

**INTERNATIONAL WORKSHOP ON COMPARATIVE STUDIES
OF THE NORTH ANATOLIAN FAULT (NORTHWEST TURKEY)
AND THE SAN ANDREAS FAULT (SOUTHERN CALIFORNIA)**

**ISTANBUL TECHNICAL UNIVERSITY
AUGUST 14-18, 2006**



GUIDE BOOK

**FIELD TRIP TO THE NORTH ANATOLIAN FAULT SYSTEM
BETWEEN İZMİT AND YALOVA**

Prepared by

Ömer Emre, Volkan Özaksoy (MTA) Namık Çağatay (İTÜ)

August 17, 2006 Thursday

**INTERNATIONAL WORKSHOP ON COMPARATIVE STUDIES
OF THE NORTH ANATOLIAN FAULT (NORTHWEST TURKEY)
AND THE SAN ANDREAS FAULT (SOUTHERN CALIFORNIA)**

ISTANBUL TECHNICAL UNIVERSITY

AUGUST 14-18, 2006

GUIDE BOOK

**FIELD TRIP TO THE NORTH ANATOLIAN FAULT SYSTEM
BETWEEN İZMİT AND YALOVA**

Field Trip Leaders

Ömer Emre, Volkan Özaksoy (MTA) & Namık Çağatay (İTÜ)

August 17, 2006 Thursday

CONTENTS

	Page
CONTENTS	I
PROGRAM	II
THE NORTH ANATOLIAN FAULT SYSTEM IN THE EASTERN MARMARA REGION	2
OUTLINE OF THE SURFACE RUPTURE OF THE 1999 İZMİT EARTHQUAKE	4
SITE DESCRIPTIONS	7
Stop 1: Kavaklı District of Gölcük Town	7
Stop 2: Yüzbaşılar District of Gölcük Town	12
Stop 3: Kaytazdere / East of Altınova	14
Stop 4: Hersek promontory / North of Altınova town	14
Stop 5: Çukurköy normal fault south of Yalova	17
SELECTED REFFERENCES	18

PROGRAM*

Date: Thursday, August 17, 2006

Departure: 08.00 am / front of Faculty of Mines Building of ITU

08:00-10:00

Transportation from ITU to Gölcük town

10:00-11:00

Stop 1: Ford Otosan Factory-Kavaklı District / Gölcük Town

11:15-11:45

Stop 2: Yüzbaşılar District / Gölcük Town

12:30-13:00

Stop 3: Kaytazdere / İzmit-Yalova roadcut / Altınova

13:00-14:00

Lunch Break / Altınova

14:30-16:30

Stop 4: Hersek promontory / Altınova

17:00-17:30

Stop 5: Armutlu peninsula / South of Yalova

18:20

Return to Istanbul

Estimated Arrival time to Faculty of Mines-ITU at 20.30

** Field trip route and locations of the stops are shown on Figure 1.*

FIELD TRIP TO THE NORTH ANATOLIAN FAULT SYSTEM BETWEEN İZMİT AND YALOVA
August 17, 2006 Thursday

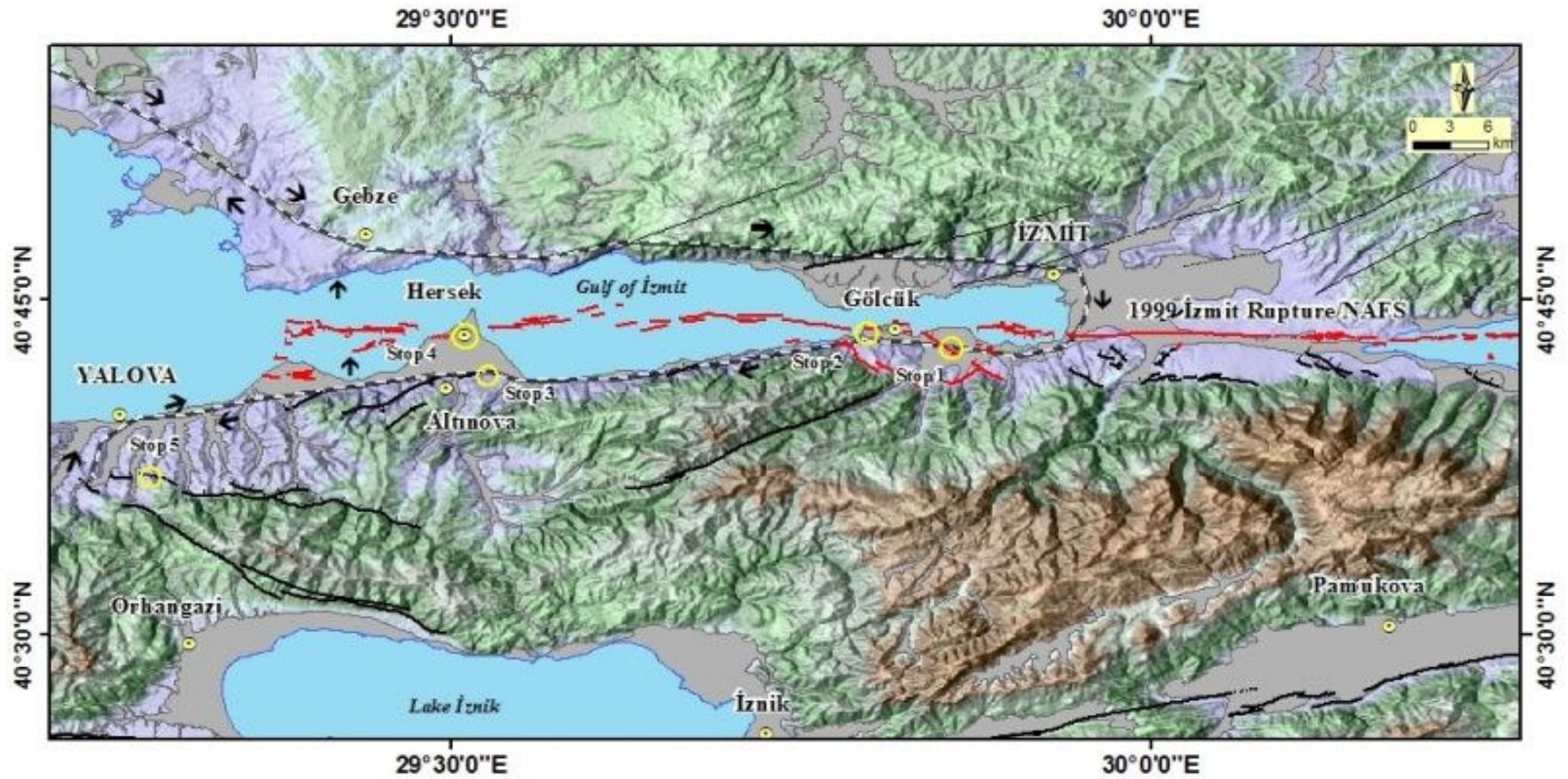


Figure 1. The map showing the route and stops of the “Field trip to the North Anatolian Fault System between Yalova and İzmit”.

THE NORTH ANATOLIAN FAULT SYSTEM IN THE EASTERN MARMARA REGION

The North Anatolian Fault System (NAFS) is a seismically active continental plate boundary transform system that extends between the Anatolian Block and the Eurasian plate. It is a 1500 km-long, right lateral strike slip fault running along the northern Anatolia in E-W direction. Together with the left lateral East Anatolian Fault System, the NAFS accommodates westward extrusion of the Anatolian block (Figure 2 and 3). The recent GPS data reveals that the average slip rate along NAFS is 24 mm/year.

The NAFS extends in a relatively narrow zone between Karlıova and Bolu. However, it turns into a broad deformation zone and bifurcates into two main strands in the Marmara region, northern and southern. The northern strand that is master zone in the NAFS extends beneath the Sea of Marmara. Lateral motion along the NAFS is essentially accommodated by this strand. The southern strand extends between Dokurcun valley and Bandırma bay and it is included in the NW Anatolia transition zone between NAFS and Egean extensional tectonic regime.

The NAFS between Bolu and the Sea of Marmara runs along the suture zone that was formed by the closing of the Intra-Pontide Ocean in the Eocene - the Oligocene. The rocks units of the İstanbul and Sakarya zones are in contact along the transform system. The İstanbul zone comprising the pre-Neogene rocks is represented by the Ordovician to the Lower Tertiary rocks at the north of the NAFS. The Sakarya zone that is situated south of the fault system, is represented by metamorphic basement rocks and the Jurassic to the Cretaceous sedimentary cover. The Samanlıdağ massive / Armutlu peninsula uplifted as a large scale pressure ridge or an anticlinorium between both strands of NAFS. Kocaeli peninsula on the northern block of the NAFS is morphologically characterized by a well-developed peneplain with average elevation of 150-200 m. The peneplain surface was tilted towards to north. This peneplain also forms summit flatness on the Armutlu peninsula. Therefore it is concluded that the amount of uplifting of the Armutlu peninsula is about 1000 m between both strands of NAFS from the Pliocene to Recent period (Emre et al., 1998).

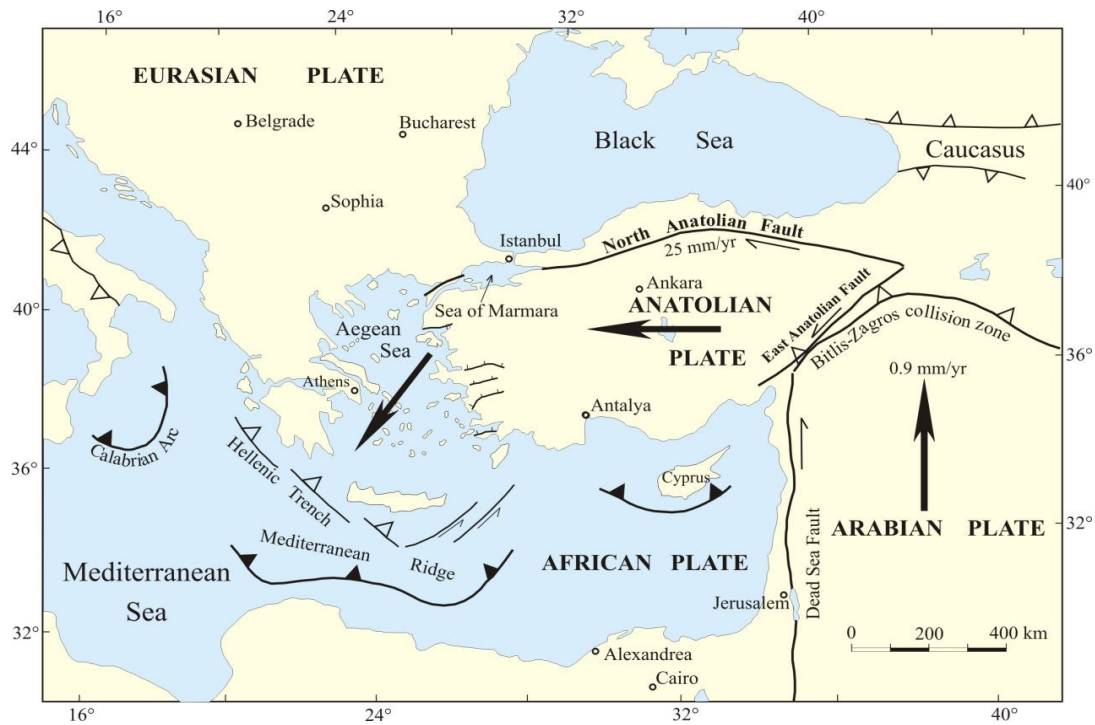


Figure 2. Major tectonic elements of the Eastern Mediterranean region. The North Anatolian Fault System accommodates westward extrusion of the Anatolian block together with the left lateral East Anatolian Fault.

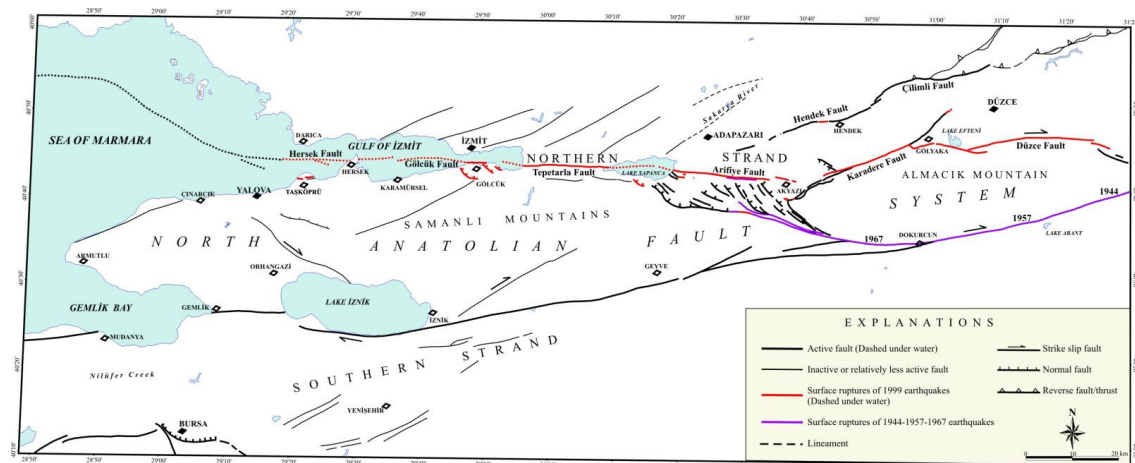


Figure 3. Fault pattern along the North Anatolian Fault System in the Eastern Marmara region (after Emre and Awata, 2003).

OUTLINE OF THE SURFACE RUPTURE OF THE 1999 İZMİT EARTHQUAKE

The seismically active NAFS is one of the important major intra-continental transform fault in the world. It is known that many destructive earthquakes were produced in the last two millennia by the NAFS. The NAFS ruptured in a sequence of large earthquakes between 1939 and 1999, generally progressing from east to west. About 900 km-long surface faulting was formed by the seven large earthquakes along the NAFS between Erzincan and Sakarya basins before the 1999 İzmit earthquake (Figure 4). Each earthquake transferred the stress nearby segments to the west and triggered the next event. The August 17, 1999 earthquake is the westernmost large event in this sequence, and the epicenter of the mainshock is located to the west of the 1967 event.

The Mw 7.4 İzmit earthquake occurred on August 17, 1999 in the Eastern Marmara region. The epicentre of the earthquake was at 40.74°N and 29.96°E, several km southeast of İzmit and focal depth was 17.1 km (Ito et al., 2002). Multi-segment right lateral surface faulting totally 150 km-long along the northern strand of NAFS between Düzce basin and Yalova, occurred during the earthquake. Between Gölcük and Yalova, approximately 45 km western part of the surface rupture lies in the Gulf of İzmit (Figure 5). The surface rupture associated with the 1999 İzmit earthquake are subdivided into six segments, from west to east: Hersek, Gölcük, Tepetarla, Arifiye, Karadere, and Aksu segments, on basis geometry of the fault strands and discontinuity of slip distributions along the rupture (Figure 5 and Table 1). Segment lengths are various between 15-31 km and maximum displacement of 1.7-4.9 m. Each segment are separated from each other by releasing stepovers except for Hersek restraining bend (Table 1).

Three localities will be visited along the western part of the 1999 İzmit rupture in this trip. Stop 1 is located in the releasing stepover between Gölcük and Tepetarla segments; Stop 2 is on the right lateral Gölcük segment and Stop 4 on the Hersek restraining bend between Yalova and Gölcük segments of the 1999 İzmit rupture.

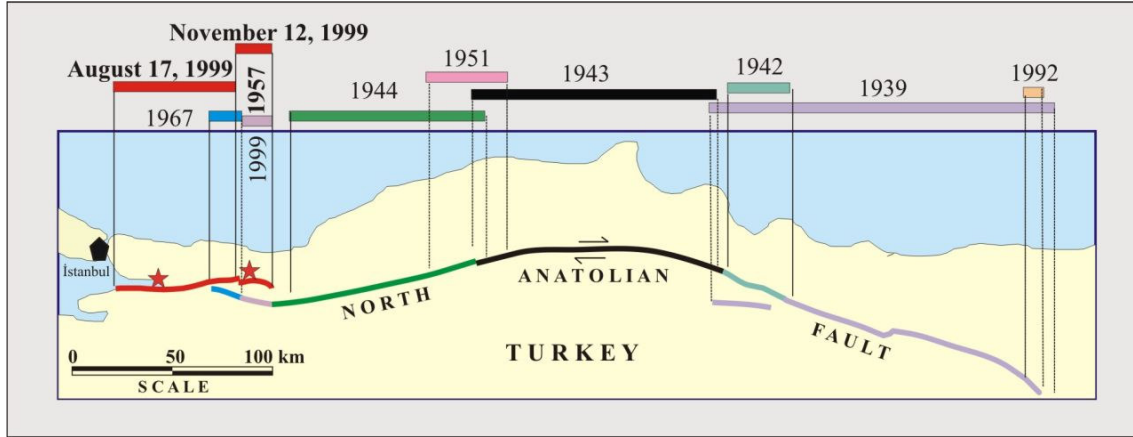


Figure 4. The surface ruptures developed during the large earthquakes in 1939 and 1999 period along the NAFS.

Table 1. Segment structure and jog characteristics of the 1999 İzmit rupture (after Awata et al., 2003)

Segment							Jog							
Total Length (km)	RL-Slip* Ave. Max (m)	Segment Name	Length (km)	Strike (der.)	Section NameAdı (km)	RL-Slip* Ave. Max (m)	Jog Name	Length (km)	Width (km)	Step (km)	Bend (deg.)			
150***	2,9	4,9	Hersek**	91	Yelkenkaya	3+	Darıca	3+	2+	---	-30 ?			
					Hersekburun	14	0,0	0,0	Karamürsel	11	2-3	---	7	
					Hereke	6	Gölcük	22						98
			Yüzbaşılar	12	4,1	4,3			Hisar	9	3	---	-7	
			Denizevler	5	Tepetarlar	34								
			Sarmeşe	23			2,9	3,6	Sapanca	11	1	1	4	
			Eşme	5			Arifiye	31						95
			Türk Çaybaşı	18	3,1	4,9			Akyazı	15	5 ?	---	-22	
			Yahyalı	7	Karadere	13								
			Çamlıca	8			1,3	2,1	Aksudere	4	0,6	---	-5	
			Kara	1			Aksu	17						68
			Dere	4	1,4	1,7			Gölyaka	7	11	---	17	
			Şerif	10										

FIELD TRIP TO THE NORTH ANATOLIAN FAULT SYSTEM BETWEEN İZMİT AND YALOVA
 August 17, 2006 Thursday

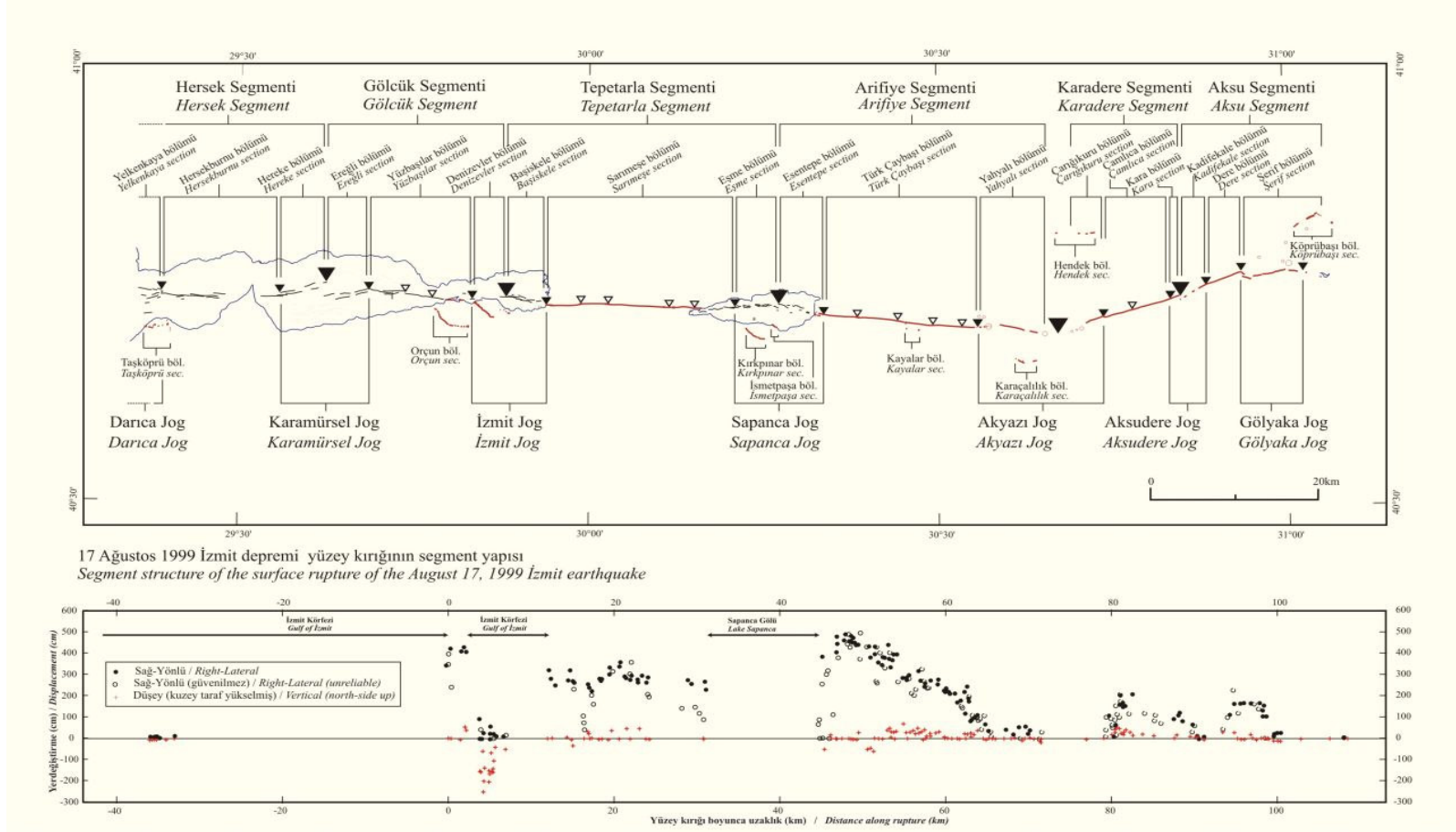


Figure 5. Segment structure and slip distribution along the surface rupture of August 17, 1999 İzmit earthquake (After Awata et al., 2003)

SITE DESCRIPTIONS

Five localities that will be visited during the field trip are shown on the Figure 1. Three sites are situated along the western part of the surface rupture associated with the 1999 İzmit earthquake. Information and figures for the site description on the surface rupture of the 1999 İzmit earthquake are taken from the Special Publication Series-1 of the MTA (Surface Rupture associated with the August 17, 1999 İzmit Earthquake: Editors; Ömer Emre, Yasuo Awata and Tamer Yiğit Duman, 1999).

Stop 1: Kavaklı District of Gölcük Town

Normal faulting in Gölcük releasing step-over between Tepetarla and Gölcük segments of the 1999 İzmit rupture: A pull apart basin formed between both segments. A 5 km-long normal faulting was formed in the northwest-southeast trending and incurving to the north southern margin of the pull apart basin. The submarine data indicate that a serial normal faulting is also occurred on the northern margin of the pull apart basin. The Kavaklı normal fault in which 2.5 m vertical offset occurred in the 1999 İzmit earthquake will be seen at the site (Figures 6, 7, 8, 9). Also lateral spreading and inundated coastal zone of the Hisar dere delta on the northern block of the normal fault will be seen (Figures 10, 11).

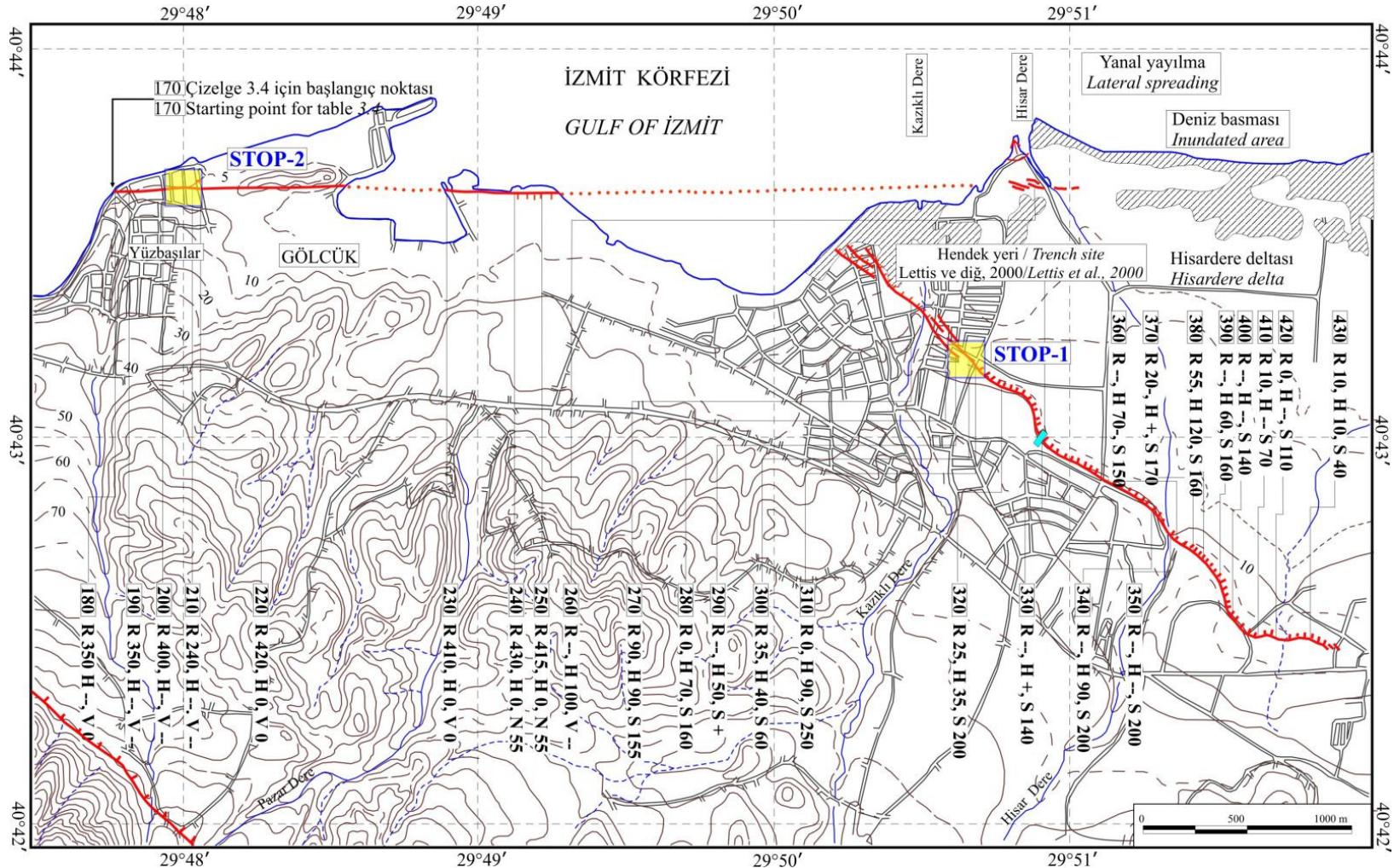


Figure 6. Detailed rupture map of the 1999 İzmit earthquake and slip measurements in the Gölcük area (after Duman et al., 2003).

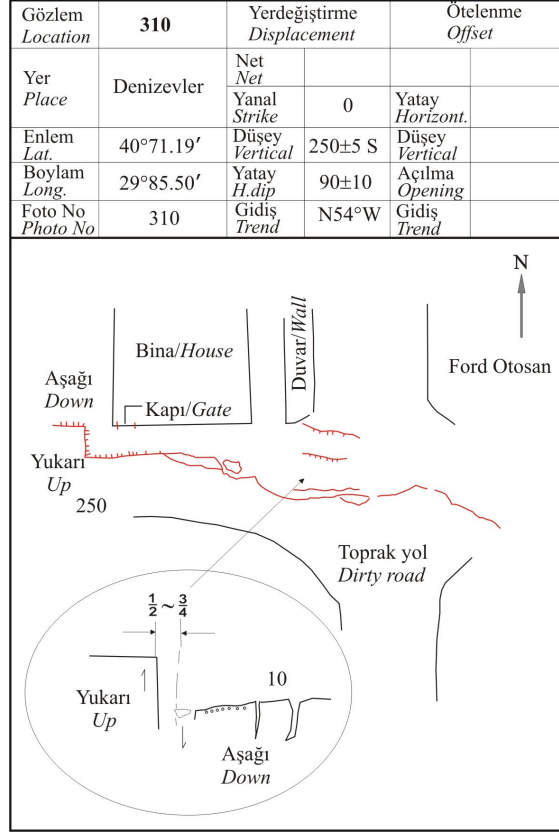


Figure 7. Sketch of the normal fault that occurred in 1999 İzmit earthquake at Stop 1, Denizevler district, Gölcük town (Duman et al., 2003).



Figure 8. Normal fault scarp at the Stop 1 in the Kavaklı district of the Gölcük town.



Figure 9. Flexure scarplet and left stepping en-echelon cracks along the oblique faulting in Kavaklı district of Gölcük town.



Figure 10. Lateral spreading developed along the coastal zone of Hisar dere delta in the 1999 İzmit earthquake.



Figure 11. Inundated area due to normal faulting and lateral spreading in Kavaklı district of Gölcük town.

Stop 2: Yüzbaşılar District in Gölcük Town

The site is located on the eastern section of the Gölcük segment of the 1999 İzmit rupture which is 22 km-long between offshore Karamürsel and Gölcük stepover. Western part of the segment lies beneath the Gulf of İzmit (Figure 5). Eastern section of the segment cuts the Gölcük promontory on land in E-W direction with 3.5-4.3 m of right lateral displacement (Figures 6, 12). At the site, 4.30 m of right lateral displacement developed in the 1999 İzmit earthquake on a road and the stone-wall in the Yüzbaşılar district of town of Gölcük will be visited (Figure 13).

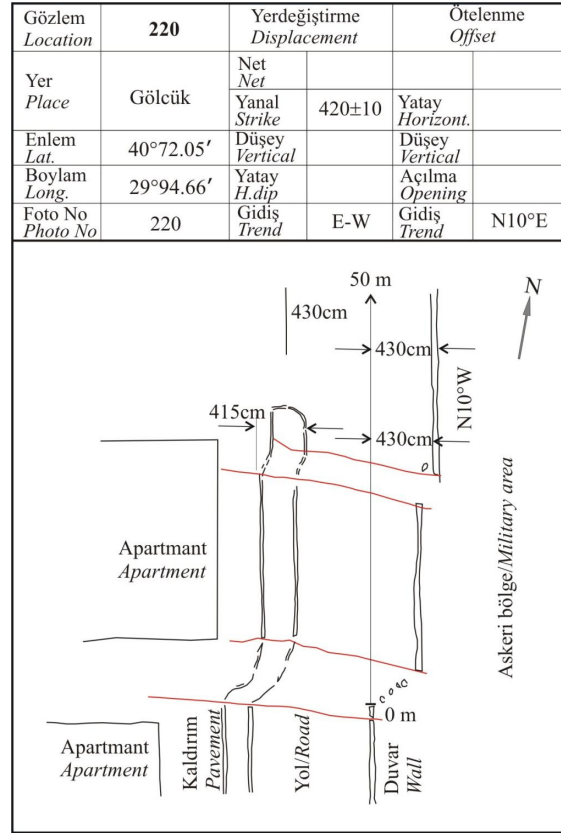


Figure 12. Offset features of the Gölcük segment of the 1999 İzmit rupture at Stop 2. (Duman et al., 2003).



Figure 13. Stone wall of the Navy base at Stop 2 displaced 4.30 m in a 50 m width of deformation zone in the 1999 İzmit earthquake.

Stop 3: Kaytazdere / East of Altınova

The uplifted Tyrrhenian Terrace on the southern coast of Izmit bay: The Quaternary deposits in the form of marine terraces and delta deposits occur on the southern coast of the Gulf of İzmit (Figure 1). The Tyrrhenian Marine terraces (sensu-lato) are found in Hersek, Altınova and Kaytazdere (Sakinç and Bargu, 1989; Paluska et al., 1989; Görür et al., 1997). In Kaytazdere, the terrace sediments overlay the Eocene turbidites with an angular unconformity and consist, from base to top, of pebble conglomerate, green fossiliferous mud, fossiliferous gray pebbly sand and a 9 m-thick oyster (*Ostrea edulis*) bank. The terrace sequence is 12-15 m above the present sea level. The marine terrace deposits in Altınova and Kaytazdere were dated by U-Th series method to be from 130 to 260 kyr old (Paluska et al., 1989). Recent ¹⁴C-dating indicates that the top part of these terraces could be as young as 36 kyr BP (Çağatay et al., 2003).

Stop 4: Hersek promontory / North of Altınova town

Hersek ridge and uplifted the late Holocene marine terraces and paleoshorelines: The Hersek promontory separates Karamürsel and Darıca submarine basins in the Gulf of İzmit. The peninsula consists of Hersek ridge characterized by the Pleistocene and the late Holocene marine deposits in the north and recent deltaic sediments in the south. Hersek ridge which is an emerged sea mount forming in a restraining bend between Yalova and Gölcük segments in the North Anatolian Fault System has an asymmetric topography in N-S direction. The ridge is bounded by a serial thrust faults from the south. Submarine data show that seafloor rupturing of 1999 İzmit earthquake was clear in the Karamürsel basin, but there was no clear surface ruptures on land except for some cracks (Figure 14). However, SAR and seismological data indicate that the faulting of the 1999 İzmit earthquake might be reached to the east of the Çınarcık basin. Although 4.60 meters of maximum right lateral displacement was measured on the Gölcük segment, the maximum displacement on Yalova segment is only 1.5 meters obtained from SAR data. Rapid decreasing in the amount of the lateral displacement indicates existence of a barrier for propagation of the rupture towards to the west in the Hersek area. Therefore, it was

concluded that during the 1999 İzmit event, the restraining Hersek bend should be played an absorbent jog structure for the overall strike motion along the NAF in the Gulf of İzmit (Emre et al., 2003).

Four uplifted Holocene coastal terraces and paleoshorelines on the northern flank of the Hersek ridge were observed (Figure 15). The oldest terrace surface is about +7-8 m above the current sea level while the youngest one is at an elevation of +2,04 m. The six trenches were excavated on the terraces by MTA team. The oldest unit in the trenches consists of bluish gray mud with turbiditic sand intercalations. The soft sedimentation related deformational structures are commonly seen within this unit. It is overlain by the fossiliferous, gently seaward dipping, shoreface and fossiliferous beach sand deposits respectively. Each coastal terrace formed due to large earthquakes and elevated up to 8 m. The ^{14}C dating results of the terraces correspond with the some historical events occurred in the region. It is suggested that the youngest terrace uplifted by the great 1509 event (Özaksoy et al., 2006; in this workshop).

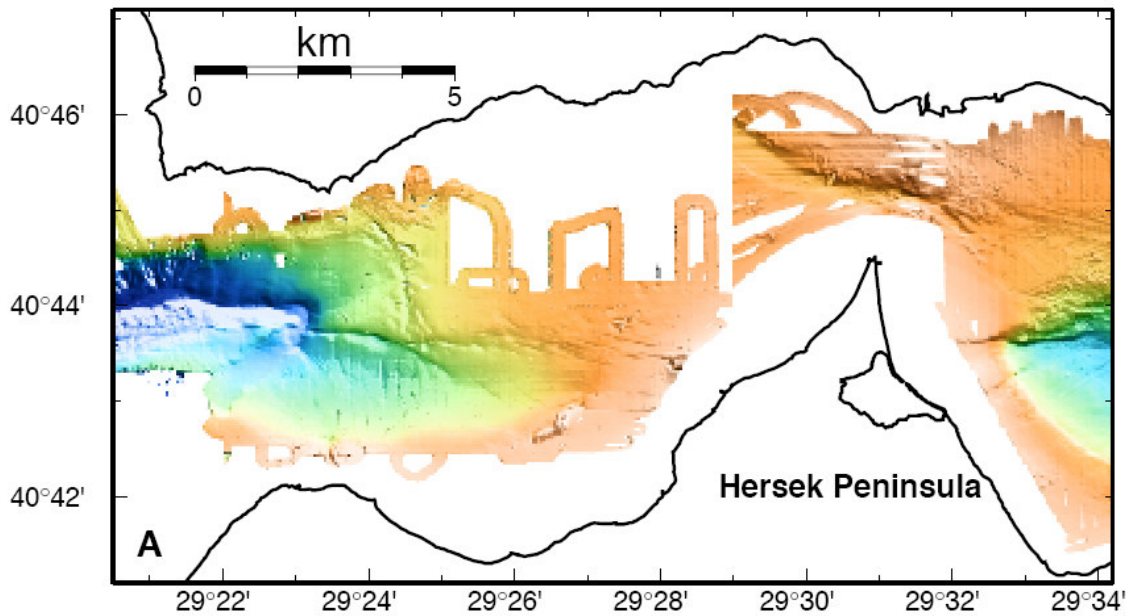


Figure 14. Multibeam bathymetry of the Gulf of İzmit vicinity of Hersek promontory. There is a 7° restraining bend between Gölcük and Yalova segments of the NAFS (from Cormier et al., in review).

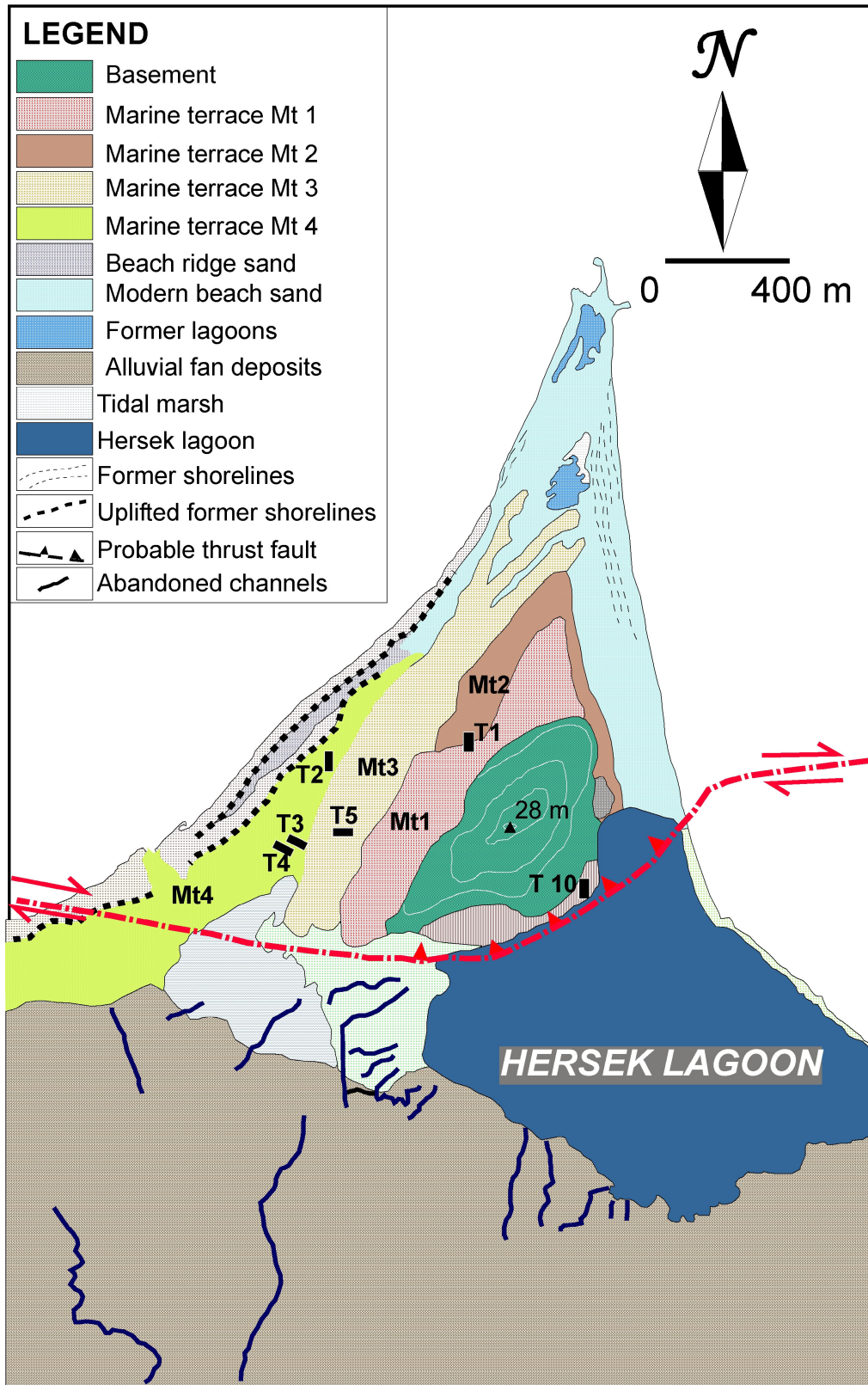


Figure 15. Geomorphologic map of Hersek promontory (after Özaksoy et al, 2006).

Stop 5: Çukurköy normal fault south of Yalova

Çukurköy fault extends in the NW-SE direction on the northern margin of the Armutlu peninsula at the south of Yalova. On the northern margin of the peninsula, a conjugate active fault pattern is represented (Figure 16). The active faults trending in NW and WNW are normal dip slip with right lateral component (Orhangazi and Çukurköy faults), whereas the faults trending in NE are reverse dip slip or right lateral strike slip (Yalakdere and Altınova Faults) in the area. These faults form the secondary structures within the NAFS and accommodate uplifting of the Samanlıdağ massive between northern and southern strands of the NAFS. Çukurköy fault is a normal dip slip fault, about 20 km-long and northern block is downthrown. In general, the fault forms geological contact between the Miocene sequence (Yalova formation) and the pre-Miocene basement rocks. Morphotectonic data indicate the late Quaternary activity of the fault such as triangular fault facets and back tilted surfaces (Emre et al, 1998, Emre et al. in press). The aftershocks at the westernmost end of the 1999 Izmit rupture clustered on the area located at the western termination of the Çukurköy and Orhangazi faults. The normal dip slip fault plane and back tilted land forms will be seen along the Çukurköy normal fault at the Stop 5.

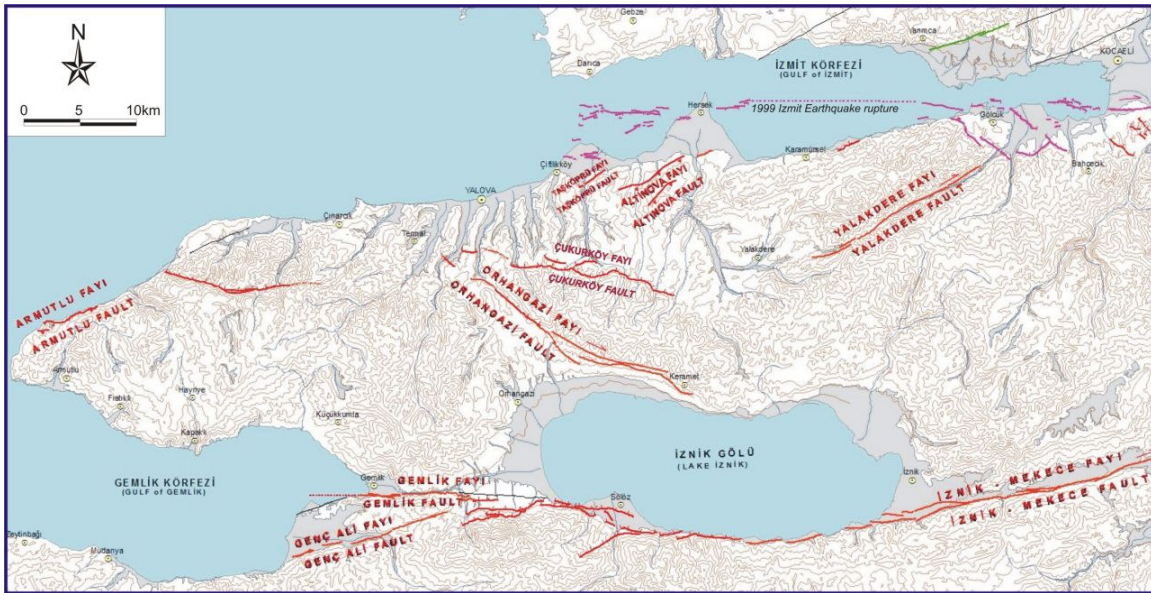


Figure 16. Active fault map of the Armutlu peninsula (Emre et al., in press).

SELECTED REFFERENCES

- Awata, Y., Yoshioka, T., Emre, Ö., Duman, T.Y., Doğan, A., Tsukuda, E., Okamura, M., Matsuoka, H. and Kuşçu, İ., 2003, Outline of the surface rupture of 1999 İzmit Earthquake. In: Surface Rupture Associated with the August 17, 1999 İzmit Earthquake, (eds: Ö. Emre, Y. Awata and T.Y. Duman), General Directorate of Mineral Research and Exploration, Special Publication Series: 1, 41-50, Ankara.
- Cormier, M.-H., Seeber, L., McHugh, C.M.G., Polonia, A., Çağatay, N., Emre, Ö., Gasperini, L., Görür, N., Bortoluzzi, G., Bonatti, E., Ryan, W.B.F. and Newman, K.R., (in review), The North Anatolian Fault in the Gulf of İzmit (Turkey): Rapid vertical motion in response to minor dip and bends of a continental transform. *Journal of Geophysical Research*
- Çağatay, M.N., Görür, N., Polonia, A., Demirbağ, E., Sakınç, M., Cormier, M.-H., Capotondi, L., McHugh, C. Emre, Ö., Eriş, K. (2003). Sea level changes and depositional environments in the İzmit Gulf, eastern Marmara Sea, during the late glacial-Holocene period. *Marine Geology*, 202, 159-173.
- Duman, T.Y., Awata, Y., Yoshioka, T., Emre, Ö., Doğan, A. and Özalp, S., 2003, Detailed maps and inventories of the 1999 İzmit Surface Rupture. In: Surface Rupture Associated with the August 17, 1999 İzmit Earthquake, (eds: Ö. Emre, Y. Awata and T.Y. Duman), General Directorate of Mineral Research and Exploration, Special Publication Series: 1, 51-55, Ankara.
- Emre, Ö. and Awata, Y., 2003, Neotectonic characteristics of the North Anatolian Fault System in the Eastern Marmara region. In: Surface Rupture Associated with the August 17, 1999 İzmit Earthquake, (eds: Ö. Emre, Y. Awata and T.Y. Duman), General Directorate of Mineral Research and Exploration, Special Publication Series: 1, 31-39, Ankara.
- Emre, Ö., Erkal, T., Tchepalyga, A., Kazancı, N., Keçer, M. and Ünay, E., 1998, Neogene-Quaternary evolution of the eastern Marmara region, Northwest Turkey: *Mineral Res. Expl. Bull.*, 120, 119-145.
- Emre, Ö., Doğan, A., Özaksoy, V., Özalp, S., Yıldırım, C., Tokay, F., Seeber, L., Cormier, M.-H., Kuşçu, İ., Polonia, A., Matsuoka, H. and Awata, Y., 2003, The Restraining Hersek Bend: Is it a barrier to rupture propagation for the 1999 İzmit earthquake? International Workshop on the North Anatolian, East Anatolian and Dead Sea Fault Systems, Recent Progress in tectonics and Paleoseismology and Field Training Course in Paleoseismology, 31 August-12 September 2003, Middle East Technical University, p. 13, Poster No: T4-50, Ankara, Turkey.
- Emre, Ö., Doğan, A., Yıldırım, C., Duman, T.Y. and Özalp, S., (in press), Active Fault Map of Turkey, 1:250.000 scale Bursa (NK 35-12) Quadrangle. 1:250.000 Scale Active Fault Map Series, No:3, Ankara. Görür, N., Çağatay, M.N., Sakınç, M., Sümengen, M., Şentürk, K., Yalıtırak, C., Tchepalyga, A., 1997. Origin of the Sea of Marmara from Neogene to Quaternary paleogeographic evolution of its frame. *International Geology Review*, 39, 342-352.
- Ito, A., Üçer, B., Barış, Ş., Nakamura, A., Honkura, Y., Kono, T., Hori, S., Hasegawa, A., Pektaş, R., and Işıkara, A. M., 2002, Aftershock activity of the 1999 İzmit, Turkey earthquake revealed from microearthquake observations: *Bull. Seismol. Soc. Am.*, 92, 418-427.
- Özaksoy, V., Emre, Ö., Yıldırım, C., Doğan, A., Özalp, S. and Tokay, F., 2006, Late Holocene uplift of the Hersek Ridge on the restraining bend of NAFS. In: International Workshop on comparative studies of the North Anatolian Fault (Northwest Turkey) and the San Andreas Fault (Southern California), Istanbul Technical University, August 14-18, 2006, Istanbul.
- Paluska, A., Poetsch, S., Bargu, S., 1989. Tectonics, paleoseismic activity and recent deformation mechanism in the Sapanca-Abant region (NW Turkey, North Anatolian Fault Zone). Turkish German Earthquake Research Project. Earth Research Institute, Ankara, Turkey, Univ. Of Kiel, West Germany, 18-33.
- Sakınç, M. and Bargu, S., 1989. İzmit körfezi güneyindeki Geç Pleistosen (Tireniyen) çökel stratigrafisi ve bölgenin neotektonik özellikleri. *Türkiye Jeoloji Kurumu Bülteni*, 32, 51-64.

