Measuring Earthquakes

INTENSITY

- Subjective
- Used where Instruments are not Available
- Very useful in Historical Seismicity

MAGNITUDE

- Measured with Seismometers
- Direct Measure of Energy Released
- Possible Confusion due to Different Measures

Modified Mercalli Intensity

I. Not felt except by a few under especially favorable circumstances

II. Felt only by a few persons at rest, especially on upper floors of buildings. Suspended objects may swing.

III. Felt quite noticeably indoors, especially on upper floors of buildings. Standing automobiles may rock slightly. Vibration like passing truck.

Modified Mercalli Intensity

IV. During the day felt indoors by many, outdoors by few. At night, some awakened. Dishes, windows, doors disturbed; walls make creaking sound. Sensation like heavy truck striking building. Standing automobiles rocked noticeably. [0.015 to 0.02g]

V. Felt by nearly everyone, many awakened. Some dishes and windows broken. Cracked plaster. Unstable objects overturned. Disturbance of trees, poles and other tall objects. [0.03 to 0.04g]

VI. Felt by all. Many frightened and run outdoors. Some heavy furniture moved. Fallen plaster and damaged chimneys. Damage slight. [0.06 to 0.07g]

Modified Mercalli Intensity

VII. Everybody runs outdoors. Damage negligible in buildings of good design and construction, slight to moderate in well-built ordinary structures, considerable in poorly built or badly designed structures. Noticed by persons driving cars. [0.10 to 0. 15g]

VIII. Damage slight in specially designed structures, considerable in ordinary construction, great in poorly built structures. Fall of chimneys, stacks, monuments. Sand and mud ejected in small amounts. Changes in well water. Persons driving cars disturbed. [0.25 to 0.30g]

Modified Mercalli Intensity

IX. Damage considerable in specially designed structures, well-designed frame structures thrown out of plumb, damage great in substantial buildings with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken. [0.50 to 0.55g]

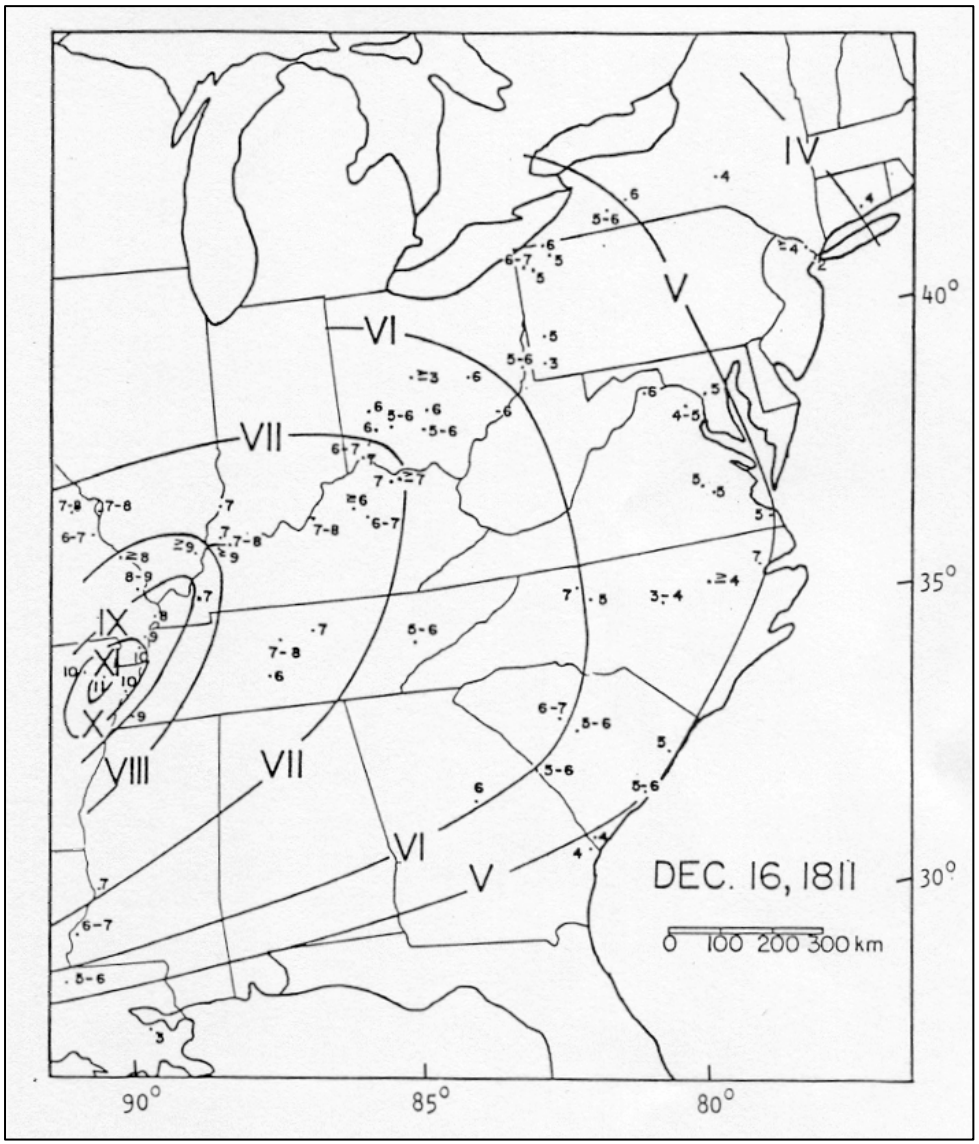
X. Some well-built wooden structures destroyed. Most masonry and frame structures destroyed with foundations badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed over banks. [More than 0.60g]

Modified Mercalli Intensity

XI. Few, if any (masonry) structures left standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.

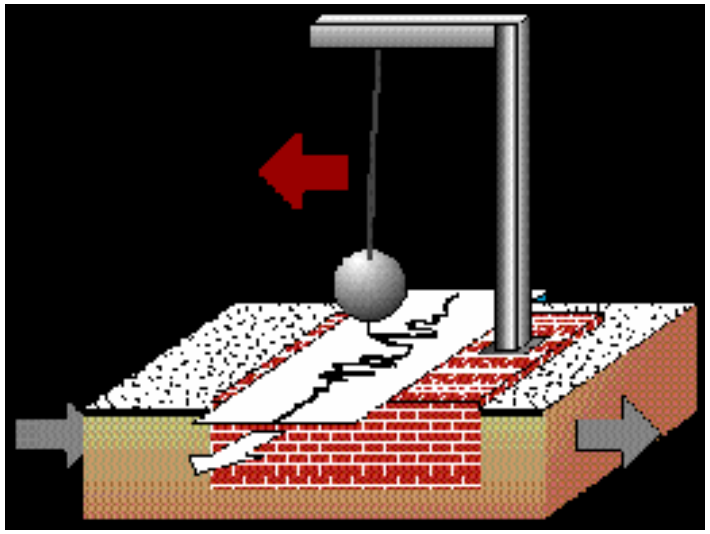
XII. Damage total. Waves seen on ground surface. Lines of sight and level distorted. Objects thrown into air.

MMI Contours from Dec. 16, 1811 New Madrid EQ



Credit: USGS

Seismographs Record Earthquake Motions



Common Types of Magnitude Scales:

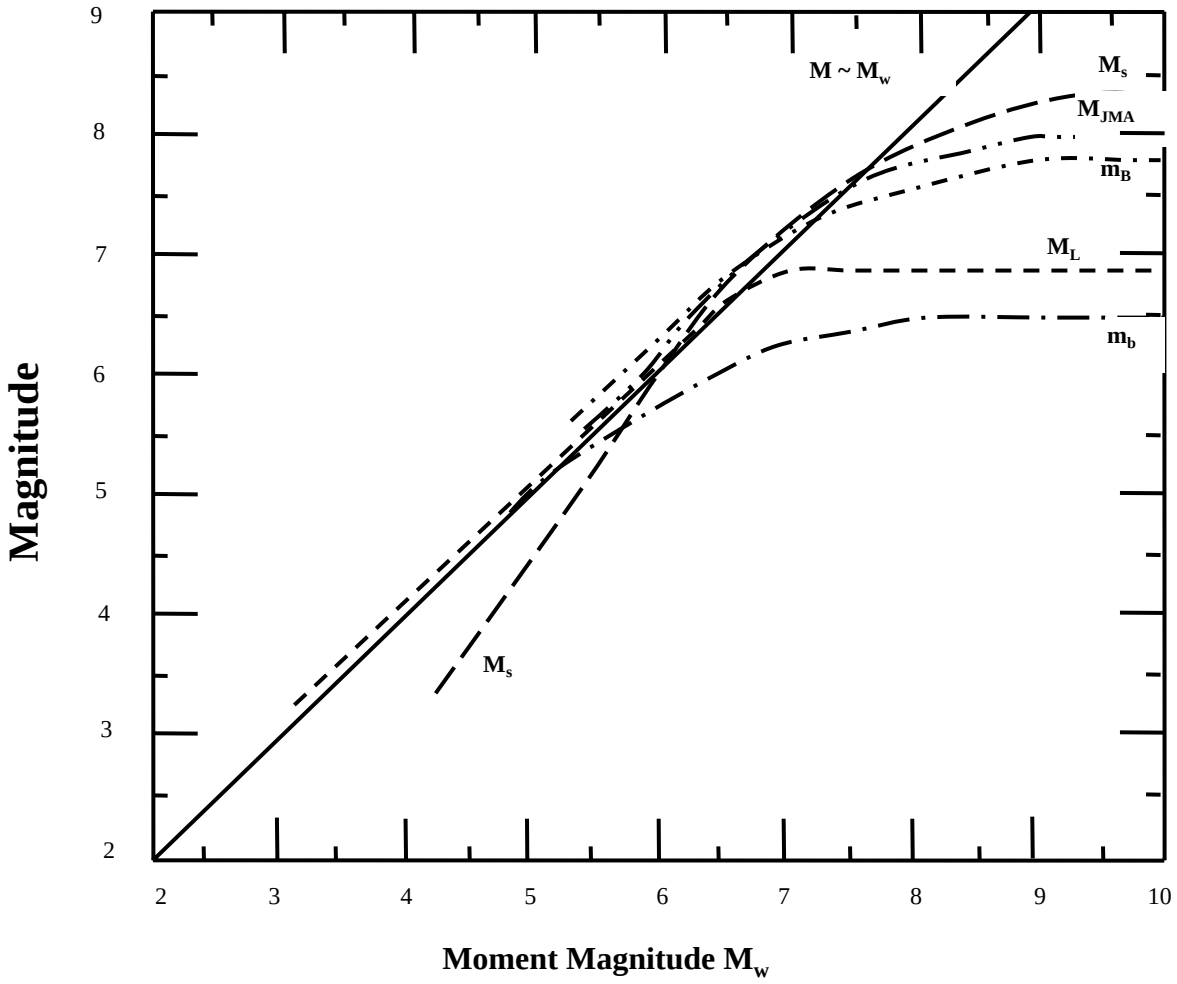
M_L Local (Richter's original magnitude scale)

M_S Surface-Wave Magnitude

m_b Body-Wave Magnitude

M_w Moment magnitude (now considered the true "standard")

Moment Magnitude vs. Other Magnitude Scales



Visual 5.10

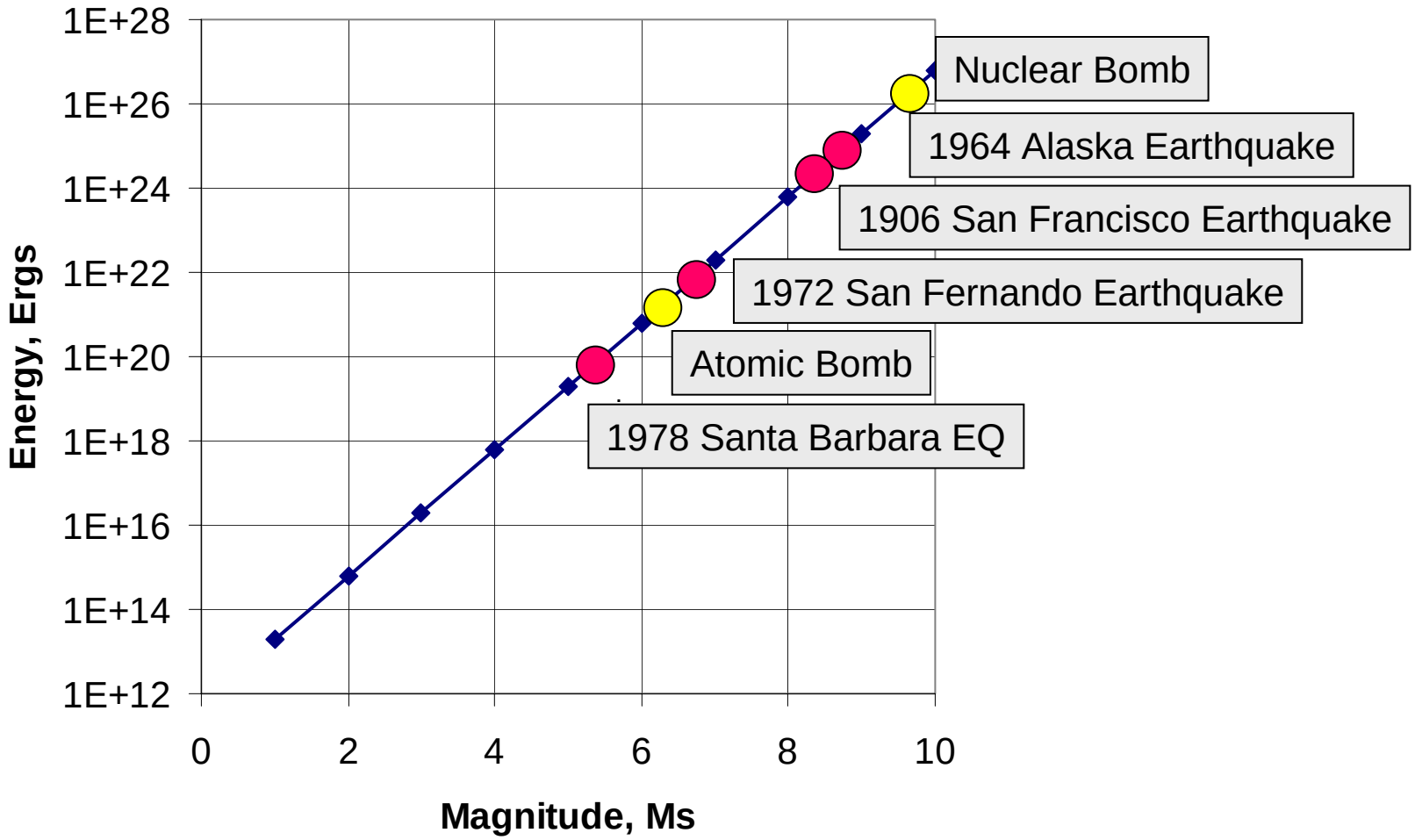
Magnitude Versus Fault Length (CA)

Magnitude	Date	Location	Length (km)	Duration (secs)
7.8	January 9, 1857	Fort Tejon	360	130
7.7	April 18, 1906	San Francisco	400	110
7.5	July 21, 1952	Kern County	75	27
7.3	June 28, 1992	Landers	70	24
7.0	October 17, 1989	Loma Prieta	40	7
6.9	May 18, 1940	Imperial Valley	50	15
6.7	February 9, 1971	San Fernando	16	8
6.7	January 17, 1994	Northridge	14	7
6.6	November 24, 1987	Superstition Hills	23	15
6.5	April 9, 1968	Borrego Mountain	25	6
6.4	October 15, 1979	Imperial Valley	30	13
6.4	March 10, 1933	Long Beach	15	5
6.1	April 22, 1992	Joshua Tree	15	5
5.9	July 8, 1986	North Palm Springs	20	4
5.9	October 1, 1987	Whittier Narrows	6	3
5.8	June 28, 1991	Sierra Madre	5	2

Ave. No. of Annual Earthquakes Worldwide

Descriptor	Magnitude	Average Annually
Great	8 and higher	1
Major	7 - 7.9	17
Strong	6 - 6.9	134
Moderate	5 - 5.9	1319
Light	4 - 4.9	13,000 (estimated)
Minor	3 - 3.9	130,000 (estimated)
Very Minor	2 - 2.9	1,300,000 (estimated)
Based on observations since 1900. Data source: USGS		

Seismic Energy Release

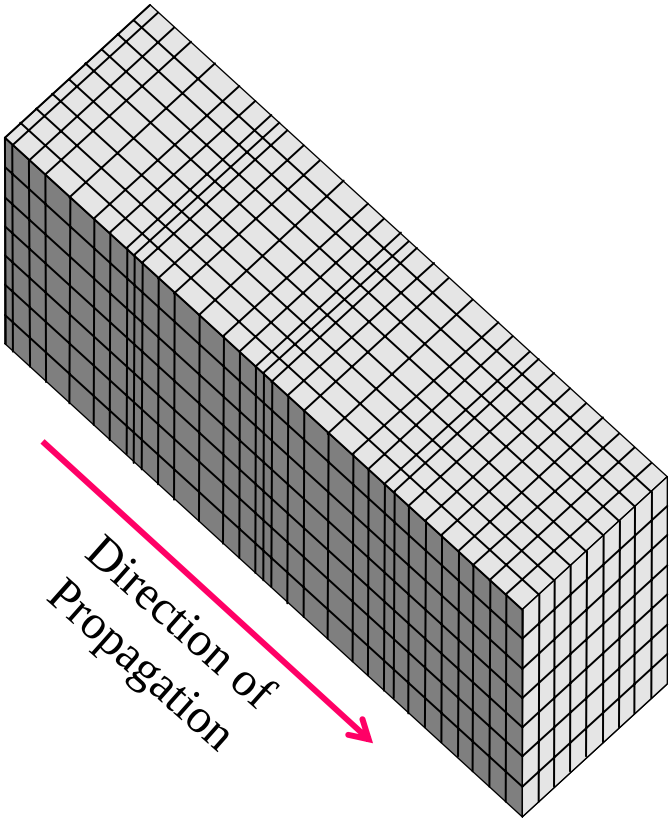


Credit: USGS

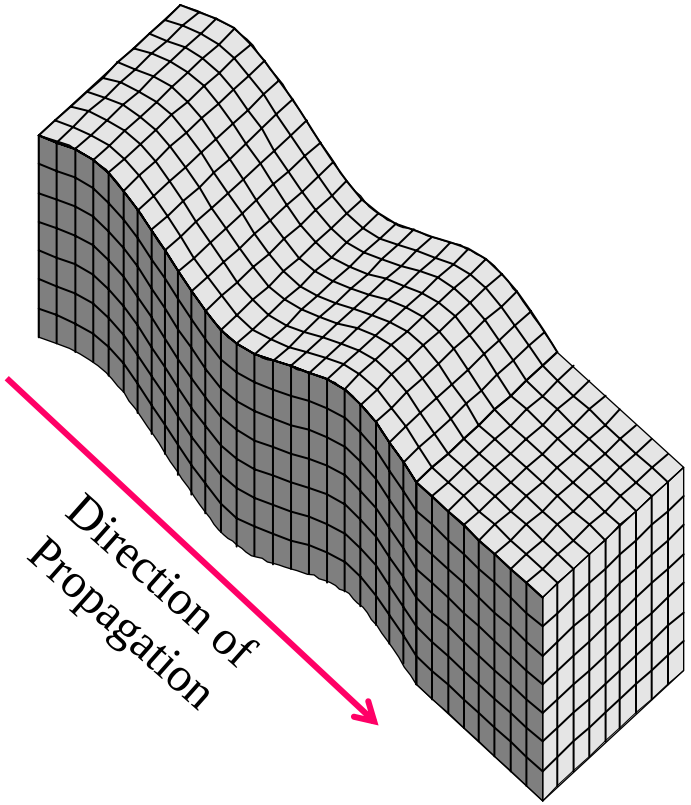
Magnitude, Intensity, and Earthquake Energy

Magnitude	Equivalent energy in weight of TNT*	Equivalent energy in Hiroshima-size atomic bombs	Mercalli intensity near epicenter	Witnessed observations:
3-4	15 tons	1/100	II-III	Feels like vibration of nearby truck
4-5	480 tons	3/100	IV-V	Small objects upset, sleepers awaken
5-6	15,000 tons	1	VI-VII	Difficult to stand, damage to masonry
6-7	475,000 tons	37	VII-VIII	General panic, some walls fall
7-8	15,000,000 tons	1160	IX-XI	Wholesale destruction, large landslides
8-9	475,000,000 tons	36,700	XI-XII	Total damage, waves seen on ground surface

Seismic Wave Forms (Body Waves)



Compression Wave
(P Wave)

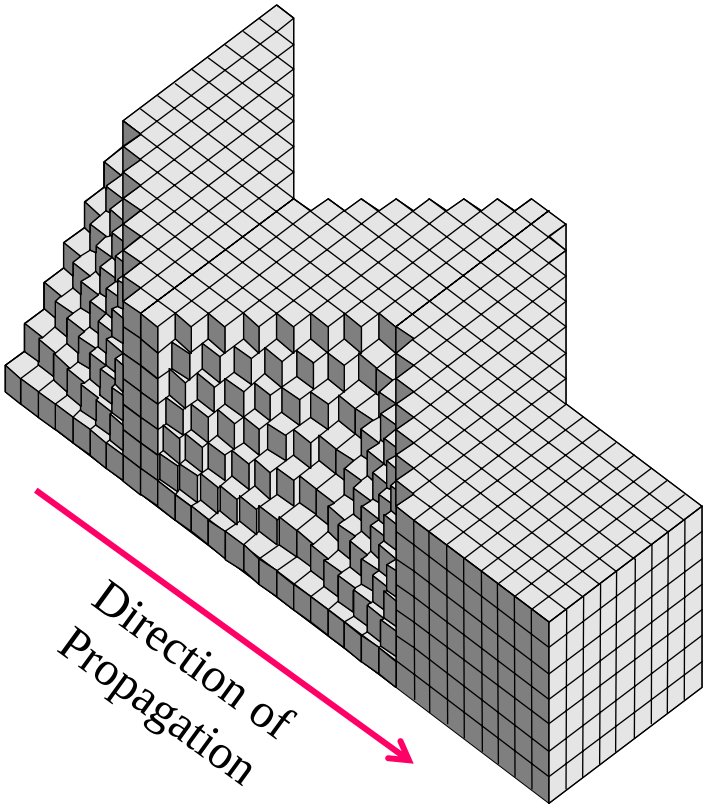


Shear Wave
(S Wave)

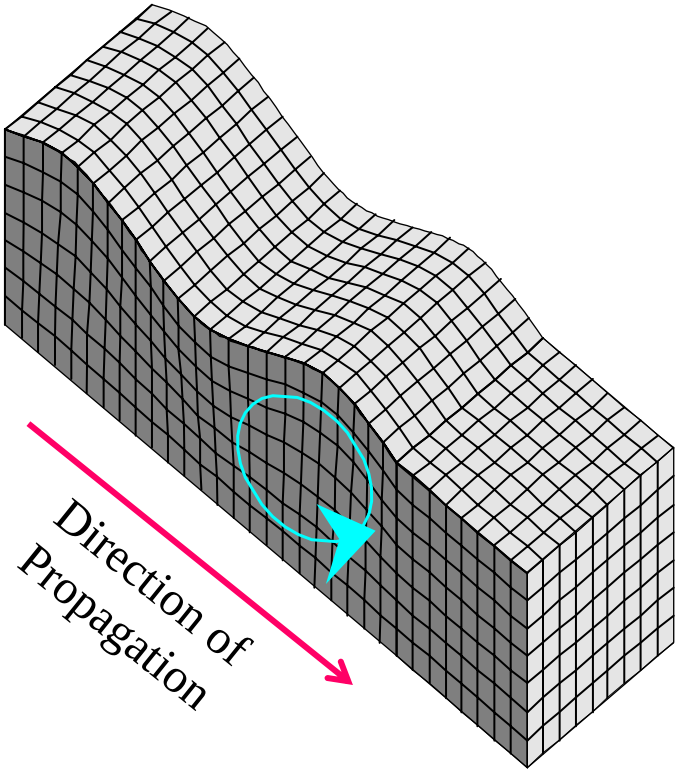
Typical P-Wave and S-Wave Travel Speed

Medium	P-Wave Velocity, Vp (ft./sec.)	S-Wave Velocity, Vs (ft./sec.)
Water	5,000	0
Soft Clay	1,600 - 2,400	250 - 500
Medium Sand	3,000 - 4,500	800 - 1,200
Dense Sand	4,500 - 6,000	1,200 - 1,800
Soft Rock	8,000+	2,500+
Hard Rock	18,000+	12,000+

Seismic Wave Forms (Surface Waves)

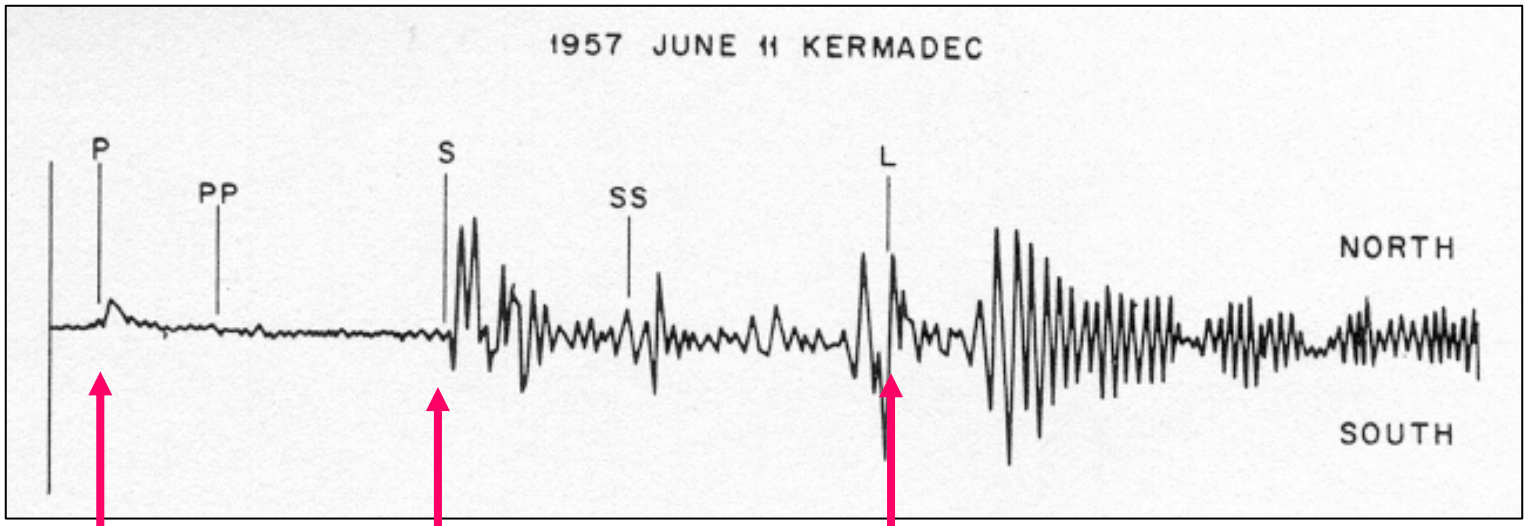


Love Wave



Rayleigh Wave

Arrival of Seismic Waves at Seismograph



P Waves

S Waves

Love Waves

Credit: USGS

Epicenter and hypocenter