Aktif fay zonlarında ikincil kırıklardan yararlanılarak ana makaslama hattının belirlenmesi: Eskişehir Fay Zonu'nda bir kinematik tasarım uygulaması

Ankara Üniversitesi Jeoloji Müh. Bölümü

JEM 428 Jeoloji Mühendisliğinde Tasarım

Dr. Korhan Esat

ANKARA ÜNİVERSİTESİ UNIVERSITY TAG TEKTONİK ARAŞTIRMA GRUBU TECTONICS RESEARCH GROUP

Fay analiz türleri

Fay Analizi

Yapısal jeologlar bir bölgenin yapısal geçmişi hakkında olabildiğince çok bilgi edinebilmek ve yerkabuğunun deformasyon süreçlerini daha iyi anlayabilmek için fay analiz yöntemlerini kullanırlar.

Dinamik Analiz

- Fayları oluşturan gerilme alanının konumunu ve büyüklüğünü belirlemeyi amaçlar.

Kinematik Analiz

- Kuvvet ve gerilmelere değinmeden fayları oluşturan hareket ya da yerdeğiştirmeyi tanımlamayı amaçlar.
- Kinematik analiz yöntemiyle bir bölge için **daralma** (shortening) ya da **genişleme** (extension)'yi gösteren ana yamulma eksenlerinin (kinematik eksenler) konumları belirlenebilir.

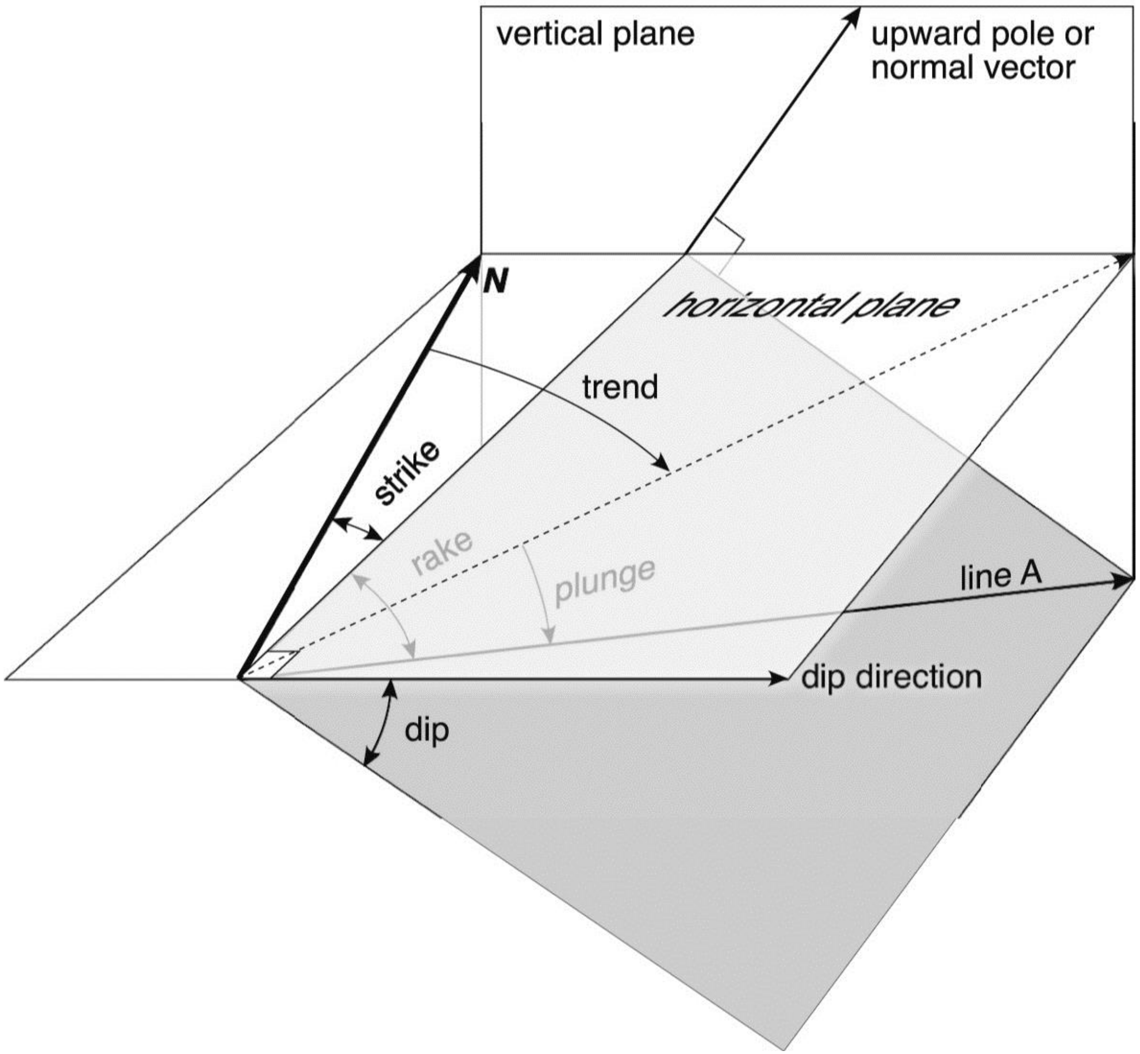
Kinematik analiz için veri eldesi

Fayların kinematik analizi için gerekli olan temel veri

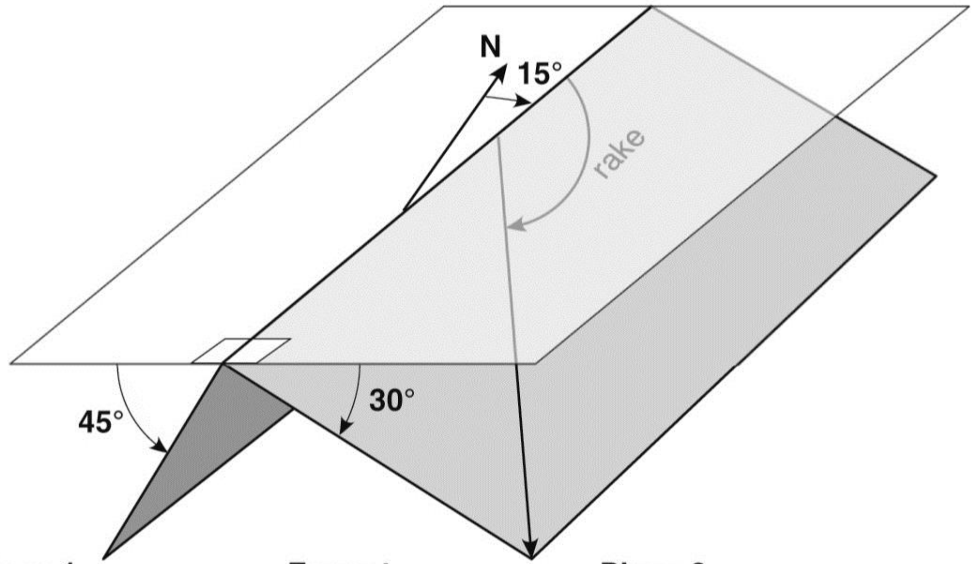
1) Fay yüzeyinin doğrultu ve eğimi

2) Fay düzlemi üzerindeki fay çiziğinin gidiş ve dalımı ya da yan yatım açısı

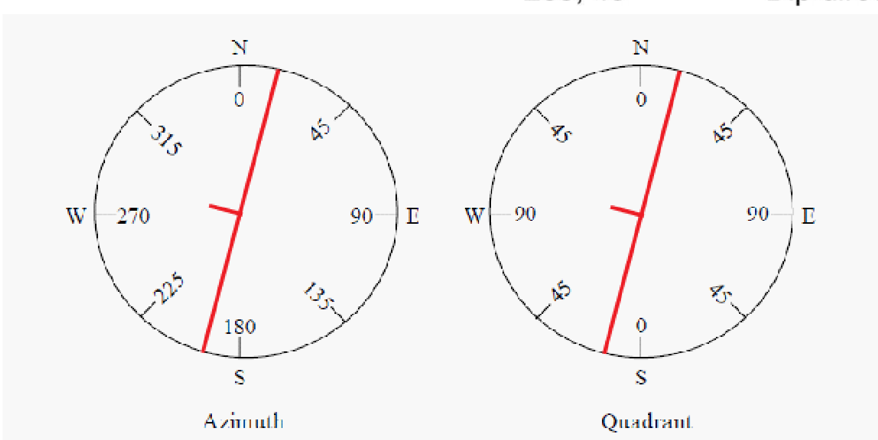
3) Fay düzlemi üzerindeki hareket yönü

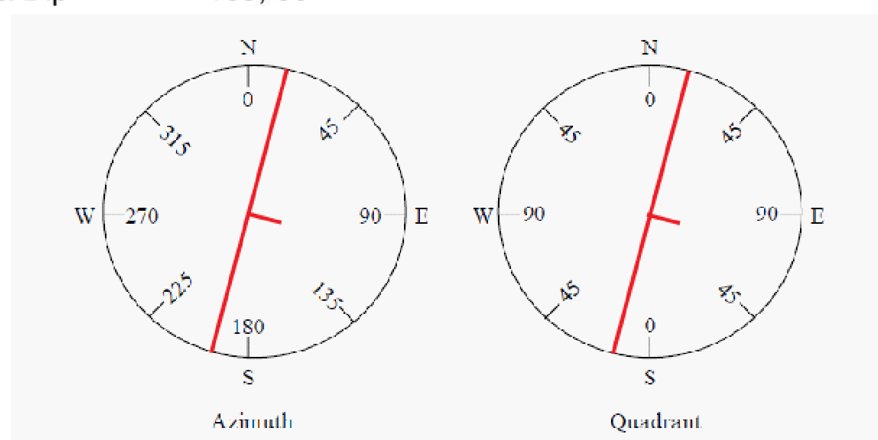


Kinematik analiz için veri eldesi



Plane 1	Format	Plane 2
N 15 E, 45 W	Quadrant	N 15 E, 30 E
015, 45 W	Azimuth	015, 30 E
195, 45	Right-hand Rule	015, 30
285, 45	Dip direction & Dip	105, 30





Kinematik analiz için veri eldesi

Kinematik veri:

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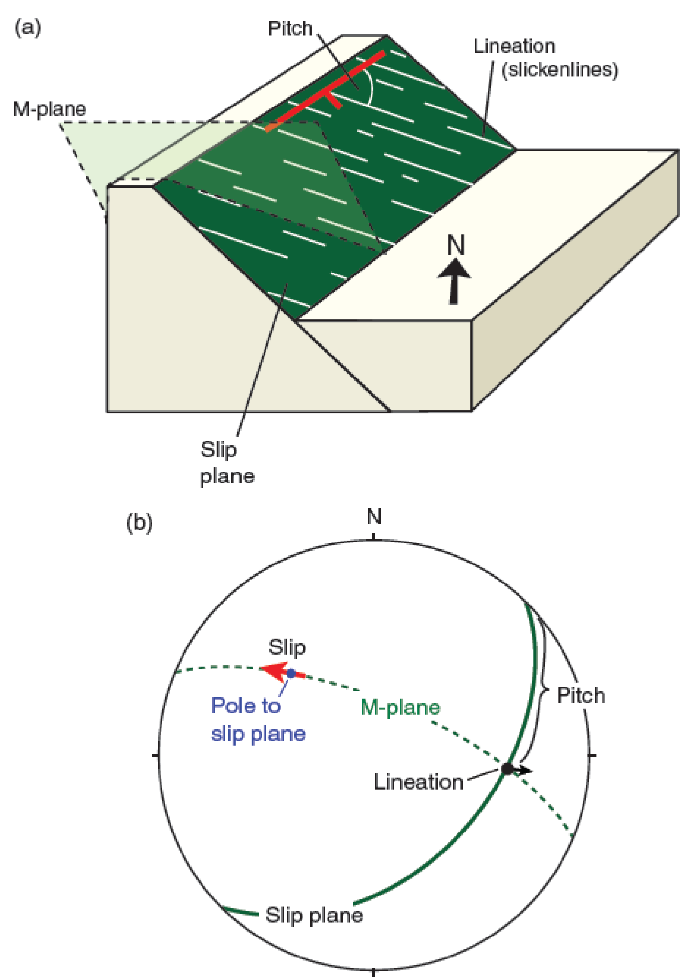
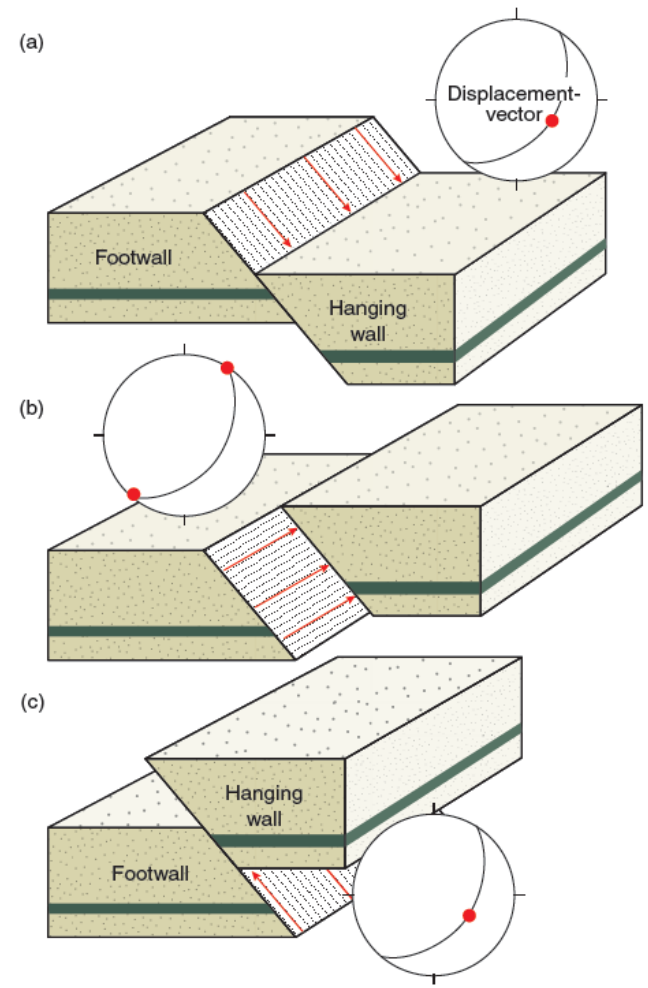
2) Deprem odak mekanizması çözümünden elde edilebilir.





Kinematik analiz için veri eldesi

Kinematik veri:

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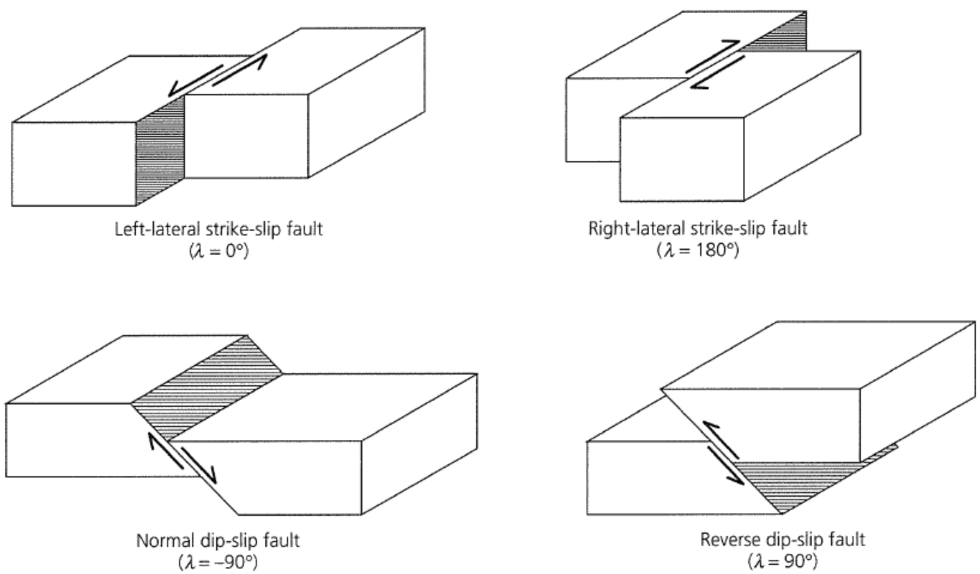
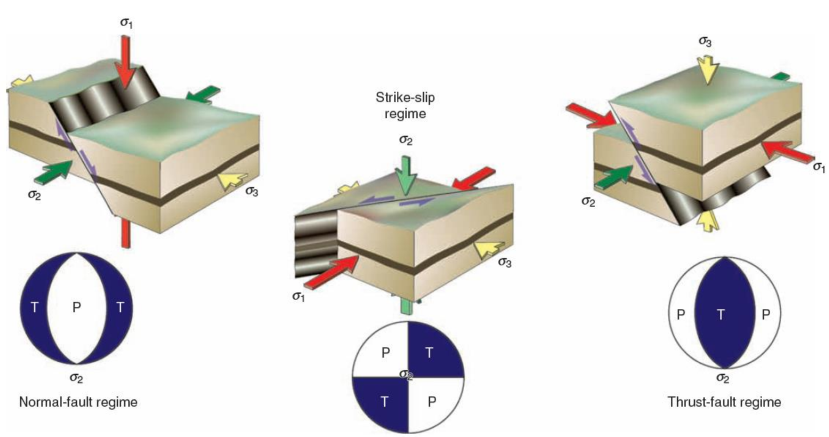
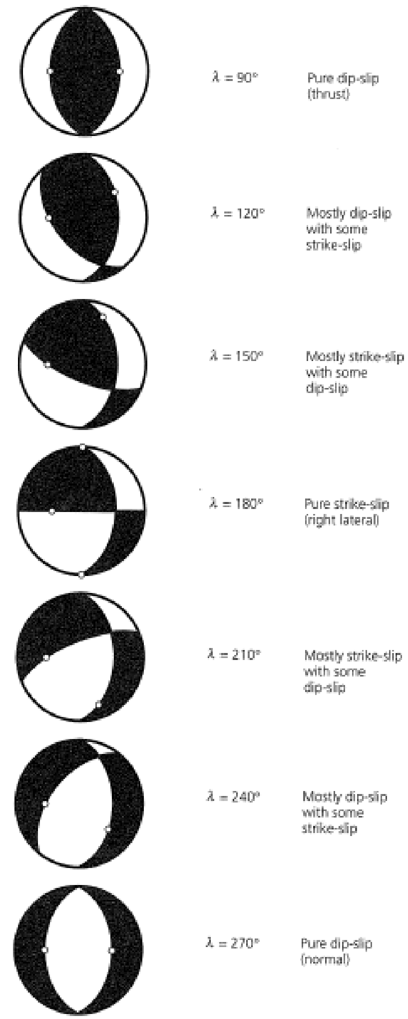
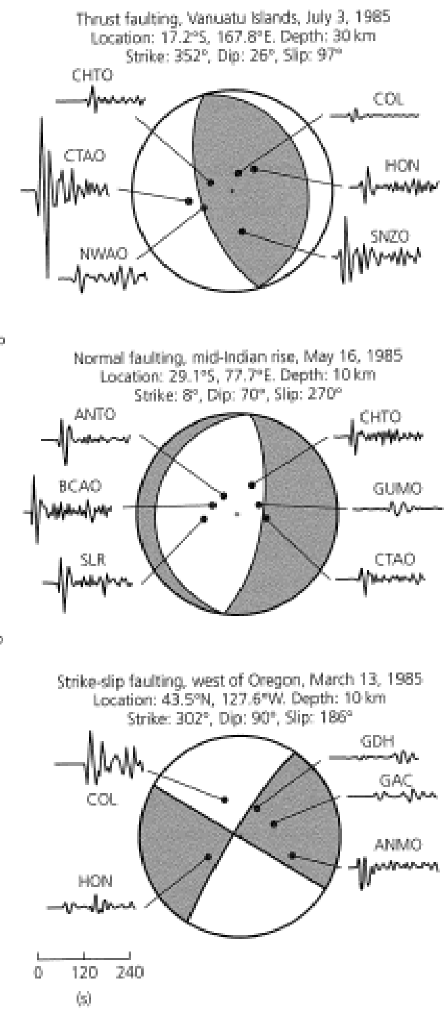
2) Deprem odak mekanizması çözümünden elde edilebilir.

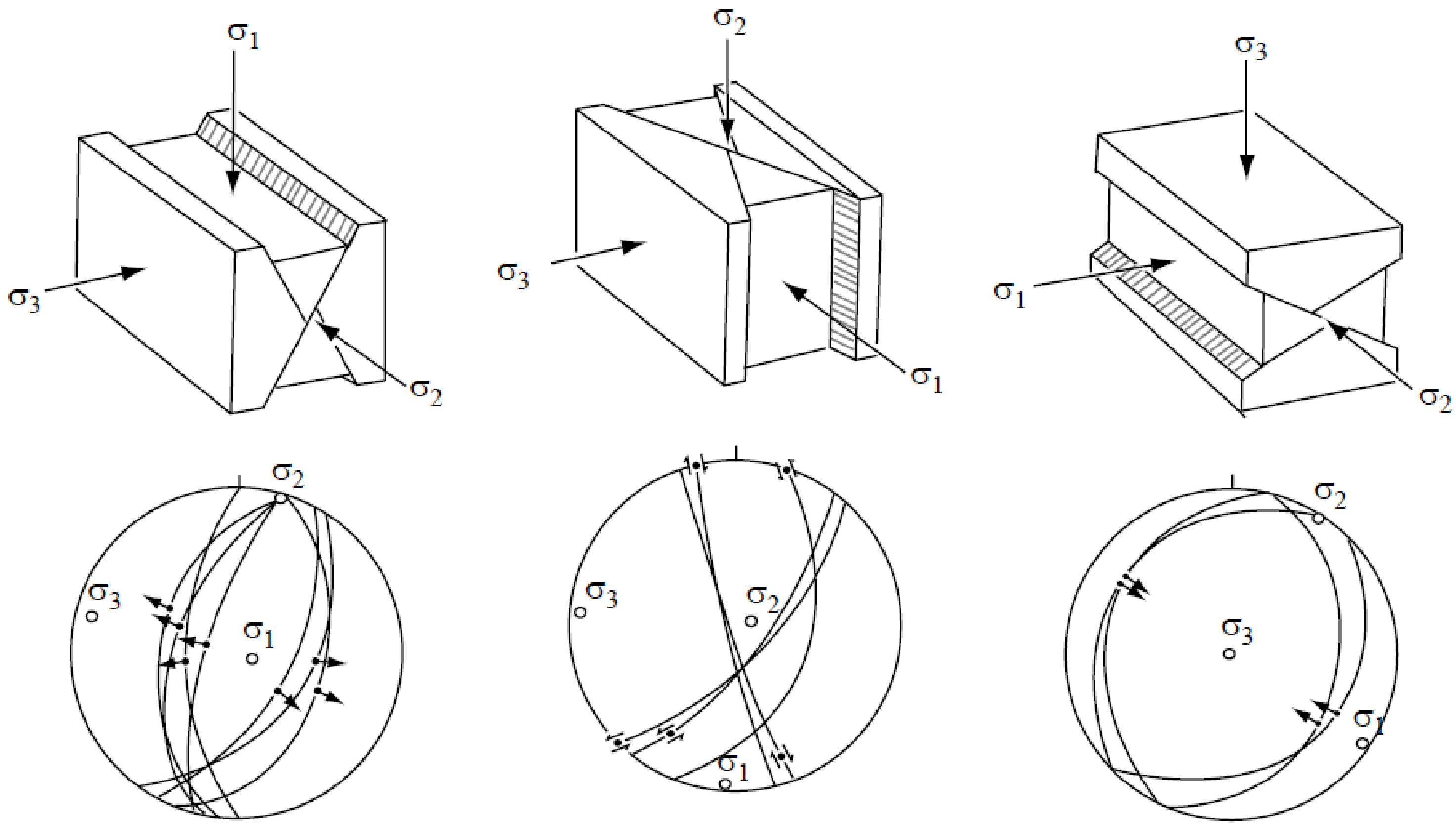








Kinematik verinin küresel projeksiyon gösterimi



a Normal faults **b** Strike-slip faults **c** Thrust faults

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Determining the main strand of the Eskişehir strike-slip fault zone using subsidiary structures and seismicity: a hypothesis tested by seismic reflection studies

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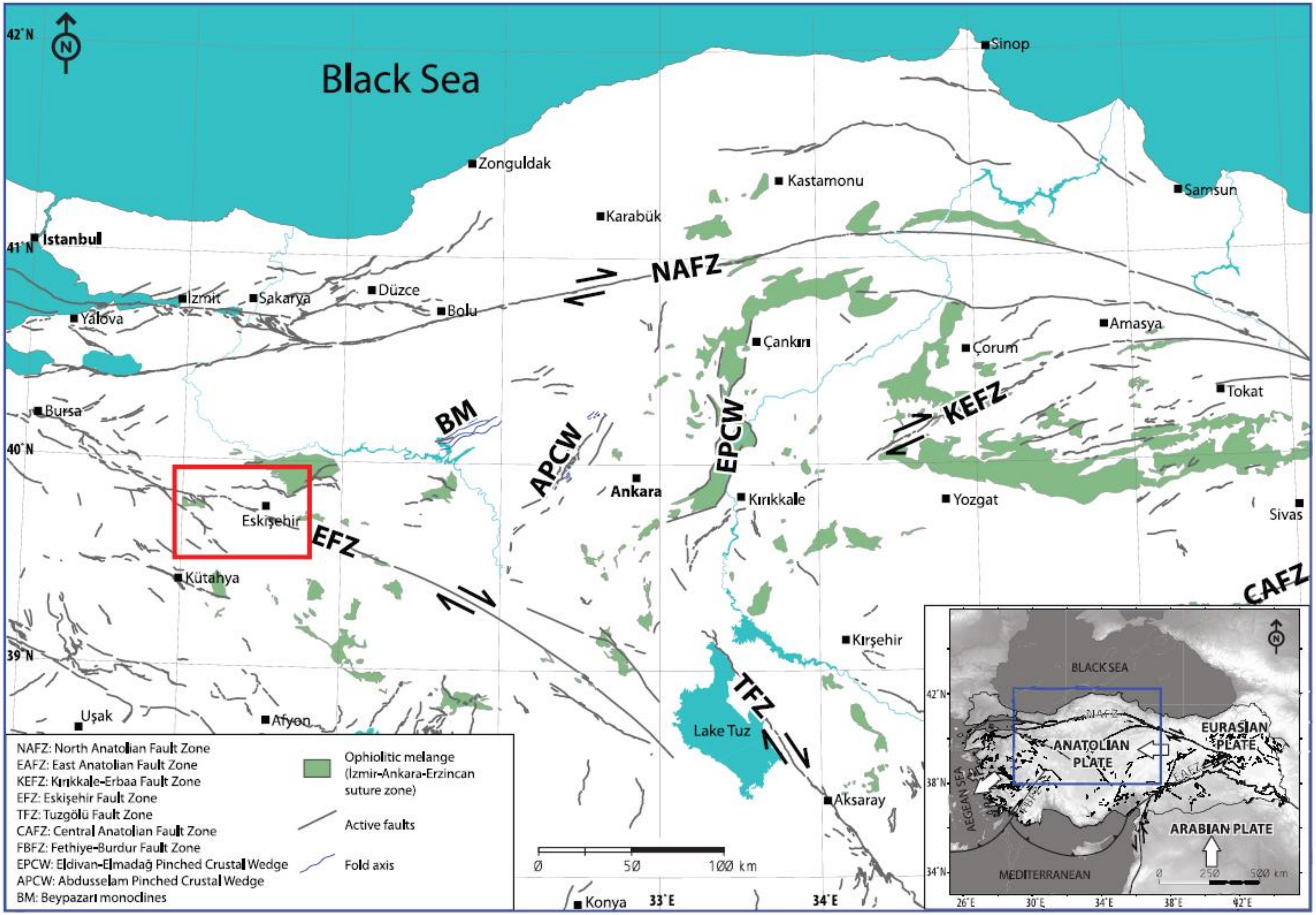
Abstract: The Eskişehir Fault Zone is one of the major neotectonic structures of Turkey, extending from İnegöl (Bursa) to Cihanbeyli (Konya). The fault zone presents a considerable seismic risk for the city of Eskişehir but the exact locations of active segments and the source of the major seismic event, the 1956 earthquake (M = 6.5) that occurred in the instrumental period (from 1900 to 2013), have been debated in recent literature. The structural data obtained from field studies indicate an approximately N60W-trending main strand of the right lateral strike-slip Eskişehir Fault Zone. This trend corresponds to the en echelon bends on the course of the Sarısu River. Using this concurrence, the positions of Bahçehisar and the Çukurhisar-Sultandere segments are proposed and checked by seismic reflection studies. The seismic sections disclosing positive flower structures confirm the hypothesized position of the Çukurhisar-Sultandere segment. The relocation of epicenters and focal mechanism solutions of seismic events in 1956, 1990, 2010, and 2013 indicate that the Çukurhisar-Sultandere segment might be the rupture source of the 1956 event and is a possible potential seismic source for an earthquake that could seriously affect the Eskişehir settlement.



Black Sea
42˚N
41˚N
40˚N
39˚N
33˚E
34˚E
Sinop
Zonguldak
Kastamonu
Samsun
Karabük
İstanbul
NAFZ
İzmit
Sakarya
Düzce
Bolu
Yalova
Çankırı
Amasya
Çorum
Tokat
KEFZ
BM
Bursa
APCW
EPCW
Ankara
Kırıkkale
Yozgat
Sivas
Eskişehir
EFZ
CAFZ
Kütahya
Kırşehir
TFZ
Lake Tuz
Uşak
Afyon
Aksaray
Konya
NAFZ: North Anatolian Fault Zone
EAFZ: East Anatolian Fault Zone
KEFZ: Kırıkkale-Erbaa Fault Zone
EFZ: Eskişehir Fault Zone
TFZ: Tuzgölü Fault Zone
CAFZ: Central Anatolian Fault Zone
FBFZ: Fethiye-Burdur Fault Zone
EPCW: Eldivan-Elmadağ Pinched Crustal Wedge
APCW: Abdusselam Pinched Crustal Wedge
BM: Beypazarı monoclines
Ophiolitic melange (İzmir-Ankara-Erzincan suture zone)
Active faults
Fold axis
0 50 100 km
BLACK SEA
EURASIAN PLATE
ANATOLIAN PLATE
ARABIAN PLATE
MEDITERRANEAN
AEGEAN SEA
42˚N
38˚N
34˚N
26˚E 30˚E 34˚E 38˚E 42˚E
0 250 500 km

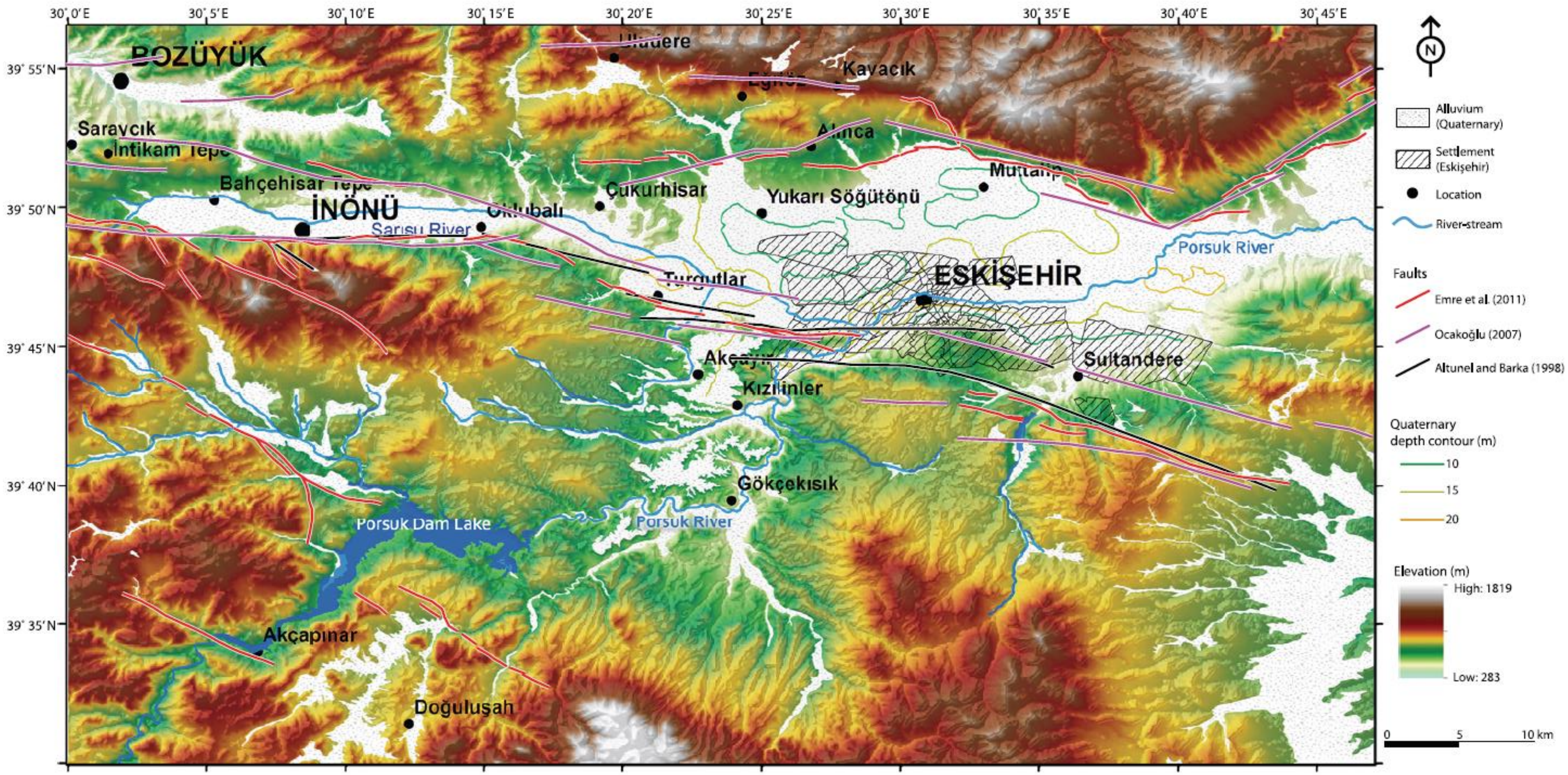
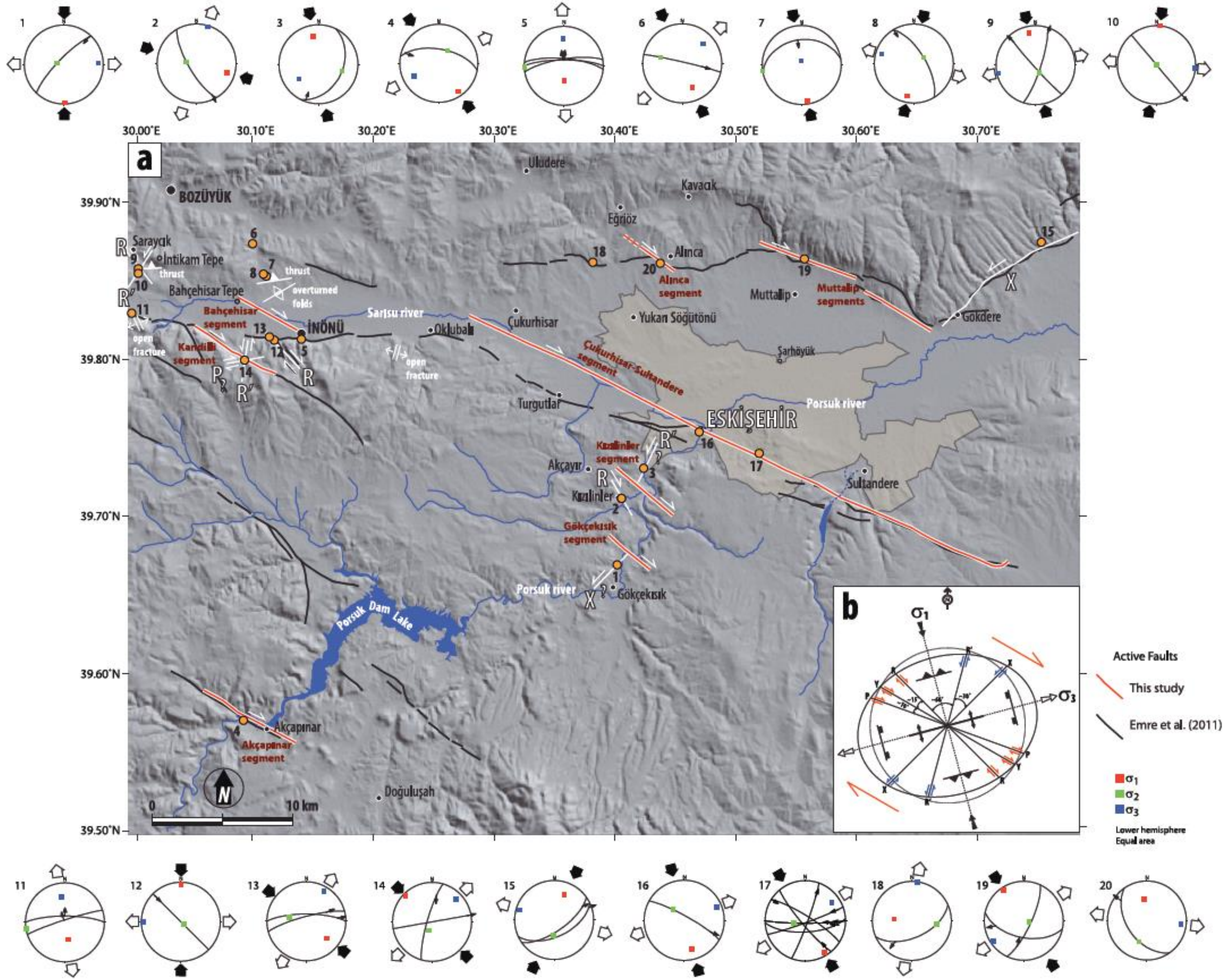


Figure 2. The geomorphology of the Eskişehir area and active fault traces from previous studies (Altunel and Barka, 1998; Ocakoğlu, 2007; Emre et al., 2011).



a
b
30.00°E
30.10°E
30.20°E
30.30°E
30.40°E
30.50°E
30.60°E
30.70°E
39.90°N
39.80°N
39.70°N
39.60°N
39.50°N
BOZÜYÜK
Uludere
Kavacık
Eğriöz
Alınca
Sarayçık
İntikam Tepe
thrust
Bahçehisar Tepe
overturned folds
Sarısu river
İNÖNÜ
Oklubalı
Çukurhisar
Yukarı Söğütönü
Muttalip
Gökdere
Şarhöyük
Bahçehisar segment
Kandilli segment
Alınca segment
Muttalip segments
Çukurhisar-Sultandere segment
open fracture
Turgutlar
Porsuk river
ESKİŞEHİR
Kızılinler segment
Akçayır
Kızılinler
Sultandere
Gökçekısık segment
Gökçekısık
Porsuk Dam Lake
Akçapınar
Akçapınar segment
Doğuluşah
0
10 km
N
σ1
σ3
Active Faults
This study
Emre et al. (2011)
σ1
σ2
σ3
Lower hemisphere
Equal area

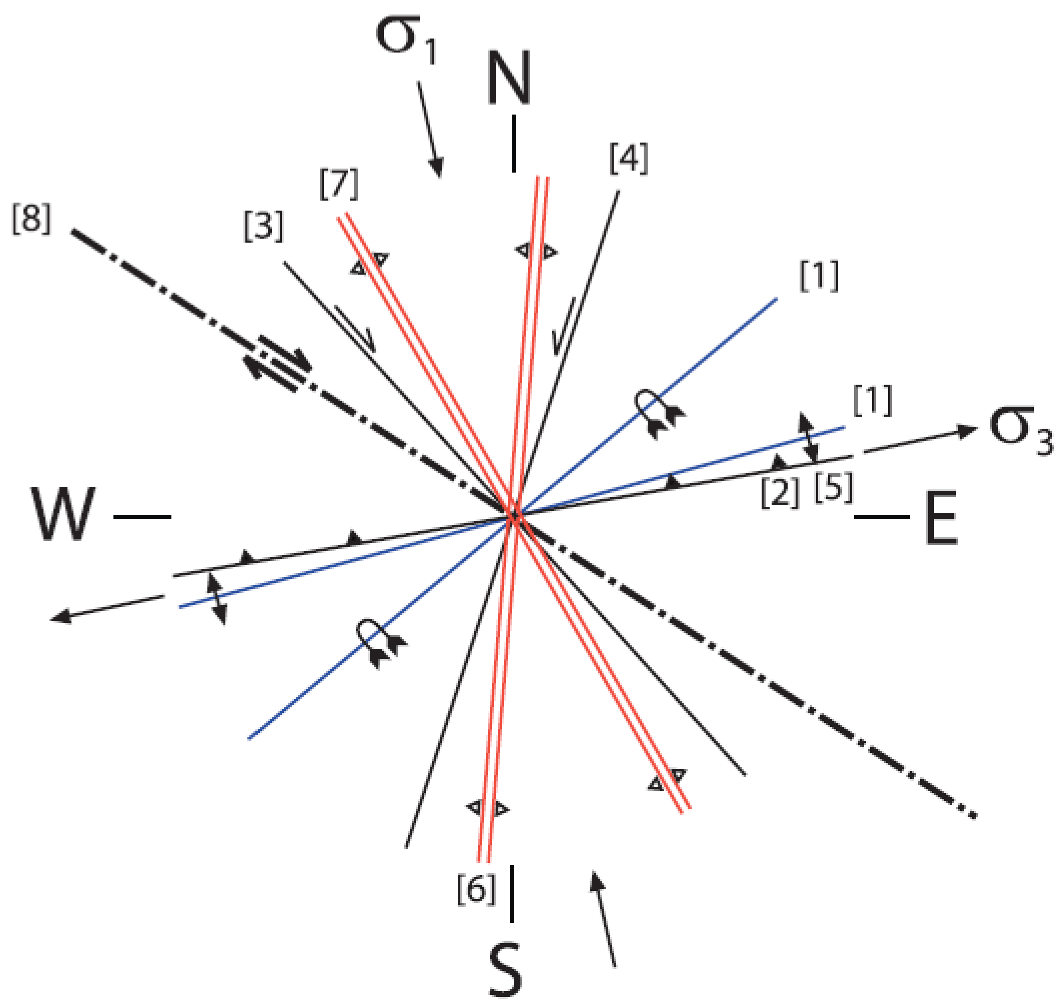


Figure 5. The positions of observed subsidiary structures [1 to 7], and the determination of the main strike-slip strands of the Eskişehir Fault Zone, namely Bahçehisar and Çukurhisar-Sultandere segments [8]. See text for further explanation.

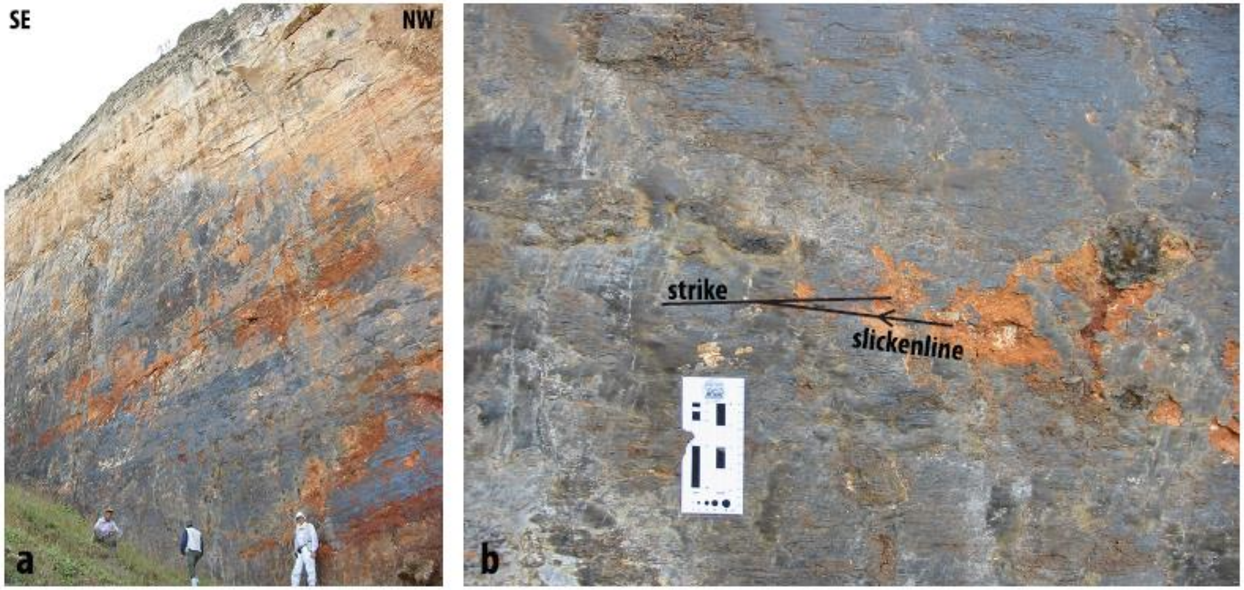


Figure 6. Photos of a Riedel shear (N45W, 90°, rake: 8°) of the major Eskişehir Fault Zone near the Turkish Aeronautical Association Training Center. This structure cuts the nearly E-W-trending normal fault. For position, see Figures 3a and 7, location 12.

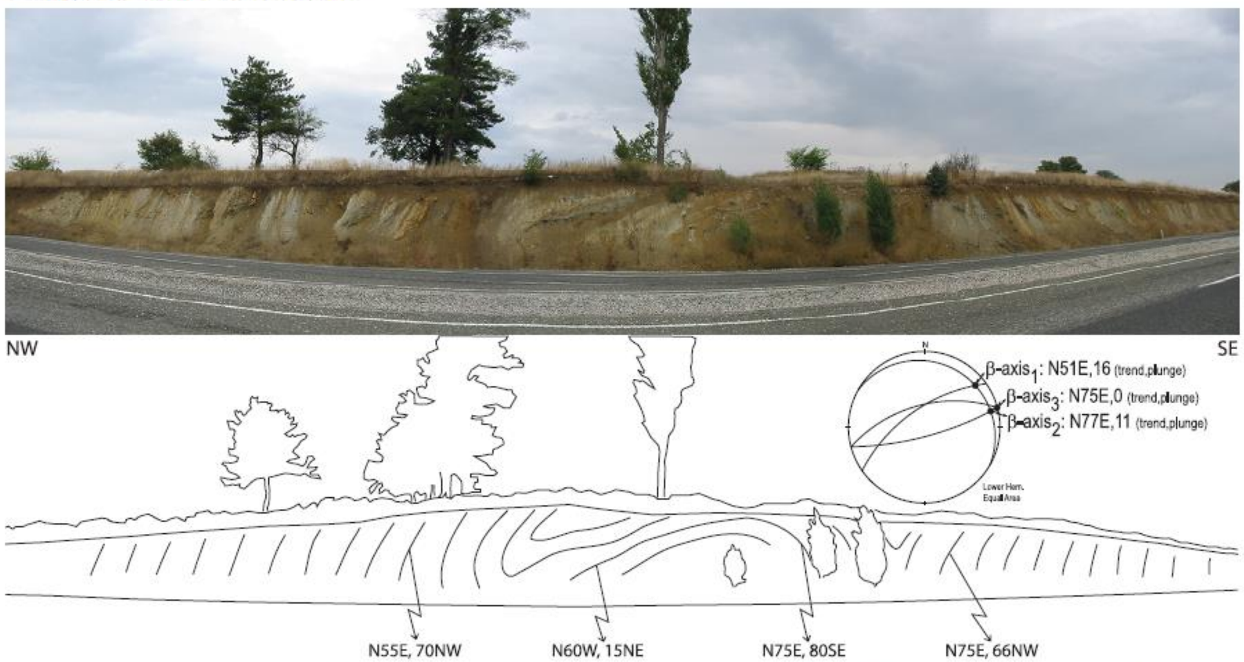


Figure 4. Photograph and its sketch of the overturned folds with beta diagram along the road cut between Bozüyük and İnönü. For position, see Figure 3a, locations 7 and 8.

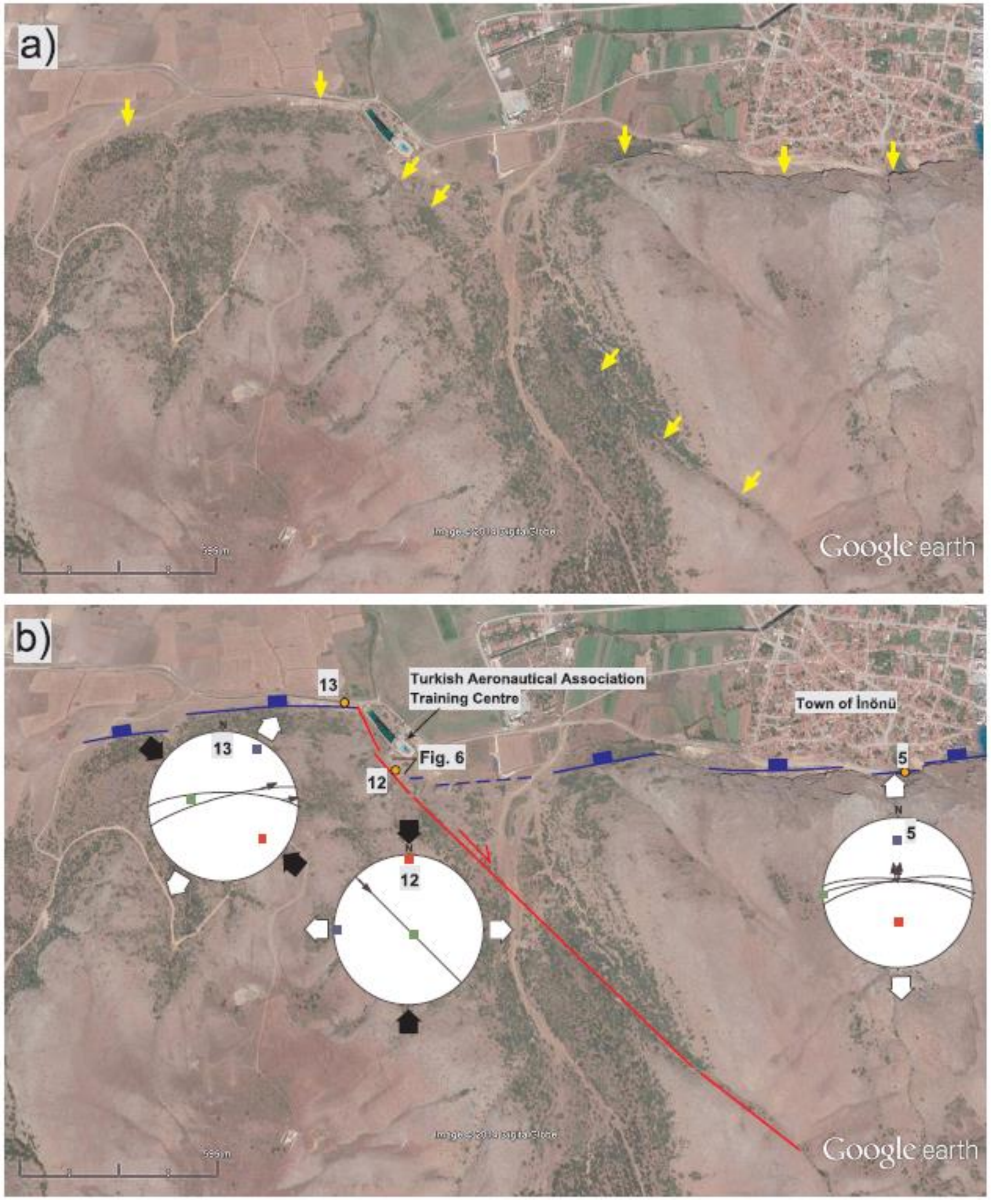


Figure 7. The cross-cutting relationship between NW-SE-trending strike-slip and E-W-trending normal faulting in the west of İnönü town. (**a**) Uninterpreted Google Earth image. Yellow arrows show fault traces. (**b**) Normal fault traces (blue) and strike-slip fault traces (red) with the structural data. For the overall positions of locations 5, 12, and 13, see Figure 3a.

No.	Coordinates (geographic)		Strike	Dip	Rake	Sense of slip	σ_1		σ_2		σ_3	
	°E	°N					Trend	Plunge	Trend	Plunge	Trend	Plunge
1	30.402164	39.669112	N44E	78NW	7N	Reverse	179	4	283	76	88	13
2	30.405558	39.711393	N30W	73SW	13S	Normal	108	21	278	69	16	3
3	30.424091	39.730543	N26E	38SE	8S	Reverse	350	30	106	38	233	38
4	30.093083	39.570313	N80W	60NE	13N	Reverse	145	13	35	58	242	29
5	30.141070	39.812724	E-W	78N	90	Normal	179	59	269	0	359	31
			N81E	76NW	90	Normal						
			N85W	75NE	90	Normal						
6	30.100708	39.873372	N77W	87NE	47S	Normal	158	34	286	43	46	29
7	30.112004	39.852683	N81E	36NW	90	Reverse	171	9	261	0	351	81
8	30.109727	39.854032	N31W	66NE	0	Right Lateral	191	17	59	66	287	17
9	30.006285	39.857459	N18E	79SE	15N	Normal	349	18	154	72	258	5
			N42W	86SW	20N	Normal						
10	30.006230	39.854422	N40W	90	0	Right Lateral	5	0	90	90	95	0
11	29.994309	39.825487	N72E	85NW	90	Normal	169	54	261	1	352	36
			E-W	77N	90	Normal						
12	30.118567	39.812023	N45W	90	8N	Reverse	0	6	135	82	270	6
13	30.114554	39.814130	E-W	75N	22E	Normal	129	33	282	54	31	13
			N75E	80NW	44N	Normal						
14	30.094129	39.799342	N80E	90	9N	Normal	314	7	202	71	47	17
			N16E	80NW	33N	Reverse						
15	30.754791	39.873429	N65E	55SE	9N	Normal	22	31	182	57	286	9
			N55E	67SE	25N	Normal						
16	30.466386	39.754374	N61W	81NE	30S	Normal	165	27	314	59	68	14
17	30.518927	39.743069	E-W	85S	40E	Reverse	149	8	259	67	56	21
			N58W	80NE	0	Right Lateral						
			N20E	85SE	30S	Normal						
			N70E	86SE	20N	Reverse						
			N87E	67SE	26N	Reverse						
			N40W	82SW	19S	Reverse						
			E-W	85S	18E	Reverse						
18	30.378889	39.862512	N66E	55SE	42S	Normal	276	53	99	38	8	1
19	30.558884	39.861560	N78W	55SW	35N	Normal	327	8	103	79	236	8
			N25E	75SE	35S	Reverse						
20	30.434294	39.863860	N35W	48SW	25N	Normal	352	44	200	42	97	15

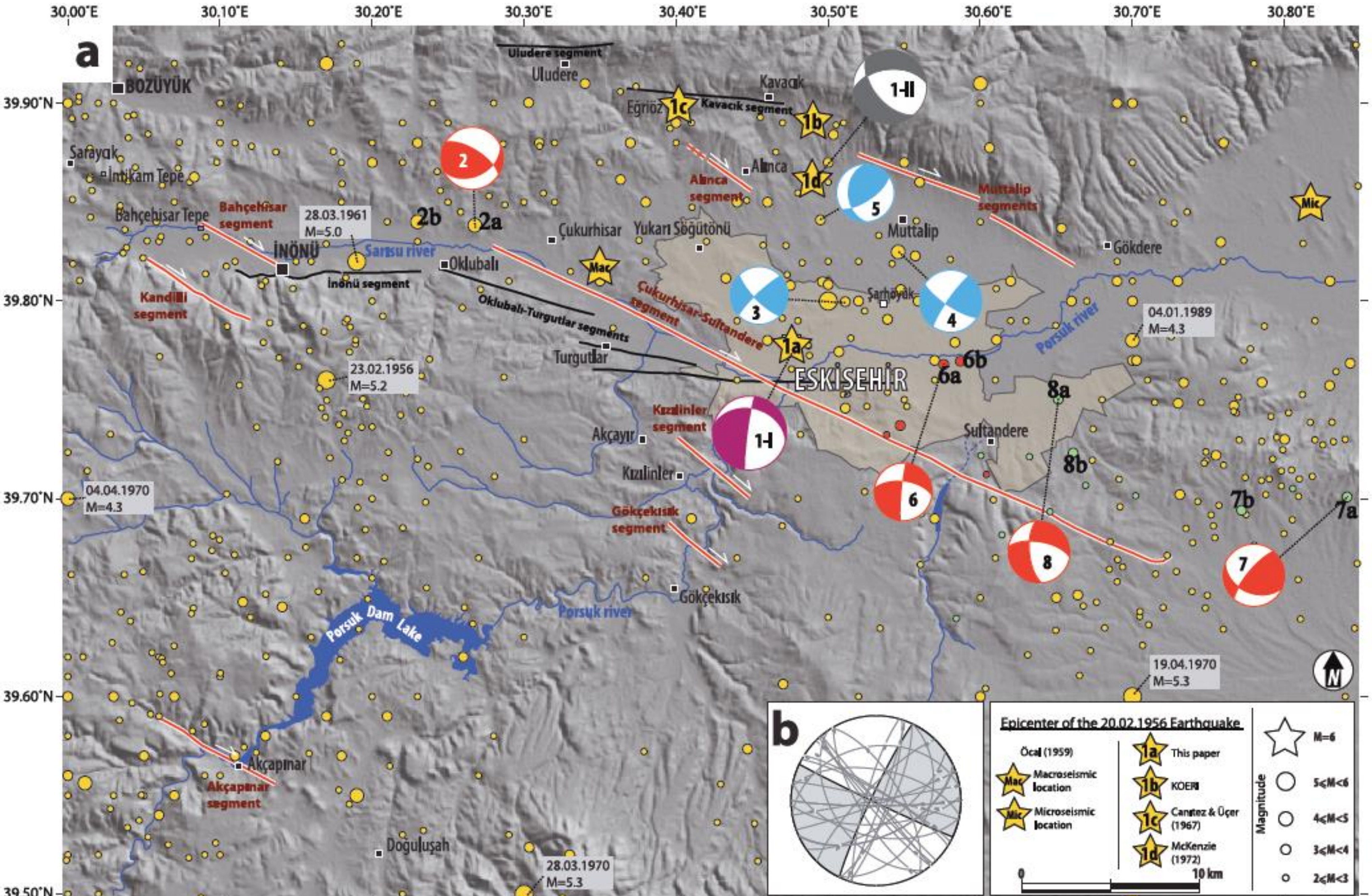


Figure 13. **(a)** The seismicity map of the Eskişehir area. Data from the earthquake catalog (1900–2013) of Boğaziçi University, Kandilli Observatory and Earthquake Research Institute (KOERI). Focal mechanism solutions (1-I) 20.02.1956, Canıtez and Üçer (1967); (1-II) 20.02.1956, McKenzie (1972); (2) 24.10.1990, this paper; (3) 02.10.2003, (4) 03.10.2003, (5) 04.10.2003, Ocakoğlu et al. (2005); (6) 07.02.2010, (7) 17.02.2013, (8) 01.03.2013, this paper. Aftershock distributions of 2010 and 2013 events are shown with red and green dots, respectively. See Table 2 for details of the earthquakes. The black fault segments are from Altunel and Barka (1998) and Ocakoğlu (2007). **(b)** The overall evaluation of structural data, except for locations 5, 11, and 13, is given for comparison with the focal mechanism solution of Canıtez and Üçer (1967). FaultKin software was used for kinematic analysis of fault-slip data (Marrett and Allmendinger, 1990; Allmendinger et al., 2012).

Table 2. Earthquake parameters and focal mechanism solutions of the seismic events around Eskişehir.

#	Date (d.m.y)	Earthquake parameters						Fault plane parameters			
			Time (GMT)	Latitude (N°)	Longitude (E°)	Depth (km)	Magnitude		Strike 1 Strike 2	Dip 1 Dip 2	Rake 1 Rake 2
1	20.02.1956	a	20:31:40.93	39.778	30.476	18.3	-	I	284 187	34 85	–172 –56
		b	20:31:37.00	39.890	30.490	40	6.4	II	140 264	56 50	–51 –133
		c	20:31:39.00	39.900	30.400	-	6.5				
		d	20:31:38.10	39.860	30.490	9	6.0				
		Mac.	20:31:35.00	39.817	30.350	23	6.4				
		Mic.	20:31:35.00	39.850	30.817	23	6.4				
2	24.10.1990	a	11:16:43.41	39.838	30.268	0.5	-	III	65	40	40
		b	11:16:44.32	39.840	30.230	18.2	4.4		302	66	123
3	02.10.2003	b	17:22:05.00	39.799	30.511	16.1	3.9	IV	135 226	76 82	172 14
4	02.10.2003	b	22:27:47.00	39.825	30.546	17.4	4.2	IV	123 214	76 82	172 14
5	04.10.2003	b	17:53:06.00	39.841	30.495	8.6	3.7	IV	56 178	67 38	122 38
6	07.02.2010	a	17:21:33.20	39.768	30.576	4.1	3.6	III	278	60	–174
		b	17:21:32.15	39.770	30.587	5.0	3.7		185	85	–30
7	17.02.2013	a	08:34:28.83	39.701	30.841	10.4	3.1	III	220	75	50
		b	08:34:28.00	39.694	30.772	7.6	2.3		113	42	158
8	01.03.2013	a	14:37:16.18	39.751	30.651	0.1	3.4	III	175	65	–30
		b	14:37:16.00	39.723	30.661	1.5	3.5		279	63	–152

a: New hypocentral parameters computed in this study.
b: Original hypocentral parameters provided by KOERI.
c: Original hypocentral parameters provided by Canıtez and Üçer (1967).
d: Original hypocentral parameters provided by McKenzie (1972).
Mac./Mic.: Original hypocentral parameters provided by Öcal (1959).

I: Canıtez and Üçer (1967).
II: McKenzie (1972).
III: This study.
IV: Ocakoğlu et al. (2005).