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1999 Izmit, Turkey Earthquake Was No Surprise

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ABSTRACT

The magnitude (M) 7.4 Izmit earthquake was the largest and most deadly earthquake in Turkey in the past 60 years, and the most destructive in terms of property damage in Turkey's recorded history. It struck on a segment of the North Anatolian fault ~100 km east of Istanbul, one of the most heavily populated and industrially developed regions of the country. The earthquake caused a 120 km surface rupture (with an unmapped extension beneath Izmit Bay) with right-lateral offsets of 1.5–5 m. Apart from the loss of life and property, the Izmit earthquake is remarkable in being the latest in a series of 11 major (M >6.7) earthquakes this century that have broken more than a 1000 km length of the North Anatolian fault from near the Karliova triple junction in eastern Turkey to the Aegean Sea. The detailed record of surface offsets for these earthquakes, the tight geodetic constraints on present-day North Anatolian fault slip rates, and geologic evidence for total offset and age provide a rich data set for placing the historic earthquakes in the broader context of regional tectonic processes, and for determining the role of static stress transfer in triggering sequential earthquakes. The quantitative information on pre-, co-, and post-seismic deformation being developed for the Izmit event is providing important information for evaluating the likelihood and mitigating the impact of future earthquakes in the vulnerable Istanbul region.

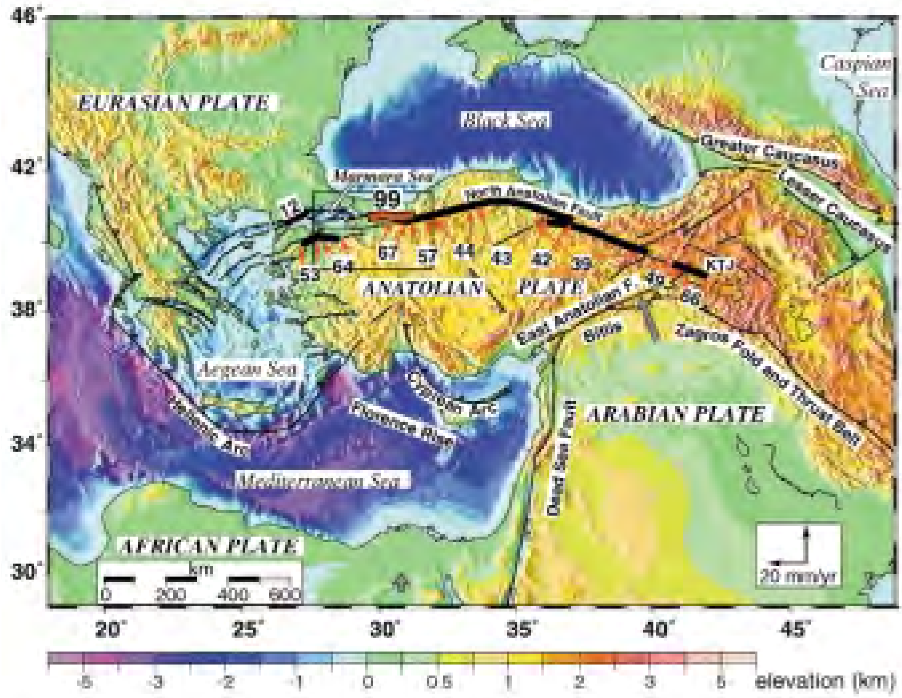

Figure 1. Simplified tectonic map of eastern Mediterranean superimposed on topography and bathymetry. Solid lines—strike-slip faults; lines with tick marks—normal faults, ticks on downthrown block; lines with triangles—thrust faults, triangles on overriding block. Large gray arrows show NUVEL-1A estimates for Africa and Arabia motion relative to Eurasia (DeMet et al., 1994). Heavy dark lines indicate segments of North Anatolian fault zone that showed coseismic surface breaks; red arrows indicate approximate limit of breaks for each event in year indicated (i.e., 44 = 1944). Heavy red line shows location of the 1999 Izmit and Duzce earthquake surface breaks (November 12, 1999, Duzce event, M = 7.1, ruptured easternmost 30–40 km segment shown in red). Area enclosed by rectangle is shown in Figure 4. KTJ—Karliova triple junction.

INTRODUCTION

The Izmit earthquake caused more than 30,000 deaths and up to $6.5 billion in direct property losses (September 14, 1999, World Bank report). The economic impact will be higher, likely exceeding $10 billion, and possibly $20 billion, including indirect and secondary losses. The psychological impact on the people of Turkey has been immense, if difficult to measure in purely economic terms.

The Izmit earthquake represents the latest in a series of major (M >6.7) earthquakes this century that collectively resulted in surface breaks along a 1000 km section of the North Anatolian fault (Ambraseys, 1970; Toksoz et al., 1979; Barka, 1996; Fig. 1 here). Because many of these earthquakes occurred after the deployment of a substantial global seismic network, significant seismic information is available. In addition, fault offsets accompanying each of these major earthquakes have been mapped in detail (Barka, 1996), providing a basis for evaluating the role of static stress transfer in triggering sequential earthquakes (Stein et al., 1997).

On the basis of the history of major earthquakes along the North Anatolian fault, Toksoz et al. (1979) identified the Marmara segment as a seismic gap. Consequently, substantial efforts have been underway to monitor seismicity and tectonic deformation in this area. Most recently, a program was begun to install

Earthquake *continued on p. 2*

The Second 1999 Turkey Earthquake

The November 12, 1999, M = 7.1, Duzce earthquake appears to be a second event extending the Izmit break approximately 30–40 km to the east (Fig. 4). The focal mechanism and surface faulting indicate predominately right-lateral slip of 1.5–4 m on a steeply dipping fault. There is some evidence for a small component of dip-slip with the north side moving down. This earthquake highlights the importance of static stress changes from one earthquake triggering subsequent events, and further demonstrates the current increased seismic hazards in the greater Istanbul region.

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In Memoriam

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October 12, 1999

Olcott Gates
Wiscasset, Maine
July 27, 1999

Donald E. Gault
Vallecito, California
March 29, 1999

James E. Gillis, Jr.
Fairfax, Virginia
September 19, 1999

Ernest E. Glick
North Little Rock, Arkansas
December 30, 1998

Melvin L. Hill
Lakewood, Colorado
April 8, 1999

Russell M. Jeffords
Houston, Texas
January 1999

John H. Johnsen
Sedona, Arizona
September 30, 1999

Richard W. Lounsbury
Knoxville, Tennessee
September 3, 1999

Troy L. Péwé
Tempe, Arizona
October 1999

Karl M. Waage
North Branford, Connecticut
October 18, 1999

Please contact the GSA Foundation for information on contributing to the Memorial Fund.

Earthquake *continued from p. 1*

continuously recording Global Positioning System (GPS) stations and a relatively dense network of GPS survey sites to monitor strain accumulation on the various branches of the fault in the Marmara region. This effort is providing information on the various phases of the earthquake cycle for the Izmit event, including pre-earthquake strain accumulation, coseismic deformation, and postseismic relaxation. Furthermore, regional GPS studies undertaken over the past 10 years provide quantitative constraints on slip rates along the North Anatolian fault and place the motions along the fault in the context of regional tectonic processes associated with the interaction of the Arabian, African, and Eurasian plates (Straub et al., 1997; Reilinger et al., 1997a; McClusky et al., 2000). As a result, rather complete seismic, geologic, and deformational records are available for the fault that produced the Izmit event. These records hold the promise of improving our understanding of the fundamental nature of earthquake processes on this and similar faults. Here, we describe the Izmit earthquake and place it in the context of prior earthquakes on the North Anatolian fault and the regional tectonic framework of the eastern Mediterranean zone of active plate interactions.

ACTIVE TECTONICS OF THE EASTERN MEDITERRANEAN REGION

The tectonic framework of the eastern Mediterranean and Middle East region is dominated by the collision of the Arabian

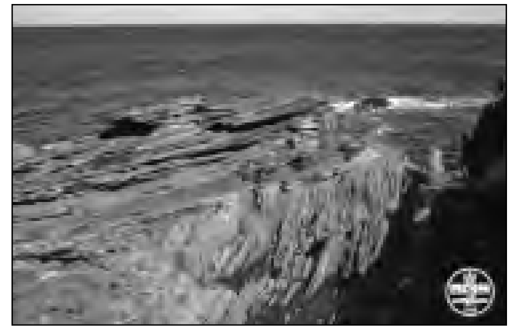
Earthquake *continued on p. 3*

Dialogue

Sara Foland, CEO

Geology As An Art Form

> "The result of this physical inquiry [into the age of Earth] is that we find no vestige of a beginning, no prospect of an end."
>
> —James Hutton, 1795



Hutton's unconformity, Siccar Point, Scotland. © NERC. Courtesy of British Geological Society.

You may laugh or even guffaw, feel emotionally moved, or seriously disagree with me when I state that geology is as much an art form as a science. But let's think about what we do. We are attempting to quantify an experiment that has been going on for more than 4.55 billion years. In this experiment, we don't know the input parameters or the experimental design. We don't know the beginning point or the expected end. Yet we classify, attempt to quantify, and define from observations, the natural system around us. We cannot identify all of the independent variables or their feedback loops in this grand experiment, so we rely on analogy, estimation, and, ultimately, interpretation.

In his book *Guns, Germs, and Steel,* Jared Diamond provides an interesting illustration of the problem of defining natural systems. He writes, "One can provide *a posteriori* explanations (e.g., why an asteroid impact on Earth 66 million years ago may have driven dinosaurs but not many other species to extinction), but *a priori* predictions are more difficult (we would be uncertain which species would be driven to extinction if we did not have the actual past event to guide us)."

The Role of Observation. Recall that the word "science" means "knowledge." It is derived from the Latin scire, "to know," and scientia, "knowledge." The ways of obtaining this knowledge are to use whatever methods are most appropriate to a particular field of study. In geology, one's interpretation is based in observational experimentation. It is only as good as the breadth of experience one brings to bear on the problem, or the breadth of experiences a team brings to bear. The result seems to be that one who's seen the most rocks wins, or at least may have a better interpretation.

The first geologists were naturalists, true observers of the world around them. Their observations form the foundation of modern geological thought and theory. James Hutton recognized that the vertical Llandovery shales beneath the gently dipping Old Red Sandstone strata at the "Great Unconformity" were formed at different times and by different processes.

Experimentation and Geologic Time. Today, we augment our observations with experimental results from other physical sciences including chemistry, physics, and biology. This allows us to better refine our interpretations of Earth and other planetary bodies. But geoscience differs from the other physical sciences because of an added dimension within the natural system—geological time. The addition of this temporal dimension, extending over billions of years, alters the scale of the problem at hand—be it relative time as in Hutton's day, or absolute time as determined with today's geochronological techniques.

Geoscientists continually balance the broad definition of Earth and her systems with quantifiable experiments on specific pieces and parts. In support of this work, GSA provides its members with various venues to share their ideas, interpretations, and experimental results. Next month, we'll look at some of the ways GSA assists members and students in their quest to quantify the art of geology. ■

Earthquake *continued from p. 2*

and African plates with Eurasia (e.g., McKenzie, 1970; Jackson and McKenzie, 1988). Plate tectonic models (e.g., NUVEL-1A; DeMets et al., 1994) suggest that the Arabian plate is moving in a north-northwest direction relative to Eurasia at a rate of about 18–25 mm/yr, averaged over about 3 m.y. These models also suggest that the African plate is moving in a northward direction relative to Eurasia at a rate of about 10 mm/yr. Differential motion between Africa and Arabia (~10–15 mm/yr) is thought to be taken up predominantly by left-lateral motion along the Dead Sea transform fault. The northward motion of Arabia results in continental collision along the Bitlis-Zagros fold and thrust belt, intense earthquake activity (Fig. 2), and high topography in eastern Turkey and the Caucasus Mountains. The northward motion of Arabia is also thought to contribute to westward extrusion of the Anatolian plate, which is accommodated by right-lateral slip on the North Anatolian fault and left-lateral slip on the East Anatolian fault (McKenzie, 1970). The leading edge of the African plate is being subducted along the Hellenic trench at a higher rate than the relative northward motion of the African plate, requiring that the trench moves southward relative to Eurasia proper (e.g., Sonder and England, 1989; Royden, 1993). This qualitative picture of present-day kinematics is well illustrated by the distribution and focal mechanisms of earthquakes in Figure 2. The lack of events within the Anatolian plate attests to the low level of internal deformation in this area, and the nature of strike-slip faulting along the North Anatolian (right-lateral) and East Anatolian (left-lateral) faults are consistent with westward motion and counterclockwise rotation of Anatolia relative to Eurasia. Although this qualitative description of eastern Mediterranean tectonics has proven robust and useful, quantitative estimates of plate motions, intraplate deformation, and fault slip rates, now being provided by GPS observations, help to better constrain models for dynamic processes and lithospheric rheology (e.g., Thatcher, 1995) and provide a physical basis for effectively illuminating earthquake generation processes.

GPS results (Fig. 3) provide direct estimates of Arabia-Africa-Eurasia motion, the counterclockwise rotation and associated westward motion of the Anatolian (Turkish) plate, and the rapid (>30 mm/yr) southward motion of the southern Aegean region (block?) relative to Eurasia. These results also quantify strain partitioning and crustal shortening in eastern Turkey and the Caucasus, fault-slip rates on the main, active faults, and partitioning between seismic and aseismic deformation. The kinematic results in turn provide constraints on dynamic processes and the rheological character of the lithosphere in this region. For example, the increase in velocities from eastern Turkey toward the Hellenic trench requires forces other than pushing from Arabia to account for Anatolian motion. The apparently coherent motion of much of Anatolia (i.e., little internal deformation) is consistent with relatively strong continental lithosphere (e.g., Reilinger et al., 1997; Barka and Reilinger, 1997; Lundgren et al., 1998; McClusky et al., 2000).

NORTH ANATOLIAN FAULT ZONE

The North Anatolian fault is a major, right-lateral, continental strike-slip fault that accommodates the westward motion

Earthquake *continued on p. 4*

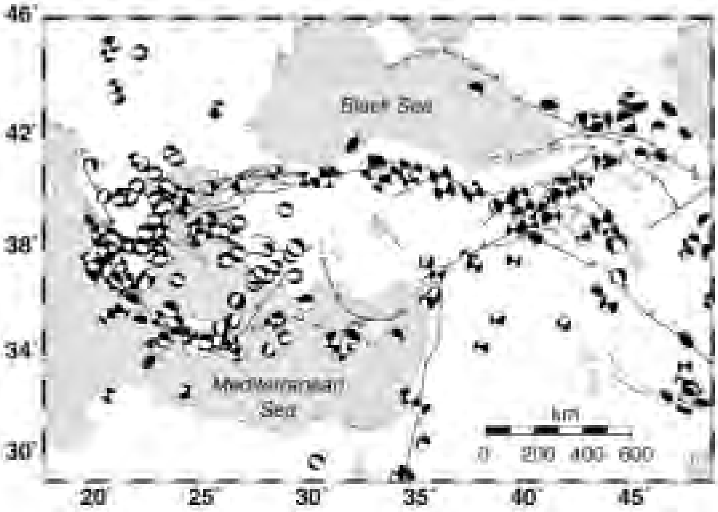


Figure 2. Focal mechanisms (lower hemisphere projection) for shallow (<100 km), major earthquakes (M >5.0) (Dziewonski et al., 1981; Jackson and McKenzie, 1988), indicating nature of fault slip during an earthquake. Mechanisms along North Anatolian fault indicate right-lateral, strike-slip faulting along strike of mapped surface fault; those in western Turkey indicate normal faulting (i.e., white center and dark around the edges); those in Caucasus indicate thrust faulting (dark center and light edges).

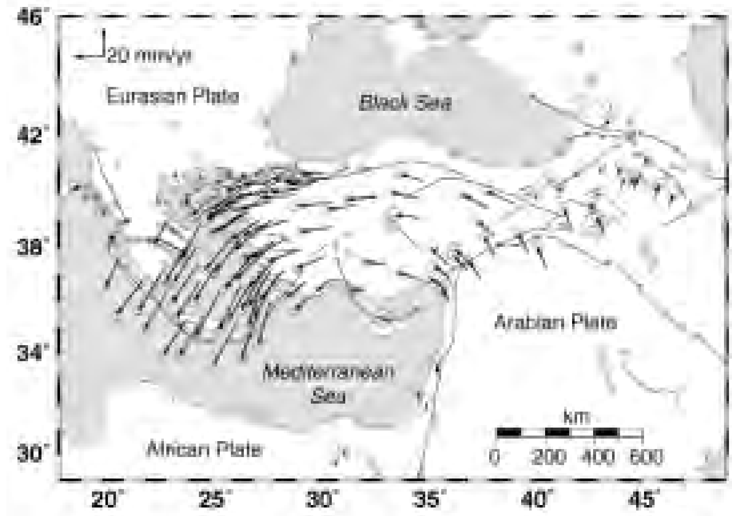


Figure 3. GPS horizontal velocities and 95% confidence ellipses in Eurasia-fixed reference frame for period 1988–1998 (McClusky et al., 1999). To avoid clutter, not all sites are plotted in Marmara region (see Fig. 4).

Earthquake *continued from p. 3*

and counterclockwise rotation of Anatolia and extends approximately 1200 km from the Karliova triple junction to the Aegean Sea (Fig. 1). Right-lateral deformation continues east of the triple junction, but the fault has a more complex character and is not easily identified as a single surface trace (e.g., Toksoz et al., 1977; Westaway, 1994; Reilinger et al., 1997b). In the Marmara region, the fault becomes more complex, bifurcating into two or three separate branches. Right-lateral deformation extends west of the Marmara Sea into the Aegean and is thought to connect with the east-west–striking normal faults bounding the Gulf of Corinth (Armijo et al., 1996; McClusky et al., 2000).

On the basis of the regional GPS velocity field, McClusky et al. (2000) estimated an upper bound on North Anatolian fault slip rate of 24 ± 1 mm/yr. This estimate is made by assuming that all motion of Anatolia is accommodated by slip on the North Anatolian fault, which serves as the primary boundary between Anatolia and Eurasia. Independent GPS estimates of Anatolia-Eurasia relative motion in the Marmara area by Straub et al. (1997) indicate a rate of 22 ± 3 mm/yr for Anatolia relative to a station in Istanbul (and hence a lower bound). These present-day fault slip rates are in reasonable agreement with geologic slip rates based on total fault offset and the estimated age of faulting (e.g., Şengör, 1979; Westaway, 1994; Armijo et al., 1999). This agreement suggests that Anatolia-Eurasia motion has continued in its present configuration and at approximately the same rate for the past 4–5 m.y. Such a first-order kinematic model (i.e., Anatolia moving as a coherent unit, the motion being accommodated within a narrow fault zone relative to the size of the plates) provides a physical basis for relating fault slip for specific events to the overall motion of the plates, for identifying seismic gaps (i.e., slip deficient segments), and, to the extent that the characteristic earthquake model is applicable, for estimating average earthquake repeat times (Reilinger and Barka, 1997).

A series of 11 large (M >6.7) earthquakes on the North Anatolian fault this century resulted in continuous surface breaks along more than 1000 km of the surface trace (Fig. 1). Surface offsets for many of these events have been mapped in detail (e.g., Barka, 1996), providing a basis for investigating the relationship between earthquakes and regional tectonics, as well as the interaction between successive events (e.g., Barka and Reilinger, 1997; Stein et al., 1997). Subsequent to the 1912, M = 7.4 Ganos earthquake, which broke the western segment of the northern fault branch (Fig. 1), and beginning with the 1939, M = 7.8 Erzincan rupture, four successive earthquakes (1939, 1942, 1943, 1944) migrated to the west (Dewey, 1976; Toksoz et al., 1979). Westward migration continued with the 1957 and 1967 earthquakes. Most other large earthquakes on the North Anatolian fault (1949, 1951, 1966, 1992) occurred on fault segments with low coseismic slip in prior earthquakes, or extended the break to the east (e.g., Stein et al., 1997; Fig.1). The 1999 Izmit earthquake, on a fault segment specifically identified as a seismic gap (Toksoz et al., 1979; Stein et al., 1997), appears to be a continuation of the westward migrating historic earthquake sequence.

As indicated in Figure 4, the North Anatolian fault bifurcates into several active strands in the Marmara region. While faults beneath the Marmara Sea are known to generate earthquakes (e.g., Barka, 1997), the geometry and nature of these active faults remain unclear, and the distribution of slip on specific faults within the Marmara is unknown. However, the large increase in westward velocities for GPS stations located south of the northern branch of the North Anatolian fault indicates that the majority of strain occurs on the northernmost fault segments (Straub et al., 1997; McClusky et al., 2000). In fact, preliminary modeling indicates that the pre-earthquake GPS velocity gradient across the eastern Marmara can be explained by strain accumulation along a single, approximately east-west–striking fault, including the segment that broke in the Izmit earthquake (R. Bergmann, 1999, personal communication).

1999 IZMIT EARTHQUAKE

The 1999, M = 7.4 Izmit earthquake epicenter was near the town of Izmit at the east end of Izmit Bay. The quake involved predominantly right-lateral, strike-slip motion on a vertical fault plane (Harvard CMT) (Fig. 4). Observed surface offsets ranged from 1.5 to 5 m along a 120 km fault break (Barka, 1999). The largest offsets were observed along the western end of the fault where it entered the Bay of Izmit. Offsets decrease to the east where the Izmit break lies north of the 1967 Mudurnu Valley earthquake fault break. The extent of faulting beneath Izmit Bay is unknown. Although significant aftershock activity reached as far west as 28.7°E, there is no evidence for right-lateral offsets in the Hersek delta (29.5°E, 40.7°N; Fig. 4). In addition, data from continuously recording GPS stations located north and south of Izmit Bay prior to the earthquake show a substantial component of north-south coseismic motion, consistent with a fault that ends (or slip decreases sharply) near or east of 29.5°E.

Because the Marmara region is home to about 25% of Turkey's population and a large part of Turkey's industrial activity, and the area had been identified as a seismic gap, substantial seismic and geodetic work was underway prior to the earthquake. Part of this effort included using continuous GPS (CGPS) and survey-mode GPS (S-MGPS) to monitor the distribution of Anatolia-Eurasia motion on the various faults that compose the North Anatolian fault zone. Figure 4 shows the locations of those CGPS stations in operation prior to the earthquake (all continue to operate), and S-MGPS sites that had been observed less than two years before the main shock. In addition, the Marmara Research Center in Gebze, Turkey, installed four CGPS stations along the highest coseismic slip segment of the fault within 48 hours of the main shock (Fig. 4). The S-MGPS stations are now being reobserved and together with the CGPS stations, INSAR, seismic estimates of fault slip, and surface offsets should provide fairly detailed estimates of coseismic slip distribution on the Izmit fault. This is of more than academic interest, because the details of coseismic slip distribution are critical for estimating future earthquake hazards in the Marmara region (i.e., the extent to which the Izmit earthquake filled the seismic gap and advanced or retarded future earthquakes on other fault segments). Furthermore, some of the S-MGPS stations are being observed multiple times after the earthquake to monitor continuing postseismic motions. The resulting data, together with the data from CGPS stations, will help constrain models of postseismic after-slip and viscoelastic relaxation. Such postseismic processes can substantially increase the overall earthquake moment and can result in rapid, postseismic strain accumulation, which could affect estimates of future earthquake occurrences.

SUMMARY

Quantitative information on pre-, co-, and postseismic deformation for the Izmit earthquake provides an important opportunity to further our understanding of basic earthquake processes, with implications for forecasting and mitigating the effects of future events on the North Anatolian fault and similar faults like the San Andreas fault in California. The remarkable series of earthquakes along virtually the entire length of the North Anatolian fault this century (excluding the Marmara Sea segments) provides an ideal data set to investigate the relationship between successive earthquakes on a major continental strike-slip fault, as well as the relationship among earthquakes, regional tectonics, and geologic deformation. Most critically, understanding the Izmit event and the nature of active faulting in the Marmara Sea is prerequisite to determining the probability and nature (location, magnitude) of future earthquakes west of the Izmit event. The vulnerability of the greater Istanbul region, as well as other large population centers in earthquake-prone areas, demands that we do our utmost to extract information from this tragic event, with the expectation that this knowledge will lead to an improved ability to mitigate future earthquake losses.

ACKNOWLEDGMENTS

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REFERENCES CITED

Ambraseys, N. N., 1970, Some characteristic features of the Anatolian fault zone: Tectonophysics, v. 9, p. 143–165.

Armijo, R., Meyer, B., King, G. C. P., Rigo, A., and Papanastassiou, D., 1996, Quaternary evolution of the Gulf of Corinth rift and its implications for the Late Cenozoic evolution of the Aegean: Royal Astronomical Society Geophysical Journal, v. 126, p. 11–53.

Armijo, R., Meyer, B., Hubert, A., and Barka, A., 1999, Propagation of the North Anatolian fault into the north Aegean: Timing and kinematics: Geology, v. 27, p. 267–270.

Barka, A. A., 1996, Slip distribution along the North Anatolian fault associated with large earthquakes of the period 1939–1967: Seismological Society of America Bulletin, v. 86, p. 1238–1254.

Barka, A., 1997, Neotectonics of the Marmara Sea, *in* Schindler, C., and Pfister, M., eds., Active tectonics of northwest Anatolia: The Marmara Project: Zurich, Verlag der Fachvereine, p. 55–87.

Barka, A. A., 1999, The 17 August, 1999, Izmit earthquake: Science, v. 285, p. 1858–1859.

Barka, A., and Reilinger, R., 1997, Active tectonics of the eastern Mediterranean region deduced from GPS, neotectonic, and seismicity data: Annali Geofisica, v. 40, p. 587–610.

DeMets, C., Gordon, R. G., Argus, D. F., and Stein, S., 1994, Effects of recent revisions to the geomagnetic reversal time scale on estimates of current plate motions: Geophysical Research Letters, v. 21, p. 2191–2194.

Dewey, J. W., 1976, Seismicity of northern Anatolia: Seismological Society of America Bulletin, v. 66, p. 843–868.

Dziewonski, A. M., Chou, T.-A., and Woodhouse, J. H., 1981, Determination of earthquake source parameters from waveform data for studies of global and regional seismicity: Journal of Geophysical Research, v. 86, p. 2825–2852.

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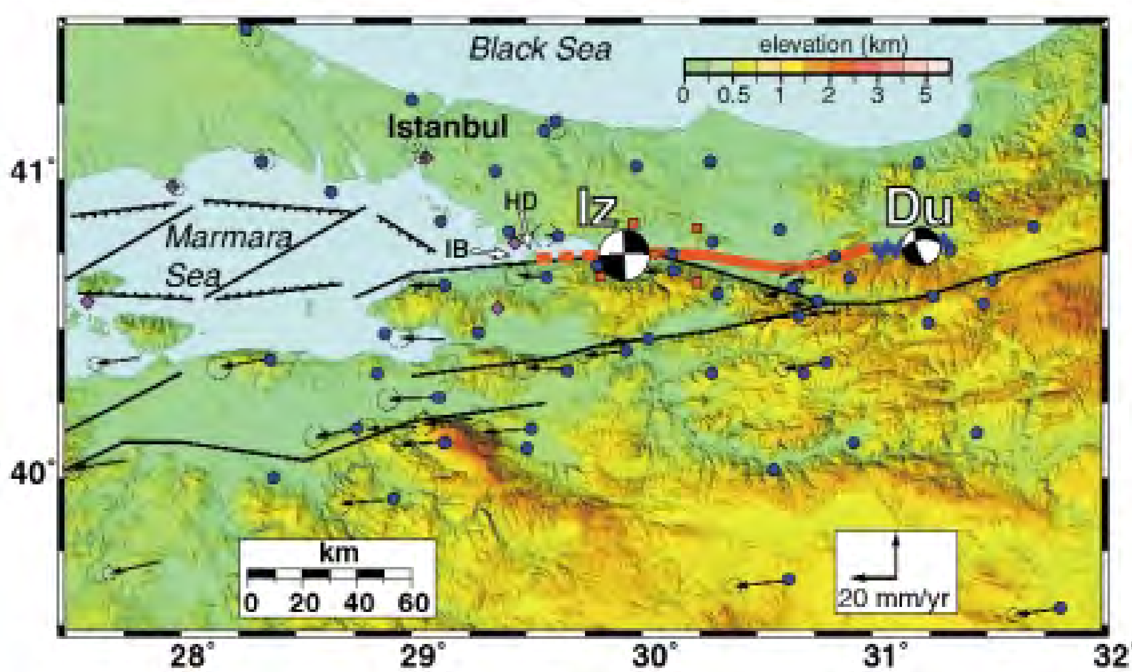

Figure 4. Topographic and simplified tectonic map (symbols as in Fig. 1) of Izmit-Duzce earthquake area showing epicenters and focal mechanisms (lower hemisphere "beachball" projections from Harvard CMT; larger is Izmit break, smaller is Duzce break), surface faulting (Izmit: heavy red line, dashed where inferred; Duzce: heavy blue line), pre-earthquake GPS–velocity field and 95% confidence ellipses, and GPS sites. Purple diamonds—continuous GPS stations operating prior to earthquakes; red squares—continuous GPS stations installed within two days of Izmit main shock; blue dots—survey-mode GPS sites observed less than two years prior to earthquakes and currently being reobserved to estimate coseismic motion. IB—Izmit Bay, HD—Hersek delta.

Allen W. Hatheway Named GSA Engineering Geology Division/AEG Richard H. Jahns Distinguished Lecturer

Allen W. Hatheway, past chair of the GSA Engineering Geology Division (1980) and past president of the Association of Engineering Geologists (AEG) (1985), will be available throughout 2000 as the Richard H. Jahns Distinguished Lecturer. His theme will be “Site Characterization.”

Interested university departments, as well as AEG, GSA, and American Society of Civil Engineers (ASCE) sections can contact Hatheway directly to set up visits. He says he will attempt to spread his travel budget to the limit and is willing to give multiple lectures or strings of lectures in the same or regional cities. Hosts are asked to stretch the budget by providing a night of local housing and meals. For same-city lectures, Hatheway will offer additional talks: “Characterizing Former Manufactured Gas Plants: Facing SVOCs First Hand”; “Geotechnical and Geoenvironmental Case Histories with Twists”; and “Urban Geology: Carrying on a Grand Tradition.”

Hatheway has announced his early retirement from the Department of Geological Engineering at the University of Missouri—Rolla, which will allow great flexibility in his lecture travel. He will practice in troubleshooting, forensics and expert testimony, mitigation of geologic constraints, hazardous waste cleanup, gas works and coal tar sites, rock jobs and railroad incidents, and other areas.

Hatheway holds degrees from the University of California, Los Angeles (geology) and the University of Arizona (geological engineering) and is registered as a geologist, engineering geologist, and geological and civil engineer in several states. He has received the Burwell Award of GSA, the Johnston Award of AEG, and the Mead Prize of ASCE. He is a GSA Fellow, Life Member of AEG, and Fellow of ASCE and the Geological Society of London. He has practiced for 39 years, in every state and most provinces, and in Latin and South America, Singapore, South Korea, eastern Europe, Scandinavia, and South Africa. He retired from the U.S. Army and Army Reserve as Colonel of Engineers in 1991.

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Jackson, J., and McKenzie, D., 1988, The relationship between plate motions and seismic tremors, and the rates of active deformation in the Mediterranean and Middle East: Royal Astronomical Society Geophysical Journal, v. 93, p. 45–73.

Lundgren, P., Giardini, D., and Russo, R., 1998, A geodynamic framework for eastern Mediterranean kinematics: Geophysical Research Letters, v. 25, p. 4007–4010.

McClusky, S., et al., 2000, GPS constraints on plate motion and deformation in the eastern Mediterranean: Implications for plate dynamics: Journal of Geophysical Research (in press).

McKenzie, D. P., 1970, Plate tectonics of the Mediterranean region: Nature, v. 226, p. 239–243.

Reilinger, R., and Barka, A., 1997, GPS constraints on fault slip rates in the Arabia-Africa-Eurasia plate collision zone: Implications for earthquake recurrence times, in Giardini, D., and Balassanian, S., eds., Historical and prehistorical earthquakes in the Caucasus: Dordrecht, Netherlands, Kluwer, p. 91–108.

Reilinger, R., et al., 1997a, Global positioning system measurements of present-day crustal movements in the Arabia-Africa-Eurasia plate collision zone: Journal of Geophysical Research, v. 102, p. 9983–9999.

Reilinger, R., McClusky, S. C., Souter, B. J., Hamburger, M. W., Prilepin, M. T., Mishin, A., Guseva, T., and Balassanian, S., 1997b, Preliminary estimates of plate convergence in the Caucasus collision zone from global positioning system measurements: Geophysical Research Letters, v. 24, p. 1815–1818.

Royden, L., 1993, The tectonic expression of slab pull at continental convergent boundaries: Tectonics, v. 12, p. 303–325.

Şengör, A. M. C., 1979, The North Anatolian transform fault: Its age and tectonic significance: Geological Society [London] Journal, v. 136, p. 269–282.

Sonder, L., and England, P., 1989, Effects of temperature dependent rheology on large scale continental extension: Journal of Geophysical Research, v. 94, p. 7603–7619.

Stein, R. S., Barka, A. A., and Dieterich, J. D., 1997, Progressive failure on the North Anatolian fault since 1939 by earthquake stress triggering: Geophysical Journal International, v. 128, p. 594–604.

Straub, C., Kahle, H.-G., and Schindler, C., 1997, GPS and geologic estimates of the tectonic activity in the Marmara Sea region, NW Anatolia: Journal of Geophysical Research, v. 102, p. 27,587–27,601.

Thatcher, W., 1995, Microplate versus continuum descriptions of active tectonic deformation: Journal of Geophysical Research, v. 100, p. 3885–3894.

Toksoz, M. N., Arpat, E., and Saroglu, F., 1977, East Anatolia earthquake of 24 November, 1976: Nature, v. 270, p. 423–425.

Toksoz, M. N., Shakal, A. F., and Michael, A. J., 1979, Space-time migration of earthquakes along the North Anatolian fault zone and seismic gaps: Pure and Applied Geophysics, v. 117, p. 1258–1270.

Westaway, R., 1994, Present-day kinematics of the Middle East and eastern Mediterranean: Journal of Geophysical Research, v. 99, p. 12,071–12,090.

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