

SUMMARY REPORTS of RECENT EARTHQUAKES inTURKEY

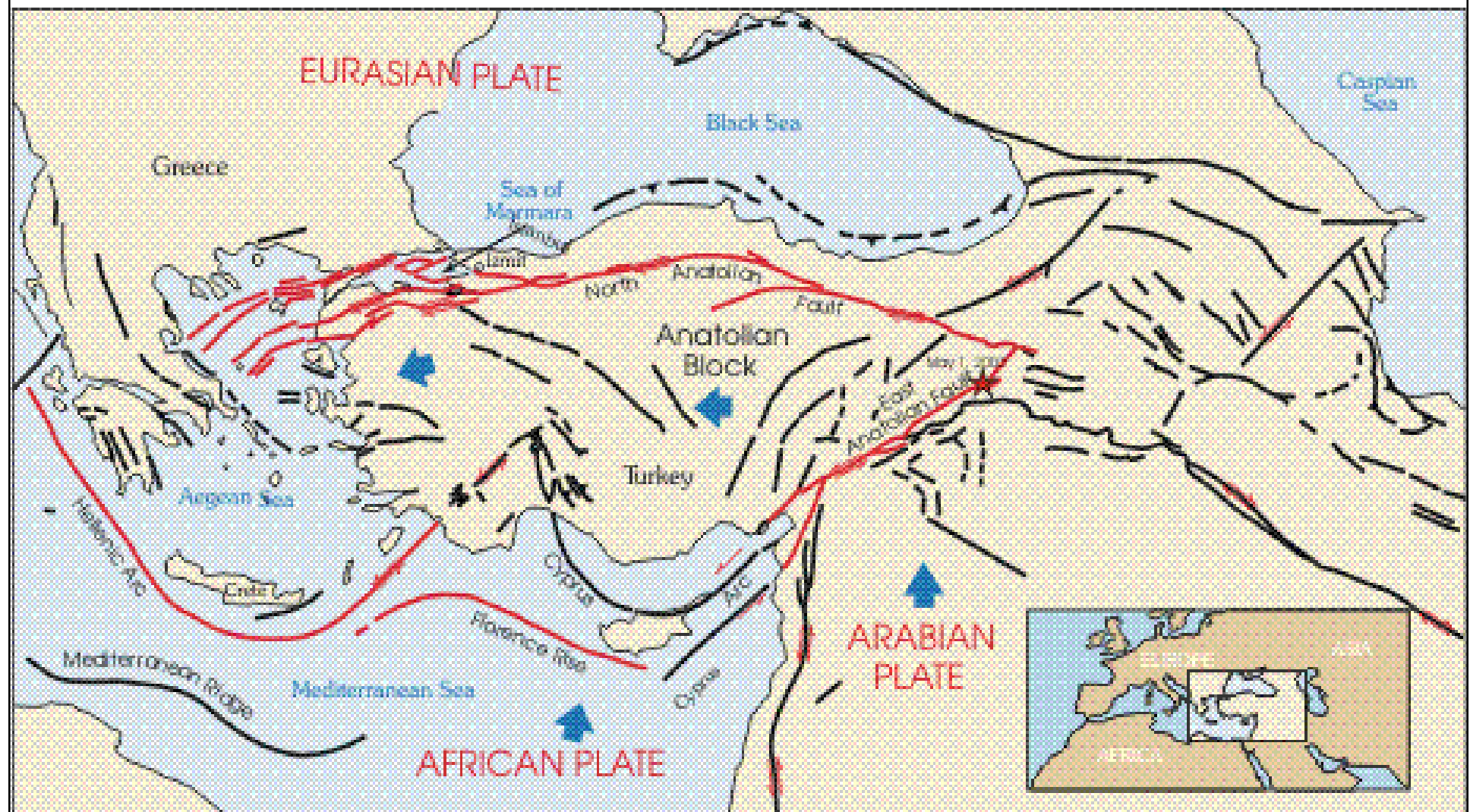




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GENERAL INFORMATION

Turkey is a tectonically active region that experiences frequent destructive earthquakes. At a large scale, the tectonics of the region near the recent earthquake are controlled by the collision of the Arabian Plate and the Eurasian Plate. At a more detailed level, the tectonics become quite complicated. A large piece of continental crust almost the size of Turkey, called the Anatolian block, is being squeezed to the west. The block is bounded to the north by the North Anatolian Fault and to the south-east by the East Anatolian fault. The North Anatolian fault system is one of the most studied and best-understood fault systems. The recent earthquake occurred near the east end of the East Anatolian fault. The faulting in the region is very complicated and extensive.



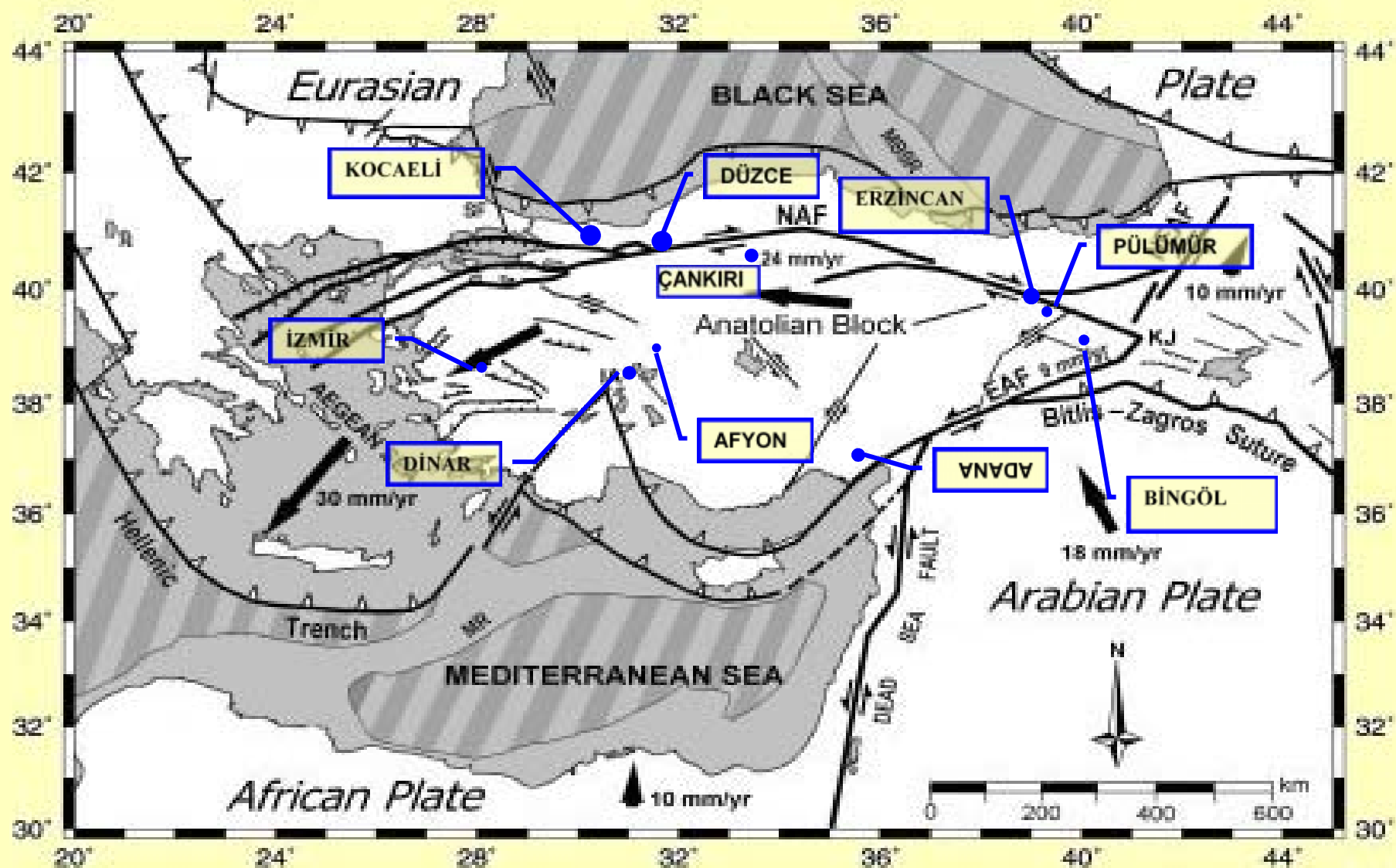
The devastating Kocaeli (Gölcük) earthquake of 1999 (M=7.8) broke a section of the North Anatolian Fault 1,500 km to the west of the recent quake and killed 17,000 people, injured 50,000, and left 500,000 homeless (<http://neic.usgs.gov>).

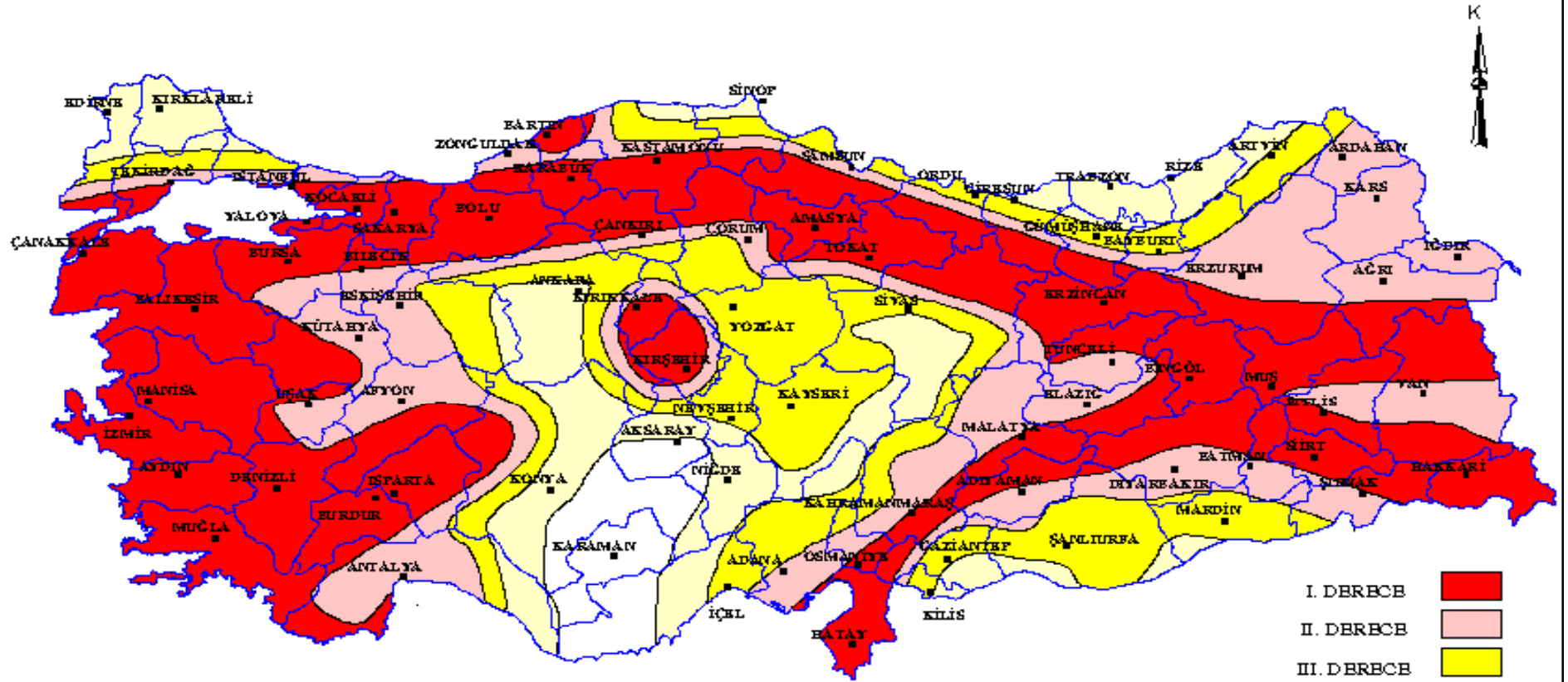
The earthquake source parameters that were determined by using mostly far-field data, geological evidences and damage pictures have quickly been published on the web sites by several organizations in Turkey as well as in the World. The following report is introductions and/or summaries of results or data on the recent earthquakes mostly from those web sites.

LATEST EARTHQUAKES in TURKEY

(<http://www.koeri.boun.edu.tr>)

No	Date	Local Time	Location	Intensity	Magnitude	Causality	Damaged Buildings
1	13.03.1992	19:08	ERZİNCAN	VIII	6.8	653	8057
2	01.10.1995	17:57	Dinar (AFYON)	VIII	6.1	90	14156
3	27.06.1998	16:55	Ceyhan (ADANA)	VIII	6.2	146	31463
4	17.08.1999	03:01	Gölcük (KOCAELİ)	X	7.8	17480	73342
5	12.11.1999	18:57	DÜZCE	IX	7.5	763	35519
6	06.06.2000	05:41	Orta (ÇANKIRI)	VII	6.1	1	1766
7	03.02.2002	09:11	Sultandağı (AFYON)	VII	6.0	43	2598
8	27.01.2003	08:26	Pülümür (TUNCELİ)	VII	6.0	1	24
9	10.04.2003	03:40	Urla (İZMİR)	VII	5.6	-	87
10	01.05.2003	03:27	BİNGÖL	VIII	6.4	168	2874





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| I. DERECE | |
| II. DERECE | |
| III. DERECE | |
| IV. DERECE | |
| V. DERECE | |

İl merkezi ●

İl sınırı —

• T.C. Bayındırlık ve İskan Bakanlığı, 1996

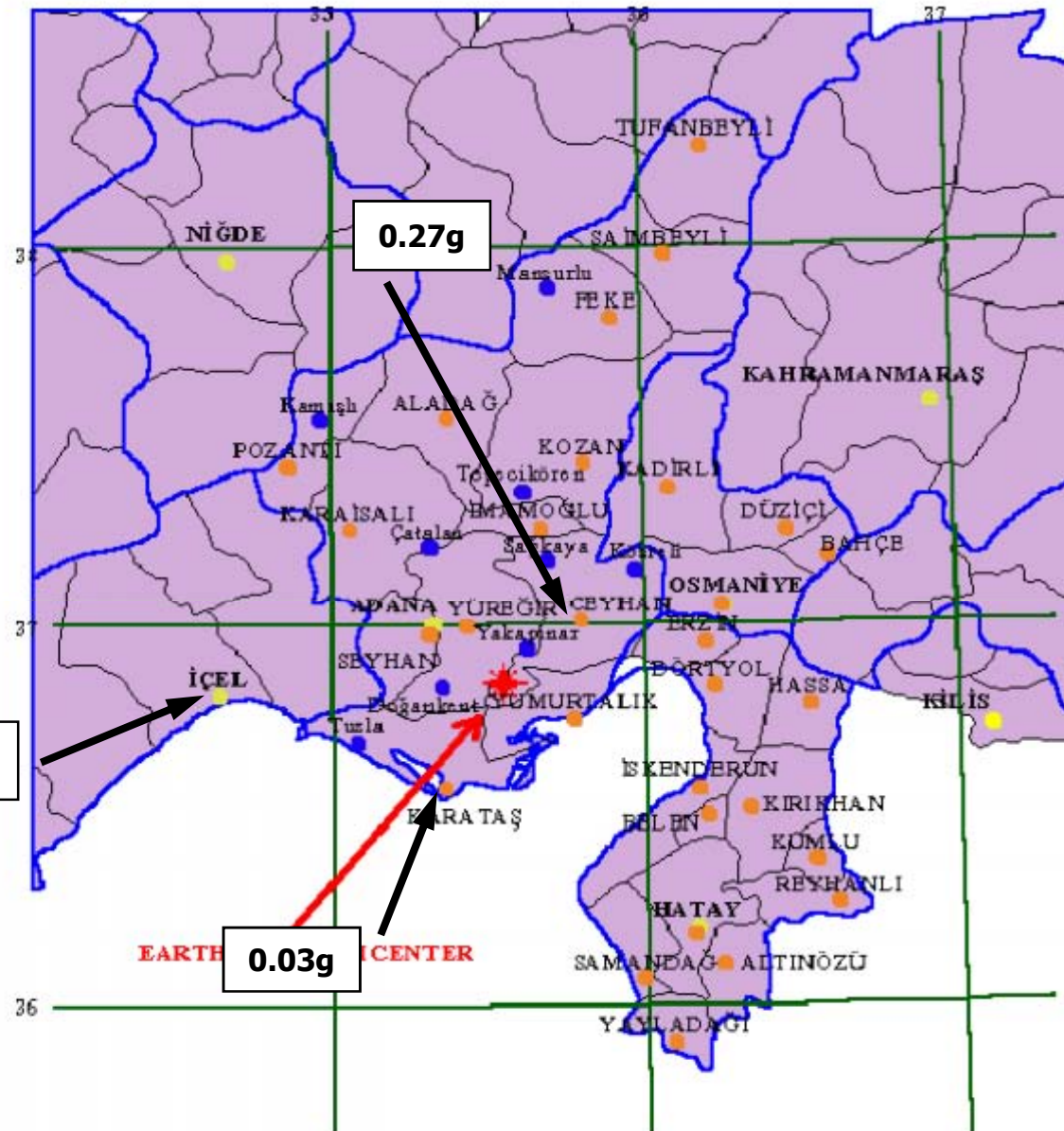
B. Özmen, M. Nurki ve H. Güler'in 1997 yılında hazırladıkları,

"Coğrafi Bilgi Sistemi ile Deprem Bölgelerinin İncelenmesi" kitabından alınmıştır.

AFET İŞLERİ GENEL MÜDÜRLÜĞÜ
DEPREM ARAŞTIRMA DAİRESİ
ANKARA-TÜRKİYE

THE ADANA EARTHQUAKE OF 27 JUNE 1998

At 16:56 local time on June 27, 1998, the earthquake ($M_d = 5.9$, $M_s = 6.2$, $M_w = 6.3$) hit Adana-Ceyhan area and affected 2 million people. The epicentral coordinates of the earthquake was identified as: 36.85N (latitude) and 35.55E (longitude) by the Earthquake Research Center in Ankara. The earthquake epicenter is approximately 50 km to the east of Tarsus, the birthplace of Paul of Tarsus and the putative meeting place of Antonius and Cleopatra. Local seismological stations reported the depth of the earthquake as 13 km and 22 km by two different sources (the Marmara Research Center in Gebze and Earthquake Research Department in Ankara).



- Province Center
- District Center
- SubDistrict Center

ADANA EARTHQUAKE

DATE : 27.06.1998

TIME : 13:55:53.04 (GMT)

Md : 5.9

LOCATION : 36.85 N 35.55 E

DEPTH : 23 km

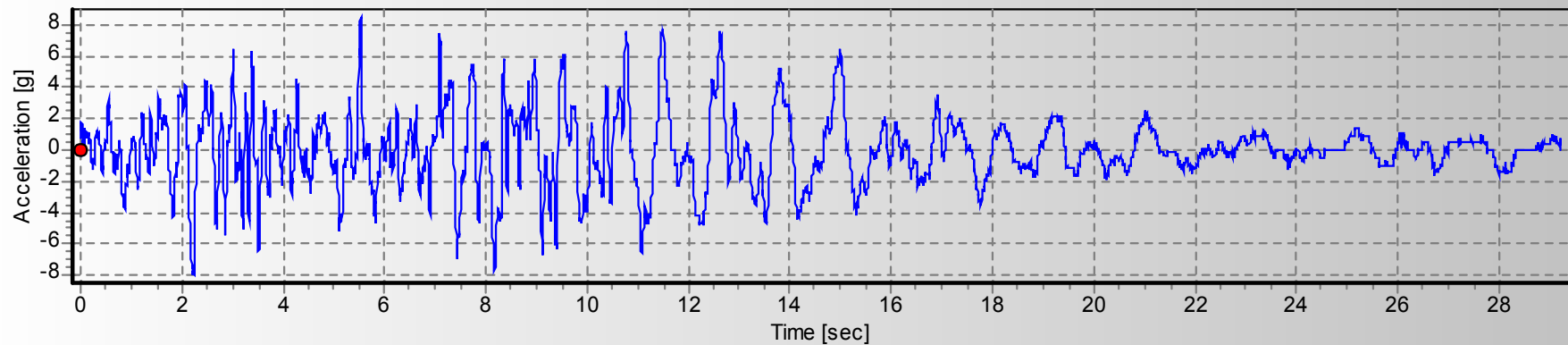
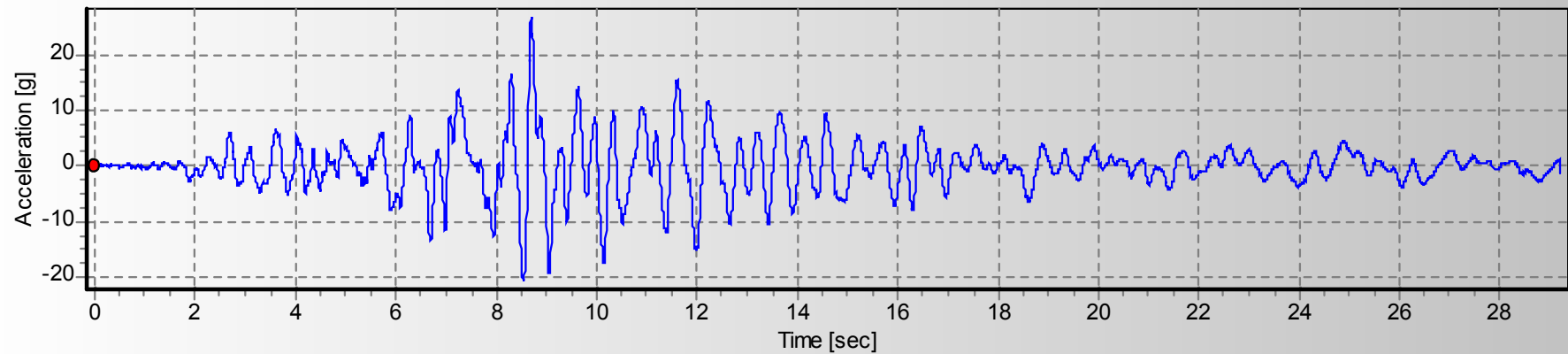
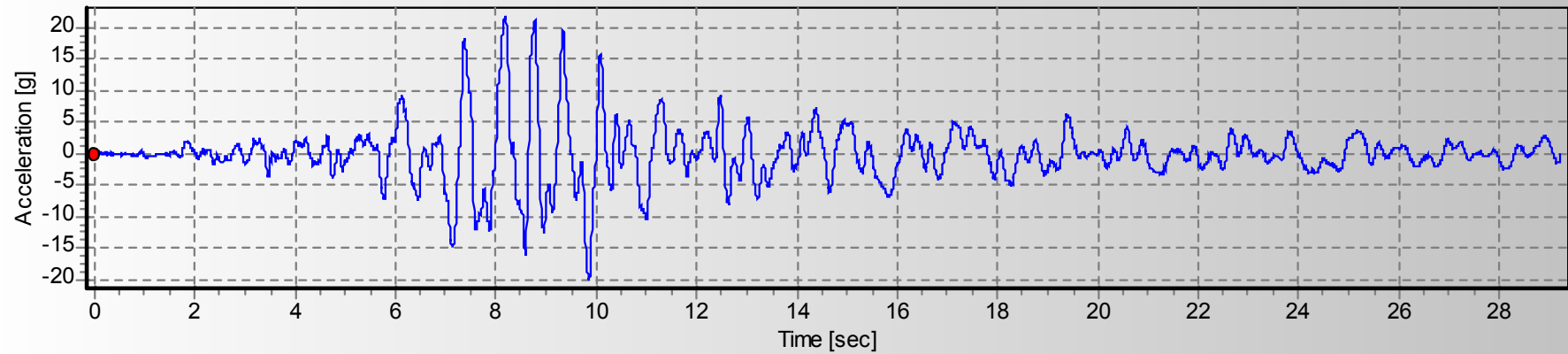
Reference : BRD

0 50 Kilometers

The main shock Adana-Ceyhan Earthquake has been recorded by 9 stations. The nearest station to the epicenter was Ceyhan where has recorded 223.27mG, 273.55mG and 86.47mG peak acceleration values for N-S, E-W and U-D directions respectively.

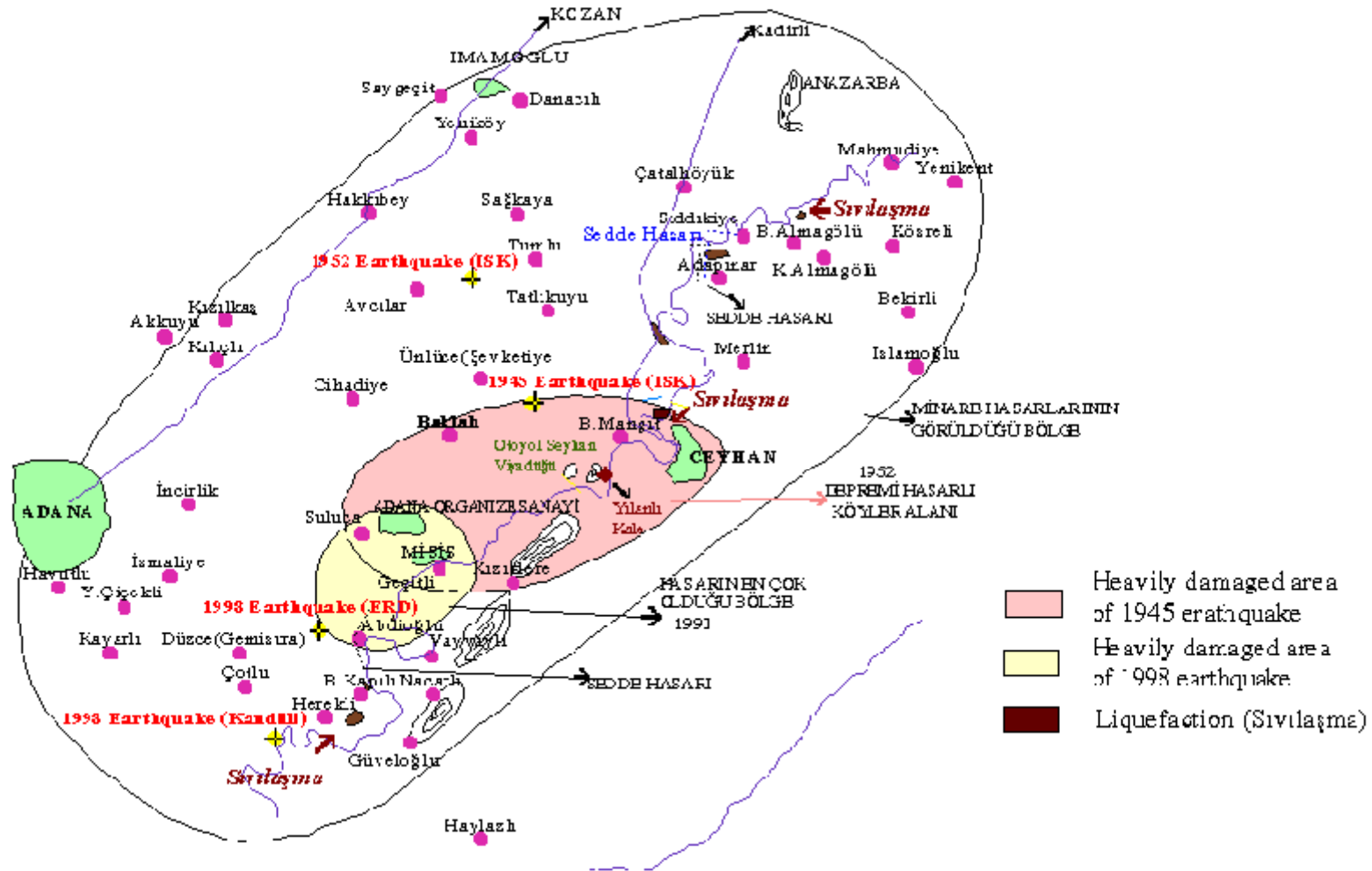
The earthquake caused 146 deaths and 1600 injured. The damage was within a 30 km radius of the epicenter. 40 collapsed and thousands damaged structures have been reported (Ministry of Publicworks).

On July 4, 1998, at 5:05 AM local time, a magnitude 5.1 aftershock occurred. Approximately 1,000 people were injured during this aftershock - most while jumping out of windows. Adana is the fourth largest city in Turkey, and the whole Çukurova Basin is a major industrial and agricultural region with significant contribution to the Turkish economy.



June 27, 1998 Adana – Ceyhan Earthquake, North-South, East-West and Vertical Directions' recorded acceleration from Ceyhan Station.

HASAR DAĞILIMI HARİTASI DAMAGE DISTRIBUTION MAP



EARTHQUAKE RESEARCH DEPARTMENT

GIS ile harita düzenlemesi Bülent Özmen , Gülşah Bilgi tarafından yapılmıştır.

Building Inventory

Residential buildings' construction type in the region is reinforced concrete framed building with infill walls of lightweight concrete blocks type (cinder block or hollow-brick) and often, filler block joist floor system with shallow beams. There are many stone/brick masonry and timber-reinforced hybrid buildings of 2-3 stories in the "older" districts of the city and villages. Number of steel construction is almost none in the building inventory. Practically, most of the industrial plants are of prestressed and precast concrete construction.

Observed Damage

In general, most of the new mid-rise and tall buildings in Adana (5-15 stories) performed well. The buildings damaged and/or collapsed in Adana were older and shorter. Most of the reinforced concrete buildings collapsed during the earthquake located in Ceyhan city. Many RC buildings had a damage of separation of infill walls from the frame, X-cracks of infill walls, some column damage due to insufficient concrete cover.









**Collapsed Gable and Parapet Wall of The Police
Headquarters (Bayulke,1998)**



**Collapsed Facade
Walls,
Story Height > 3.60
meters.
Filler Block Joist Slab,
at Ceyhan
(Bayulke, 1998)**

Shear Failure In Column (Bayulke,1998)



The Adana-Ceyhan Earthquake effected large number of single story factory and warehouse buildings constructed with prefabricated reinforced concrete elements and the behavior of prefabricated system indicated serious deficiencies.





No bridge had been damaged on the Ceyhan River except an historical stone arch bridge, Misis, that had been constructed in IV Century AC, and it was partially damaged.



THE KOCAELI EARTHQUAKE OF AUGUST 17, 1999

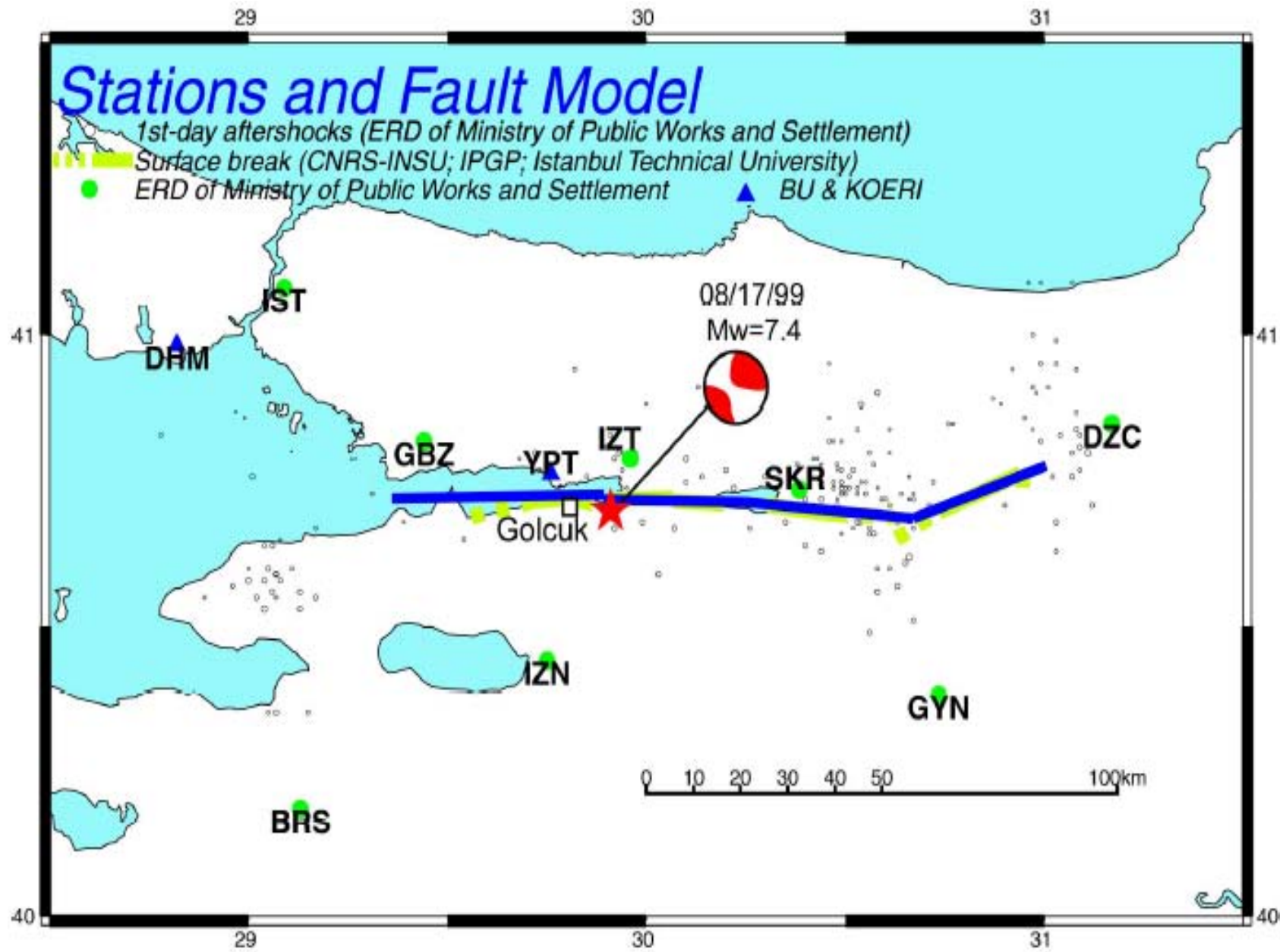
Source Characteristics and Ground Motion Features

The 1999 Kocaeli earthquake that struck the western Turkey was a complex rupture characterized by a right lateral strike-slip fault with a moment magnitude of 7.4. This was one of the strongest earthquakes ever to hit western Turkey. The earthquake was produced by the western part of the North Anatolian fault east of the Marmara Sea. Approximately 130km of surface rupture was observed (CNRS-INSU, IPGP, Istanbul Technical University).

**Earthquake Information has been
captured from website of KOERI as follows;**

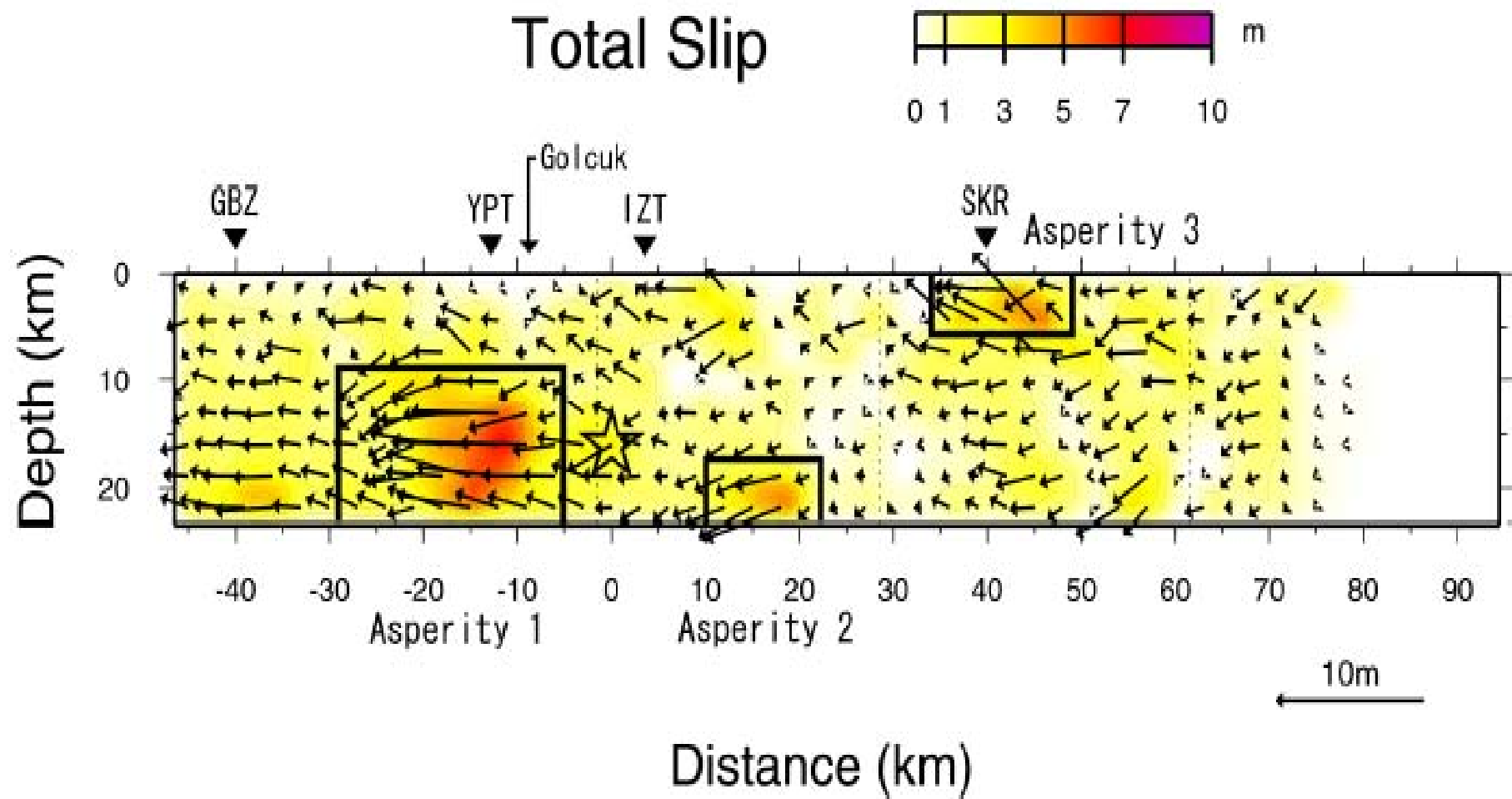
- Date: 1999-08-17 at 00:01:39.80(UTC), 03:01:37 a.m local time
- Surface Wave Magnitude: 7.8 (USGS)
- Body Wave Magnitude: 6.3 (USGS)
- Duration Magnitude: 6.7 (Kandilli)
- Moment Magnitude: 7.4 (USGS, Kandilli)
- Epicenter: 40.702N, 29.987E (USGS)
- Depth: 17 km. (USGS)

Sekiguchi and Iwata's rupture process study took place in EDM-Reiken Report for understanding the kinematic rupture process of the earthquake. A kinematic inversion of the source was performed using the strong motion stations shown in figure below. The fault model used for the inversion is also shown in that figure. As we can see the fault model follows approximately the fault surface break.



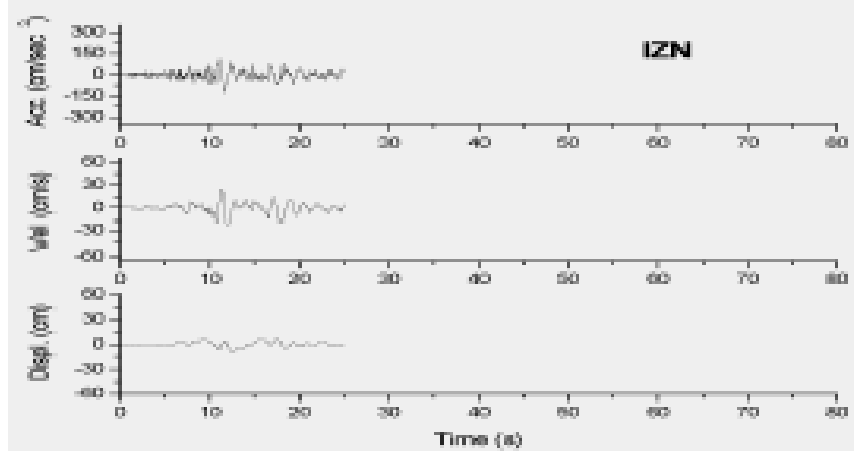
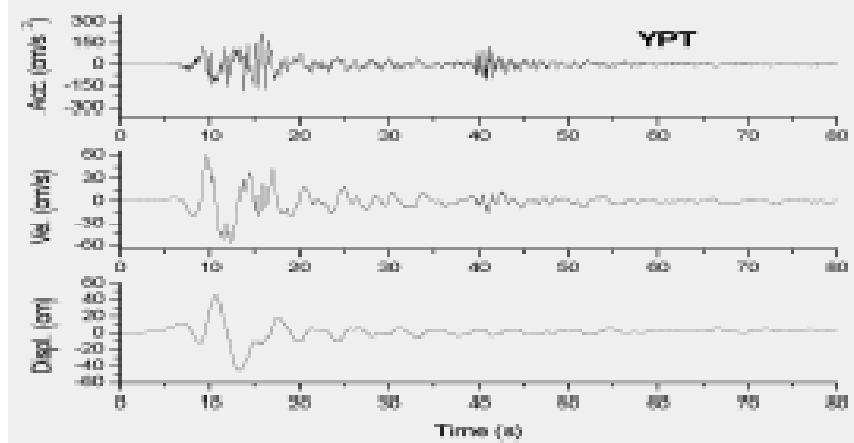
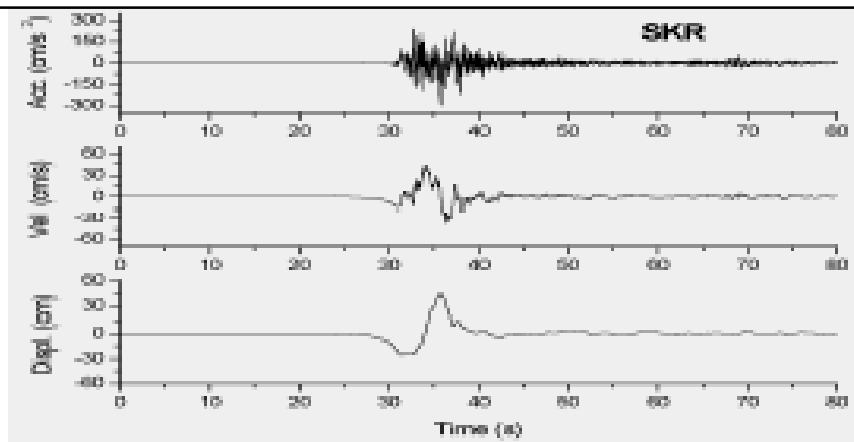
(Sekiguchi and Iwata, 2000)

The final slip solution shows three patches of large slip, the first one localized in the bottom of the fault, 10km west of the hypocenter. The second one 15km to the east of the hypocenter at the bottom of the fault and the third one localized in the upper part of the fault 40km to the east of the fault. These three patches correspond to asperities Nos. 1, 2, and 3 as shown in kinematic model of the 1999 Kocaeli earthquake, following figure. We also can appreciate that the maximum slip of the fault was approximately 9 meters localized in the largest asperity 10km to the west of the hypocenter (asperity No. 1). In the figure, the hypocenter is shown by a star. Horizontal distance is measured from the hypocenter. Arrows denote final slip vector.



General Ground Motion Features

It is interesting to observe the waveforms corresponding to stations located close to the fault trace (few kilometers) like SKR and YPT. The velocity waveforms show a very simple one or two-pulse shape, which is actually related with the radiation of seismic waves from the nearest asperity to each station. It is also interesting to compare the velocity waveforms of SKR and YPT with that of IZN. The IZN station, which is located about 40km from the fault trace, does not show the impulsive characteristic of the near field waveforms. Acceleration, velocity, and displacement wave forms for the EW component of the SKR, YPT, and IZN stations. The waveforms were band-passed filtered between 0.1 and 10 Hz.



Building Damages

This was the first earthquake with major faulting to strike through heavily populated areas. Approximately 18,000 casualties were declared officially. 24% of overall population had settled in the affected region. 8% of total population has been effected by the catastrophic phenomena. Several thousand buildings collapsed in the earthquake. Nearly 15,000 buildings totally collapsed (13,600 reported). Most of the buildings are typically multi-story commercial/residential structures built of reinforced concrete. Most have nominally reinforced concrete frames with architectural (non-structural) unreinforced masonry infill walls. A large percentage of the severely damaged and collapsed buildings were typically in the 6- to 8-story range, either under construction or built within the last few years. The number of damaged housing units was estimated to 60,000 at preliminary report on 24 August (1 week after). On 28 August (10 days after), the number of damaged building was officially published to be 54,294 as the ongoing damage survey data. From 30 Aug, PMCMC (Prime Minister's Crisis Management Center) begun to report the data of each province and level of damage about housing damage assessment data, Collapsed 1332, Condemned 1423, Heavy 13681, Moderate 14701, Light 1788. On 31 August, the classification of damage has changed and reported by following classification. Destroyed 19324, Uninhabitable 31322, Inhabitable 38113, total 88,759) and on 18 September, the intermediate but practically final report about building damage was published. Though the data of table below is published on October 10, the amount of damage is same with September 18.

Damages of the 1999 Kocaeli, Turkey earthquake reported by General Directorate of Disaster Affairs, Earthquake Research Department, Ankara, Turkey.

	Casualties*	Damaged house units **		
		Collapsed or heavily damaged	Moderately damaged	Slightly damaged
Sakarya	2,629	19,043	12,200	18,720
Golcuk	5,025	12,310	7,789	9,299
Kocaeli	4,093	19,315	21,287	22,452
Istanbul	981	3,073	13,339	12,455
Yalova	2,502	9,462	7,917	12,685
Bolu	264	3,095	4,180	3,303
Bursa	268	29	104	401
Eskisehir	86	76	47	315

*: The information from the Crisis Center in Ankara, Turkey (the latest on October 10, 1999).

**: The damage evaluation report of the General Directorate of Disaster Affairs of the Ministry of Public Works and Settlement (the latest on October 10, 1999).

Economic Impact

World Bank has published Executive Summary of Report, “Turkey: Marmara Earthquake Assessment” on 14 September. It tells about direct loss, indirect cost, and secondary effect. The direct cost is range from US\$ 3.0-6.5 billion on the basis of the partial data available. It corresponded to 1.5-3.3% of GNP. This is the only data that is available about economic impact.

**Direct losses (Quoted from World Bank, Executive
Summary of Report,
“Turkey: Kocaeli Earthquake Assessment”, 1999)**

	Damage assessment (US\$ million)	
	Lower bound	Upper bound
Housing	1100	3000
Municipal Infrastructure	70	70
Environment	NA	NA
Road, bridge and highways	78	78
Port	12	12
Railway, railcar factory	72	72
Telecom	38	38
Electricity	82	82
Oil and Gas (includes Tupras Refinery)	387	387
Enterprises (rounded)	1100	2600
Education	100	100
Health	37	37
Total	3076	6476

Preparedness

Disaster management system in Turkey was started from the earthquake in 1509 at Istanbul. After the establishment of Republic of Turkey, there was no regulations or laws about disaster management. In 1944, the law on “measures before and after earthquakes” was established from the lessons from the earthquake between 1939-1944. In 1958, “Civil Defense Law” was established. In 1959, “the Preventive and Protective Measures to be taken against disaster affecting the daily life in general” was established. This law has the statement about individual recovery. It defined that the government has the responsibility of rebuilding of all the houses hit by disasters. However, the completion rate of rebuilding by the government is only 30.5%. In 1968, the regulation named “Emergency Aid Organizations and Program Related to Disaster Management” was established. This law has defines that the Ministry of Pubic Works has the responsibility about disaster management. In 1988, “Regulations on Emergency Aid and Planning for Disasters” were established and amended in 1993. These amendments stated that the Ministry of Public Works is primarily works for disaster management agency but the disaster management organization direct under the Prime Minister would be established in case of catastrophic disaster. The organization directory under the Prime Minister conducted disaster management for Kocaeli Earthquake Disaster.

Disaster Response

Organizations

As mentioned in post-event countermeasures, the ministry of construction is the primary organization for disaster response. However, the scale of disaster was catastrophic and disaster response was conducted under the Prime Minister and Prime Minister's Crisis Management Center (PMCMC) was established on 18 August.

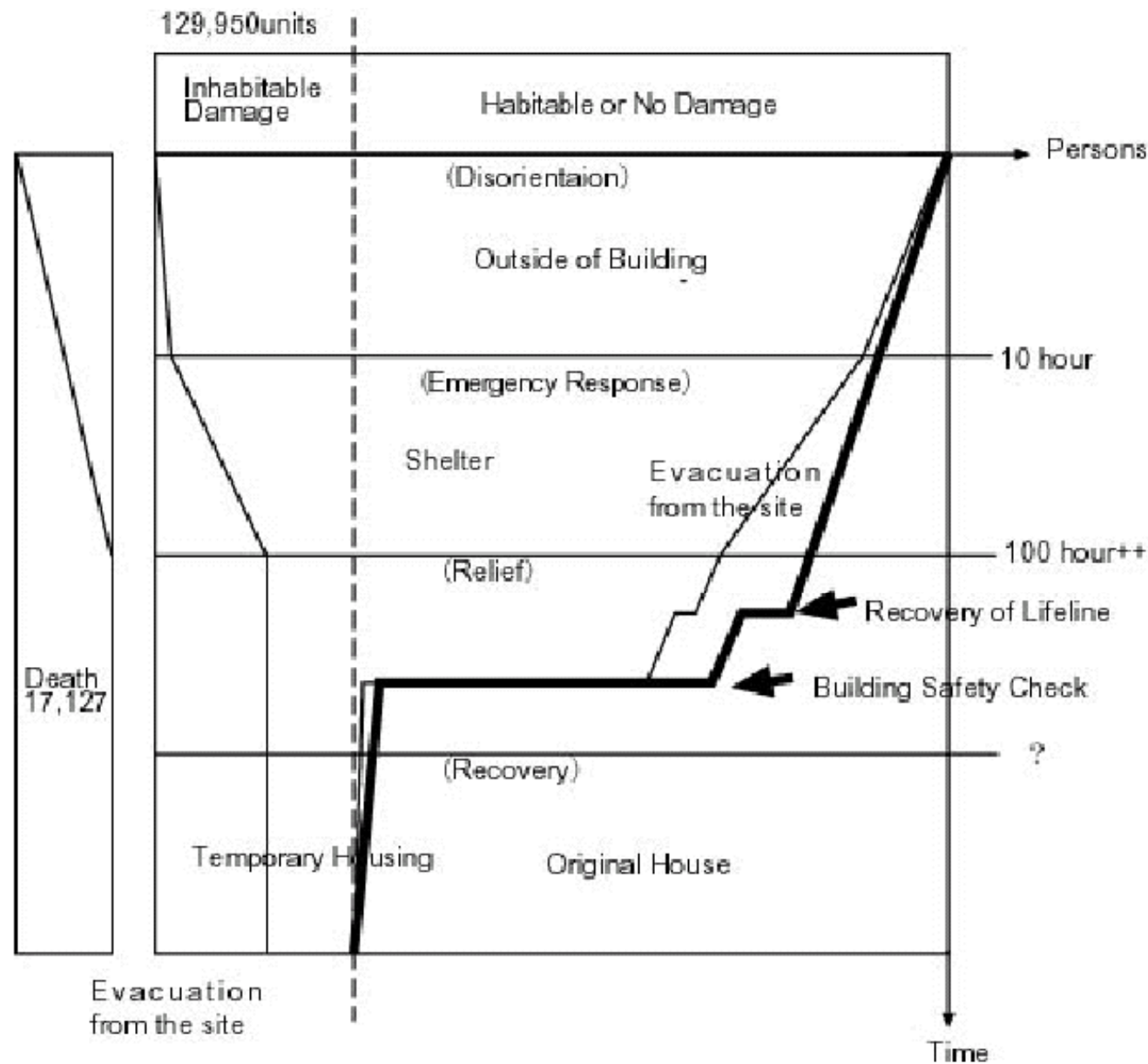
Countermeasures for Response; Sheltering Process

Countermeasures for Response has been written in report of JICA that was made with the cooperation of EDM researchers. The sheltering process of Kocaeli Earthquake Disaster is highlighted in this report. The amount of tents and tent cities would be shown in Table 3.2.2. Providing organization of tent cities were classified to four types of organizations, 1) Red Crescent, 2) Armed Forces, 3) International Donors, 4) Private Sector.

**Amounts of tent and tent cities (Sep. 16, quoted from
Turkey - Earthquake OCHA Situation Report No. 22).**

Red Crescent	Armed Forces	Int'l Donors	Private Sector	Total Tents	Tent Cities
38,080	2,122	54,841	7,970	103,013	121

There are two points about sheltering process in Kocaeli Earthquake Disaster. One is that anxiety about the safety of housing was the key factor of evacuation. Many people lived in the tent set in front of their original houses without damage. It continued the lifelines had already recovered. Second is that the evacuation from affected area is preliminary factor for sheltering process. Since the kin-relationship is strong.



Sheltering process after Marmara earthquake.

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İzmit Körfez



Gölcük



Gölcük



Gölcük Military



Gölcük Military



Gölcük Military



Adapazarı



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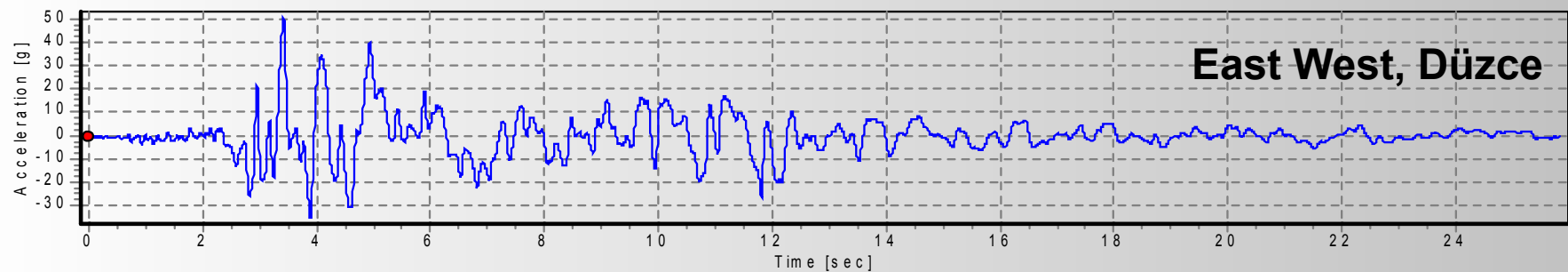
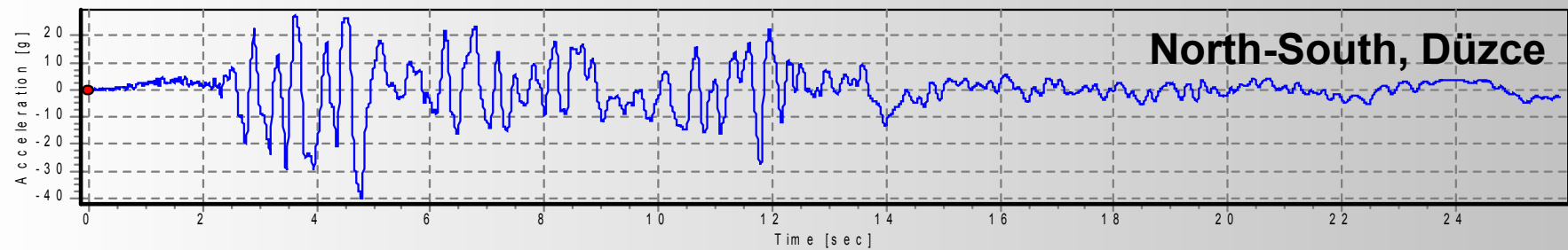
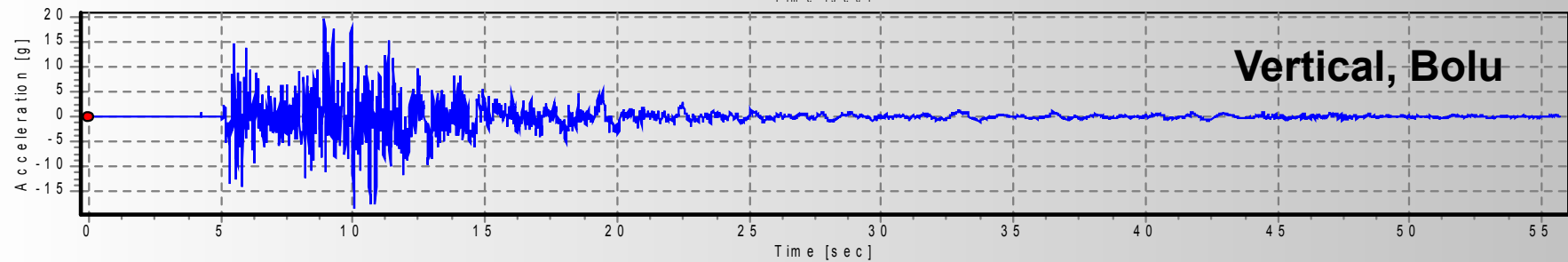
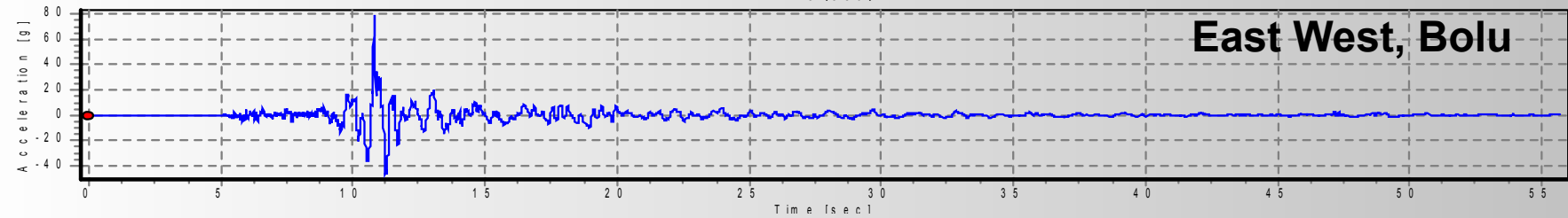
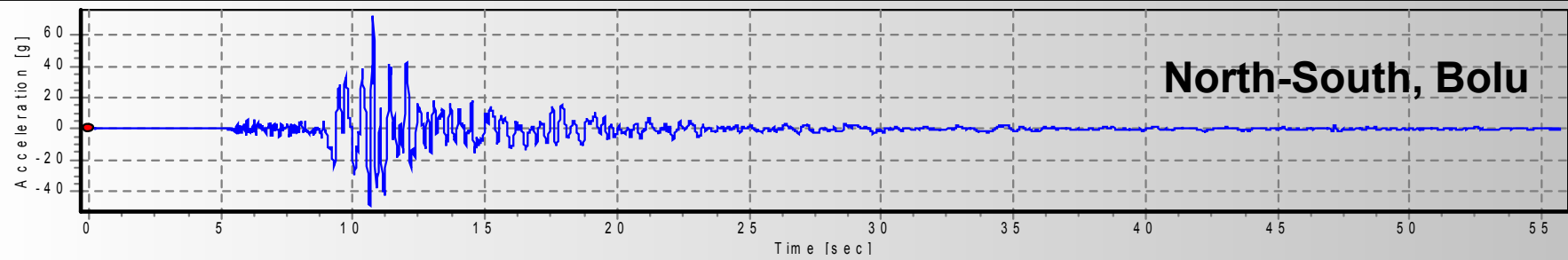
THE DUZCE-BOLU EARTHQUAKE OF NOVEMBER 12, 1999

On November 12, 1999 at 18:57 (local time), a large earthquake of magnitude $M_w=7.1$ (USGS) occurred in Duzce (70 km east of Adapazari), a province which was also affected by August 17, 1999 Kocaeli EQ. The epicentral coordinates of the earthquake was identified as: 40.768 N (latitude) and 31.148E (longitude) and depth of 14.0 km by USGS. The damage predominated in Duzce, Kaynasli, and Bolu. The numbers of loss of life, injured, and collapsed structures (to be torn down) during the Duzce-Bolu earthquake, as of November 12, 1999, were 759, 4948, and 1,332, respectively (Ansal et al., 1999).

The most of the damage is concentrated in Kaynasli. The town is located on Duzce Basin that has been formed by the expansion between Karadere and Kaynasli segments of right-lateral slip Duzce fault. Based on the first observations, the length of the surface fracture was found out to be around 40 km having lateral offsets up to 450 cm.



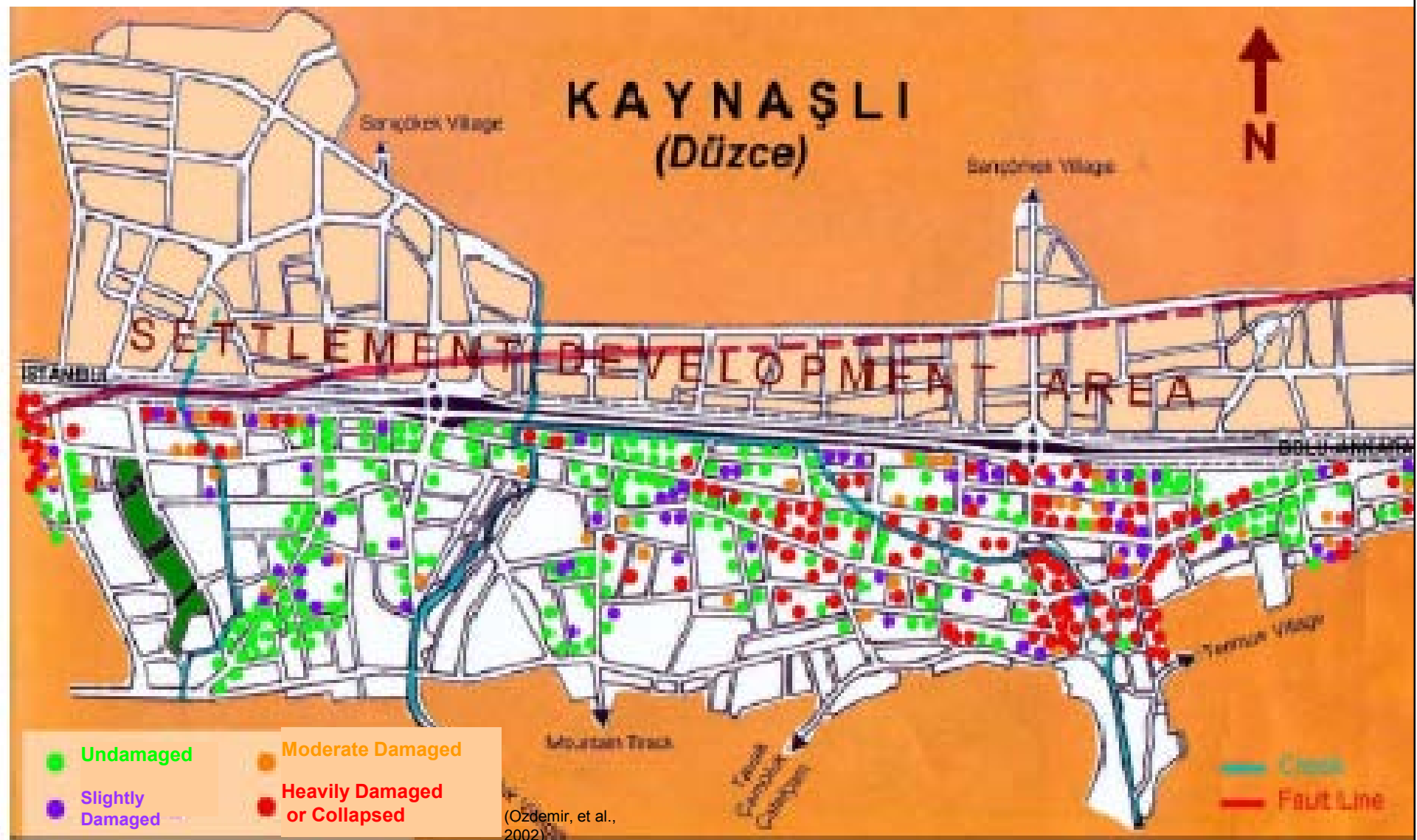
The nearby Strong Motion Network equipment to Kaynasli town were placed in two provinces, Bolu and Duzce. The recorded peak ground accelerations were up to 806 cm/s^2 in Bolu and 514 cm/s^2 in Duzce. The acceleration time histories recorded in Bolu and Duzce can be seen in following figures.



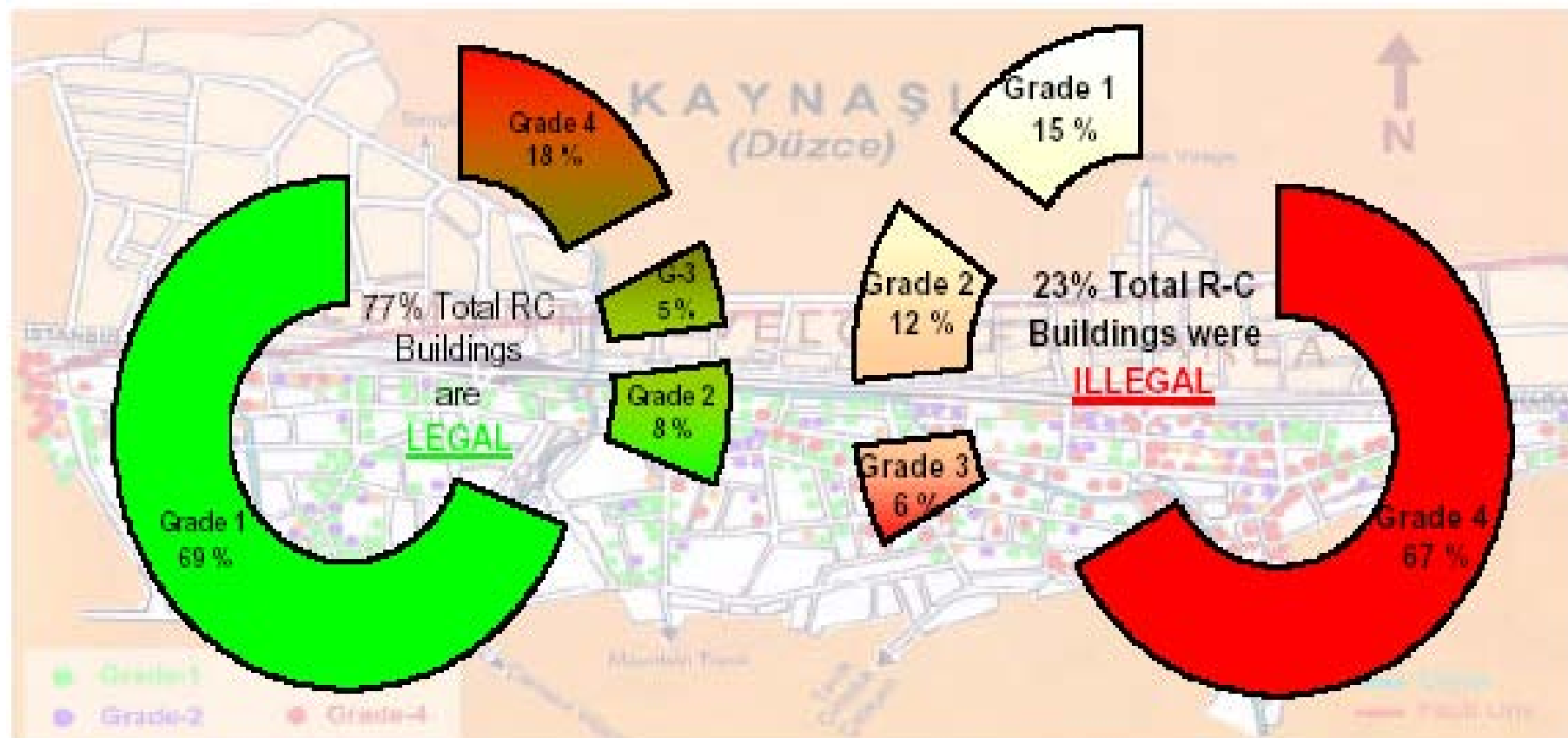
Totally 578 building structures constituting the 98% of the total in the town were inspected according to their structural types as; R-C buildings, Masonry and Traditional buildings and Mixed-Type buildings. All of the surveyed buildings with respect to their damage levels, are plotted on Kaynasli town map.

407 of inspected 578 buildings' structural type was found out to be R-C frames. Only one building consisting of shear wall-frame structure was inserted in this group. 148 were masonry or traditional and 22 were of hybrid-type.

Damage Distribution in Kaynasli Town



Damage level of 27% of the surveyed buildings were found out to be heavily or some of which were totally collapsed, 7% of buildings for moderate, 13% for slight and 53% for undamaged or lightly non-structural damaged. Another concerning point during the survey was the number of storeys. The regulations permit a maximum of 3 storeys for R-C buildings in the town but only 76% of total buildings were within this range. This striking fact led 67% of the illegal buildings to be heavily damaged or totally collapsed during the earthquake while the same ratio is only 18% for the legal ones.



Kaynasli



Duzce



Kaynasli



Kaynasli

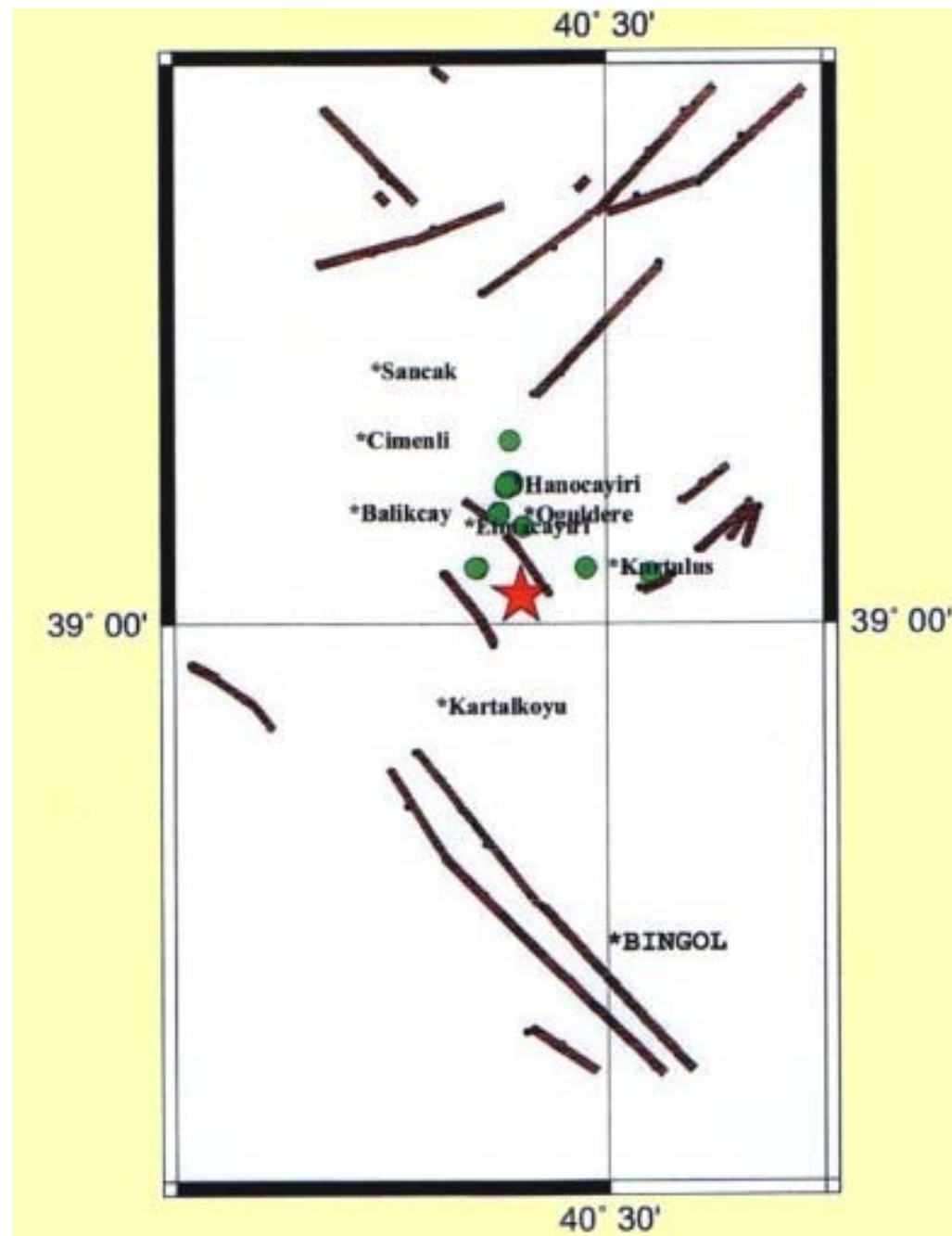


Kaynasli



THE BINGOL EARTHQUAKE OF MAY 1, 2003

On May 1, 2003 at 03:27 (local) an earthquake of magnitude $M_s=6.4$ (KOERI) occurred in Bingol. The epicenter coordinates of the earthquake was identified as 38.99N (latitude) and 40.46E (longitude) and the depth of 10.0 km by USGS. The epicenter location of the 2003 Bingol earthquake agrees well with the NW-SE trending fault shown in the figure.



The green circles show sites where fault traces, fault breaks in the surface, settlements, landslides and toppled rocks were observed which is associated this earthquake with the N-NE trending fault passing from Kurtulus-Elmacayiri-Hanocayiri and continuing towards Balikcay-Cimenli.

The earthquake was recorded by four strong motion recording stations operated by the Earthquake Research Department of General Director of Disaster Affairs The peak ground accelerations that were recorded at Bingol Station are presented in the following page.

The numbers of loss of life, injured, and collapsed structures at villages in the vicinity of Bingöl and in city center have been reported as 168, 520, and 1,351, respectively by the Government sources.

The damage predominated on both sides of the that passes through the city by dividing it into two. Most of the heavily damaged and collapsed structures are in Saray, İnönü, Yen, and Yenişehir districts in the center city.

Site investigations in the earthquake region have been indicated that significant portion of the government buildings (schools, dormitories, state buildings) have the highest level of damage in reinforced concrete structures.

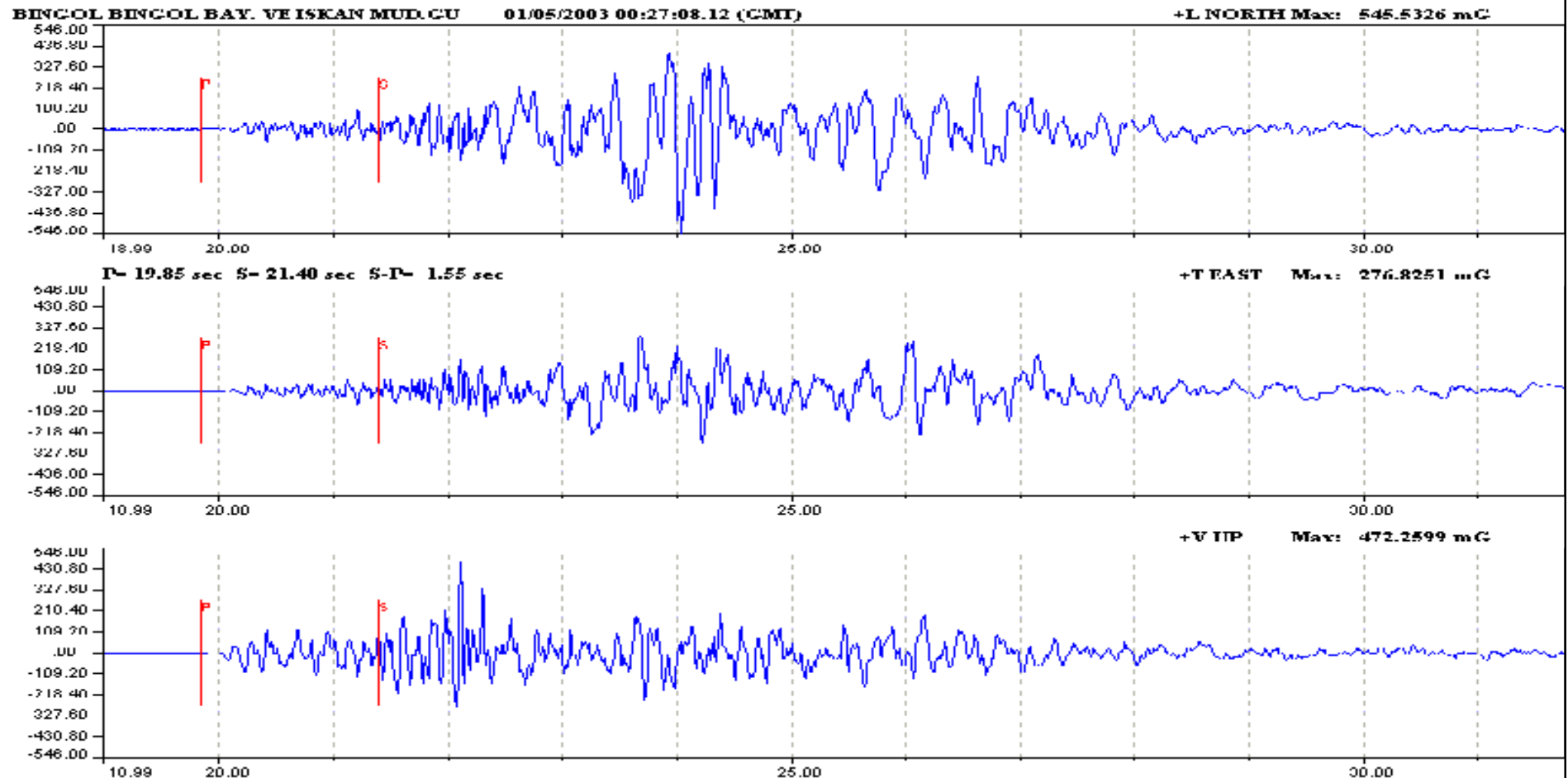
MAY 1, 2003 BİNGÖL (TURKEY) EARTHQUAKE

DATE -TIME: 2003 05 01 03:27:08 Local// DEPTH:10.0 kilometers

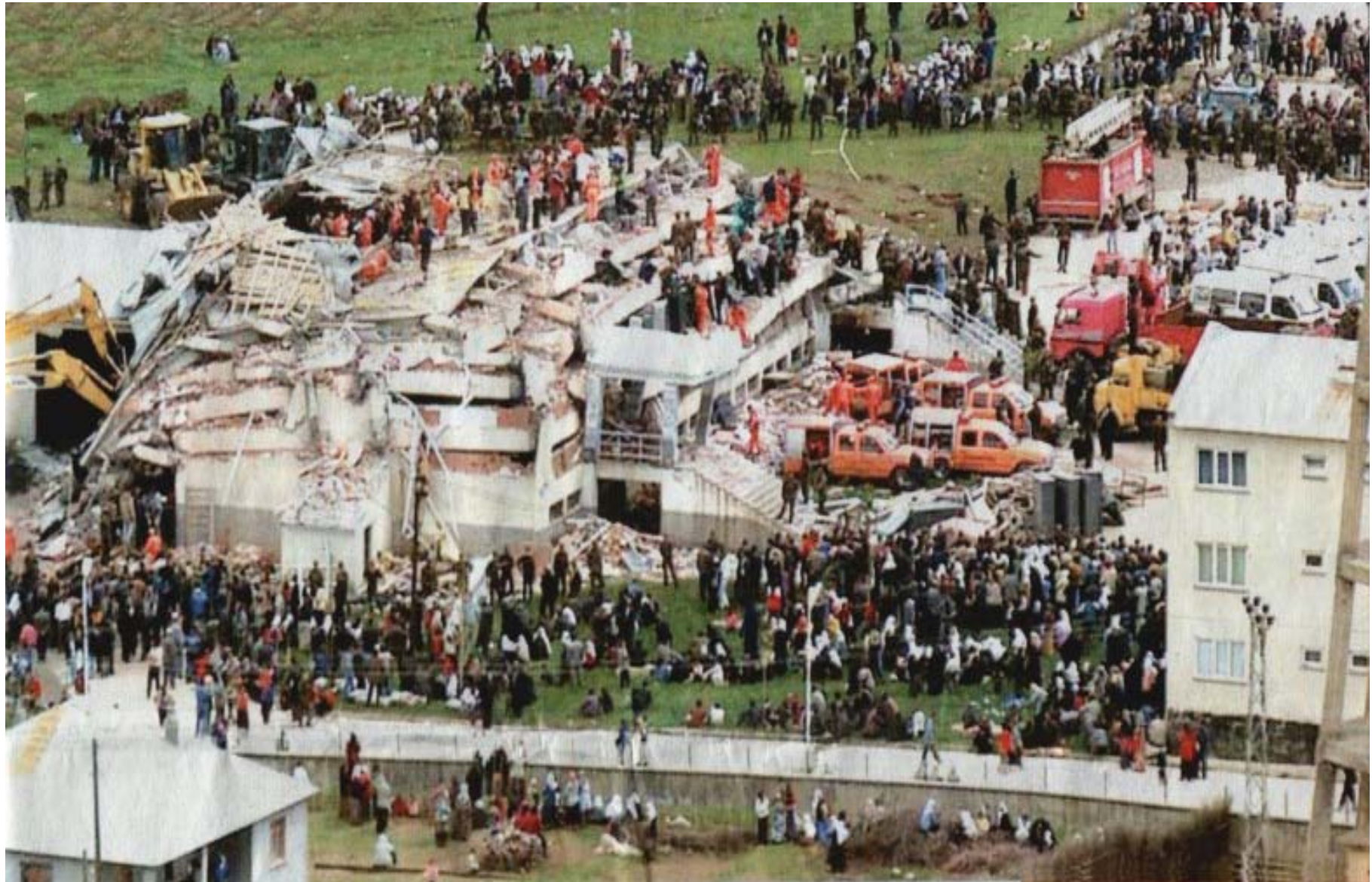
//MAGNITUDE: $M_s=6.4$ (KOERI)

LOCATION: 39.0107N 40.4923E (KOERI), 39.99N 40.46E(USGS)

$M_w=6.4$ (USGS)



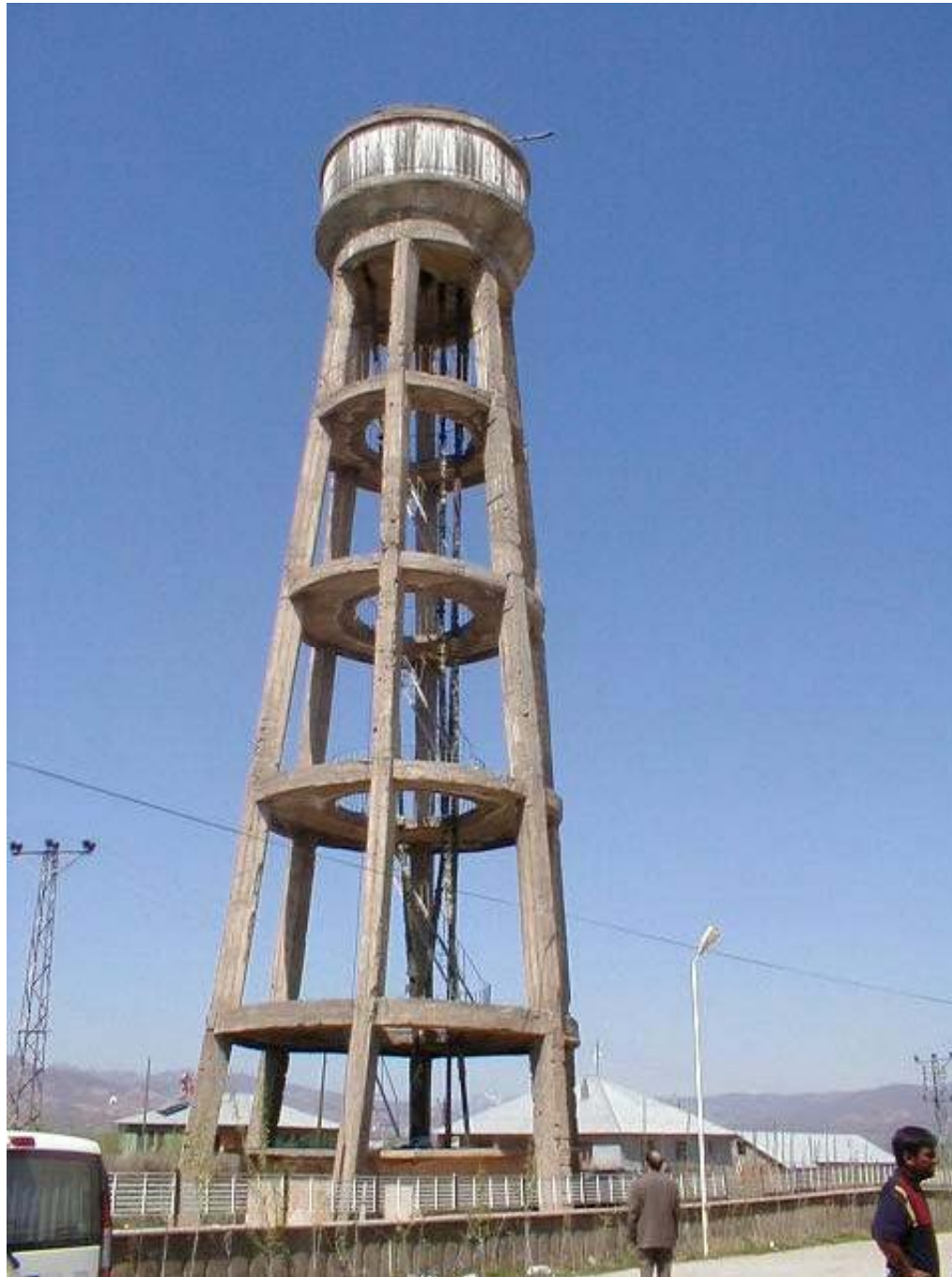
Celtiksuyu Dormitory (Aksam Newspaper)





Celtiksuyu Elementary School





Kaleonu Elementary School









Kultur Street









Masonry Building





CONCLUSION

Construction type in Turkey is mainly reinforced concrete framed buildings. There are many stone/brick masonry and timber-reinforced hybrid buildings in the older and poor districts of the cities and villages. Ratio of steel construction is 5% in overall building inventory and most of them are industrial plants, which mean number of steel construction is almost none in residential buildings inventory.

The most disturbing aspect of the damage to multi-story commercial and residential reinforced concrete buildings was that many modern buildings collapsed completely and many other buildings had partial collapsed. The majority of partial collapses involve the first two floors.

Construction is composed of different sequences if one of the chains drops, the whole construction becomes unacceptable. The causes of damage which has been given in this report can be attributed to one or a combination of the following:

1. Poorly designed, for example,
 - NOT designed by professionals!!
 - soft first story,
 - inadequate detailing and reinforcements of column-beam connections and columns,
 - design of strong beam/weak columns rather than strong-column/weak beams,
 - creation of short-columns due to infill walls or offsets in design,
 - inadequate details,
2. Lack of inspection and supervision at the design and construction stages,
3. Questionable quality of materials used,
4. Bad workmanship,
5. Site effects.

Rehabilitation stage is rather difficult than properly construct. Besides if the structure has too many members to be strengthened, and/or the lateral rigidity of the structure is not adequate, and/or there are important system deficiencies, like soft stories, weak stories, or short columns, member strengthening may not be economically feasible. A structure should have adequate lateral stiffness, strength and ductility for having satisfactory seismic performance.

All recent constructions in Turkey are supposed to be designed and built to a code which incorporates sophisticated earthquake resistant provisions. The code is an adaptation of the Uniform Building Code in California. Therefore, most of the collapsed multi-story buildings were believed to be highly earthquake resistant.

SOME EXAMPLES FOR DAMAGED CONNECTIONS and INADEQUATE DETAILS in R-C BUILDINGS













COMMERCIAL BUILDING in DUZCE (NOT designed by professionals, wrong repairing)









INDUSTRIAL BUILDING in IZMIT (KOCAELI) (Site effect)





SAFETY MEASURES













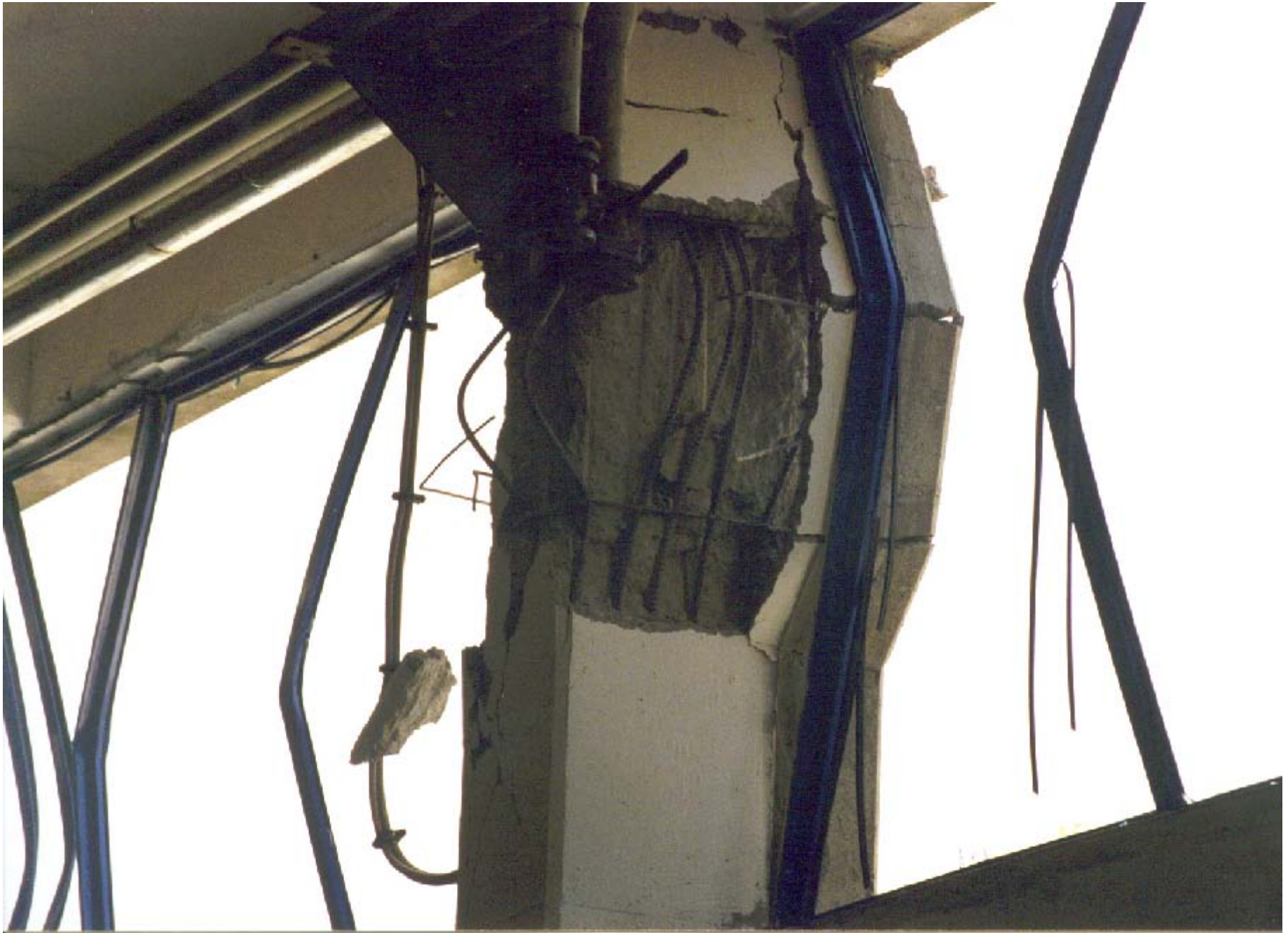
SHORT COLUMN EFFECT





INDUSTRIAL BUILDING in GEBZE







MOSQUE in KAYNASLI

