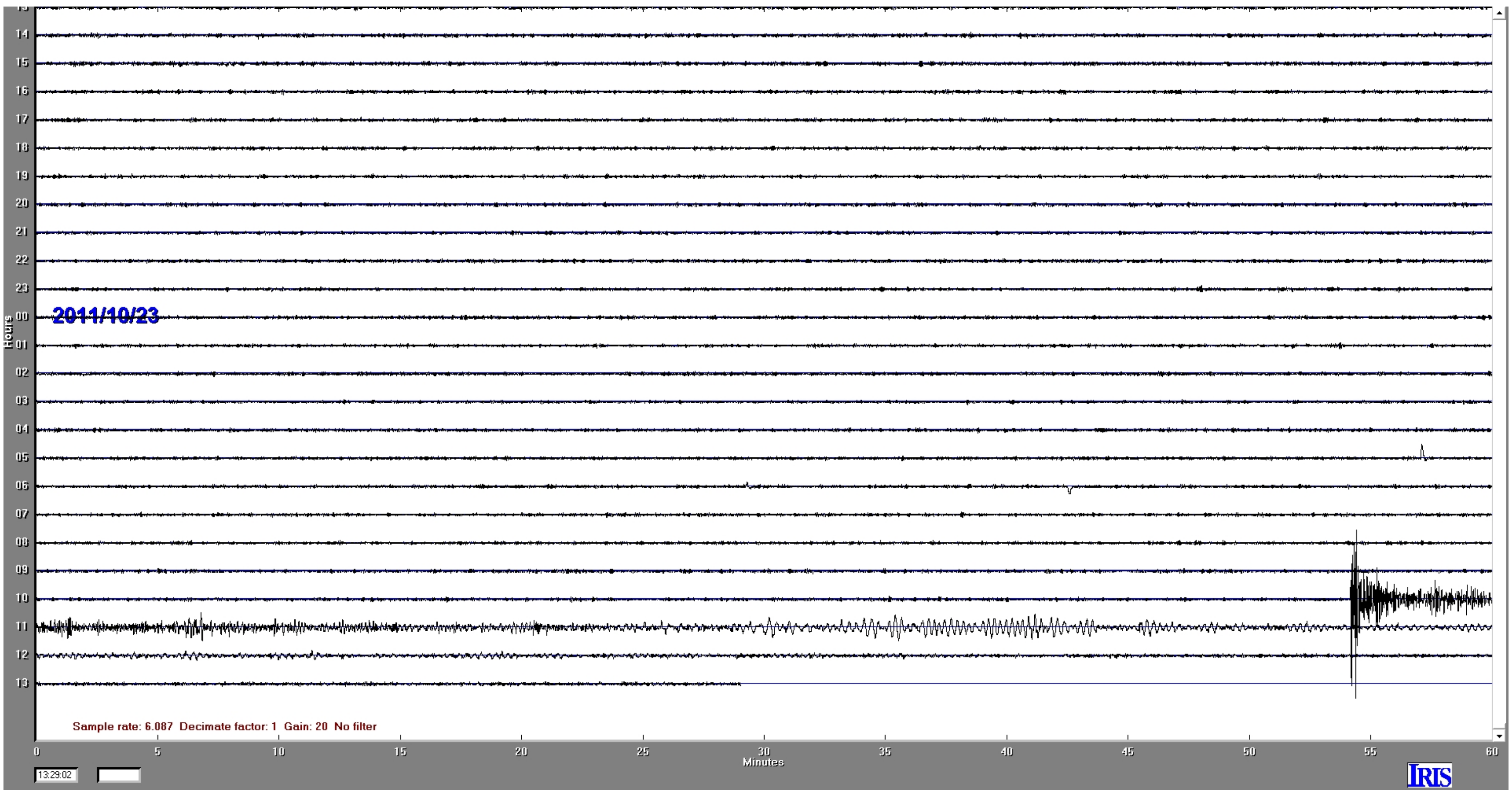
Magnitude 7.2 – EASTERN TURKEY
2011 October 23 10:41:21 UTC

Department of Geology and Planetary Science,
University of Pittsburgh

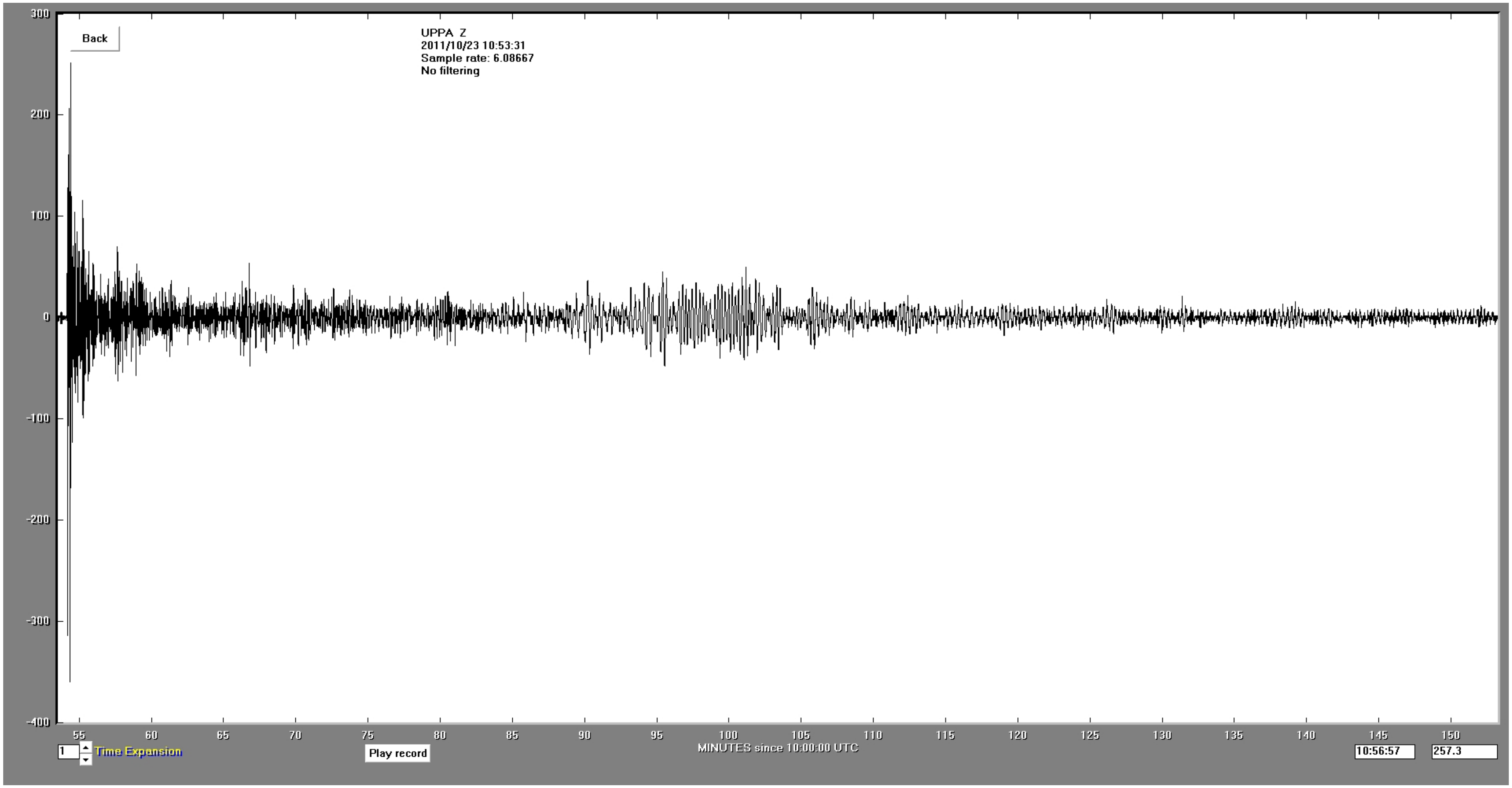
Seismic records from the University of Pittsburgh Seismograph included

University of Pittsburgh Seismograph



3 component

Horizontal scale = Minutes



Magnitude 7.2

- Magnitude**7.2**
- Date-Time**Sunday, October 23, 2011 at 10:41:21 UTC**
- Sunday, October 23, 2011 at 01:41:21 PM at epicenter
- Location38.628°N, 43.486°E
- Depth20 km (12.4 miles) set by location program
- RegionEASTERN TURKEY
- Distances 17 km (10 miles) NNE (32°) from **Van, Turkey**
- 117 km (72 miles) N (349°) from **Hakkari, Turkey**
- 128 km (80 miles) SSE (163°) from **Karakose (Agri), Turkey**
- 194 km (120 miles) SSW (207°) from **YEREVAN, Armenia**
- Location UncertaintyError estimate not available
- ParametersNph=0, Dmin=0 km, Rmss=0 sec, Gp= 0,
  M-type=centroid moment magnitude (Mw), Version=1
- SourceU.S. Geological Survey, National Earthquake Information Center:
  World Data Center for Seismology, Denver
- Event IDusb0006bqc

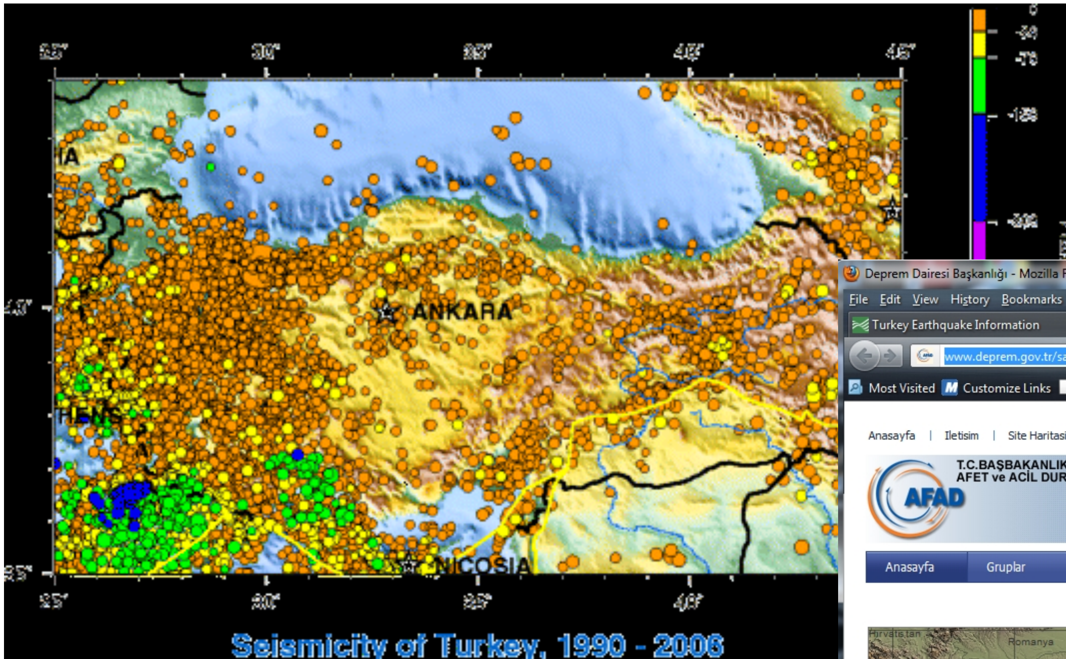
Source: quake.usgs.gov

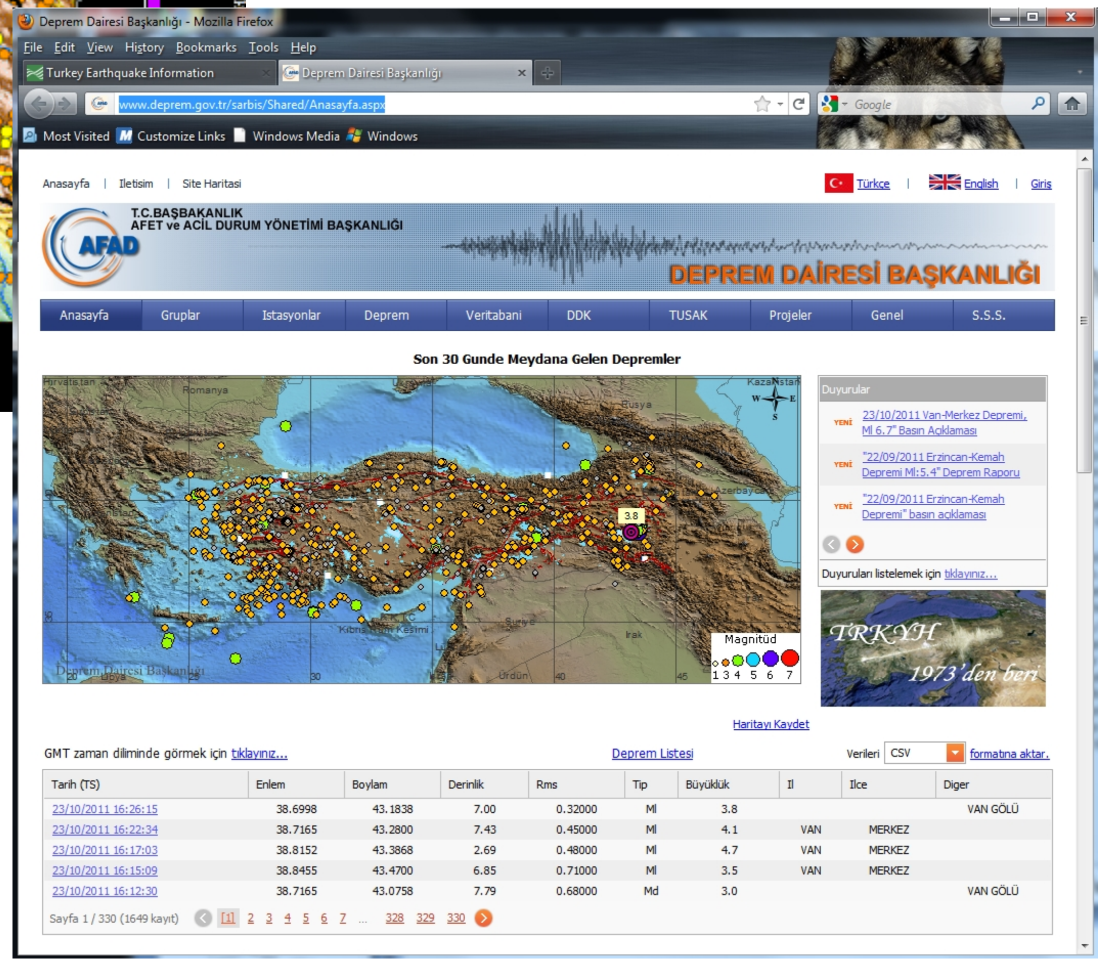
Geology of Turkey

- Turkey's varied landscapes are the product of complex earth movements that have shaped Anatolia over thousands of years and still manifest themselves in fairly frequent earthquakes and occasional volcanic eruptions. Except for a relatively small portion of its territory along the Syrian border that is a continuation of the Arabian Platform, Turkey geologically is part of the great Alpine belt that extends from the Atlantic Ocean to the Himalaya Mountains. This belt was formed during the Tertiary Period (about 65 million to 1.6 million B.C.), as the Arabian, African, and Indian continental plates began to collide with the Eurasian plate, and the sedimentary layers laid down by the prehistoric Tethyan Sea buckled, folded, and contorted. The intensive folding and uplifting of this mountain belt was accompanied by strong volcanic activity and intrusions of igneous rock material, followed by extensive faulting during the Quaternary Period, which began about 1.6. million B.C. This folding and faulting process is still at work, as the Turkish and Aegean plates, moving south and southwest, respectively, continue to collide. As a result, Turkey is one of the world's more active earthquake and volcano regions.
- Earthquakes range from barely perceptible tremors to major movements measuring five or higher on the open-ended Richter scale. Earthquakes measuring more than six can cause massive damage to buildings and, especially if they occur on winter nights, numerous deaths and injuries. Turkey's most severe earthquake in the twentieth century occurred in Erzincan on the night of December 28-29, 1939; it devastated most of the city and caused an estimated 160,000 deaths. Earthquakes of moderate intensity often continue with sporadic aftershocks over periods of several days or even weeks. The most earthquake-prone part of Turkey is an arc-shaped region stretching from the general vicinity of Kocaeli to the area north of Lake Van on the border with Armenia and Georgia.
- Turkey's terrain is structurally complex. A central massif composed of uplifted blocks and downfolded troughs, covered by recent deposits and giving the appearance of a plateau with rough terrain, is wedged between two folded mountain ranges that converge in the east. True lowland is confined to the Ergene Plain in Thrace, extending along rivers that discharge into the Aegean Sea or the Sea of Marmara, and to a few narrow coastal strips along the Black Sea and Mediterranean Sea coasts. Nearly 85 percent of the land is at an elevation of at least 450 meters; the median altitude of the country is 1,128 meters. In Asiatic Turkey, flat or gently sloping land is rare and largely confined to the deltas of the Kizilirmak River, the coastal plains of Antalya and Adana, and the valley floors of the Gediz River and the Büyükmenderes River, and some interior high plains in Anatolia, mainly around Tuz Gölü (Salt Lake) and Konya Ovasi (Konya Basin). Moderately sloping terrain is limited almost entirely outside Thrace to the hills of the Arabian Platform along the border with Syria.
- More than 80 percent of the land surface is rough, broken, and mountainous, and therefore is of limited agricultural value. The terrain's ruggedness is accentuated in the eastern part of the country, where the two mountain ranges converge into a lofty region with a median elevation of more than 1,500 meters, which reaches its highest point along the borders with Armenia, Azerbaijan, and Iran. Turkey's highest peak, Mount Ararat (Agri Dagi)--about 5,166 meters high--is situated near the point where the boundaries of the four countries meet.

http://countrystudies.us/turkey/20.htm

Turkey seismicity





http://www.deprem.gov.tr/sarbis/Shared/

Thrust mechanism is estimated for this earthquake by quake.usgs.gov

USGS Centroid Moment Solution

```
11/10/23 10:41:21.73

Epicenter:  38.710   43.446
MW 7.3

USGS CENTROID MOMENT TENSOR
11/10/23 10:41:44.50
Centroid:  39.451   43.354
Depth  16         No. of sta: 159
Moment Tensor;   Scale 10**19 Nm
  Mrr= 5.89       Mtt=-6.13
  Mpp= 0.24       Mrt= 7.73
  Mrp= 1.60       Mtp=-0.51
 Principal axes:
  T  Val=  9.83  Plg=63  Azm=344
  N        0.22       4       81
  P      -10.05      26      173

Best Double Couple:Mo=9.9*10**19
 NP1:Strike= 80 Dip=71 Slip=  86
 NP2:       272     19      101
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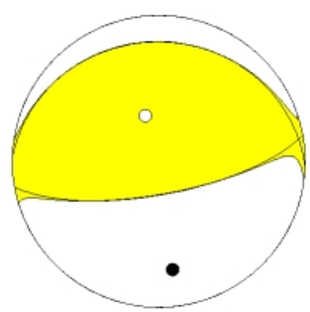
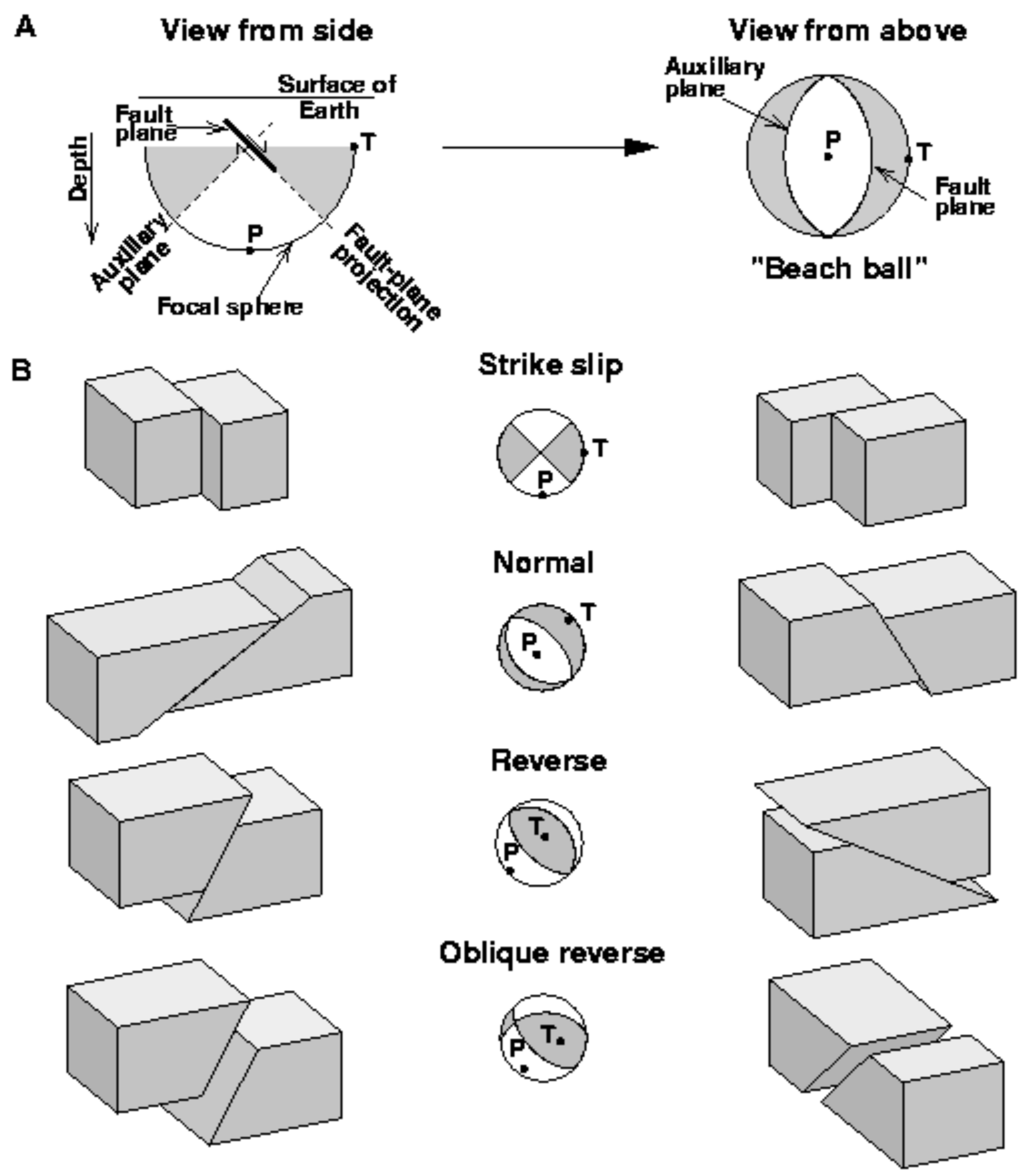
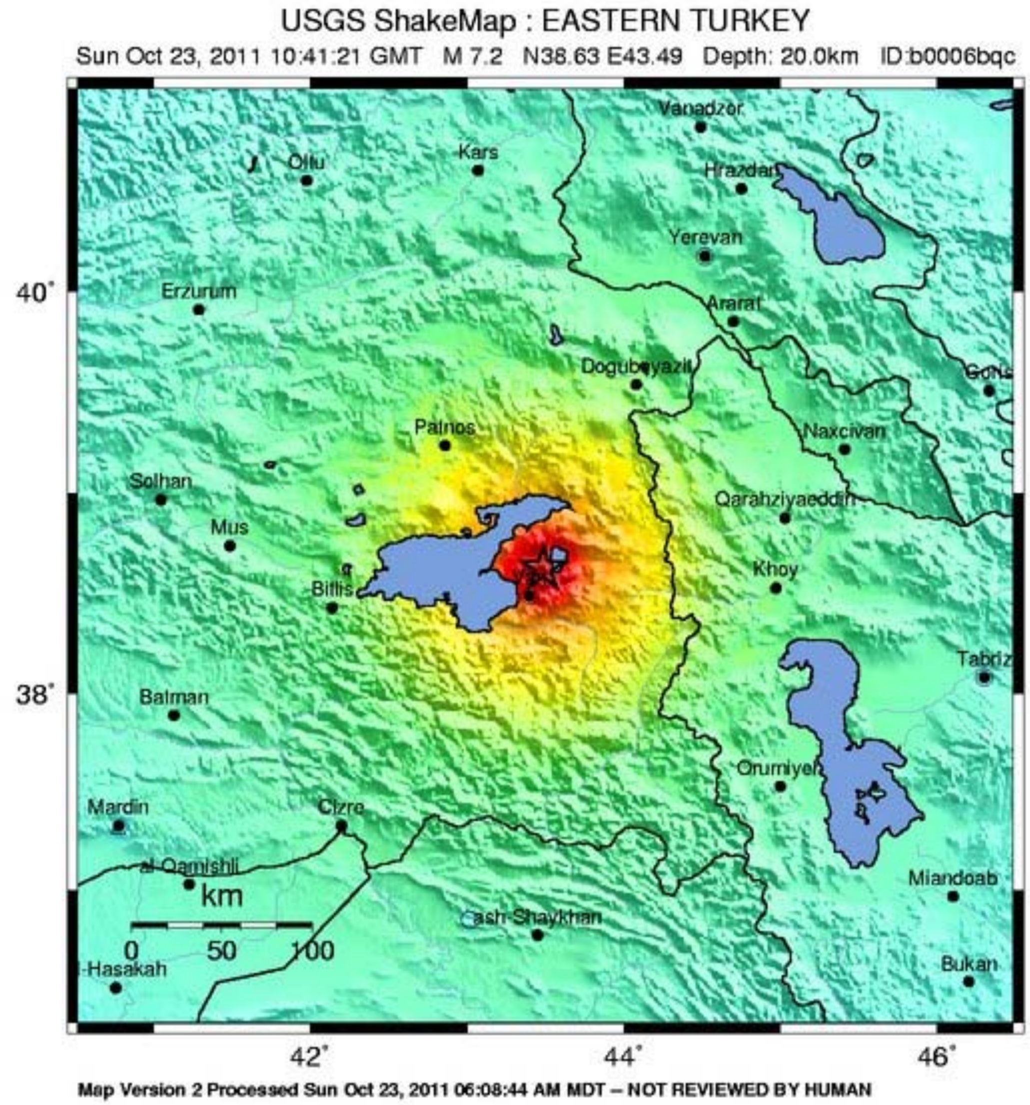


Schematic diagram of a focal mechanism



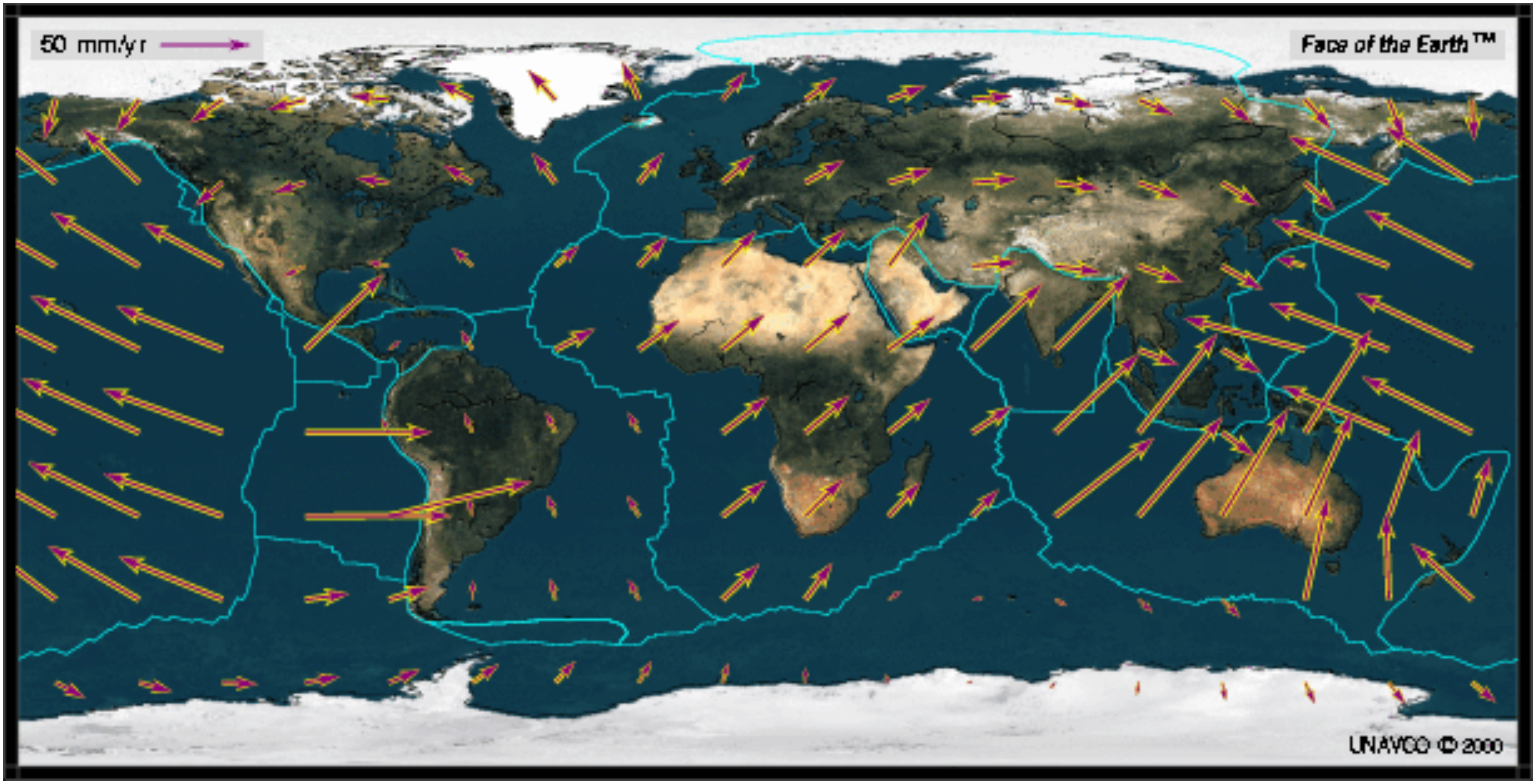
USGS, 1996



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Source: quake.usgs.gov

Plate tectonic motion: The cause of earthquakes



Some details

- Approximate energy release, 950 kt (kilotons)
- Number of 7.0 to 7.9 earthquakes (globally),

approximately 15 per year.

- Approximate Plate motion rate is 29.8 mm/yr along a direction of 70 Deg East of North.

Model	**Latitude**	**Longitude**	**Speed mm/yr**	**Azimuth (cw from N)**	**N Vel. mm/yr**	**E Vel. mm/yr**	**Plate (reference)**
GSRM v1.2	38° 40' N 38.666667°	43° 34' 60" E 43.583333°	29.75	69.86°	10.24	27.93	EU(NNR)

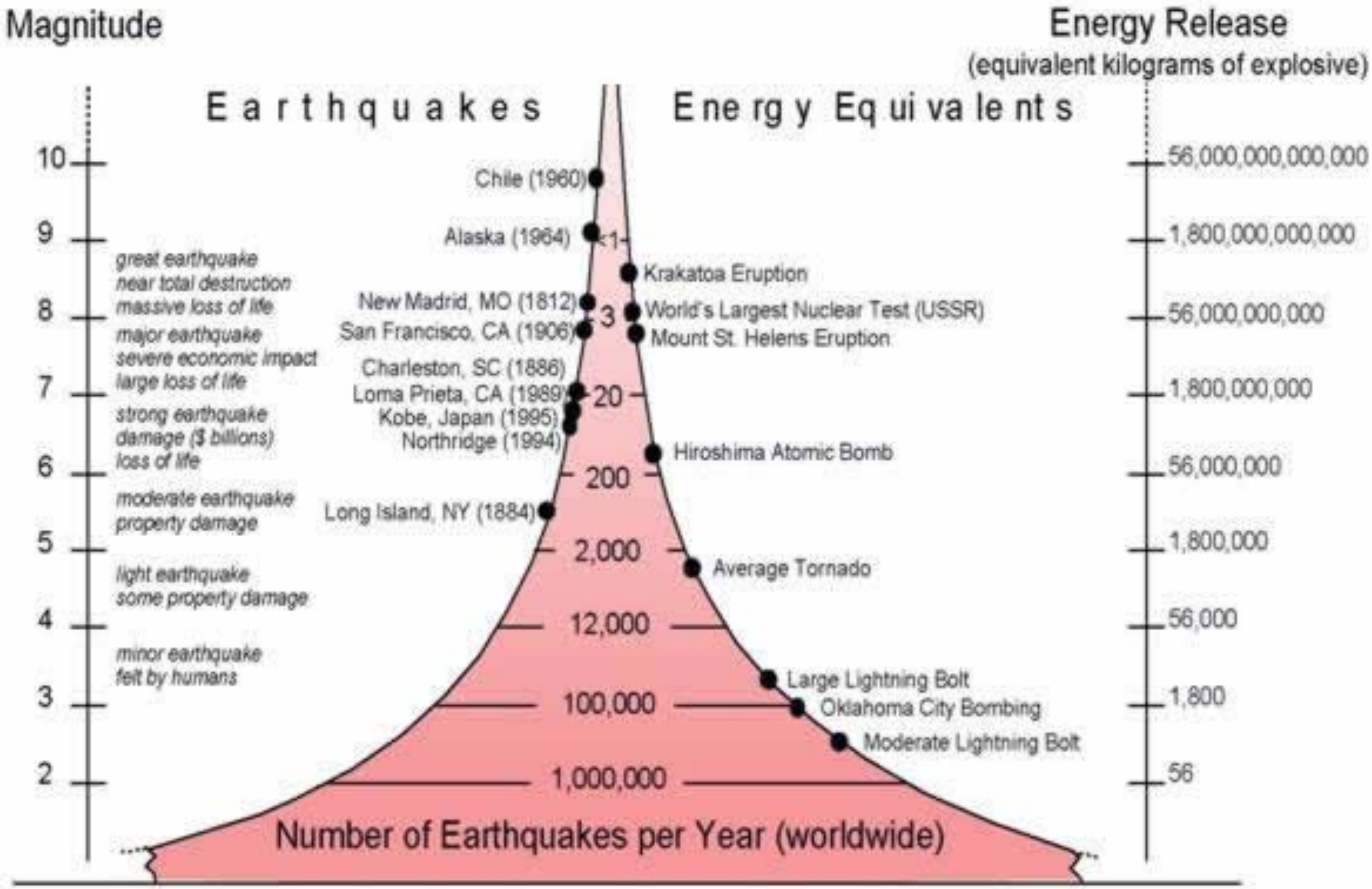
Richter Scale

Richter magnitudes	Description	Earthquake effects	Frequency of occurrence
Less than 2.0	Micro	Microearthquakes, not felt.	About 8,000 per day
2.0-2.9	Minor	Generally not felt, but recorded.	About 1,000 per day
3.0-3.9		Often felt, but rarely causes damage.	49,000 per year (est.)
4.0-4.9	Light	Noticeable shaking of indoor items, rattling noises. Significant damage unlikely.	6,200 per year (est.)
5.0-5.9	Moderate	Can cause major damage to poorly constructed buildings over small regions. At most slight damage to well-designed buildings.	800 per year
6.0-6.9	Strong	Can be destructive in areas up to about 160 kilometres (100 mi) across in populated areas.	120 per year
7.0-7.9	Major	Can cause serious damage over larger areas.	18 per year
8.0-8.9	Great	Can cause serious damage in areas several hundred miles across.	1 per year
9.0-9.9		Devastating in areas several thousand miles across.	1 per 20 years
10.0+	Epic	Never recorded; see below for equivalent seismic energy yield.	Extremely rare (Unknown)

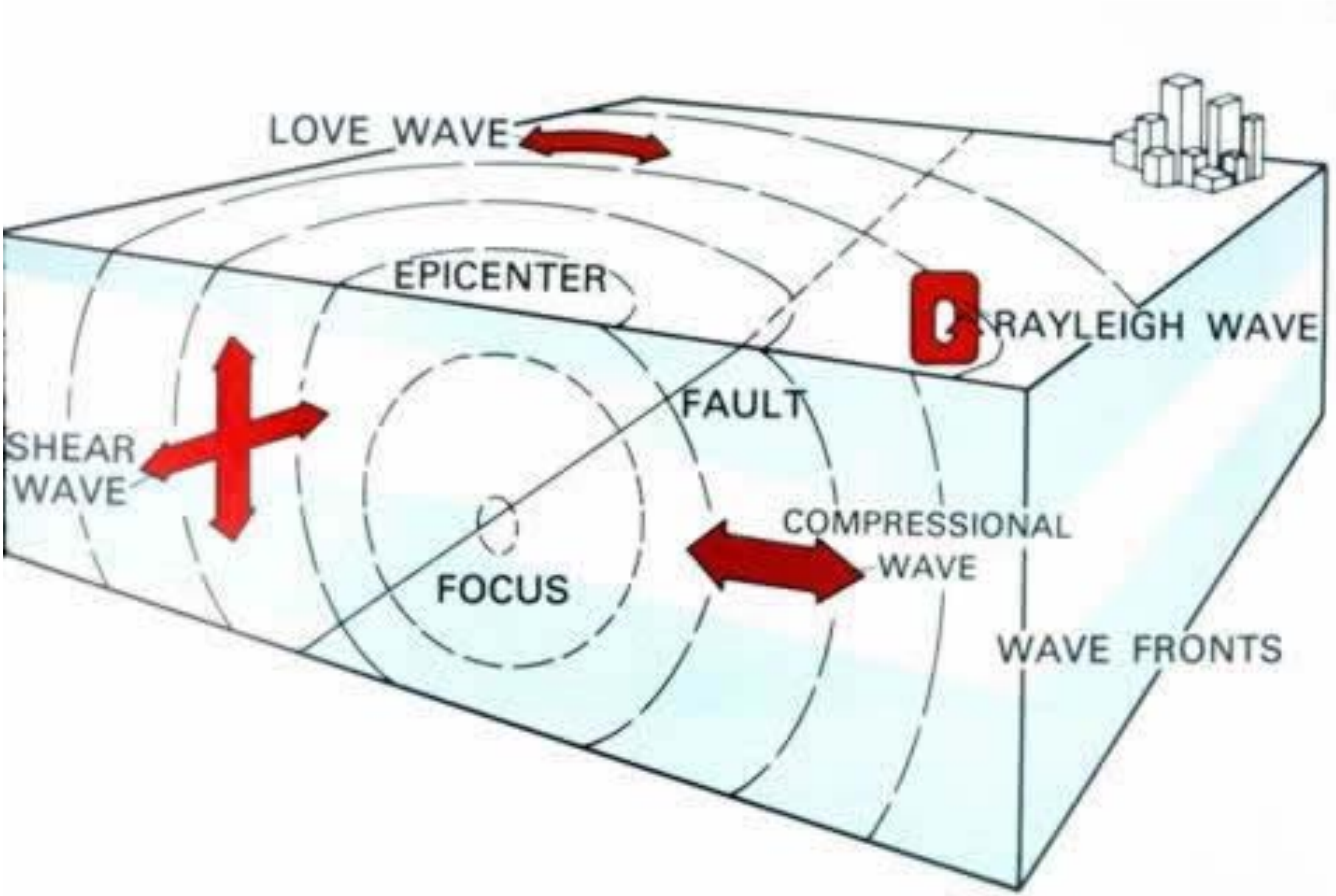
Richter Approximate Magnitude	Approximate TNT for Seismic Energy Yield	Joule equivalent	Example
0.0	15.0 g (0.529 oz)	63.1 kJ	
0.5	84.4 g (2.98 oz)	355 kJ	Large hand grenade
1.0	474 g (1.05 lb)	2.00 MJ	Construction site blast
1.5	2.67 kg (5.88 lb)	11.2 MJ	WWII conventional bombs
2.0	15.0 kg (33.1 lb)	63.1 MJ	Late WWII conventional bombs
2.5	84.4 kg (186 lb)	355 MJ	WWII blockbuster bomb
3.0	474 kg {1050 lb)	2.00 GJ	Massive Ordnance Air Blast bomb
3.5	2.67 metric tons	11.2 GJ	Chernobyl nuclear disaster, 1986
4.0	15.0 metric tons	63.1 GJ	Small atomic bomb
4.5	84.4 metric tons	355 GJ	
5.0	474 metric tons	2.00 TJ	Seismic yield of Nagasaki atomic bomb (Total yield including air yield 21 kT, 88 TJ) Lincolnshire earthquake (UK), 2008 45.862°N, 75.457°W; ONTARIO-QUEBEC BORDER REGION earthquake (CANADA) June 23, 2010[8]
5.5	2.67 kilotons	11.2 TJ	Little Skull Mtn. earthquake (NV, USA), 1992 Alum Rock earthquake (CA, USA), 2007 2008 Chino Hills earthquake (Los Angeles, USA)
6.0	15.0 kilotons	63.1 TJ	Double Spring Flat earthquake (NV, USA), 1994
6.5	84.4 kilotons	355 TJ	Caracas (Venezuela), 1967 Rhodes (Greece), 2008 Eureka Earthquake (Humboldt County CA, USA), 2010 Southeast of Taiwan (270km), 2010
6.7	168 kilotons	708 TJ	Northridge earthquake (CA, USA), 1994
6.9	336 kilotons	1.41 PJ	San Francisco Bay Area earthquake (CA, USA), 1989
7.0	474 kilotons	2.00 PJ	Java earthquake (Indonesia), 2009 2010 Haiti Earthquake
7.1	670 kilotons	2.82 PJ	Energy released is equivalent to that of Tsar Bomba (50 megatons, 210 PJ), the largest thermonuclear weapon ever tested 1944 San Juan earthquake

7.0	474 kilotons	2.00 PJ	Java earthquake (Indonesia), 2009 Haiti earthquake, 2010
7.1	670 kilotons	2.82 PJ	San Juan earthquake (Argentina), 1944 Christchurch earthquake (New Zealand), 2010
7.2	938 kilotons	3.98 PJ	Vrancea earthquake (Romania), 1977 Baja California earthquake (Mexico), 2010
7.5	2.67 megatons	11.2 PJ	Kashmir earthquake (Pakistan), 2005 Antofagasta earthquake (Chile), 2007
7.8	7.52 megatons	31.6 PJ	Tangshan earthquake (China), 1976 Hawke's Bay earthquake (New Zealand), 1931 Luzon earthquake (Philippines), 1990 Sumatra earthquake (Indonesia), 2010
8.0	15.0 megatons	63.1 PJ	Mino-Owari earthquake (Japan), 1891 San Juan earthquake (Argentina), 1894 San Francisco earthquake (California, USA), 1906 Queen Charlotte Islands earthquake (British Columbia, Canada), 1949 México City earthquake (Mexico), 1985 Gujarat earthquake (India), 2001 Chincha Alta earthquake (Peru), 2007 Sichuan earthquake (China), 2008
8.1	21.2 megatons	89.1 PJ	Guam earthquake, August 8, 1993[12]
8.35 (approx.)	50 megatons	210 PJ	Largest thermonuclear weapon ever tested
8.5	84.4 megatons	355 PJ	Toba eruption 75,000 years ago; among the largest known volcanic events.[13] Sumatra earthquake (Indonesia), 2007
8.7	168 megatons	708 PJ	Sumatra earthquake (Indonesia), 2005
8.8	238 megatons	1.00 EJ	Chile earthquake, 2010
8.9	336 megatons	1.41 EJ	Sendai earthquake (Japan), 2011
9.0	474 megatons	2.00 EJ	Lisbon Earthquake (Portugal), All Saints Day, 1755
9.2	946 megatons	3.98 EJ	Anchorage earthquake (Alaska, USA), 1964
9.3	1.34 gigatons	5.62 EJ	Indian Ocean earthquake, 2004
9.5	2.67 gigatons	11.2 EJ	Valdivia earthquake (Chile), 1960
10.0	15.0 gigatons	63.1 EJ	Never recorded by humans
12.55	100 teratons	422 ZJ	Yucatán Peninsula impact (creating Chicxulub crater) 65 Ma ago (10^8 megatons; over 4×10^{30} ergs = 400 ZJ).[14][15][16][17][18]
32.0	1×10^{21} yottatons	4.2×10^{30} YJ	Approximate magnitude of the starquake on the magnetar SGR 1806-20, registered on December 27, 2004.[19]

http://en.wikipedia.org/wiki/Richter_magnitude_scale



Magnitude
Energy Release
(equivalent kilograms of explosive)
Earthquakes
Energy Equivalents
10
9
8
7
6
5
4
3
2
56,000,000,000,000
1,800,000,000,000
56,000,000,000
1,800,000,000
56,000,000
1,800,000
56,000
1,800
56
great earthquake
near total destruction
massive loss of life
major earthquake
severe economic impact
large loss of life
strong earthquake
damage ($ billions)
loss of life
moderate earthquake
property damage
light earthquake
some property damage
minor earthquake
felt by humans
Chile (1960)
Alaska (1964)
New Madrid, MO (1812)
San Francisco, CA (1906)
Charleston, SC (1886)
Loma Prieta, CA (1989)
Kobe, Japan (1995)
Northridge (1994)
Long Island, NY (1884)
Krakatoa Eruption
World's Largest Nuclear Test (USSR)
Mount St. Helens Eruption
Hiroshima Atomic Bomb
Average Tornado
Large Lightning Bolt
Oklahoma City Bombing
Moderate Lightning Bolt
<1
3
20
200
2,000
12,000
100,000
1,000,000
Number of Earthquakes per Year (worldwide)


LOVE WAVE
EPICENTER
RAYLEIGH WAVE
FAULT
SHEAR
WAVE
COMPRESSIONAL
WAVE
FOCUS
WAVE FRONTS

Variation of earthquake shaking with increased distance from the epicenter

It is an interesting research to estimate the nature of future earthquakes by using information on potentially active seismic faults. One of the most rigorous approach to this goal is a use of fault rupture model combined with calculation of seismic wave propagation from the fault to the site of concern. This approach is, however, not able to assess acceleration for which higher frequency components are important for practice (Sect. 5.5).

Another approach is an empirical correlation between such a feature of earthquake motion as maximum velocity or acceleration and distance from the epicenter (or fault), while taking into account the seismic magnitude (Sect. 5.4). This issue stands for the decay of earthquake motion intensity and otherwise called attenuation curve (距離減衰). An early example was proposed by Kanai and Suzuki (1968) between maximum velocity and hypocentral distance (Fig. 5.19). Note that the concerned ground velocity was the one in the base rock underlying surface soil. Hence, the amplification in the surface soft soil was out of scope.

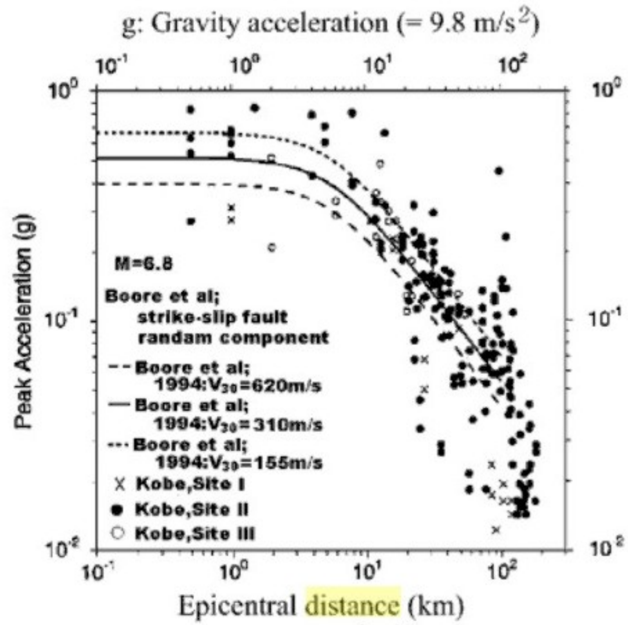


Fig. 5.20 Empirical correlation between observed maximum horizontal acceleration and distance from the surface area lying above the fault; V_{30} means the average V_s in the surface 30 m of deposit (Joyner and Boore, 1996)

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Variation of earthquake shaking with increased distance from the epicenter

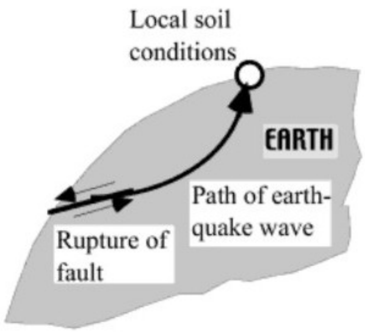

Fig. 5.24 Relationship between causative fault, intermediate path, and local soil conditions

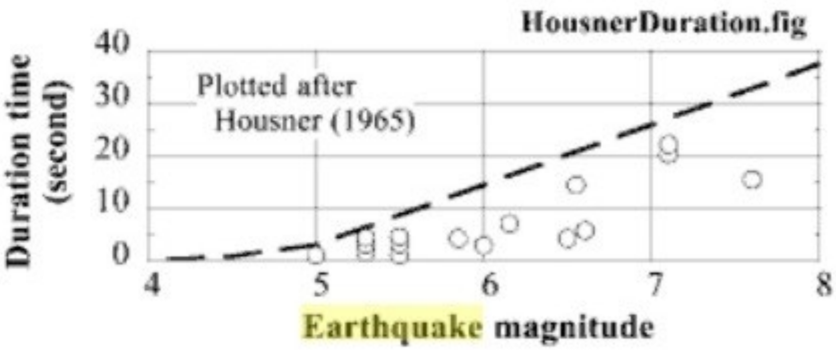

Fig. 5.21 Empirical estimation of duration time of strong motion (Housner, 1965)

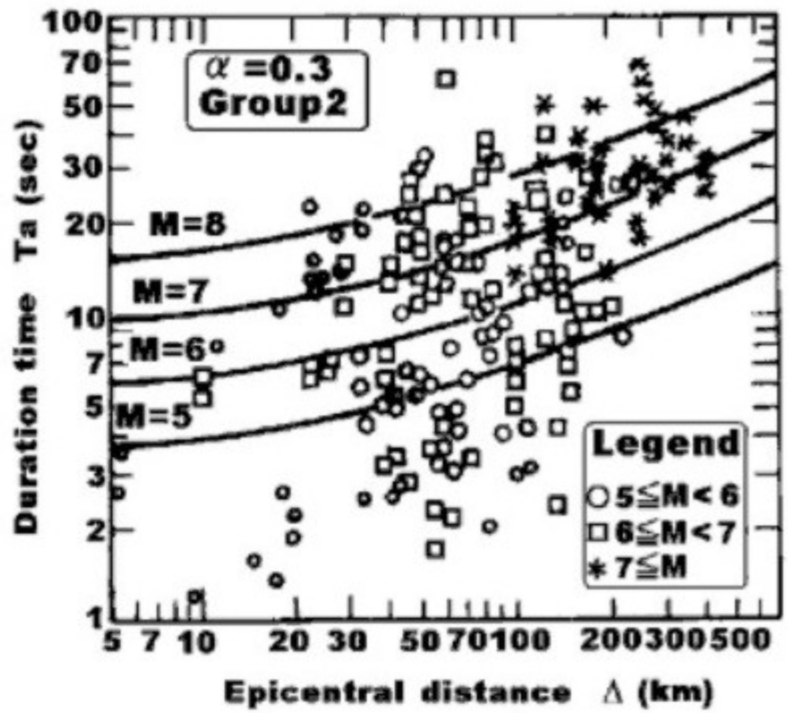

Fig. 5.22 Empirical correlation on relatively stiff ground between duration time of strong shaking and distance (Kawashima et al., 1985)

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