aftershocks having magnitude greater than 3 took place according to Kandilli Observatory (KOERI) (***This time the Earthquake Research Department (DAD-ERD) of Turkey is reluctant to release data for somewhat unknown reasons***). The author re-analysed the aftershock data until February 7, 2002 released by KOERI. The results of re-analyses will be explained herein.

Figure 12 and Figure 13 show the plots of latitude-depth and longitude-depth plot of aftershocks together with the main shock. It seems that the epicenters of the aftershocks are distributed over an area of 38km (NS) by 50km (EW). Except one aftershock having a depth of 110km, the depth of aftershocks is generally less than 20km and they took place beneath Sultandağı and Çay. Figure 12 shows also inferred fault breaks on the basis of the distribution of the hypocenters of aftershocks. The inferred inclinations are generally less than 45^{o} for faults dipping south while those dipping to north are much steeper.

The author determined the fault plane using a procedure, which he developed for Adana-Ceyhan earthquake in 1998 (Aydan et al. 1998). The fault plane was assumed to be represented by the following equation.

$$z = a + b\ LONGITUDE + c\ LATITUDE$$

Using the least square technique, parameters *a, b, c* of the above equation was found to be 1737, 2.067 and –46.46, respectively by taking into account aftershock data within a region bounded by 30.6-31.4 N and 31.1-31.9E. The three dimensional view of the fault plane is shown in Figure 14. The results indicate that the fault plane should dip towards south with an inclination of 18^{o} and its surface trace should appear at the north of Çay and Sultandağı and along the northern shore of Eber Lake and its strike is almost EW (dip direction is about 177^{o}). It is of great interest that this prediction almost coincides with the focal plane solution obtained by the Swiss Seismological Institute. There are some reports that fault breaks occurred at Kırca, Dörtköy, Yakasenek and Gedil villages and also in Maltepe. Since the author does not have a detailed map of the area, he is unable to verify whether the expected ground surface breaks correspond to the reported fault breaks. However, the author believes that the northern segment of Karadilli faults (see Figure 11 for location) has been activated in this earthquake. The sinistral sense of deformation at the northern shore of Eber Lake confirm the reasoning of the author.

Figure 15 compares the inferred fault trace together with the known active faults. Figure 16 re-shows the LANDSAT view of the area together with the inferred fault break. In the satellite picture, a lineament appears the north of Çay and Sultandağı and runs along the northern shore of Eber Lake as shown in Figure 3 and Figure 16. This may be the possible surface projection of the inferred fault plane. Figure 17 shows a model test by Cloos (1953) on a clay layer undergoing stretching deformation, which may be relevant to the mechanism of the Sultandağı earthquake of February 3, 2002.

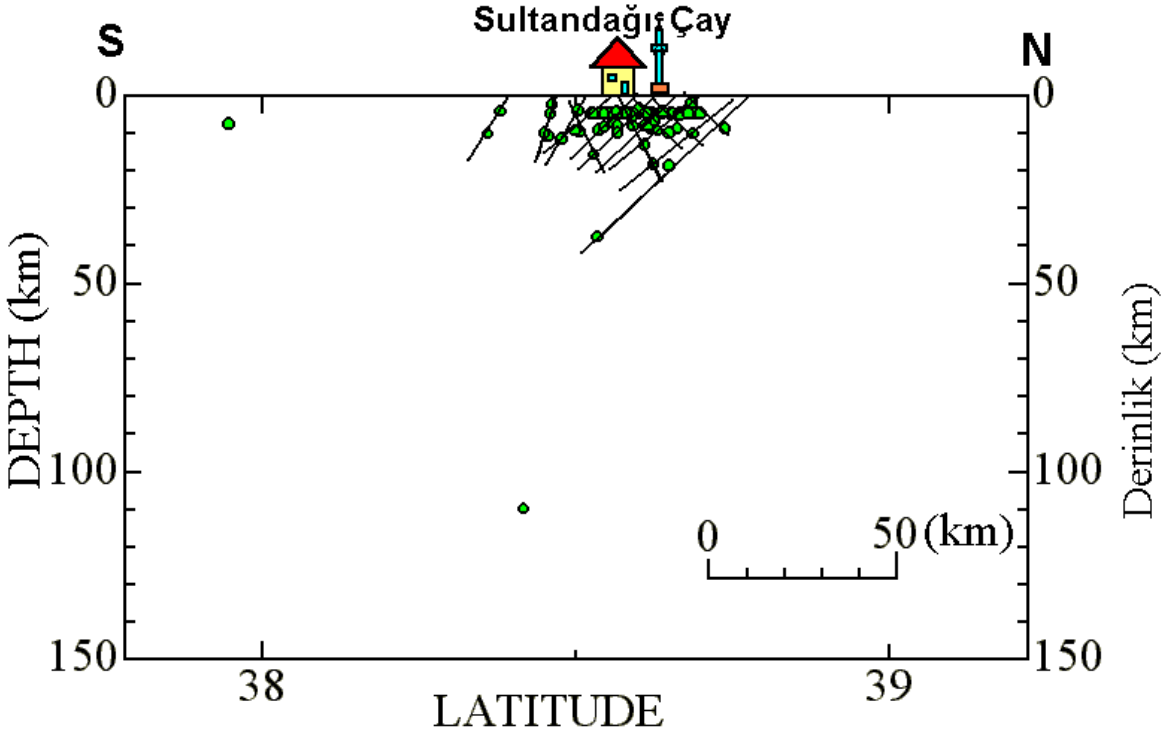


Figure 12 Plot of hypocenters of aftershocks on the space of latitude and depth

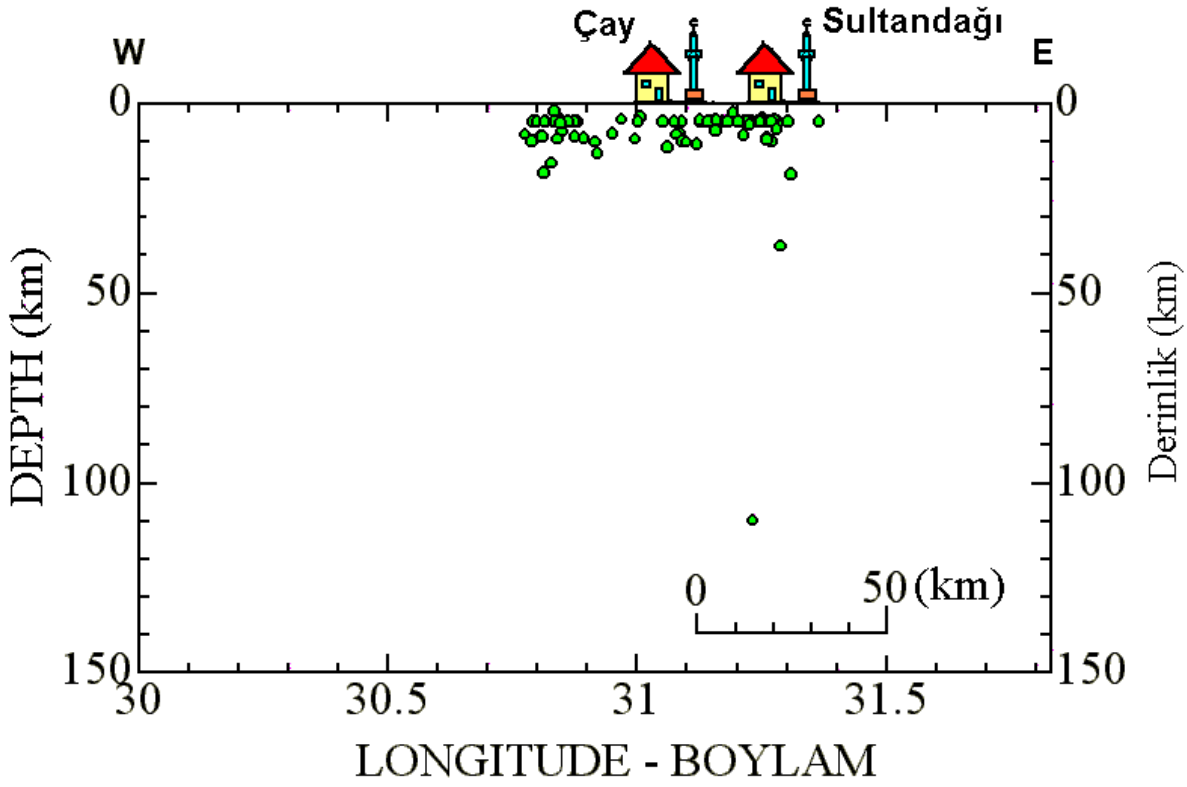


Figure 13 Plot of hypocenters of aftershocks on the space of longitude and depth

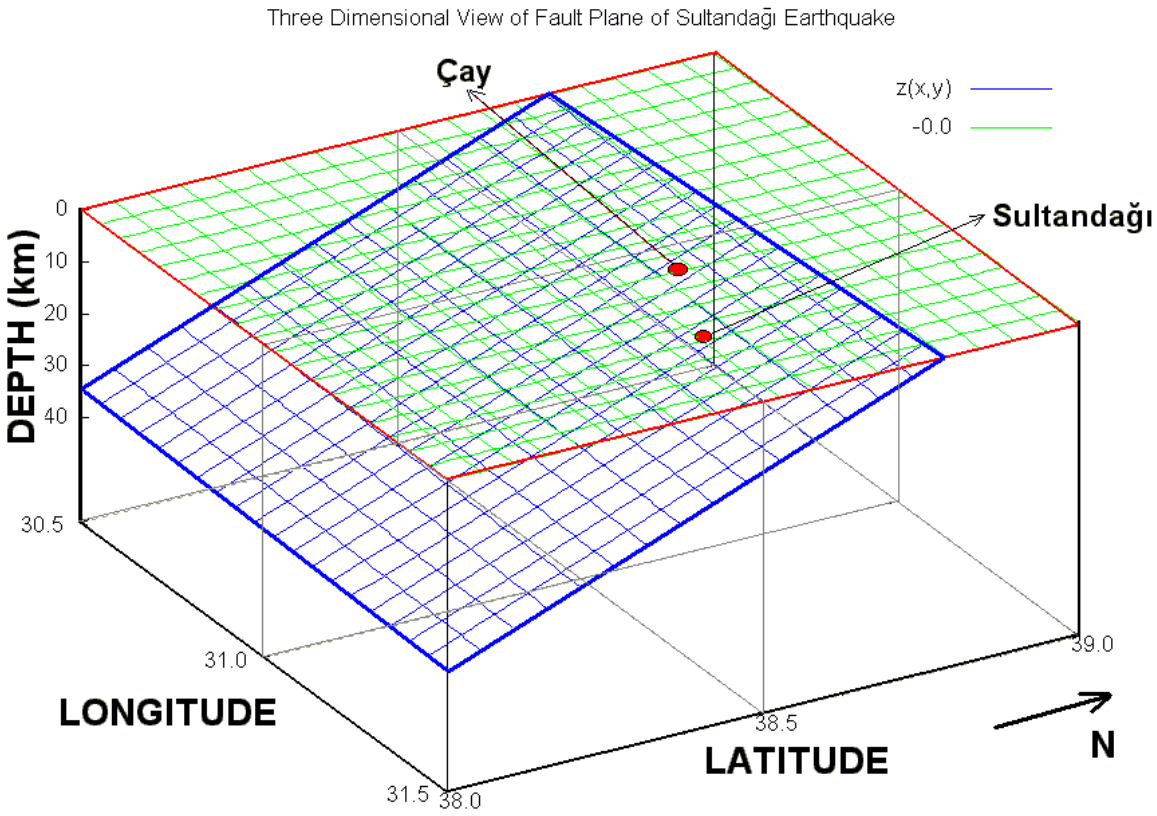


Figure 14 A three dimensional view of the inferred causative fault plane

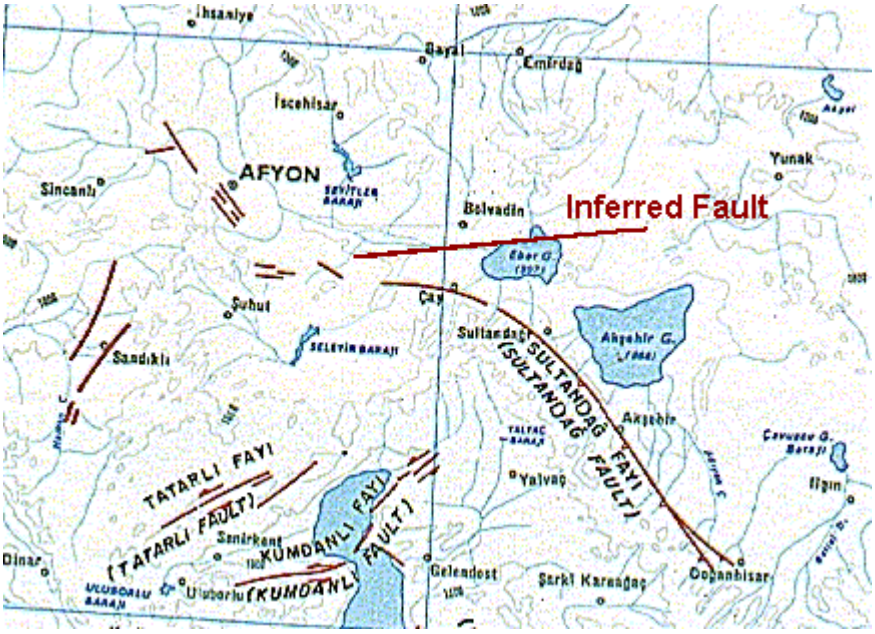


Figure 15 Comparison of newly inferred fault plane together with known active faults

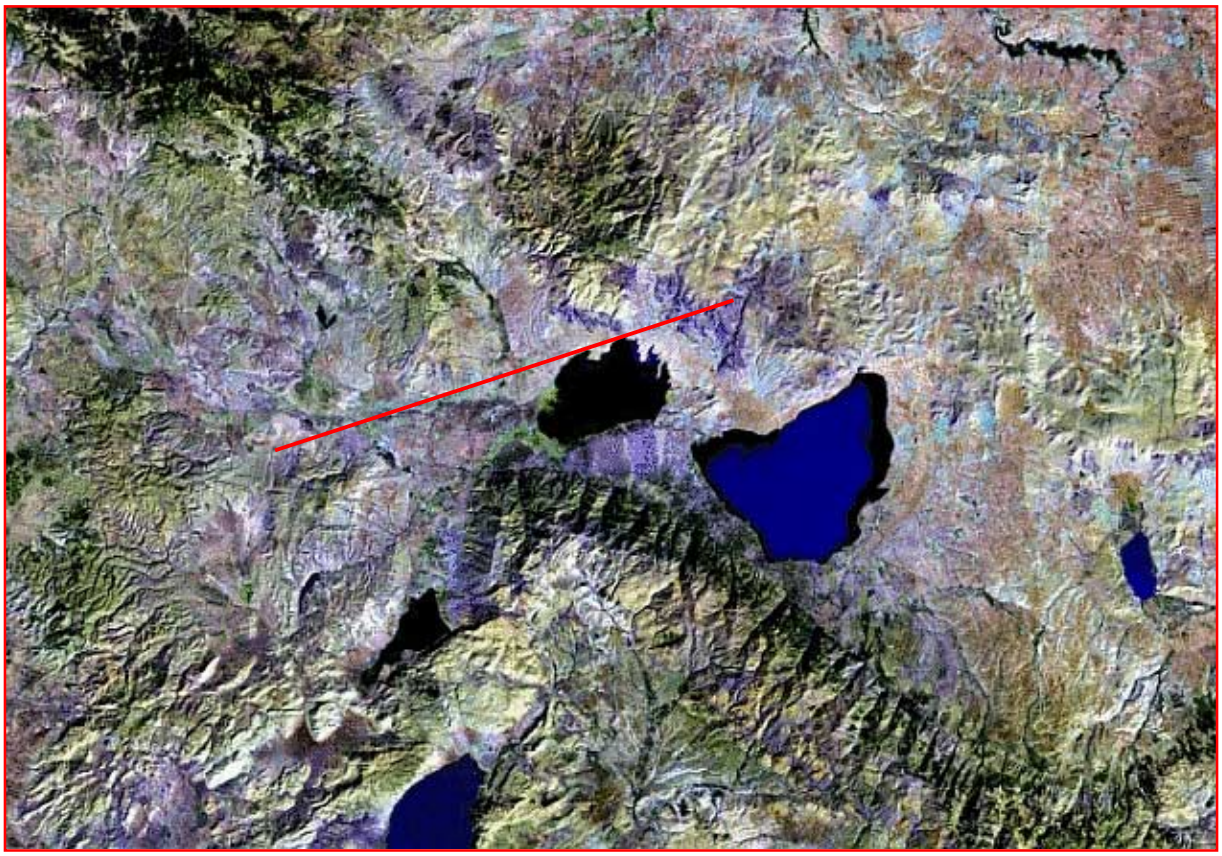


Figure 16 A LANDSAT view of the earthquake area and projection of the inferred fault trace

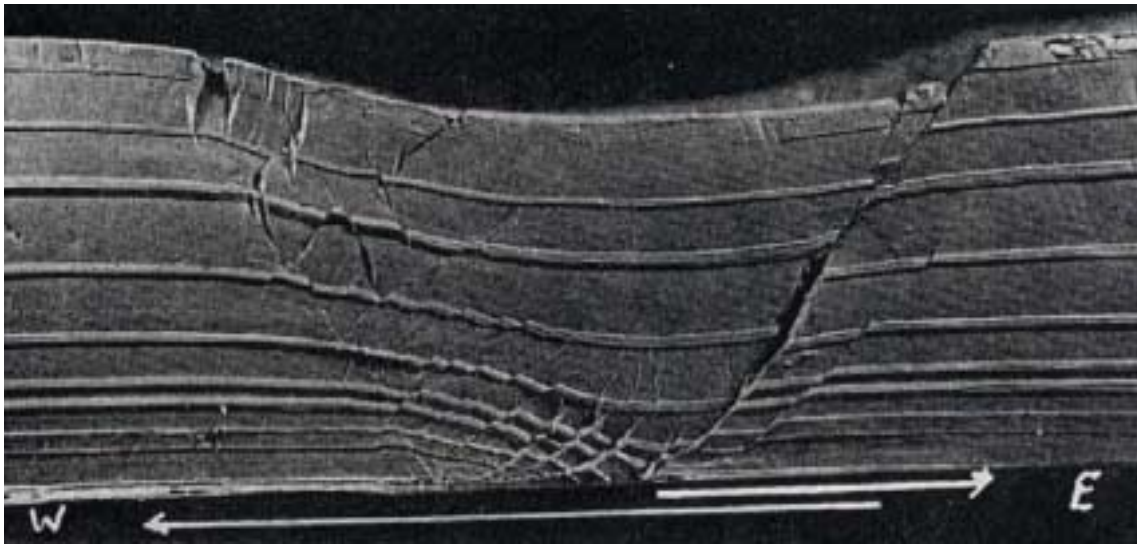


Figure 17 A model experiment on a clay layer undergoing stretching deformation (after Cloos 1953)

5 STRONG MOTION RECORDS

The national strong-motion network operated by the Earthquake Research Department of Turkey recorded the earthquake and the image files of records at Afyon, Kütahya, Uşak, Burdur, Sakarya, Bandırma and Balıkesir stations can be downloaded. From S-P time differnce, Afyon, Kütahya and Uşak stations are 60km, 145km and 179km far away from the hypocenter. The largest acceleration is recorded at Afyon and its amplitude is about 110 gal. The acceleration forms and their Fourier spectra are shown in Figure 18, 19 and 20, respectively. Figure 21 compares the maximum ground acceleration with the empirical relation proposed by Aydan (1997) for soft ground. The observations are in good corelation with the estimated curve.

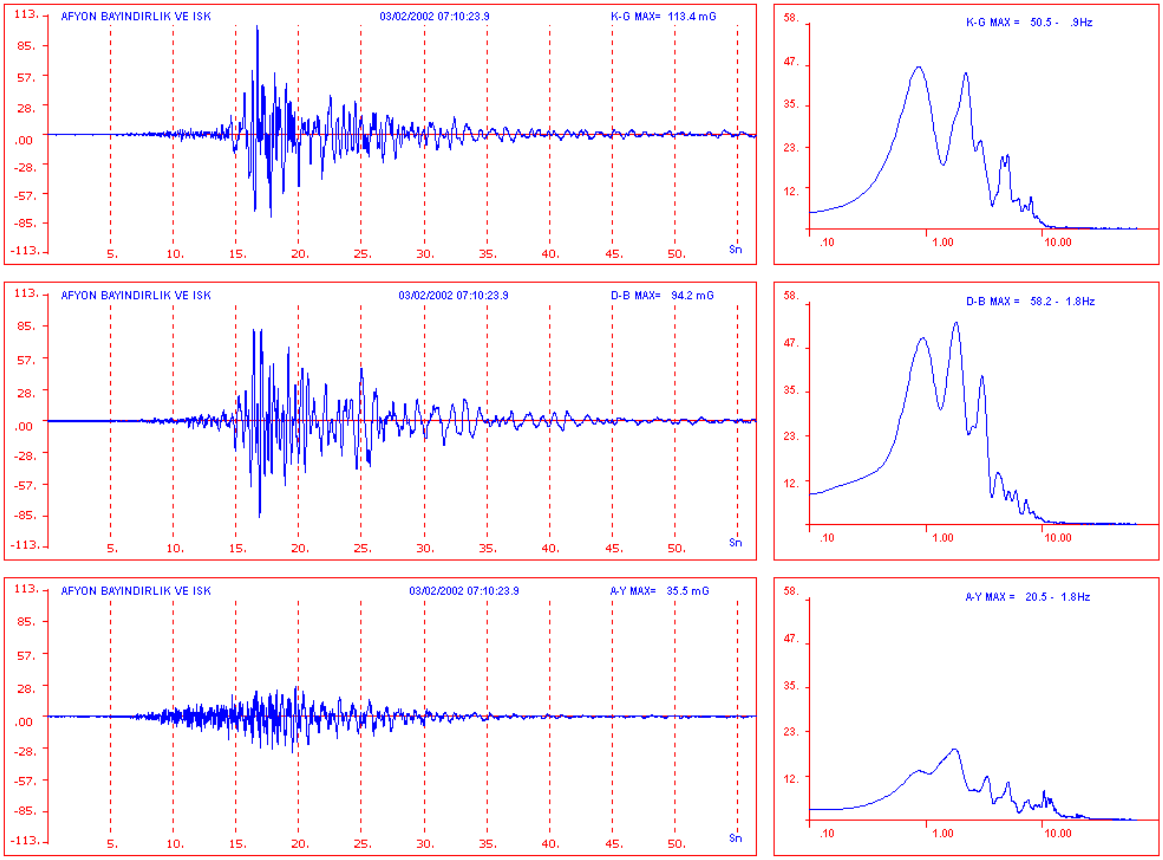


Figure 18 Acceleration records and their Fourier spectra at Afyon (from DAD-ERD)

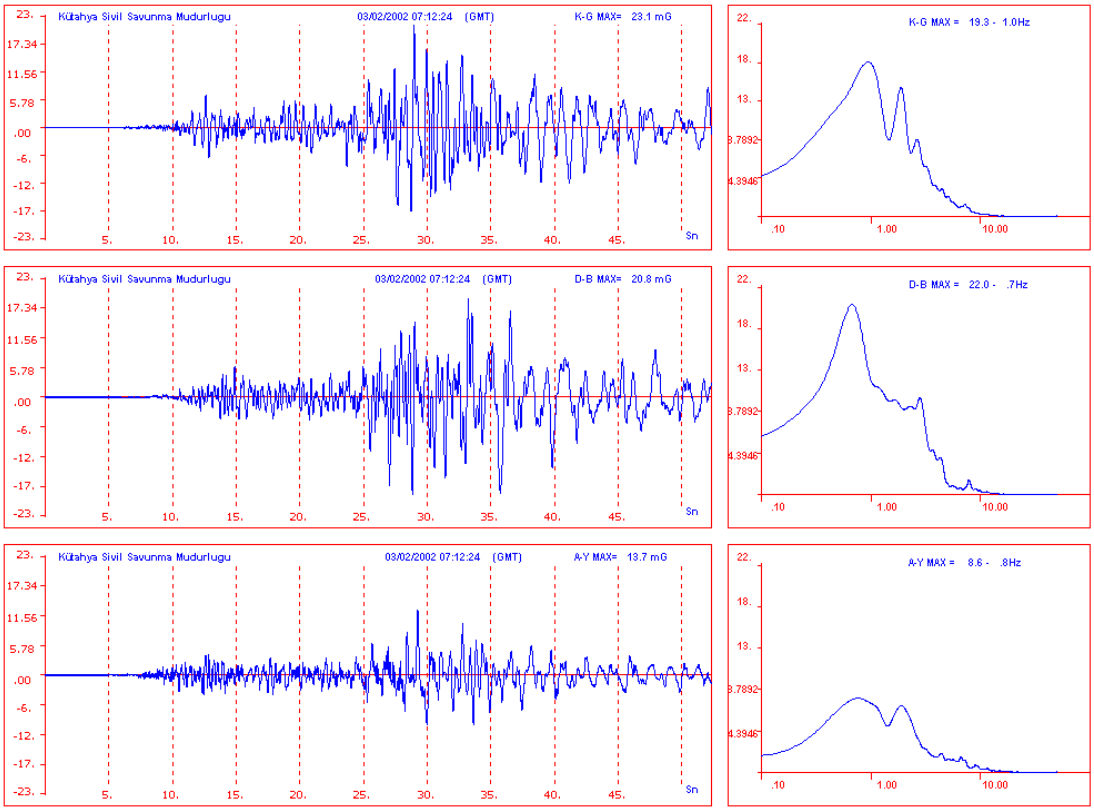


Figure 19 Acceleration records and their Fourier spectra at Kütahya (from DAD-ERD)

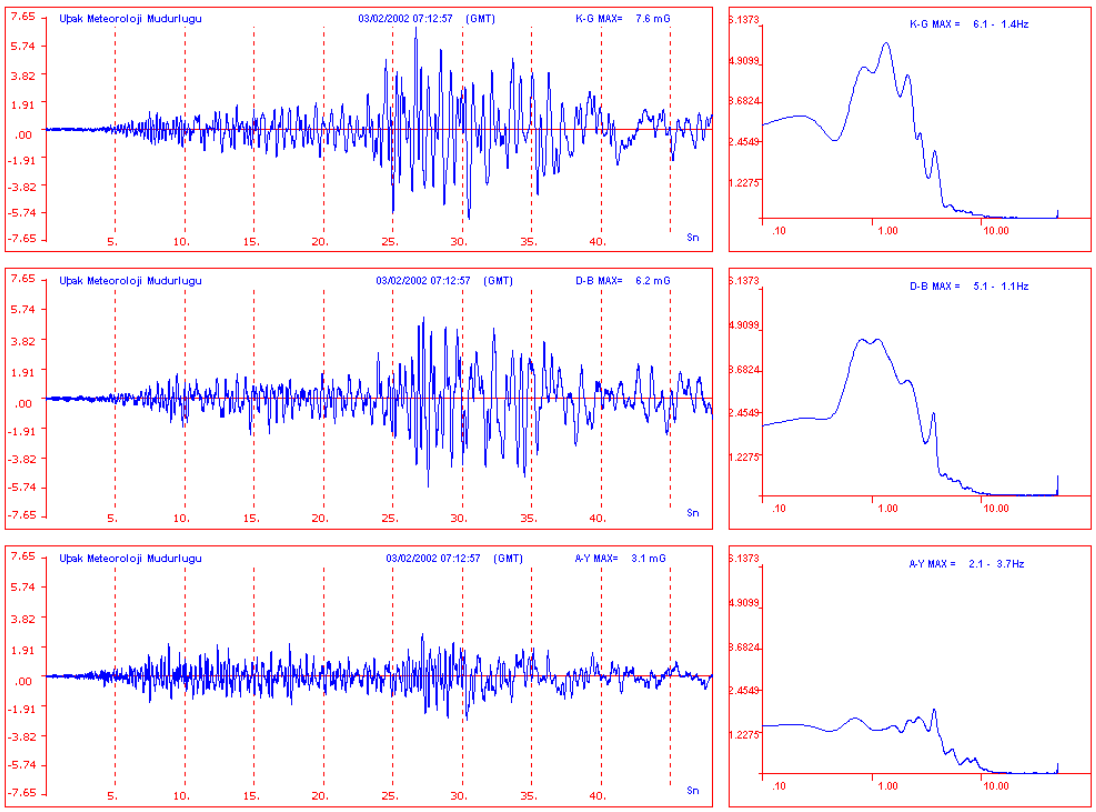


Figure 20 Acceleration records and their Fourier spectra at Uşak (from DAD-ERD)

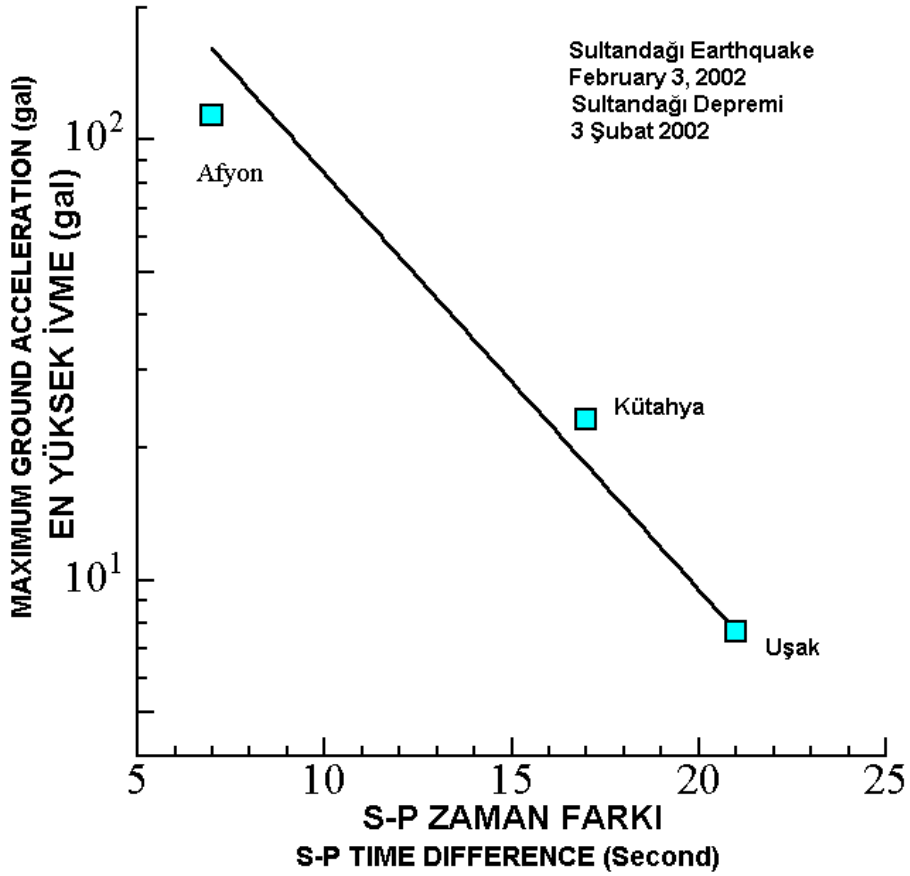


Figure 21 Variation of maximum ground acceleration with S-P time difference

6 STRUCTURAL DAMAGE

According to preliminary reports, the heaviest damage occurred in the towns of Sultandağı and Çay and their villages. Fıgure 22, 23, 24 and 25 show some examples of structural damage. The pictures are taken from the web-page of Milliyet daily newspaper. It seems that the old wooden houses of Bağdadi type and kerpiç (adobe) type masonary houses collapsed. These houses are either single story or two-story structures as seen in Figure 22. Some masonary structures with delikli tuğla (hollowed bricks) without appropriate concrete slabs for structural integrity also collapsed as seen in Figure 22. The reinforced building having 3-8 stories failed either by toppling or collapsed due to the weak-floor effect as commonly observed in other Turkish earthquakes (Figure 23). As seen in Figure 24, minarets of some mosques toppled during the earthquake. Since these structures have long shaking periods (0.7 seconds), their failure implies the existence of some long-period waves.

Figure 22 Damage and collapses of wooden and masonary structures (pictures by Milliyet)

Figure 23 Damage and collapses of reinforced concrete structures (pictures by Milliyet)

Figure 24 Damage to mosques and collapses of their minarets (pictures by Milliyet)

Figure 25 Miscellaneous pictures (pictures by Milliyet)

7 GROUND FAILURES AND LIQUEFACTION

There are a few reports on ground failures. The cause might be the hinderence of the thick snow cover in the region at the present time of the year. It is also reported that the area is covered with thick clayey or silty deposits. It seems that some ground failures occurred along the shores of Eber lake. At some parts of its shore, it is reported that some liquefaction also took place. H. Kumsar of Pamukkale University reported that liquefaction observed in Maltepe and Kadıköy villages and also in the river course of Gani çayı (creek). Figure 26 shows an example of liquefaction reported by Kumsar of Pamukkale University.

Fıgure 26 Ground liquefaction (picture by H. Kumsar of Pamukkale University)

8 UNUSUAL EVENTS

There are presently a few unusual events reported in newspapers. H. Kumsar reported that the springs at Cumhuriyet village Afyon D.S.İ. and some private water wells become turbid. In addition some springs were either dried or sprang along the shores of Eber Lake.

ACKNOWLEDGEMENTS

This report is a compilation of the available information on the internet until February 7, 2002 and at the disposal of the author on this earthquake. It is prepared with a sole purpose of providing an overall information to prospective investigators in the field for this earthquake. The author would like to particularly thank Assoc. Prof. Dr. H. Kumsar of Pamukkale University (Denizli) and Prof. Dr. R. Ulusay of Hacettepe University for providing the first-hand information they gathered.

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Kandilli Observatory: http://www.koeri.boun.edu.tr

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MTA: http://www.mta.gov.tr

SSI-ETHZ:http://seismo.ethz.ch/

USGS-NEIC: http://neic.usgs.gov