Seismic sources

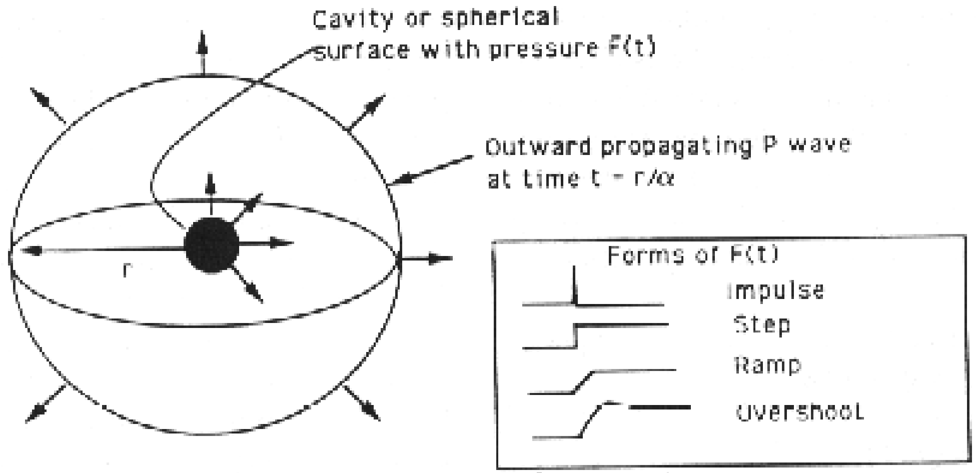
Seismic source types

- Explosions
- Strike slip
- Moment tensor
- Fault plane solution

Magnitude scales

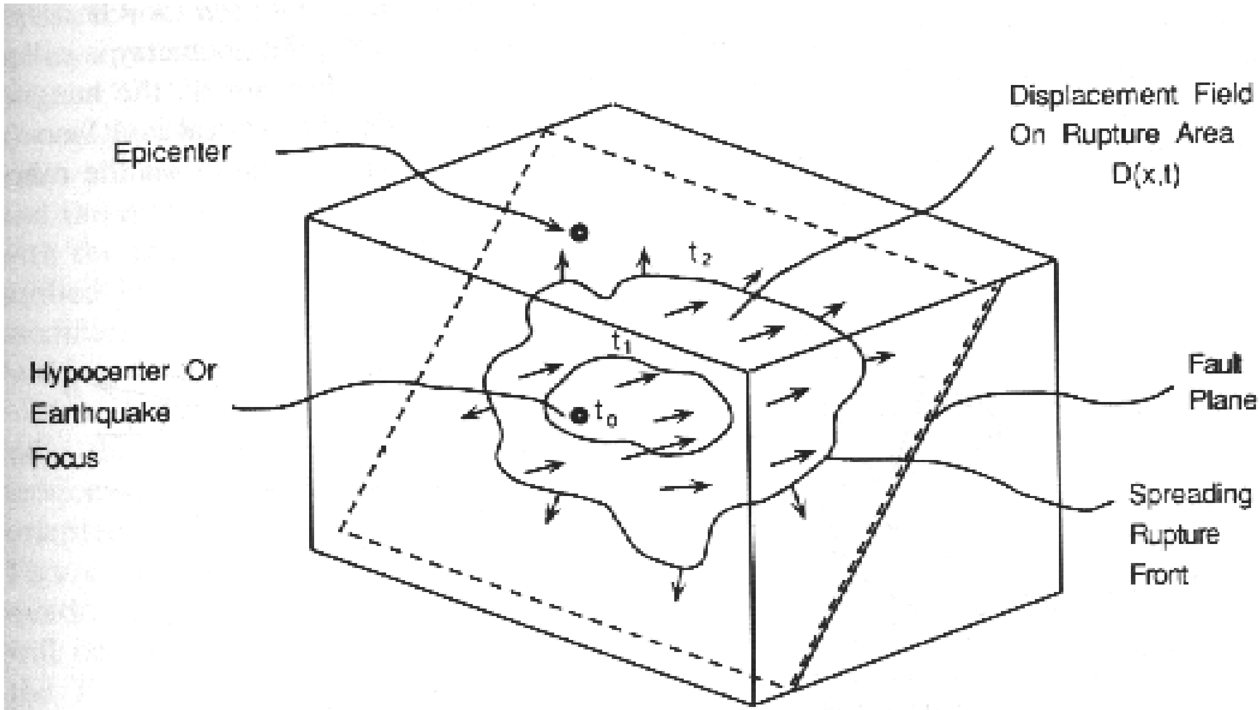
- Richter, Mercalli
- Body wave, Surface wave, Energy scale
- Richter frequency-magnitude law

Explosive source



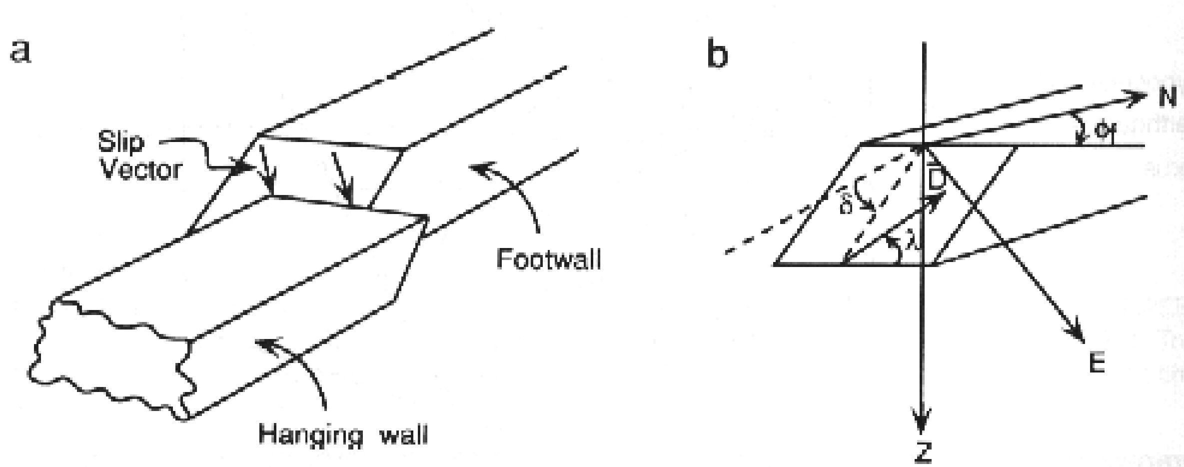
Underground explosion source, wavefield is radiated and the shape of the far-field signal reflects the pressure pulse at the source.

Fault Slip

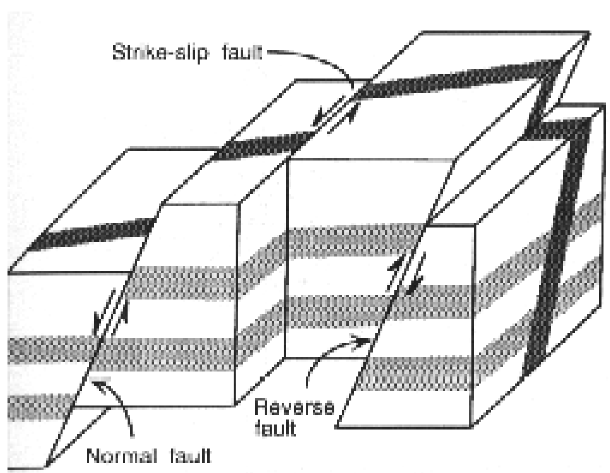


Schematic diagram of rupture on a fault. All regions sliding radiate outgoing P- and shear waves. Note that the direction of rupture propagation is not in general parallel to the slip direction.

Conventions

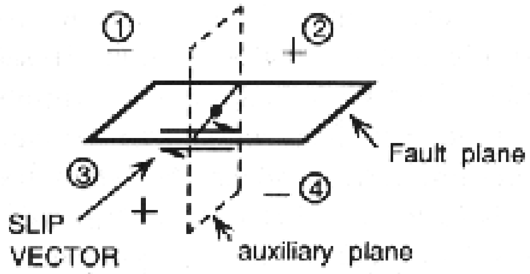


Convention for naming blocks, fault plane, and slip vector

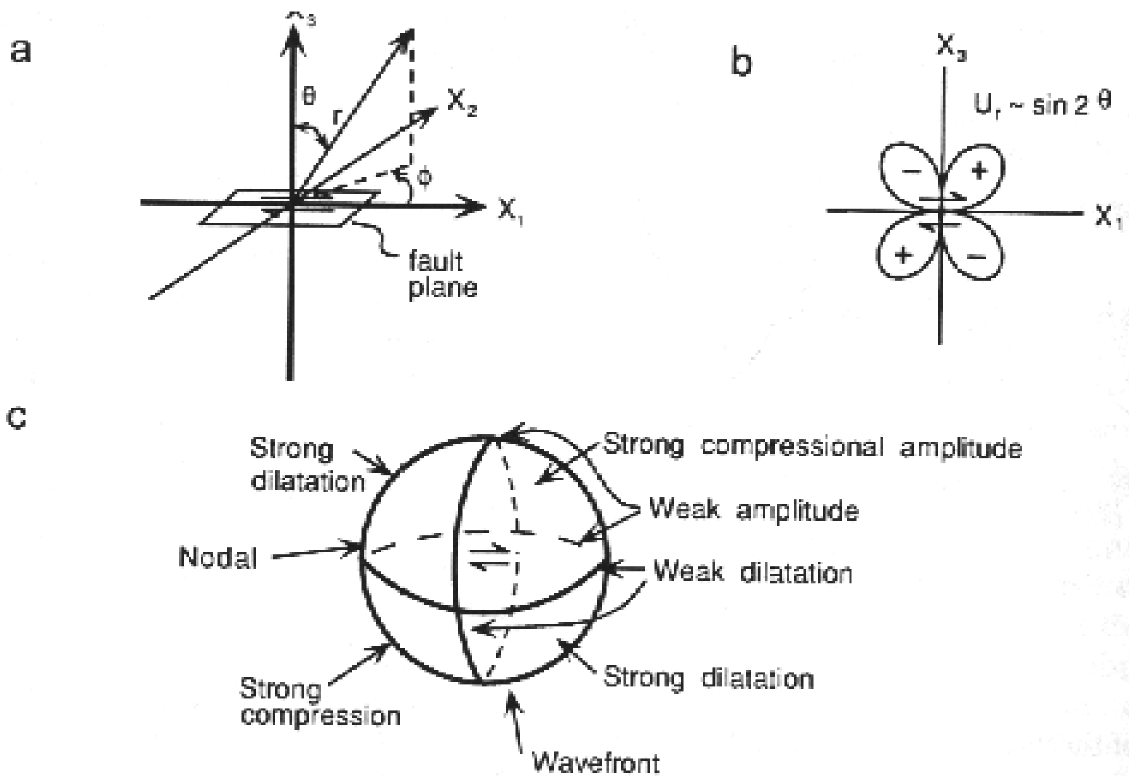


Geometrical configurations after slips.

Radiation from shear dislocation



Fault plane and auxiliary plane and sense of initial P-wave motion.

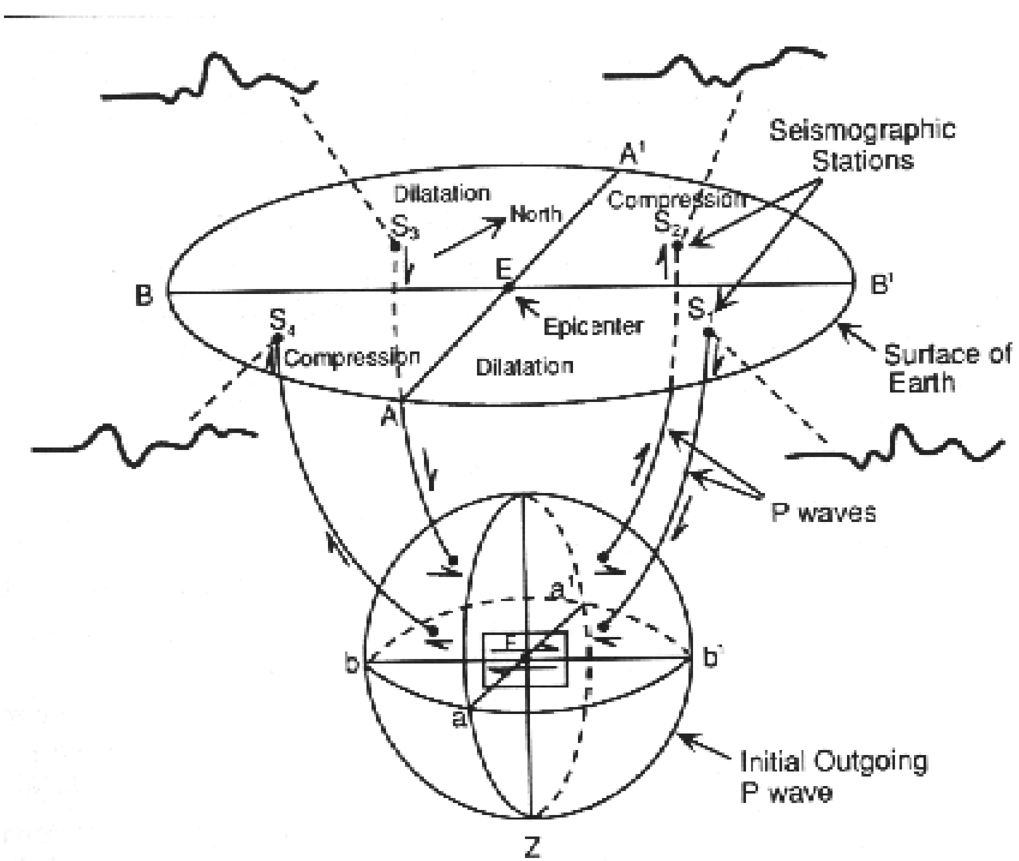


a) Coordinates parallel or perpendicular to fault plane with one axis along the slip direction.

b) radiation pattern in x-z plane

c) 3-D variation of P amplitude and polarity of wavefront from a shear dislocation

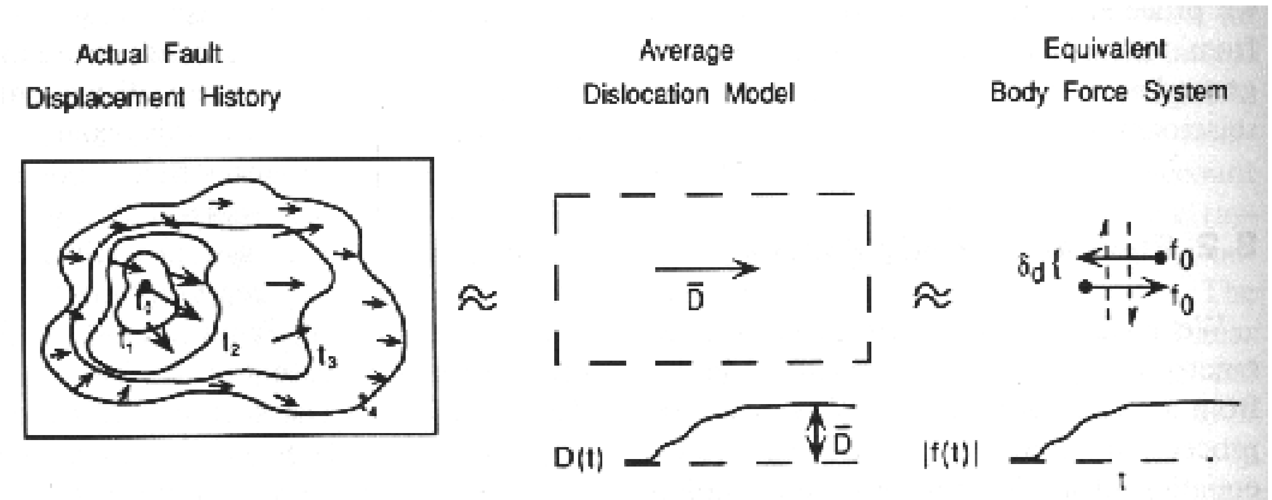
Radiation from shear dislocation



First motion of P waves at seismometers in various directions.

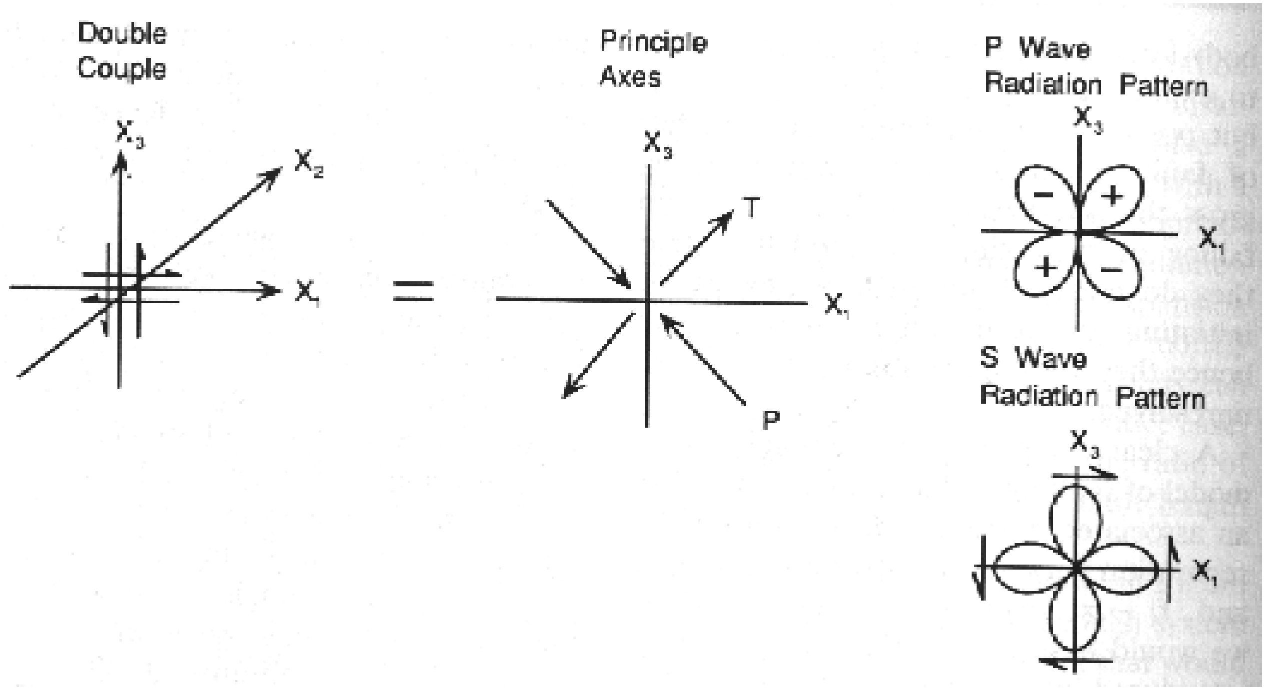
The polarities of the observed motion is used to determine the point source characteristics.

Equivalent Forces: concepts



The actual slip process is described by superposition of equivalent forces acting in space and time.

The Double Couple

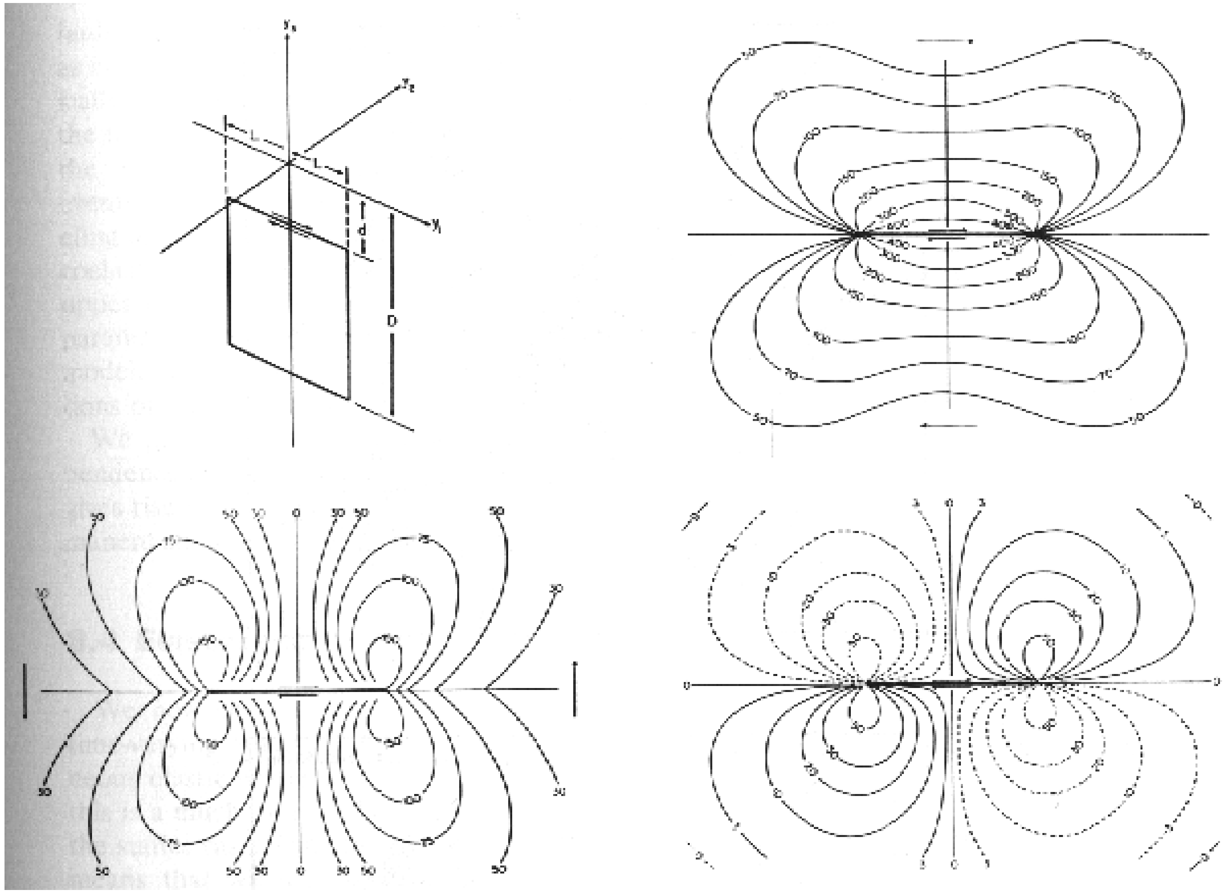


Force system or a double couple in the xz-plane

T and P axes are the directions of maximum positive or negative first break.

The orientation of a double couple determines the radiation pattern of P and S waves

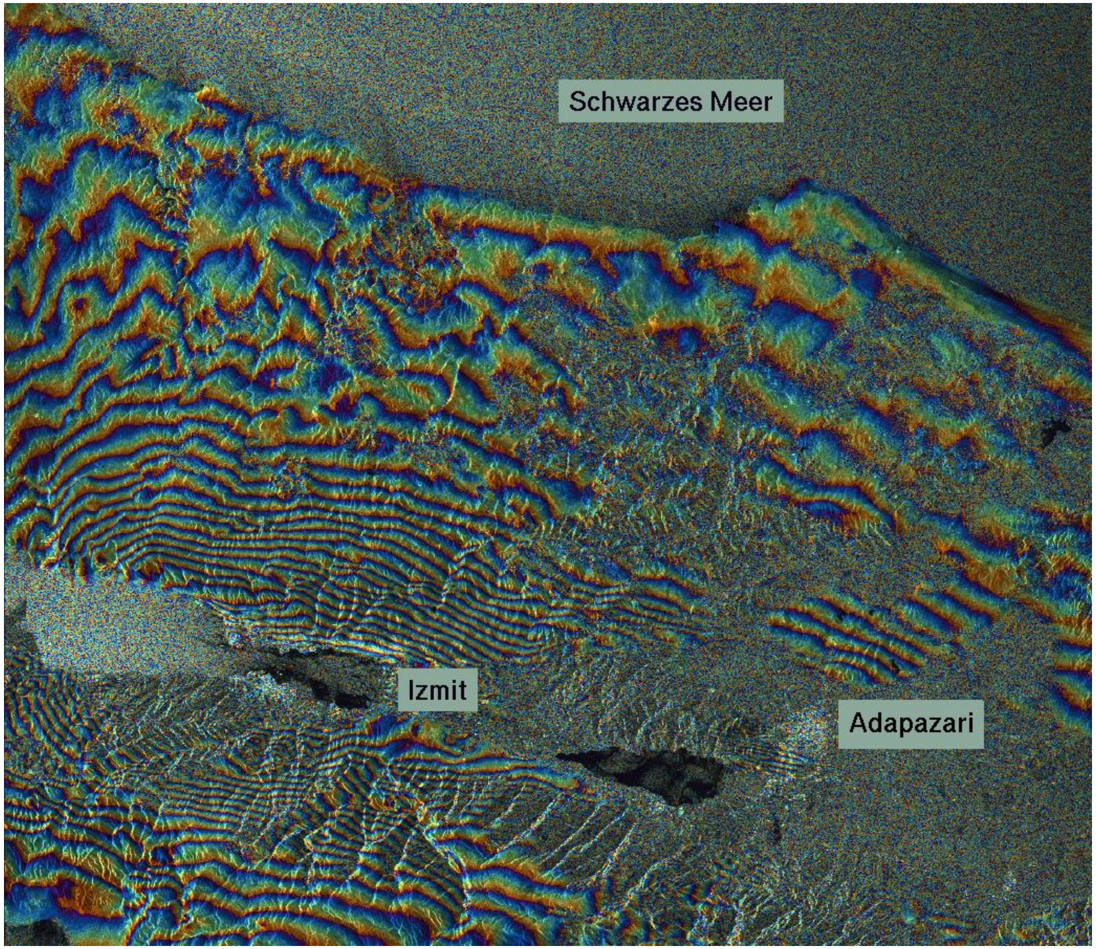
Static Displacements



Ground displacement at the surface of a vertical strike slip.

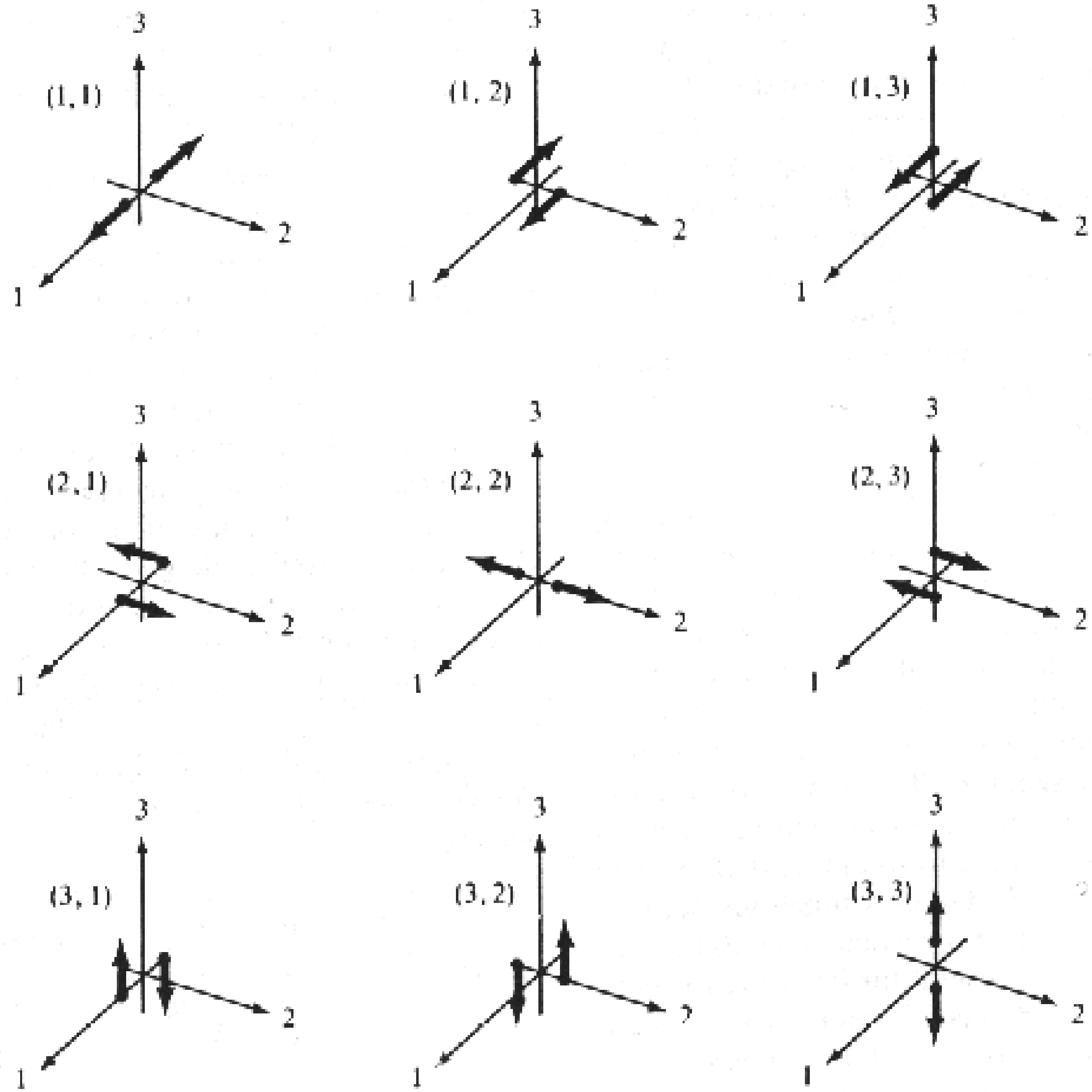
Top right: fault parallel motion
Lower left: fault perpendicular motion
Lower right: vertical motion

Static Displacements



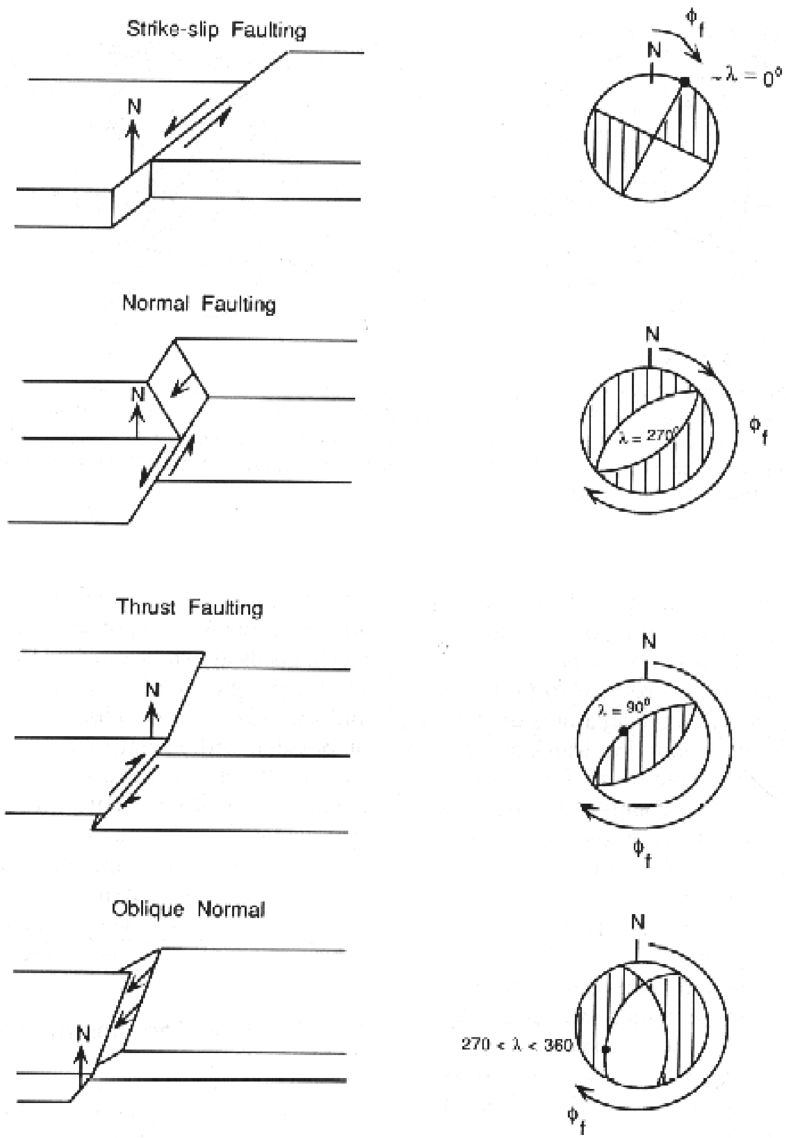
Displacements after Turkey earthquake 1999.

Moment tensor components



Point sources can be described by the seismic moment tensor M. The elements of M have clear physical meaning as forces acting on particular planes.

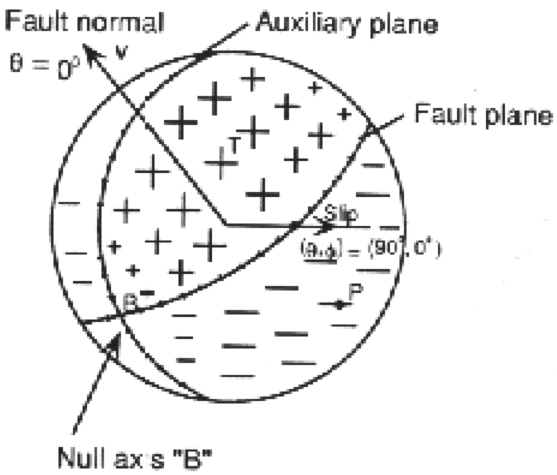
Fault types

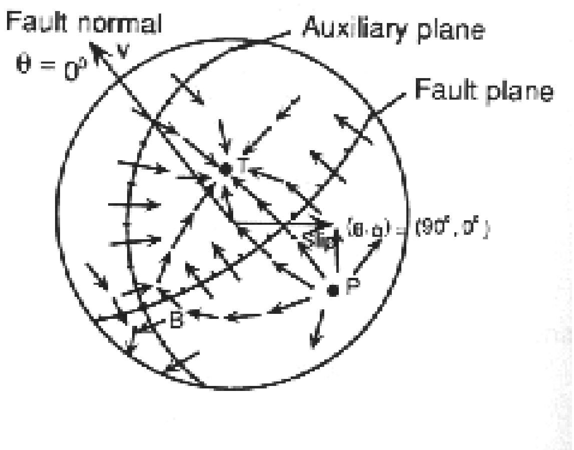


Basis fault types and their appearance in the focal mechanisms. Dark regions indicate compressional P-wave motion.

Focal Mechanisms

Focal mechanism for an oblique-slip event.



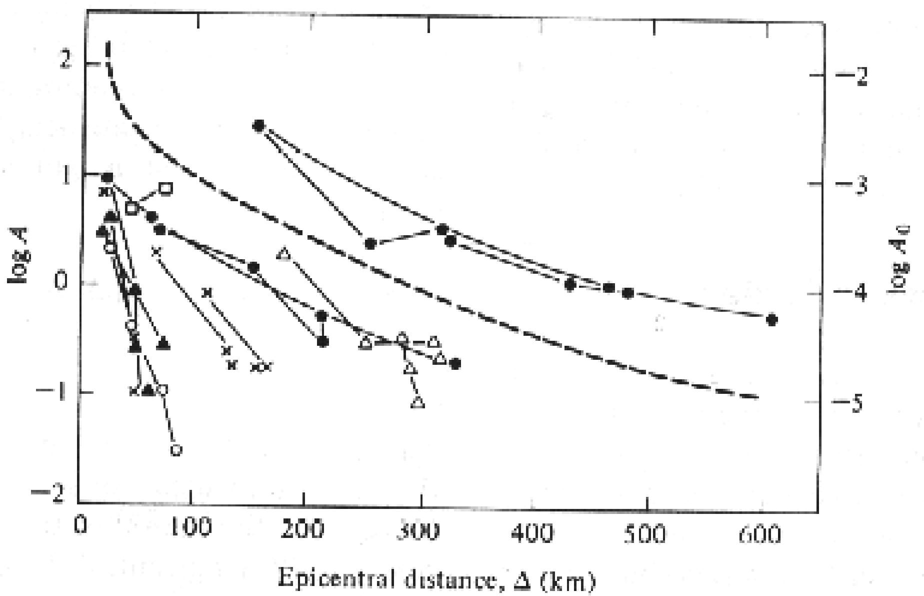


P-wave polarities and relative amplitudes

S-wave polarizations and amplitudes

Mercalli Intensity and Richter Magnitude

Magnitude	Intensity	Description
1.0-3.0	I	**I.** Not felt except by a very few under especially favorable conditions.
3.0 - 3.9	II - III	**II.** Felt only by a few persons at rest, especially on upper floors of buildings. **III.** Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.
4.0 - 4.9	IV - V	**IV.** Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably. **V.** Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
5.0 - 5.9	VI - VII	**VI.** Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight. **VII.** Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.
6.0 - 6.9	VII - IX	**VIII**. Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. **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.
7.0 and higher	VIII or higher	**X.** Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent. **XI.** Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly. **XII.** Damage total. Lines of sight and level are distorted. Objects thrown into the air.



Data from local earthquakes in California

The original Richter scale was based on the observation that the amplitude of seismic waves systematically decreases with epicentral distance.

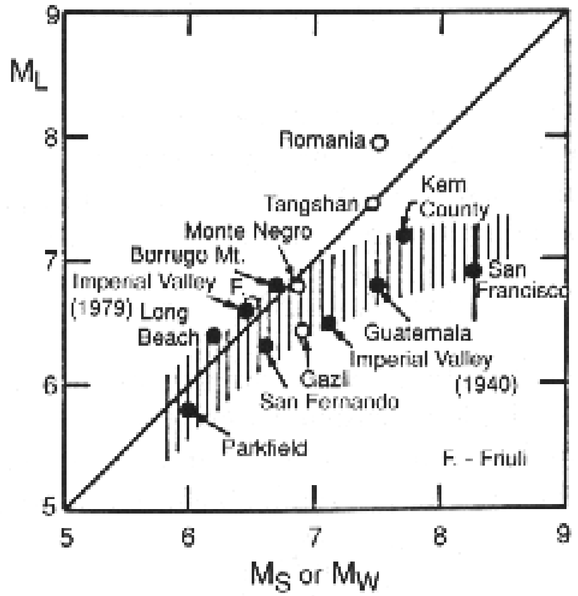
Magnitude Scales - Richter

$$M = \log(A/T) + f(\Delta, h) + C_s + C_r$$

M seismic magnitude
A amplitude
T period
f correction for distance
C_s correction for site
C_r correction for receiver

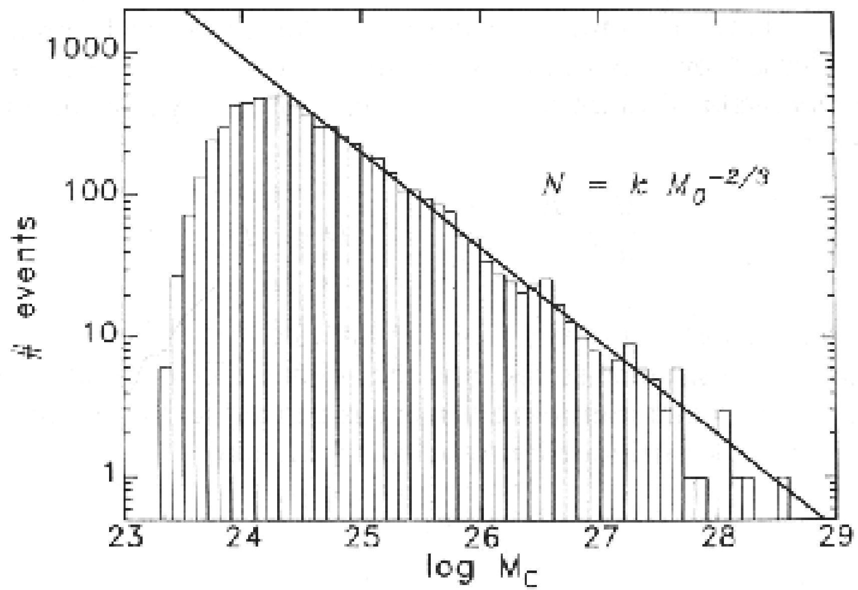
M_L Local magnitude
M_b body-wave magnitude
M_s surface wave magnitude
M_w energy release

Saturation of Local Magnitude



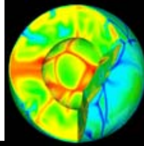
For large earthquakes the originally defined Richter scale is not appropriate. Better indicators of the size of large earthquakes are the surface wave M_s scale or the energy scale M_w.

Earthquake statistics



Number of earthquakes as a function of seismic moment from global data sets for shallow events.

Seismic sources



Far away from the source (far-field) seismic sources are best described as point-like double couple forces. The orientation of the inital displacement of P or S waves allows estimation of the orientation of the slip at depth.

The determination of this focal mechanism (in addition to the determination of earthquake location) is one of the routine task in observational seismology. The quality of the solutions depends on the density and geometry of the seismic station network.

The size of earthquakes is described by magnitude scales. Following the first quantitative scale by Richter for local earthquakes several other scales were developed. Magnitudes of distant earthquakes are best determined by averaging over surface wave, body wave, or Energy scales from different observations.