# Initial Geotechnical Observations of the August 17, 1999, Kocaeli Earthquake

### A report of the Turkey-US geotechnical earthquake engineering reconnaissance team

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## Outline



## Summary

On August 17, 1999 at 3:02 AM a magnitude $M_w$ 7.4 earthquake struck the Kocaeli area in the Northwest Turkey, which has a population of 20 million inhabitants (one third of Turkey's total population) and encompasses nearly half of the country's industry. This is one of the most devastating earthquakes of the twentieth century in view of the number of casualties and damage.

On August 29, 1999, preliminary rapid response estimates from the US 39$^{th}$ Air Expeditionary Squadron were that the death toll could be as high as 40,000, with the hardest hit cities being Golcuk/ Degirmendere with 1 million people temporarily homeless. The Office of the UN Resident Coordinator in Ankara reports that the Prime Ministry Crisis Management Center (PMCMC) put the casualty figures at 13,479 dead and 27,164 injured as of August 28, 1999. On August 28, 1999, the PMCMC also estimated that 54,295 buildings were damaged. According to the Reconstruction Minister K. Aydin, the number of buildings which have collapsed and which will have to be demolished because of heavy damage is 27,000. He expects the number to reach 35,000 when their ongoing survey is completed. The Minister estimates that more than 200,000 housing units will have to be built. These numbers are likely to change as more information becomes available. Revised estimates can be obtained from http://angora.deprem.gov.tr.

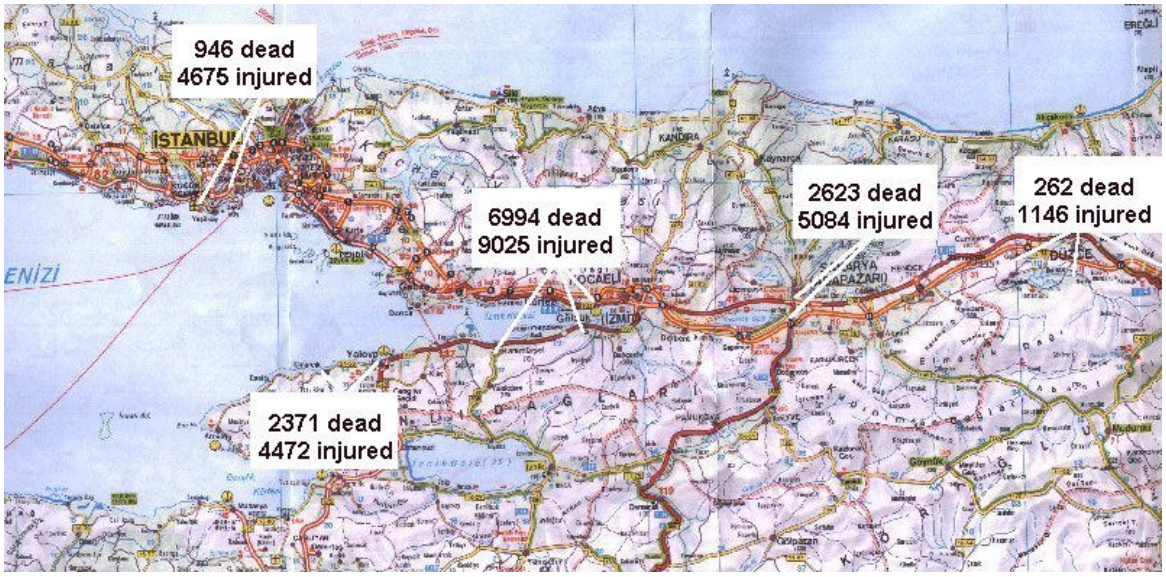
The earthquake epicenter was located at Izmit along the North Anatolian Fault, a strike-slip fault which presents many similarities to the San Andreas fault in California. Details on the fault rupture mechanisms and strong motion recordings can be obtained from the Kandilli observatory at http://www.koeri.boun.edu.tr/earthqk/earthqk.html

## Emergency Response in Turkey

1. The Ministry of Public Works and Settlements has so far deployed 550 experts to the affected area for damage assessment purposes. The Ministry also has 233 various construction machines in the area. The Department of Rural Affairs has sent 1,931 construction machines and 3,295 personnel to the affected area.
2. Wireless communication systems have been set up in tent cities to keep the residents informed of developments. All transportation routes remain fully operational and international aircraft carrying relief supplies are provided the necessary landing, ground and handling services. Power generation and transmission problems have been solved to a large extent, and repair works on water supply systems continue.
3. There are now 7 tent cities for the homeless population. A number of public facilities, with an aggregate bed capacity of 42,366, have been dedicated to the homeless. A guardianship capacity of 34,520 has been identified for children who have lost their parents, or whose families have been too heavily affected by the earthquake to take care of their children.
4. The PMCMC reports that there is no pharmaceutical shortage. A psychosocial services unit has been inaugurated in Yalova and the Gulhane Military Medical Academy has created a psychiatric research and therapy center to service the earthquake victims around the clock.
5. The Turkish Red Crescent has provided 29,725 tents, 79,200 blankets, 2,000 sleeping bags, 25,224 kg of food, 26 mobile kitchens and 4 mobile hospitals, two of them with a capacity of 200 beds each, one with 100 and one with 50 beds.

## Location of main damaged areas

The earthquake damage is widespread in the Izmit bay in the East-West direction over a length of 100-150 km and is concentrated in several areas, including Izmit, Golcuk, Avcilar, Yalova, Adapazari, and Karamursel (map from )



Location of casualties (http://www.koeri.boun.edu.tr/earthqk/earthqk.html)

## Initial reconnaissance

This brief report summarizes the initial observations of the advanced party of the Turkey/US geotechnical reconnaissance team sponsored by the US National Science Foundation and various organizations from Turkey. This report covers the initial reconnaissance efforts between August 24 and August 31, 1999. Ongoing work will lead to more comprehensive reports in the future. The members of the advanced party are:

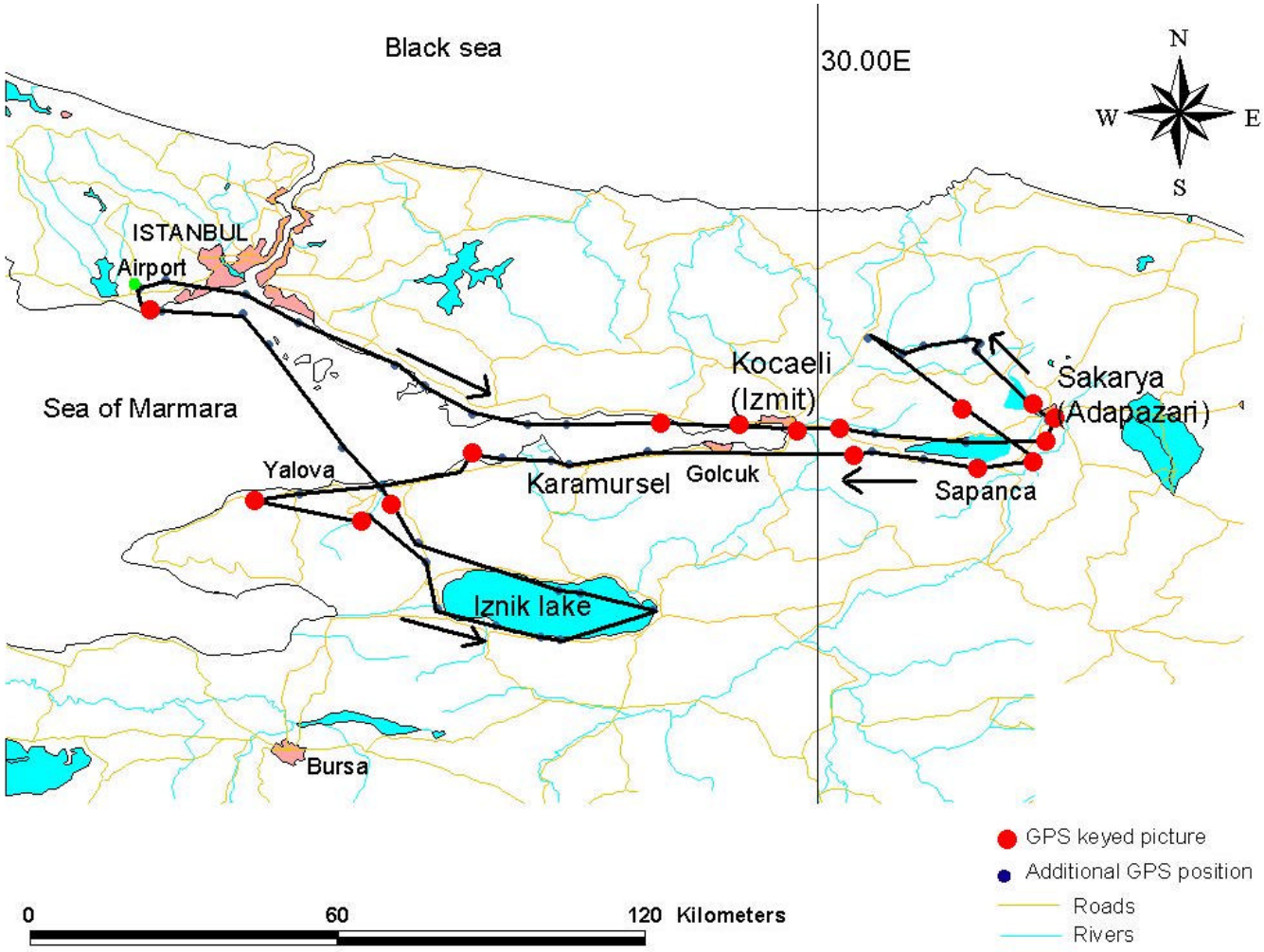
- Atilla Ansal, Istanbul Technical University, Istanbul
- Jean-Pierre Bardet, University of Southern California, Los Angeles
- Jonathan Bray, University of California, Berkeley
- Onder Cetin, University of California, Berkeley
- Turan Durgunoglu, Bogazici University and Zetas Earth Technology Corporation, Istanbul
- Mustafa Erdik, Bogazici University, Istanbul
- Abidin Kaya, Dokuz Eylul University, Izmir
- Derin Ural, Middle East Technical University, Ankara
- Tolga Yilmaz, Middle East Technical University, Ankara
- Les Youd, Brigham Young University, Salt Lake City.

## Acknowledgments

We would like to express all our thanks to our Turkish and American colleagues who helped us in our reconnaissance effort and to express our sympathy to the victims of this natural disaster.

## Day 1 (August 24, 1999): Aerial survey over Izmit, Adapazari, Lake Sapanca, Golcuk, Yalova and Lake Iznik

### *Flight path*




The flight path initiated from the Istanbul airport to the west and went over the Izmit and Derince areas, Adapazari, Sapanca Lake, Golcuk, Karamursel, Yalova, and the Iznik lake.

## Izmit and Derince areas

Overview of the TUPRAS refinery along the Izmit Bay after the fire that started right after the earthquake on August 17, 1999 (N40$^{o}$45.938', E29$^{o}$33.684', 8/24/99, 15:23:17).

View of the TUPRAS refinery along the Izmit Bay after the fire that started right after the earthquake on August 17, 1999 (N40$^{o}$45.938', E29$^{o}$33.684', 8/24/99, 15:23:17).

View of the TUPRAS refinery along the Izmit Bay after the fire that started right after the earthquake on August 17, 1999 (N40$^{o}$43.07', E29$^{o}$42.118', 8/24/99, 16:49:11).

Collapse of a reinforced concrete apartment in the Izmit area. This type of failure was commonly observed after the earthquake, and caused many casualties (N40$^{o}$45.759', E29$^{o}$51.987', 8/24/99, 15:27:36).

The roof of this warehouse in the Izmit area caved in due to the earthquake shaking. The Izmit bay area is the heart of Turkey's industry (N40$^{o}$45.406', E29$^{o}$58.063', 8/24/99, 15:31:05).

Damage to the middle tank of this chemical plant in the Kosekoy area. The short-column support of the middle tank collapsed and the tank leaned slightly and leaked (N40$^{o}$45.549', E30$^{o}$02.344', 8/24/99, 15:33:25).

## *Adapazari, Lake Sapanca and Arifiye*

Collapse of the roof of a small factory to the west of the Sapanca Lake close to Arifye (N40$^{o}$44.223', E30$^{o}$23.811', 8/24/99, 15:45:35).

One of these apartment buildings collapsed laterally while the others withstood the earthquake forces (Arifye area, N40$^{o}$46.329', E30$^{o}$24.328', 8/24/99, 15:47:42).

The collapse of buildings was widespread, but not uniform in Adapazari, possibly due to different soil conditions and inconsistent enforcement of building codes (N40$^{o}$46.329', E30$^{o}$24.328', 8/24/99, 15:47:42).

Tent camps were erected to accommodate the survivors of the earthquake. Most inhabitants were forced to sleep outside their damaged houses (Adapazari, N40$^{o}$46.329', E30$^{o}$24.328', 8/24/99, 15:47:42).

Lateral collapse of an apartment building in Adapazari. The rescue efforts were impeded by the collapsed concrete slabs that trapped many occupants (N40$^{o}$46.329', E30$^{o}$24.328', 8/24/99, 15:47:42).

Many apartment buildings underwent failure of the lower floors (Adapazari, N40$^{o}$46.329', E30$^{o}$24.328', 8/24/99, 15:47:42).

Lateral collapse of an apartment building next to an intact building in Adapazari (N40$^{o}$47.811', E30$^{o}$22.625', 8/24/99, 15:54:29).

An apartment building leaned sideways against another building in Adapazari (N40$^{o}$47.811', E30$^{o}$22.625', 8/24/99, 15:54:29).

No visible signs of damage could be detected from the reconnaissance aircraft on the upstream face of this reservoir located to the north of Sapanca Lake between Izmit and Adapazari (N40$^{o}$47.583', E30$^{o}$15.295', 8/24/99, 16:17:56).

There were no signs of damage visible from the reconnaissance aircraft on the downstream face of this reservoir located between to the north of Sapanca Lake Izmit and Adapazari (N40$^{o}$47.583', E30$^{o}$15.295', 8/24/99, 16:17:56).

The minaret of the mosque tipped over and broke in the Arifye area (N40$^{o}$42.41', E30$^{o}$22.808', 8/24/99, 16:26:18).

The fault surface rupture created an offset in the road and cut sharply through the center line of an elongated structure in the area of Arifiye (N40$^{o}$42.41', E30$^{o}$22.808', 8/24/99, 16:26:18).

Lateral spread of the bank of the Sakarya river in the Arifiye area (N40$^{o}$42.41', E30$^{o}$22.808', 8/24/99, 16:26:18).

Collapse of the bridge on the Sakarya river in the Arifiye area (N40$^{o}$42.41', E30$^{o}$22.808', 8/24/99, 16:26:18).

Subsidence of hotel Sapanca on the shore of the Sapanca lake (N40$^{o}$41.448', E30$^{o}$16.733', 8/24/99, 16:31:54).

Lateral spread on the southern shore of Lake Sapanca (N40$^{o}$41.448', E30$^{o}$16.733', 8/24/99, 16:31:54).

Tent cities have been erected for the residents that have homes with heavy damage along Lake Sapanca (N40$^{o}$42.829', E29$^{o}$23.768', 8/24/99, 16:59:06).

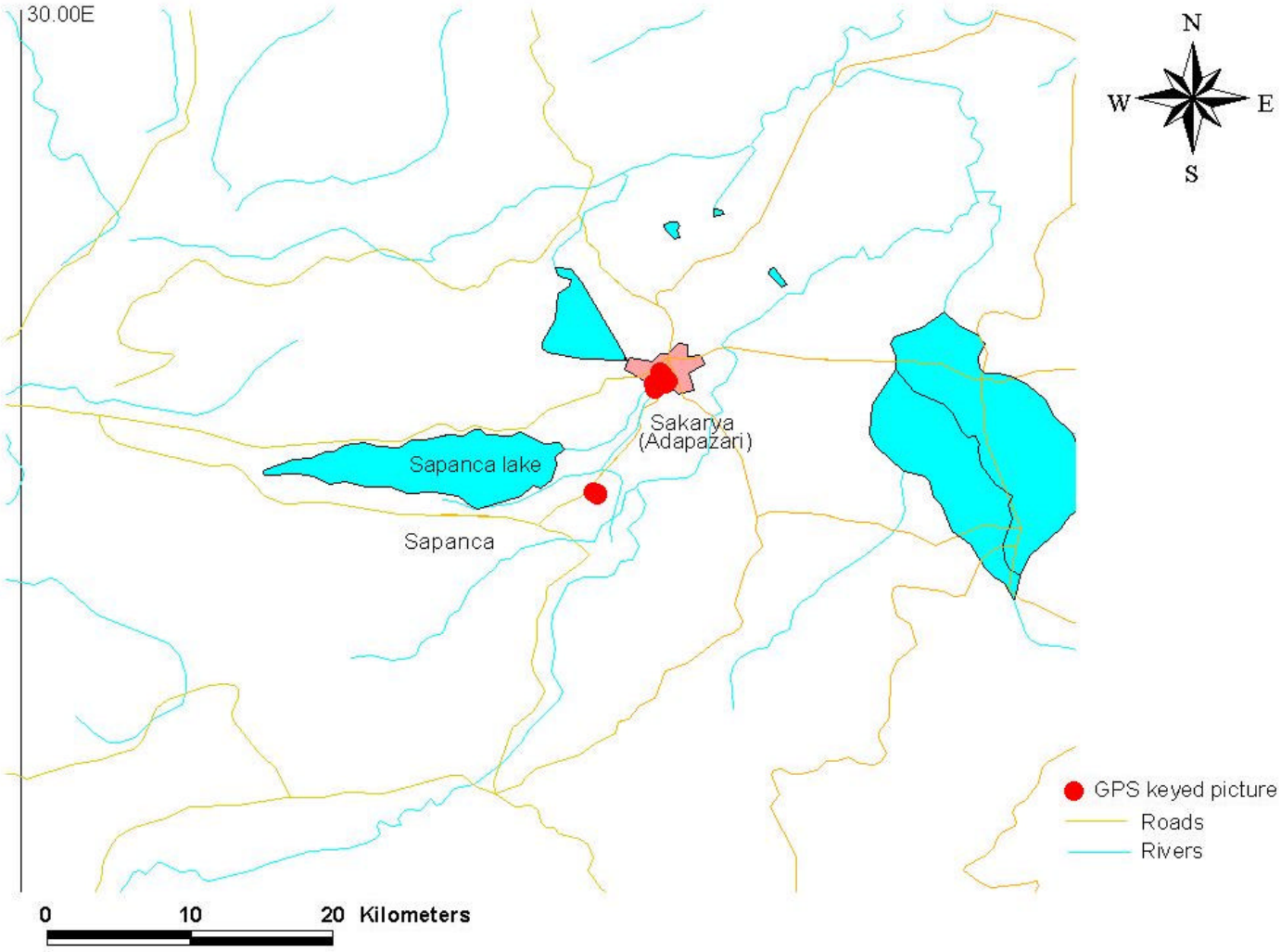
Three apartment buildings collapsed in the Arifye area (N40$^{o}$42.829', E29$^{o}$23.768', 8/24/99, 16:59:06).

## *Yalova*

An apartment complex suffered heavy damage in Yalova (N40$^{o}$47.357', E29$^{o}$15.302', 8/24/99, 17:56:42).


The reconnaissance team that flew over damaged areas in a small fixed wing aircraft on August 24, 1999. From left to right, Derin Ural, Jonathan Bray, the pilot, and J.P. Bardet (N40$^{o}$57.922', E28$^{o}$51.223', 8/24/99, 18:15:53).

## Day 2 (August 25, 1999): Adapazari and its southern vicinity




On Day 2 (August 25, 1999), the reconnaissance team drove by car to Adapazari and the mechanically stabilized earth wall to the south of Adapazari.

The bottom floors of the reinforced concrete office buildings collapsed in the city of Adaparazari (N40$^{o}$42.527', E30$^{o}$21.62', 8/25/99, 10:43:17).

Electricity and telephone lines were operational on August 25, 1999 in some office buildings despite the extensive damage in Adapazari (N40$^{o}$55.302', E29$^{o}$21.011', 8/25/99, 11:25:55, poor GPS coverage).

The reinforced concrete apartment building leaned sideways due to the unsymmetric failure of its first floor (N40$^{o}$55.202', E29$^{o}$21.011', 8/25/99, 11:38:40, poor GPS coverage).

The bottom floors of the reinforced concrete building collapsed in Adapazari (N40$^{o}$55.202', E29$^{o}$21.011', 8/25/99, 11:38:40, poor GPS coverage).

Settlement of building in downtown Adapazari. The staircase was sheared due to settlement (N40$^{o}$55.202', E29$^{o}$21.011', 8/25/99, 11:50:23). (The GPS has some problem).

An apartment building in downtown Adapazari that has tilted due to differential settlement (N40$^{o}$46.485', E30$^{o}$23.807', 8/25/99, 11:53:51).

At the entrance of the garage door of an apartment building that has settled close to 1 foot, there were traces of silty soil which had been ejected during the earthquake. The sidewalk has caved in towards the building (N40$^{o}$46.689', E30$^{o}$23.762', 8/25/99, 12:01:29).

The collapse of the lower floors of an apartment building in Adapazari crushed a car (N40$^{o}$46.716', E30$^{o}$23.821', 8/25/99, 12:15:17).

Following the emergency rescue efforts, some inhabitants of damaged buildings in Adapazari attempted to retrieve their furniture and personal belongings (N40$^{o}$46.716', E30$^{o}$23.821', 8/25/99, 12:15:17).

Many cars were crushed due to the collapse of buildings in Adapazari (N40$^{o}$46.70', E30$^{o}$23.778', 8/25/99, 12:19:03).

The foundation of this slender building in Adapazari failed and the building leaned onto its neighbor (N40$^{o}$47.068', E30$^{o}$23.976', 8/25/99, 12:36:00).

The building adjacent to the leaning building settled and shifted laterally, opening a gap between the sidewalk and the building (Adapazari) (N40$^{o}$47.068', E30$^{o}$23.976', 8/25/99, 12:36:00).

The buried metal pipe broke down at the interface between soil and building due to the building settlement and lateral movement (Adapazari, N40$^{o}$47.038', E30$^{o}$24.033', 8/25/99, 12:51:04).

Some old wood structures with masonry brick infills performed remarkably well during the earthquake, whereas nearby more modern reinforced concrete buildings collapsed (Adapazari, N40$^{o}$47.027', E30$^{o}$24.085', 8/25/99, 13:18:20).

In some of the buildings under construction in Adapazari, building codes may not have been consistently enforced as demonstrated by the separation of aggregates and concrete at the column-beam junction (N40$^{o}$47.027', E30$^{o}$24.085', 8/25/99, 13:18:20).

The building settled one foot and shifted laterally, blocking the entrance of the car garage (Adapazari, N40$^{o}$47.027', E30$^{o}$24.085', 8/25/99, 13:18:20).

The foundation of the building failed and the building tilted in the east/west direction (Adapazari) (N40$^{o}$46.862', E30$^{o}$24.133', 8/25/99, 13:47:00).

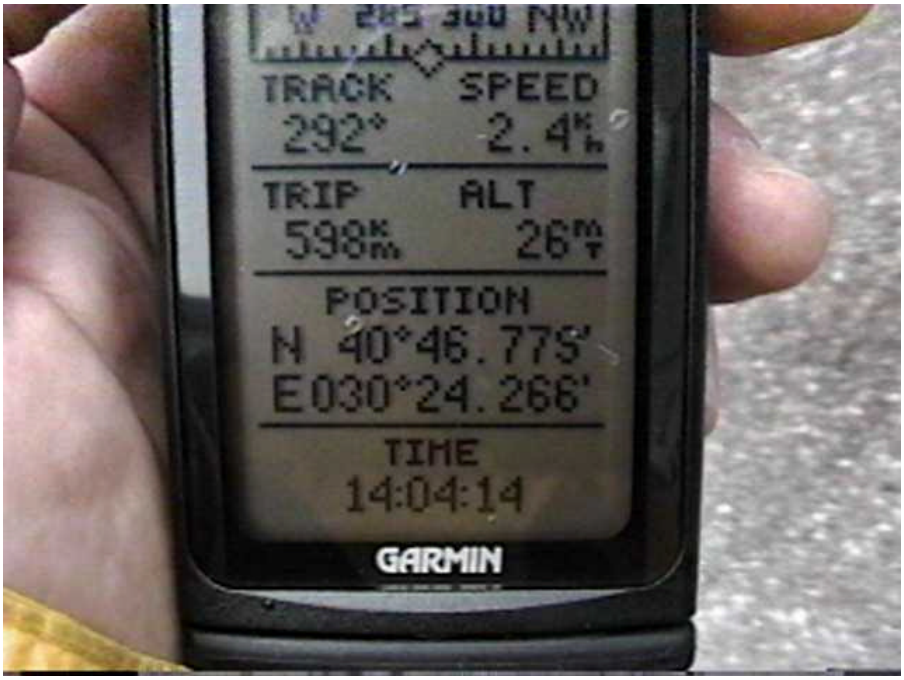
Another view of the building which underwent foundation failure (Adapazari) (N40$^{o}$46.862', E30$^{o}$24.133', 8/25/99, 13:47:00).

The minaret of the mosque tipped over and broke (Adapazari, N40$^{o}$46.822', E30$^{o}$24.128', 8/25/99, 13:53:21).

The mosque failed and leaned sideways (Adapazari) (N40$^{o}$46.822', E30$^{o}$24.128', 8/25/99, 13:53:21).

The unreinforced building with wood-frame and masonry infill performed well during the earthquake. (Adapazari, N40$^{o}$46.822', E30$^{o}$24.128', 8/25/99, 13:53:21).

All the buildings in this street in Adapazari settled at least one foot (N40$^{o}$46.779', E30$^{o}$24.266', 8/25/99, 14:04:14).




An example of a Global Positioning System (GPS) reading made by the reconnaissance team in the field (N40$^{o}$46.779', E30$^{o}$24.266', 8/25/99, 14:04:14).

The buildings settled. The sidewalk heaved and lifted up part of the asphalt pavement (Adapazari, N40$^{o}$46.742', E30$^{o}$24.185', 8/25/99, 14:12:59).

The marble tile floor of the shop bulged as the building settled into the ground (Adapazari, N40$^{o}$46.662', E30$^{o}$24.163', 8/25/99, 14:17:45).

The deck of the bridge fell down on the ground as the fault surface ruptured beneath the bridge (South of Adapazari, N40$^{o}$42.581', E30$^{o}$21.495', 8/25/99, 15:40:56).

The overall performance of the mechanically stabilized earth abutment of the bridge was remarkable (South of Adapazari, N40$^{o}$42.581', E30$^{o}$21.495', 8/25/99, 15:40:56).

One side of the mechanically stabilized earth abutment showed very few signs of damage (South of Adapazari, N40$^{o}$42.581', E30$^{o}$21.495', 8/25/99, 15:40:56).

The road on top of the mechanically stabilized earth abutment sagged, possibly due to the failure of the reinforced concrete box culvert passing under it (South of Adapazari, N40$^{o}$42.581', E30$^{o}$21.495', 8/25/99, 15:40:56).

At the location where the road sagged, one side of the mechanically stabilized earth abutment displayed relative motion between face plates (South of Adapazari, (N40$^{o}$42.581', E30$^{o}$21.495', 8/25/99, 15:40:56).


The heaving of sidewalks and settlement of buildings were a common sight in Adapazari (N40$^{o}$42.581', E30$^{o}$21.495', 8/25/99, 15:40:56).

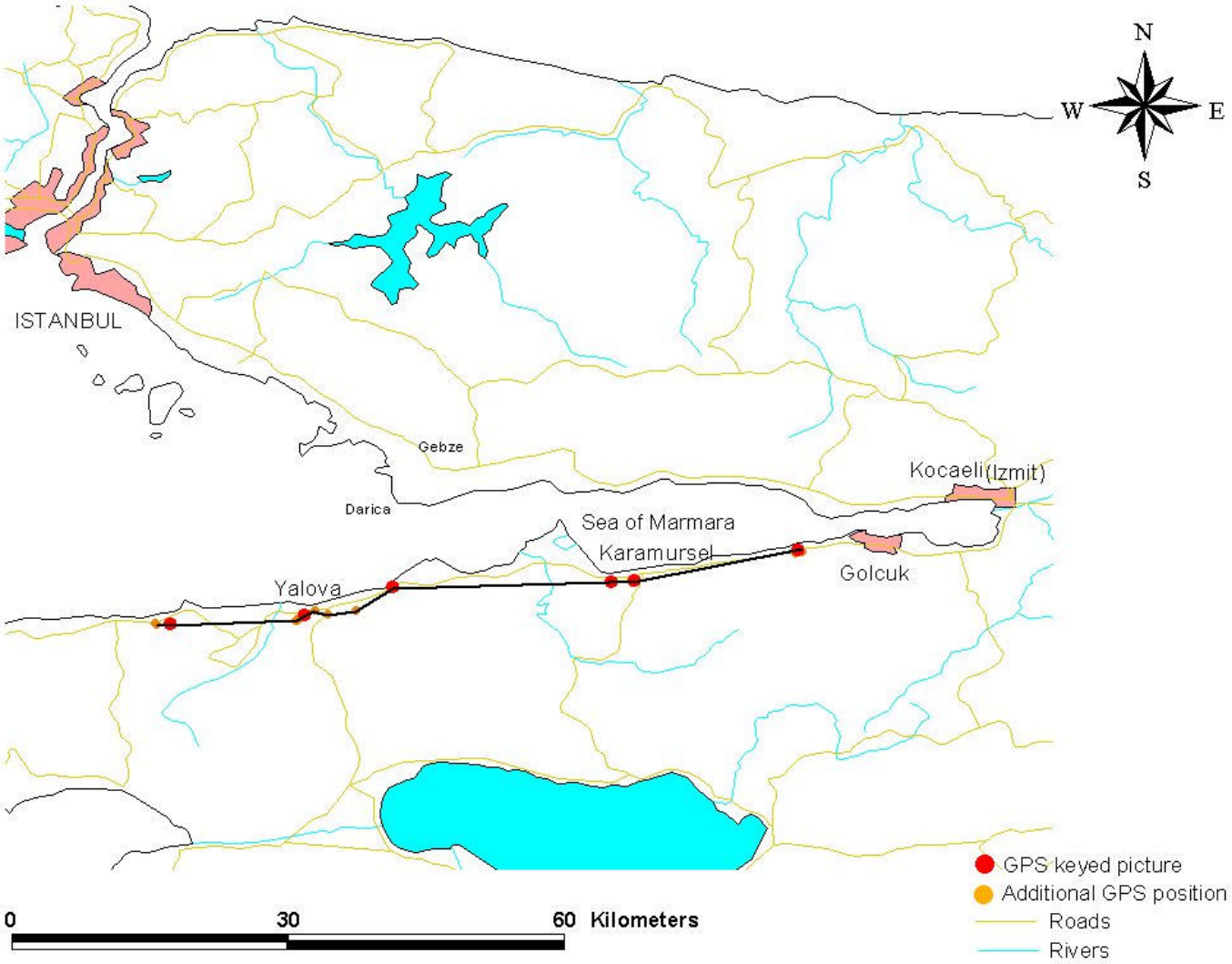
The concrete stair separated 1.5 m (58 in) from the house and moved 3.2 m (126 in) diagonally due to the fault surface rupture which went beneath the house. The house was only slightly damaged (south of Adapazari, N40$^{o}$42.581', E30$^{o}$21.495', 8/25/99, 15:40:56).

The fault surface rupture went through a group of trees, and displayed a clear offset in the tree rows (South of Adapazari, N40$^{o}$42.581', E30$^{o}$21.495', 8/24/99, 15:40:56).N40$^{o}$42.581', E30$^{o}$21.495', 8/25/99, 15:40:56).

The fault surface rupture went through a group of trees, and displayed a clear offset in the tree rows (South of Adapazari, N40$^{o}$42.581', E30$^{o}$21.495', 8/25/99, 15:40:56).

The fault surface rupture pulled apart the tree roots and split its trunk (South of Adapazari, N40$^{o}$42.568', E30$^{o}$21.612', 8/25/99, 16:21:10).

## Day 3 (August 26, 1999): Southern coast of Marmara Sea including Yalova, Karamursel and Halidere




On Day 3 (August 26, 1999), the reconnaissance team took the ferry to Yalova, drove west to Bellona, and followed the coast line up to Halidere, which is to the west of Golcuk.

In Yalova, a summer resort along the southern coast of the Izmit bay, several apartment buildings collapsed, or were severely damaged (N40$^{o}$38.822', E29$^{o}$7.503', 8/26/99, 11:58:34)

The bottom floors of this apartment building in Yalova failed (N40$^{o}$38.845', E29$^{o}$ 7.448', 8/26/99, 12:01:06).

The apartment buildings in Yalova also underwent failure of their first floors (N40$^{o}$38.845', E29$^{o}$7.448', 8/26/99, 12:01:06).


In a china store located at the first floor of an undamaged bank building in Yalova, china dishes were intact on the window shelves and very few china dishes were broken on the floor. This implies that the accelerations were not large enough to break dishes since the store had probably been cleaned after the main shock (N40$^{o}$38.855', E29$^{o}$7.45', 8/26/99, 12:05:32).

The first floors of this apartment building in Yalova collapsed (N40$^{o}$39.08', E29$^{o}$15.712', 8/26/99, 13:11:25).

Along the shoreline in Yalova, many apartment buildings collapsed. The retaining wall in front of the apartment building on the right settled and shifted laterally due to the liquefaction of its foundation. However, there were no sign of lateral spread which could have damaged the building. (N40$^{o}$40.913', E29$^{o}$21.234', 8/26/99, 14:42:20).

The steel rebars at the connection between the reinforced concrete columns and beams of some of the apartment buildings along the shoreline of Yalova were smooth and totally insufficient (N40$^{o}$40.913', E29$^{o}$21.234', 8/26/99, 14:42:20)

On the beach east of Yalova, there were oil residues washed out from the oil refinery fire across Izmit bay (N40$^{o}$41.285', E29$^{o}$34.031', 8/26/99, 16:00:34)

The first floors of the apartment buildings on the hillside east of Yalova were damaged or collapsed. There was no evidence of slope stability problems or ground failure (N40$^{o}$41.274', E29$^{o}$35.257', 8/26/99, 16:23:52).

Some of the apartment buildings on the hillside east of Yalova leaned toward the sea due to the failure of their first floor (N40$^{o}$41.274', E29$^{o}$35.257', 8/26/99, 16:23:52).

In Halidere, an apartment building collapsed., and the waterfront spread laterally toward the Marmara Sea (N40$^{o}$42.961', E29$^{o}$44.805', 8/26/99, 17:33:58).

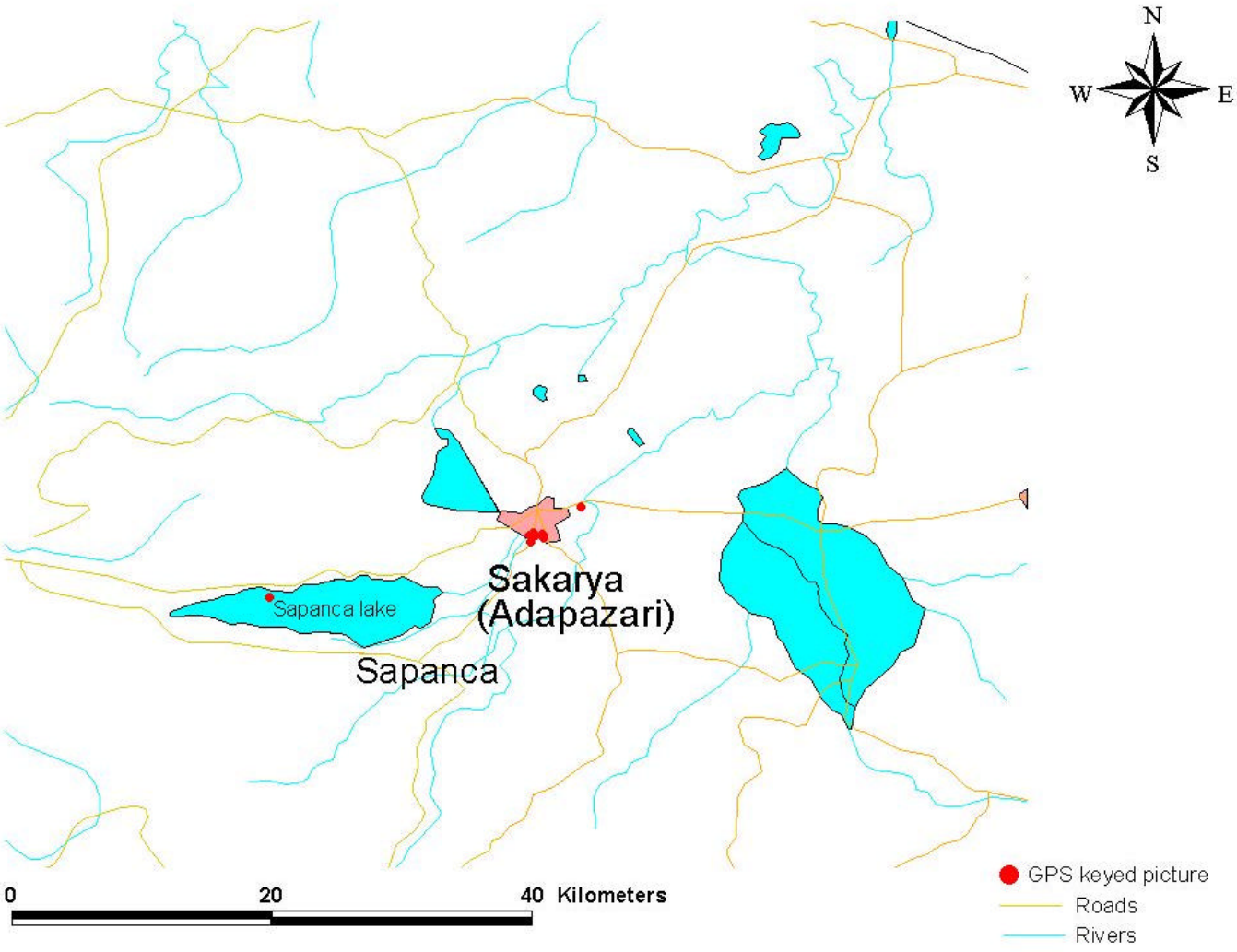
Along the shoreline in Halidere, the road and the waterfront disappeared into the Marmara sea. Some trees were left standing in the water (N40$^{o}$42.961', E29$^{o}$44.805', 8/26/99, 17:33:58).

Along the shoreline of Halidere, part of the sidewalk of the waterfront subsided into the sea. The restaurant in the background settled into the sea (N40$^{o}$43.064', E29$^{o}$45.019', 8/26/99, 18:01:02).

Most inhabitants used bottled propane gas for heating and cooking. To our knowledge there were no reported cases of fires in residential buildings ignited by gas (N40$^{o}$43.064', E29$^{o}$45.019', 8/26/99, 18:01:02).

In Halidere, part of the waterfront subsided into the sea and the rest spread laterally (N40$^{o}$43.064', E29$^{o}$45.019', 8/26/99, 18:01:02).

## Day 4 (August 27, 1999): Sapanca lake and Adapazari




On Day 4 (August 27, 1999), the reconnaissance team stopped on the north shore of Sapanca lake, and re-visited Adapazari.

Ground cracks were noticeable from the highway north of Sapanca lake. These ground cracks were attributed to the reactivation of large existing landslides after the earthquake (N40$^{o}$44.027', E30$^{o}$13.275', 8/27/99, 11:24:52).


Assumed position of existing landslide north of Sapanca lake. The geological map represents a recent quaternary deposit which could be sliding toward Sapanca lake (N40$^{o}$44.027', E30$^{o}$13.275', 8/27/99, 11:24:52).

Some streets of Adapazari were completely devastated by the earthquake (N40$^{o}$46.318', E30$^{o}$24.112', 8/27/99, 12:23:25).


The Ziraat bank building in Adapazari is one of the few buildings founded on piles. There were no apparent signs of damage to this building (N40$^{o}$46.6', E30$^{o}$24.062', 8/27/99, 12:37:58).


In Adapazari, the building settled and the sidewalk bulged and split longitudinally (N40$^{o}$46.661', E30$^{o}$24.163', 8/27/99, 12:46:27).

A deposit of ejected sand was observed in front of this building which settled into the ground. This was not systematically observed for all settled buildings (Adapazari, N40$^{o}$46.612', E30$^{o}$24.257', 8/27/99, 12:54:13).

The column punched through the floor of the building which settled (Adapazari, N40$^{o}$46.614', E30$^{o}$24.287', 8/27/99, 13:02:07).

In the garage at the first floor of an apartment building, silty sand had littered the concrete slab. Water was reported to have flooded the garage after the earthquake (N40$^{o}$46.651', E30$^{o}$24.598', 8/27/99, 13:09:48).

The building settled due to liquefaction, and the connection to the staircase was sheared (Adapazari, N40$^{o}$46.499', E30$^{o}$24.646', 8/27/99, 13:47:19).

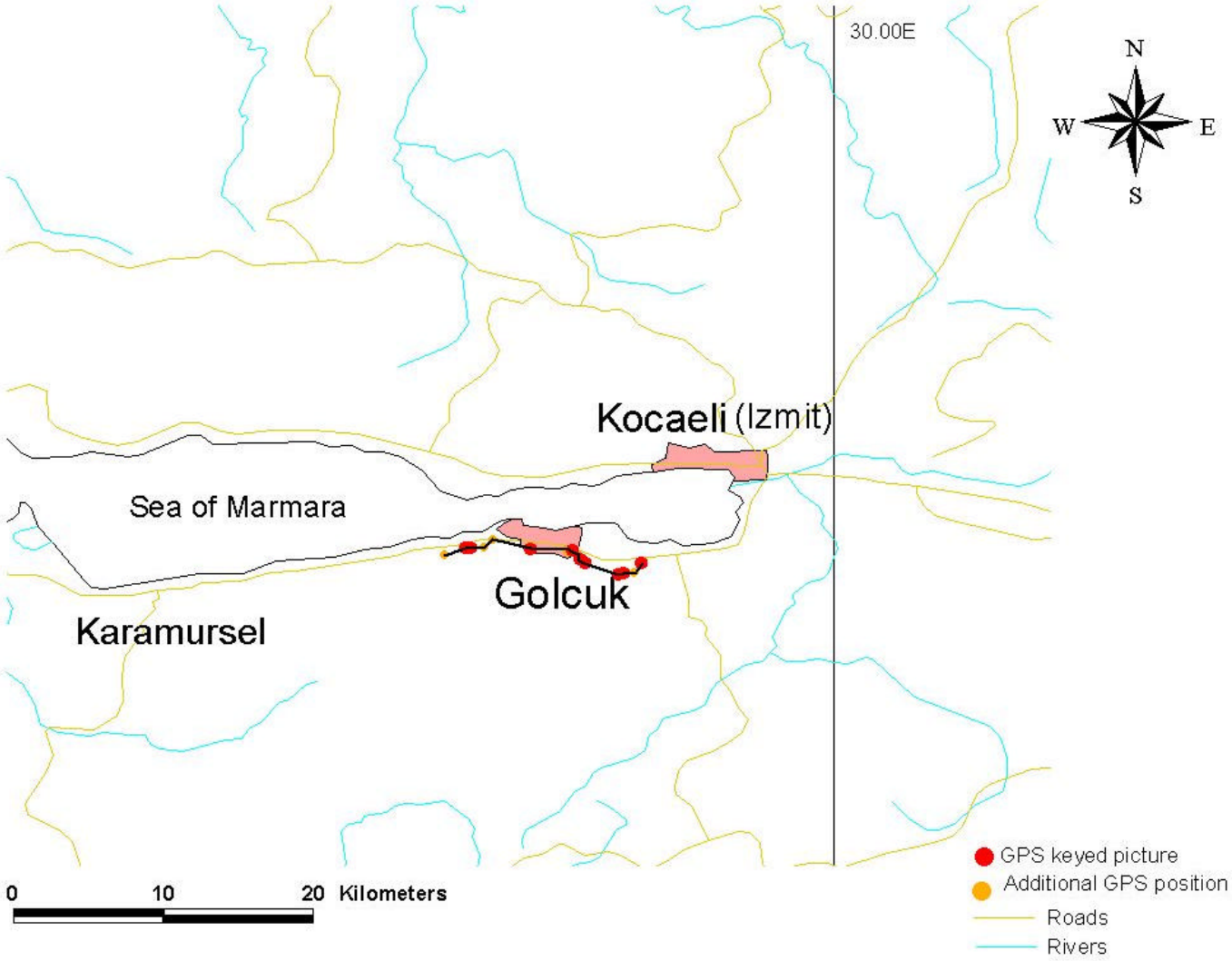
The building settled due to liquefaction, and the connection to the staircase was sheared (Adapazari, N40$^{o}$46.561', E30$^{o}$24.626', 8/27/99, 14:19:57).

The staircase of the building was sheared as the building settled due to liquefaction (Adapazari, N40$^{o}$46.561', E30$^{o}$24.626', 8/27/99, 14:19:57).

A small length of the saturated bank of the river spread laterally (N40$^{o}$47.795', E30$^{o}$26.184', 8/27/99, 16:41:35).

The office building in the center leaned sideways due to differential settlement (N40$^{o}$46.719', E30$^{o}$24.215', 8/27/99, 17:07:46).

## Day 5 (August 28, 1999): Golcuk and its vicinity




On Day 5 (August 28, 1999), the reconnaissance team covered the vicinity of Golcuk.

In a glue factory to the east of Golcuk, there was relative displacement and cracking between the foundation of the tank and the concrete slabs (N40$^{o}$42.755', E29$^{o}$53.139', 8/28/99, 12:07:23).

In Golcuk, the crane and steel frame of a construction site were standing apparently undamaged while many reinforced concrete buildings in the foreground had been destroyed by the earthquake (N40$^{o}$42.385', E29$^{o}$52.456', 8/28/99, 12:20:10).

The town of Golcuk was severely impacted by the earthquake. Many lost their lives due to the collapse of apartment buildings (N40$^{o}$42.374', E29$^{o}$52.259', 8/28/99, 12:22:44).

At the eastern entrance of Golcuk, a building collapsed and crushed a van (N40$^{o}$42.374', E29$^{o}$52.259', 8/28/99, 12:22:44).

In Golcuk, the Ford plant was under construction. There was obvious evidence of ground rupture in the site. One side of the building subsided differentially, and the wall buckled (N40$^{o}$42.947', E29$^{o}$50.89', 8/28/99, 13:21:46).

In the reinforced concrete slab inside the Ford plant in Golcuk, there were cracks caused by differential ground displacements (N40$^{o}$42.947', E29$^{o}$50.89', 8/28/99, 13:21:46).

In the unpaved ground of the Ford plant in Golcuk, there were ground cracks (N40$^{o}$42.947', E29$^{o}$50.89', 8/28/99, 13:21:46).

In the Ford plant in Golcuk, the U-shaped utilities corridor was subjected to tension and failed due to ground displacement (N40$^{o}$42.818', E29$^{o}$51.098', 8/28/99, 13:49:32).

In the Ford plant of Golcuk, the utility corridor was broken and separated due to tensile strain (N40$^{o}$42.818', E29$^{o}$51.098', 8/28/99, 13:49:32).

The ground spread laterally close to the ground rupture that went along the fence of the Ford plant in Golcuk (N40$^{o}$42.818', E29$^{o}$51.098', 8/28/99, 13:49:32).

A ground rupture ran parallel to the fence of the Ford plant in Golcuk. In some areas the vertical offset exceeded two meters (N40$^{o}$43.165', E29$^{o}$50.596', 8/28/99, 15:42:14).

Located 80 m above the ground in the painting building of the Ford plant of Golcuk, the 5-ton transformer jumped out of its housing, and scraped the floor due to earthquake acceleration (N40$^{o}$43.165', E29$^{o}$50.596', 8/28/99, 15:42:14).

In the open space between the buildings of the Ford plant of Golcuk, a large sand boil erupted and littered the ground surface with silty sand (N40$^{o}$43.165', E29$^{o}$50.596', 8/28/99, 15:42:14).

In Golcuk, the ground rupture passed beneath the corner of a house, and the corner of the house detached from the house (N40$^{o}$43.178', E29$^{o}$50.555', 8/28/99, 15:45:11).

In Golcuk, the ground rupture passed very close to the house, causing almost no visible damage to the house. Some plants were still hanging to the soil close to the house (N40$^{o}$43.178', E29$^{o}$50.555', 8/28/99, 15:45:11).

In Golcuk, the ground rupture crossed the road. The vertical offset was about 2 m (N40$^{o}$43.132', E29$^{o}$50.52', 8/28/99, 15:51:45).

In Golcuk, the ground rupture passed close to a wall, intersected it, and sheared it. Most of the wall remained intact (N40$^{o}$43.245', E29$^{o}$50.477', 8/28/99, 16:01:42).

In Golcuk, the ground rupture passed in front of three houses without apparently damaging them (N40$^{o}$43.245', E29$^{o}$50.477', 8/28/99, 16:01:42).

Golcuk was severely struck by the earthquake. The two buildings on each side of this apartment building completely collapsed (N40$^{o}$43.298', E29$^{o}$49.135', 8/28/99, 16:32:43).

To the west of Golcuk, a piece of land disappeared into the Marmara Sea (N40$^{o}$43.328', E29$^{o}$46.994', 8/28/99, 17:26:22).

To the west of Golcuk, the waterfront disappeared into the Marmara Sea (N40$^{o}$43.326', E29$^{o}$46.823', 8/28/99, 17:41:54).

To the west of Golcuk, the road and waterfront disappeared into the sea, and took with it part of the apartment building (N40$^{o}$43.326', E29$^{o}$46.823', 8/28/99, 17:41:54).

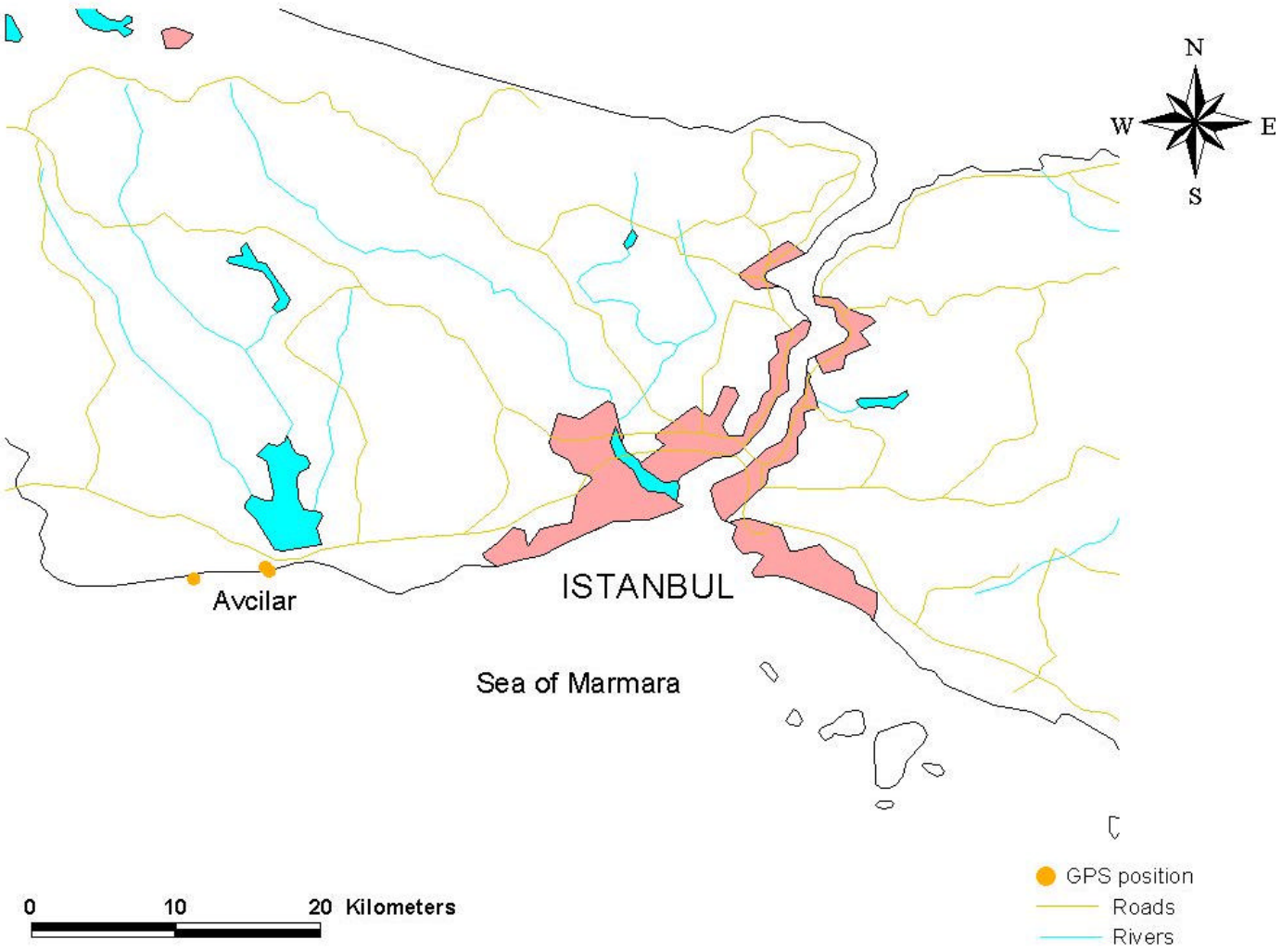
To the west of Golcuk, the second floor of two apartment buildings collapsed and their upper floors moved laterally (N40$^{o}$43.315', E29$^{o}$46.832', 8/28/99, 17:53:39).

To the west of Golcuk, a piece of land slid into the sea. There were ground cracks parallel to the new shoreline (N40$^{o}$43.074', E29$^{o}$46.083', 8/28/99, 16:20:48).

To the west of Golcuk, the waterfront slid into the sea, and exposed two tanks of a gas station (N40$^{o}$43.074', E29$^{o}$46.083', 8/28/99, 16:20:48).

To the west of Golcuk, the waterfront slid into the sea. The slide must have occurred gently as the red table and chair were still standing on the inclined concrete floor (N40$^{o}$43.074', E29$^{o}$46.083', 8/28/99, 16:20:48).

## Day 6 (August 29, 1999): Avcilar




On Day 6 (August 29, 1999), the reconnaissance team investigated Avcilar to the west of the Istanbul Airport. All the rubbles of collapsed buildings had been removed. No damage was observed in the industrial facilities that were visited.