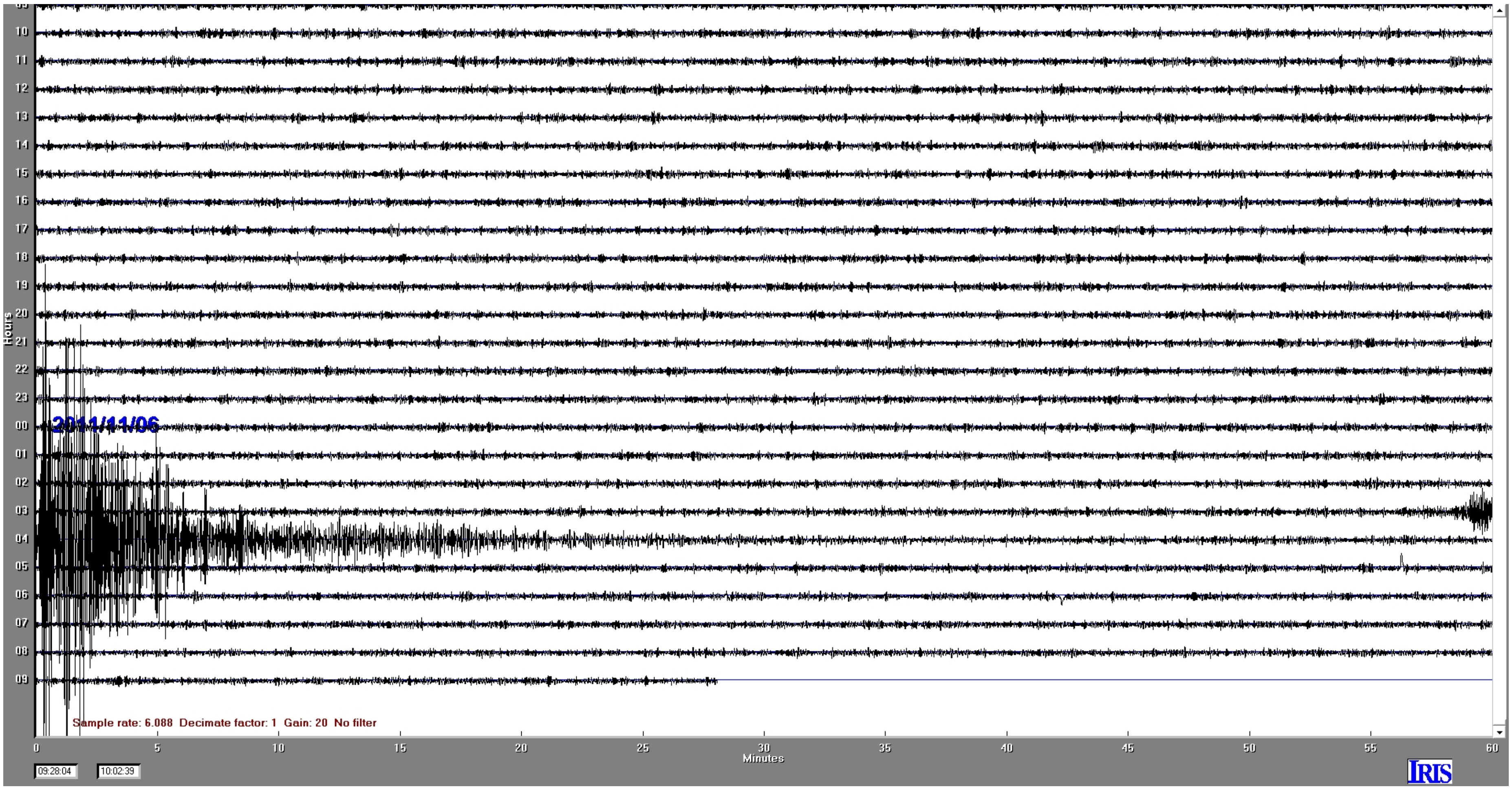
Magnitude 5.6 - OKLAHOMA
2011 November 06 03:53:10 UTC

Department of Geology and Planetary Science,
University of Pittsburgh

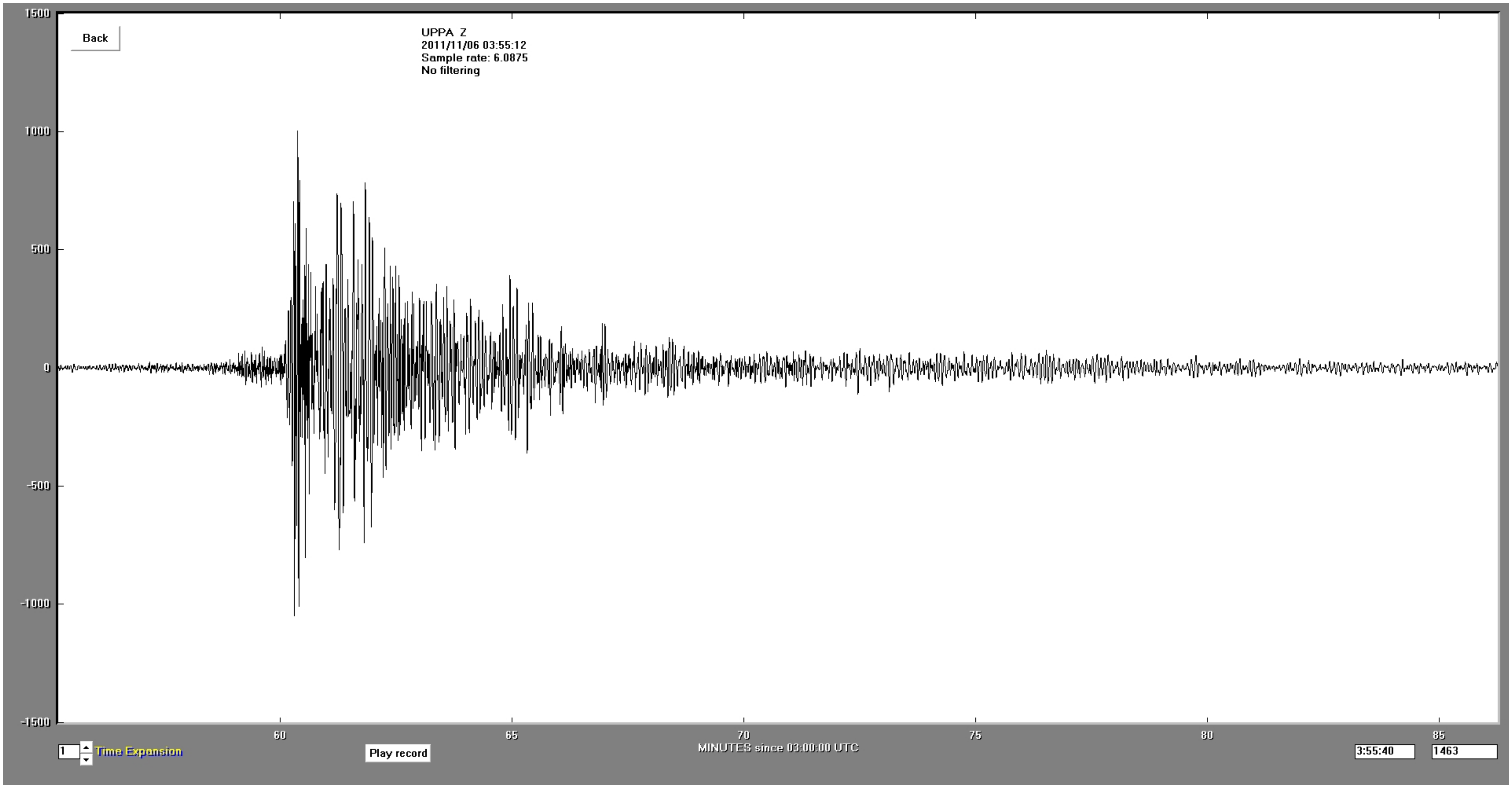
Seismic records from the University of Pittsburgh Seismograph included

University of Pittsburgh Seismograph



Vertical component

Horizontal scale = Minutes



Magnitude 5.6

- Magnitude **5.6**
- Date-Time **Sunday, November 06, 2011 at 03:53:10 UTC**
- Saturday, November 05, 2011 at 10:53:10 PM at epicenter
- Time of Earthquake in other Time Zones
- Location 35.537°N, 96.747°W
- Depth 5 km (3.1 miles)
- Region OKLAHOMA
- Distances 34 km (21 miles) NNE of **Shawnee, Oklahoma**
  63 km (39 miles) SSE of **Stillwater, Oklahoma**
  68 km (42 miles) ESE of **Guthrie, Oklahoma**
  71 km (44 miles) ENE of **OKLAHOMA CITY, Oklahoma**
  Location Uncertainty horizontal +/- 10.5 km (6.5 miles); depth +/- 2.8 km (1.7 miles)
- Parameters NST=189, Nph=192, Dmin=26.7 km, Rmss=1.06 sec, Gp= 29°, M-type=centroid moment magnitude (Mw), Version=C

Source: quake.usgs.gov

Geology of Oklahoma

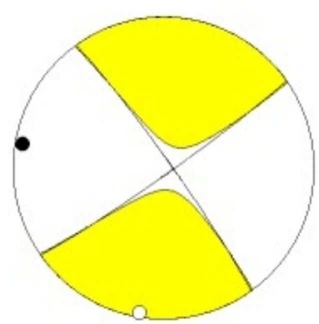
- **EARTHQUAKES IN THE STABLE CONTINENTAL REGION**
  Most of North America east of the Rocky Mountains has infrequent earthquakes. Here and there earthquakes are more numerous, for example in the New Madrid seismic zone centered on southeastern Missouri, in the Charlevoix-Kamouraska seismic zone of eastern Quebec, in New England, in the New York - Philadelphia - Wilmington urban corridor, and elsewhere. However, most of the enormous region from the Rockies to the Atlantic can go years without an earthquake large enough to be felt, and several U.S. states have never reported a damaging earthquake. The earthquakes that do occur strike anywhere at irregular intervals.
- Earthquakes east of the Rocky Mountains, although less frequent than in the West, are typically felt over a much broader region. East of the Rockies, an earthquake can be felt over an area as much as ten times larger than a similar magnitude earthquake on the west coast. A magnitude 4.0 eastern U.S. earthquake typically can be felt at many places as far as 100 km (60 mi) from where it occurred, and it infrequently causes damage near its source. A magnitude 5.5 eastern U.S. earthquake usually can be felt as far as 500 km (300 mi) from where it occurred, and sometimes causes damage as far away as 40 km (25 mi).
- **FAULTS**
  Earthquakes everywhere occur on faults within bedrock, usually miles deep. Most of the region's bedrock was formed as several generations of mountains rose and were eroded down again over the last billion or so years.
- At well-studied plate boundaries like the San Andreas fault system in California, often scientists can determine the name of the specific fault that is responsible for an earthquake. In contrast, east of the Rocky Mountains this is rarely the case. All parts of this vast region are far from the nearest plate boundaries, which, for the U.S., are to the east in the center of the Atlantic Ocean, to the south in the Caribbean Sea, and to the west in California and offshore from Washington and Oregon. The region is laced with known faults but numerous smaller or deeply buried faults remain undetected. Even most of the known faults are poorly located at earthquake depths. Accordingly, few earthquakes east of the Rockies can be linked to named faults. It is difficult to determine if a known fault is still active and could slip and cause an earthquake. In most areas east of the Rockies, the best guide to earthquake hazards is the earthquakes themselves.
- The magnitude 5.5 April 9, 1952, earthquake centered near El Reno affected most of Oklahoma and parts of Arkansas, Iowa, Kansas, Missouri, Nebraska, and Texas. Damage from the 10:30 a.m. CST earthquake was not extensive, but many people in the epicentral area were alarmed, some to near panic. Portions of chimneys fell in El Reno and Ponca City (intensity VII). Bricks loosened from a building wall and tile facing of commercial buildings bulged at Oklahoma City. Also, plate glass windows were shattered in the business district of El Reno. The total damage amounted to several thousand dollars. Aftershocks were felt on April 11, 15, and 16, July 16, and August 14; an earthquake that was felt (IV) at Holdenville and Wewoka on October 7 apparently was unrelated to the April 9th event. Homes and buildings shook and some persons were awakened (V) at El Reno from the April 16th shock, which occurred 5 minutes after midnight. Felt reports were also received from Kingfisher, Oklahoma City, Tulsa, and Union City.
- Minor damage to a building foundation and plaster (VI) at Concho resulted from two March 17, 1953, earthquakes about an hour apart. The felt area included Calumet, Edmond, El Reno, Minco, Okarche, Peidmont, and Union City.
- On February 16, 1956, a shock at Edmond broke windows and cracked plaster (VI). It was also felt strongly at Guthrie, Oklahoma City, and Pawnee. Southeastern Oklahoma was disturbed by an earthquake on April 2, 1956, that produced thundering, rattling, and bumping noises that were heard by many citizens. Buildings shook and objects fell at Antlers, and many persons were alarmed (V). Minor effects were reported from other nearby towns. On October 30, 1956, an area of about 9,500 square kilometers in northeastern Oklahoma was shaken. The maximum intensity of VII was reported west of Catoosa, where a slippage of the formation caused an oil well to be shut down. Minor damage occurred at Beggs and Tulsa; and isolated felt report was received from Electra, Texas.
- A broad area (approximately 31,000 square kilometers) of southwestern Oklahoma and the adjacent portion of Texas was affected by an early morning shock on June 17, 1959. Slight damage, consisting of cracks in plaster, pavement, and a house foundation (VI), occurred at Cache, Duncan, and Lawton. Houses were shaken, buildings swayed, and many persons were alarmed. A smaller earthquake on June 15 was felt by many at Ada and nearby places. Dishes were reported broken (V) and a trembling motion was observed.
- On January 10, 1961, a mild shock was felt in Latimer and Pittsburgh Counties in southeastern Oklahoma. Thunderous earth sounds were heard in many places (V); no damage was reported. Another earthquake on April 27, 1961, awakened many (V) at Antlers, Coalgate, Hartshorne, Leflore, McCurtain, Panola, Poteau, Talihina, and Wilburton. Once again, thunderous, deep rumbling earth sounds were heard throughout the area.
- An October 14, 1968, earthquake caused minor damage at Durant. Walls cracked, and glass in two structures broke (VI). The press reported that a 5 foot tall advertising stand fell over, and canned goods fell from a rack in a supermarket. Slight foreshocks were felt at Durant on October 10 and 11. Intensity IV effects from the October 14 shock were also noted at Caddo.
- A magnitude 4.6 earthquake caused some cracked plaster (V) at Wewoka on May 2, 1969. Intensity V effects were reported at several other towns in the region. The total felt area included approximately 33,700 square kilometers in eastern Oklahoma.

http://quake.usgs.gov

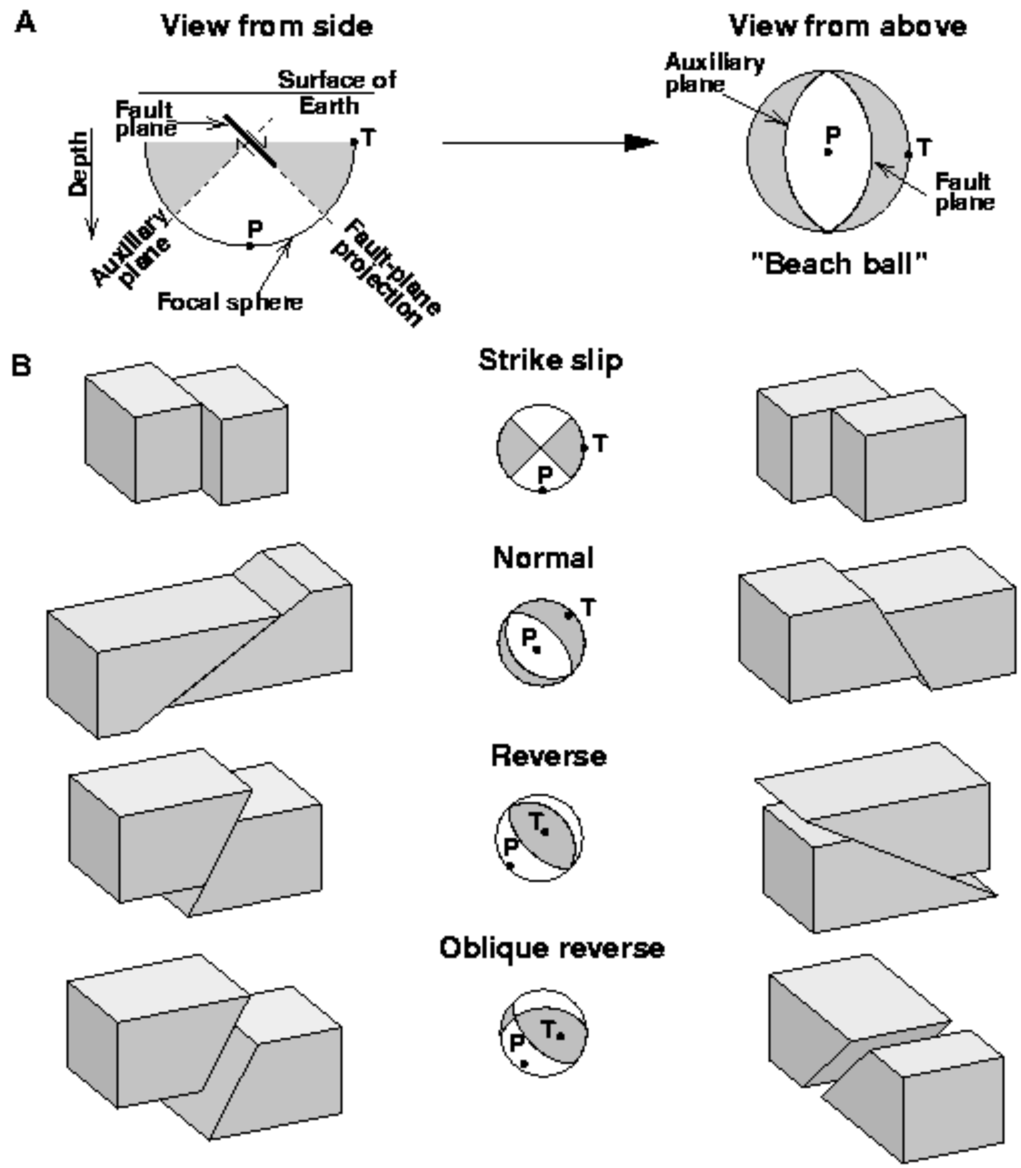
Focal mechanism is estimated for this earthquake by quake.usgs.gov

OKLAHOMA

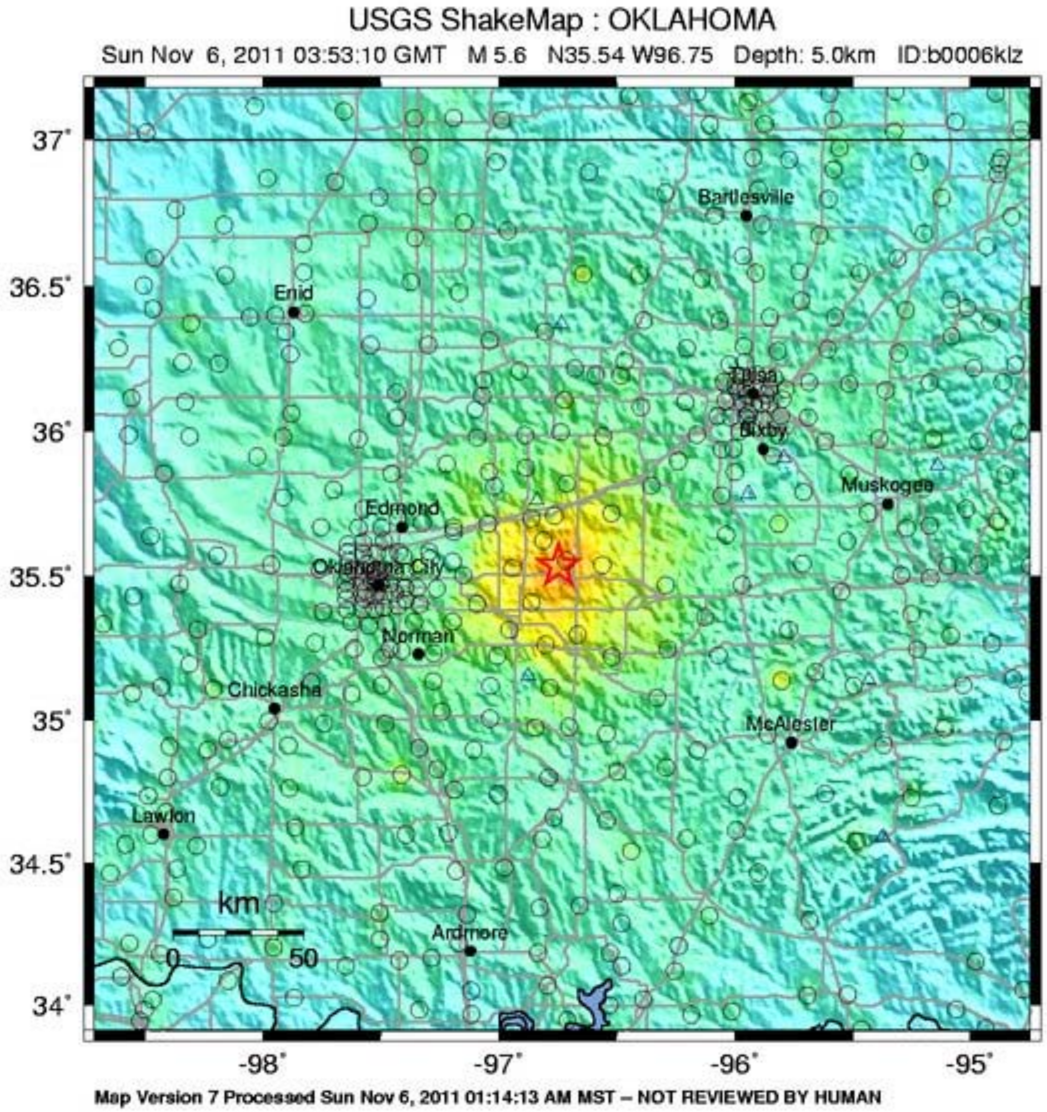
```
11/11/06 03:53:10.53

Epicenter:  35.537  -96.747
MW 5.6

USGS/SLU REGIONAL MOMENT TENSOR
Depth   7          No. of sta: 32
Moment Tensor;    Scale 10**17 Nm
  Mrr=-0.17        Mtt= 3.22
  Mpp=-3.05        Mrt=-0.07
  Mrp=-0.28        Mtp=-1.09
 Principal axes:
  T  Val=  3.40  Plg= 0  Azm=190
  N       -0.14      85       95
  P       -3.26       5      280

Best Double Couple:Mo=3.3*10**17
 NP1:Strike= 55 Dip=87 Slip=-176
 NP2:       324     86        -3
```



Schematic diagram of a focal mechanism



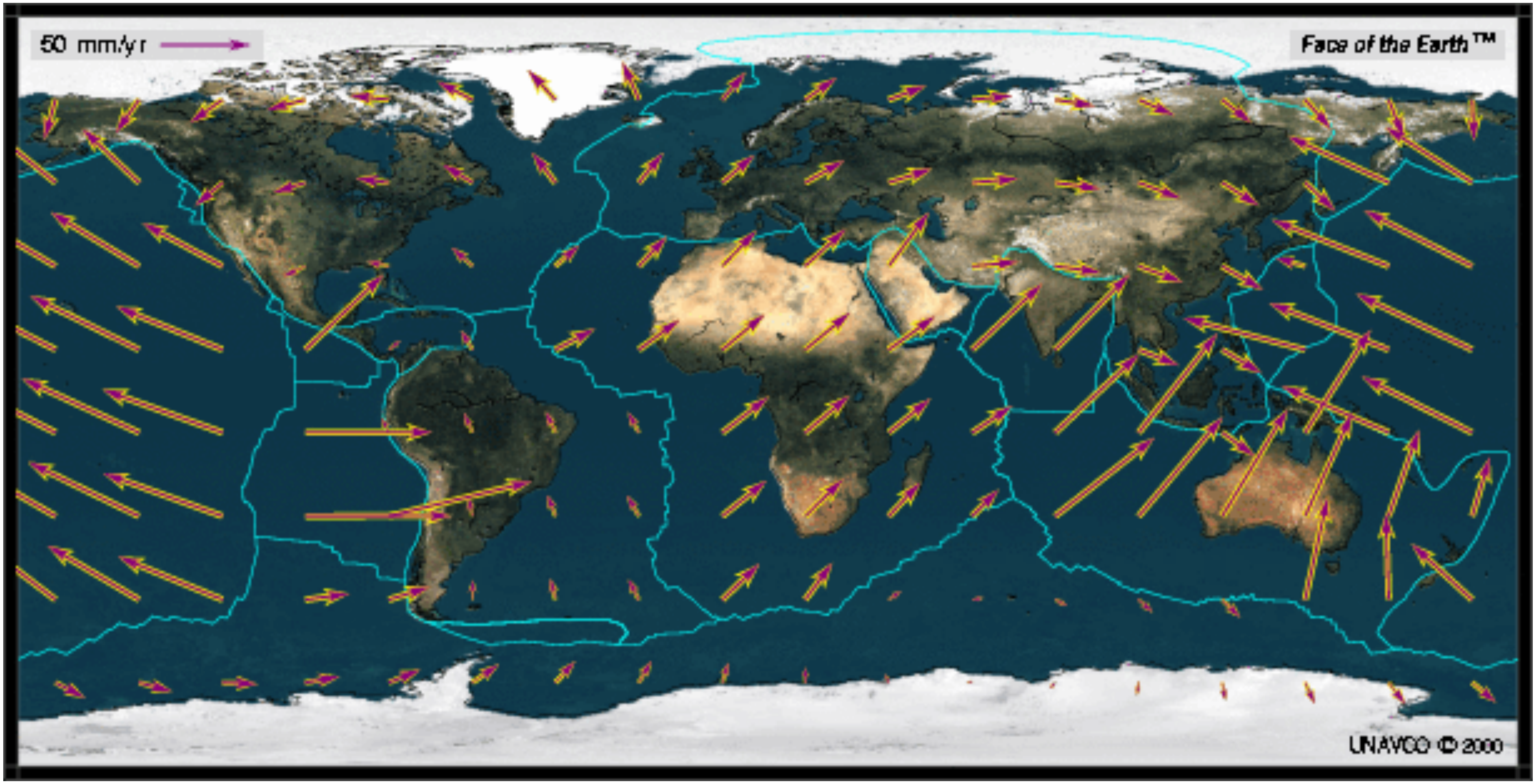
USGS, 1996



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: qua

Plate tectonic motion: The cause of earthquakes



Some details

- Approximate energy release, 3.8 kt (kilotons)
- Number of 5.0 to 5.9 earthquakes (globally),

approximately 800 per year.

- Approximate Plate motion rate is 14.3 mm/yr along a direction of 245 Deg East of North.

Model	**Latitude**	**Longitude**	**Speed mm/yr**	**Azimuth (cw from N)**	**N Vel. mm/yr**	**E Vel. mm/yr**	**Plate (referenc e)**
GSRM v1.2	35° 49' 60" N 35.83333 3°	96° 40' W -96.66666 7°	14.33	245.44°	-5.95	-13.03	NA(NNR)

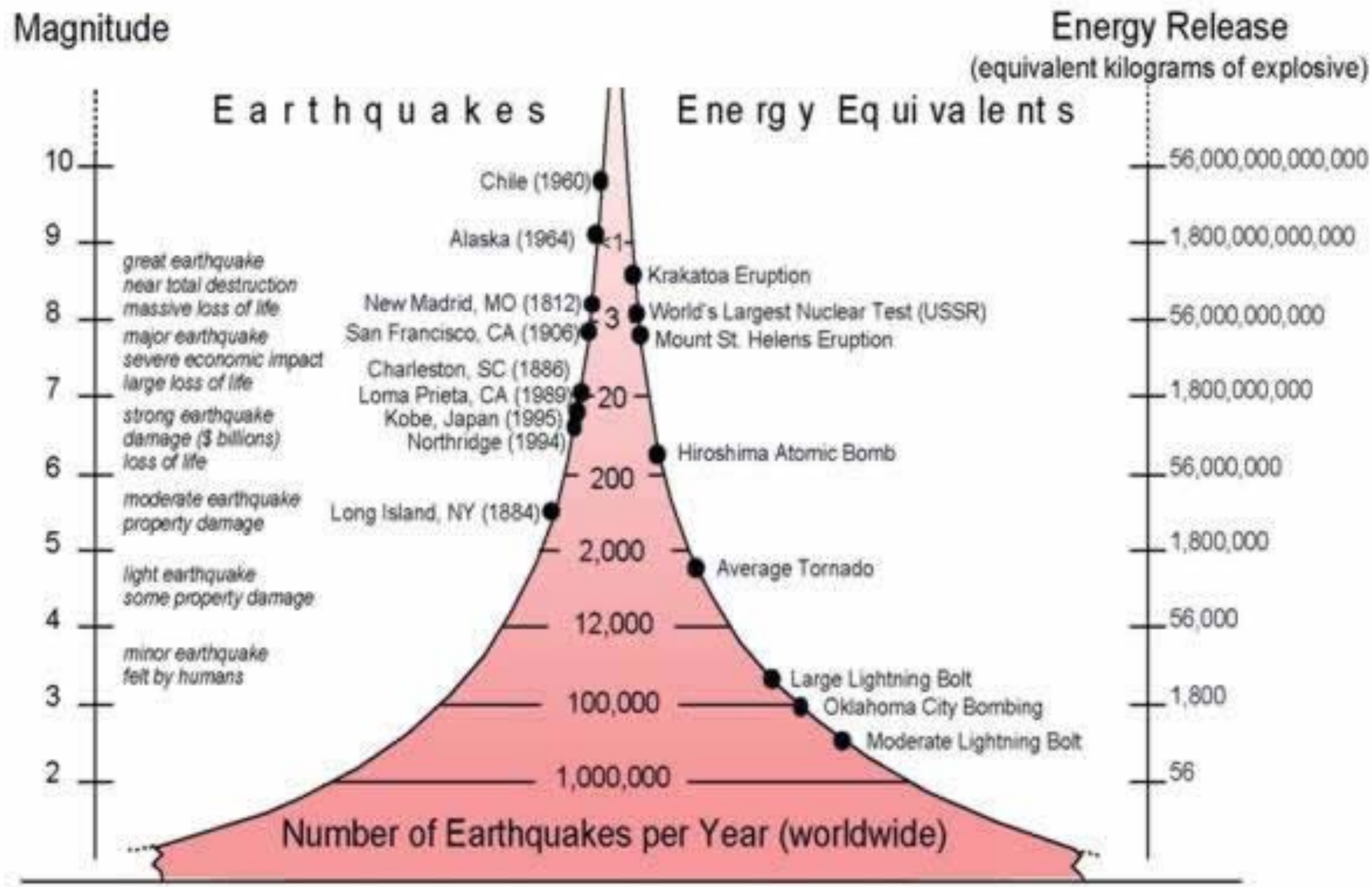
Richter Scale

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)

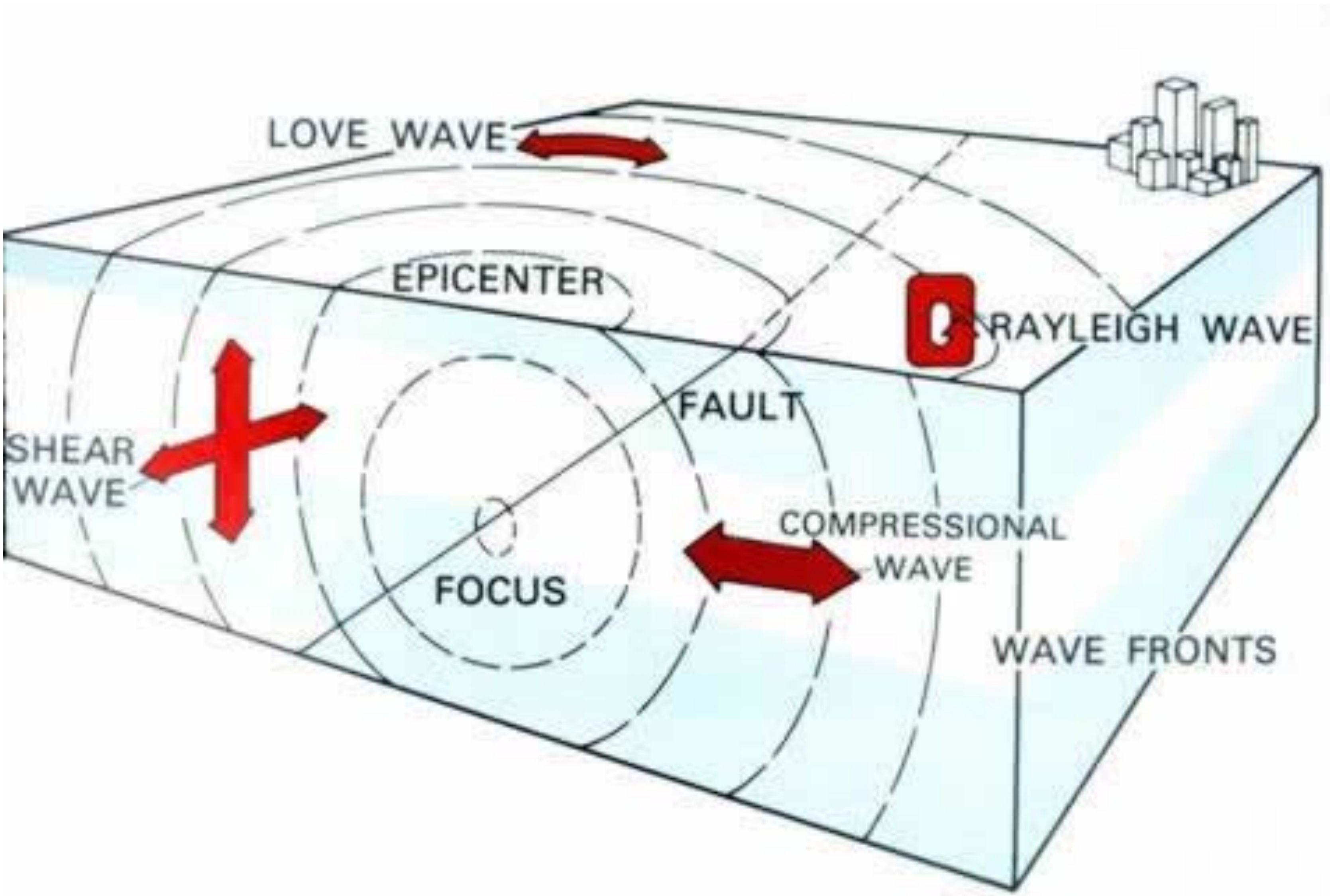
Richter Approximate Magnitude	Approximate TNT for Seismic Energy Yield	Joule equivalent	Example
0.0	15.0 g (0.529 oz)	63.1 kJ	
0.5	84.4 g (2.98 oz)	355 kJ	Large hand grenade
1.0	474 g (1.05 lb)	2.00 MJ	Construction site blast
1.5	2.67 kg (5.88 lb)	11.2 MJ	WWII conventional bombs
2.0	15.0 kg (33.1 lb)	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
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)
<1
3
20
200
2,000
12,000
100,000
1,000,000
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
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
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.

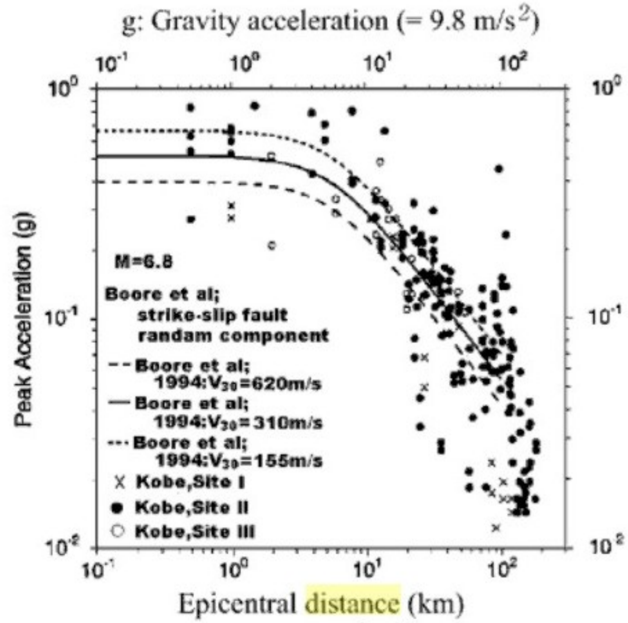


Fig. 5.20 Empirical correlation between observed maximum horizontal acceleration and distance from the surface area lying above the fault; V_{30} means the average V_s in the surface 30 m of deposit (Joyner and Boore, 1996)

From: Geotechnical Earthquake Engineering By Ikuo Towhata

Variation of earthquake shaking with increased distance from the epicenter

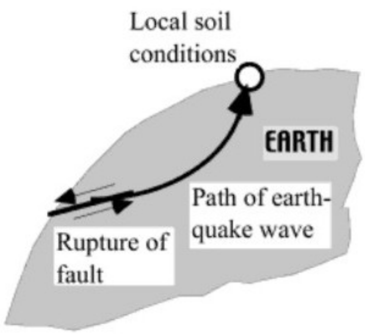


Fig. 5.24 Relationship between causative fault, intermediate path, and local soil conditions

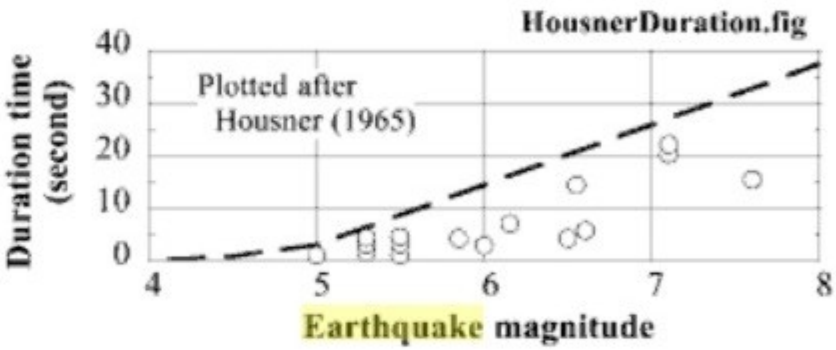


Fig. 5.21 Empirical estimation of duration time of strong motion (Housner, 1965)

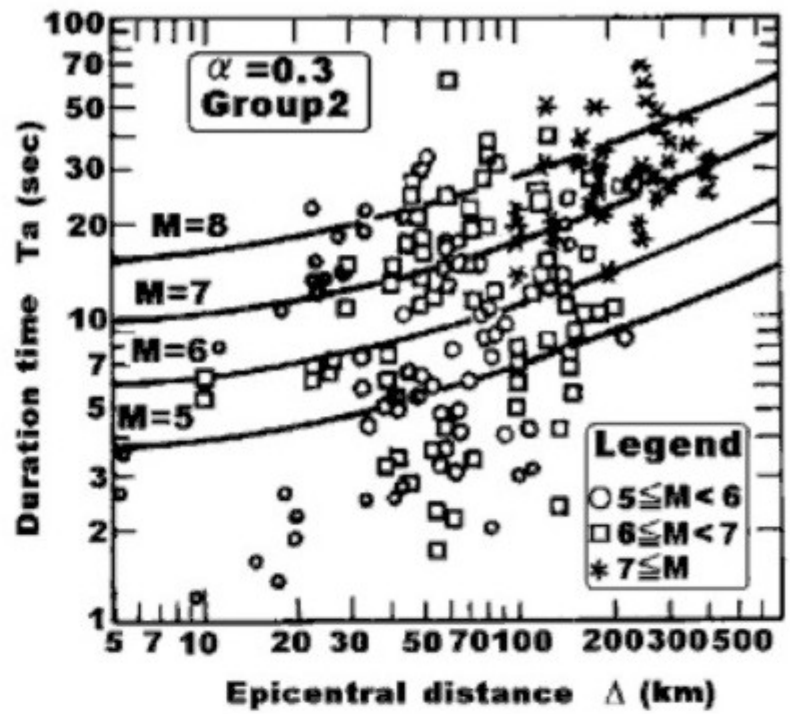


Fig. 5.22 Empirical correlation on relatively stiff ground between duration time of strong shaking and distance (Kawashima et al., 1985)

From: Geotechnical Earthquake Engineering By Ikuo Towhata