CHAPTER 1

BASIC SEISMOLOGY AND EARTHQUAKE TERMINOLGY

EARTH FORMATION

Earth interior is composed of three parts: a very thin crust on the outside (3 – 30 miles); a core of significant size in the center, and a mantle in the middle that contain most of the mass of the Earth (2000 – 3000 miles). See Fig. 1.1.

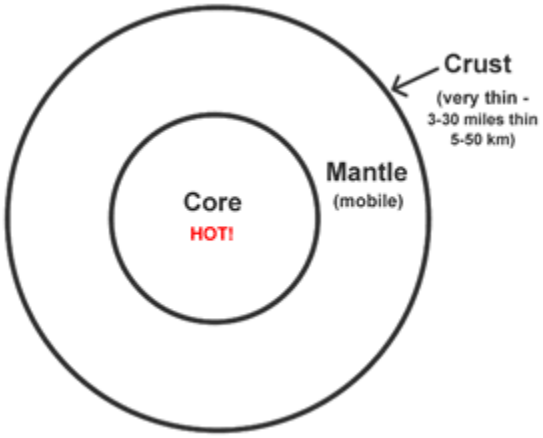

Fig. 1.1 Earth Formation

The earth core is the source of internal energy which release heat as they break down into the mantle. The mantle is composed of cool and brittle rocks towards the crust and soft and flowing rocks towards the core. Crust is made up of variable thickness plates. Thick continental plates (20 – 30 miles) are made up primarily of granite rocks and thin oceanic plates (3 – 4 miles) are made up primarily of basalt rocks.

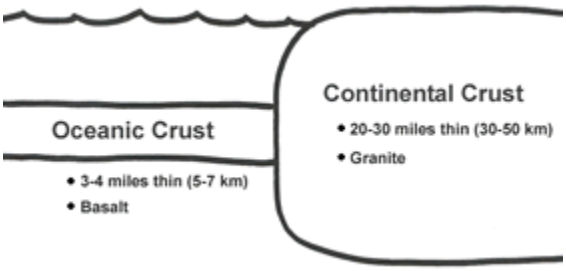

Fig. 1.2 Continental and Oceanic Crust

PLATE TECTONICS

Earth outer shell (crust) is fragmented into various large and small plates. There are seven large plates, in addition to more small plates. These plates moves relative to each other: moving apart; colliding; or sliding over or under each other.

Fig. 1.3 Major Plates of the World (Ref. 1)

When moving apart from each other, they create a ***submarine ridge***. When colliding with each other, they build ***mountain range.*** When sliding over or under another plate, they create a ***submarine trench.*** This sliding movement is also known as ***Subduction***.

The academic field to study plate motion is called *plate tectonics*. The boundaries of two large plates: Pacific Plate and North American Plate are located along the west coast of the US.

SOURCES OF EARTHQUAKES

An earthquake is a shaking movement of the ground surface resulting from an energy release in the earth's crust. Earth crust, initially strained from bending and shearing from plate movements (plate tectonics), stores energy in the rock formation of the crust. When the stored energy exceeds the ultimate strength of the rocks, the rocks break and move (snap) releasing seismic waves. In addition, earthquakes can be generated due to volcanic eruptions or manufactured explosions.

EARTH FAULTS

An earth fault is defined as a permanent fracture in the earth crust creating two blocks on either side of the fault line/plane. The two blocks move (slip) relative to each other and are called hanging wall and foot wall (Fig. 1.4). The fault movement (rupture) does not always break through to the ground surface and is then known as **Blind Fault**. Faults normally exist along boundaries of the tectonic plates (inter-plate) but can also exist within a plate (intra-plate).

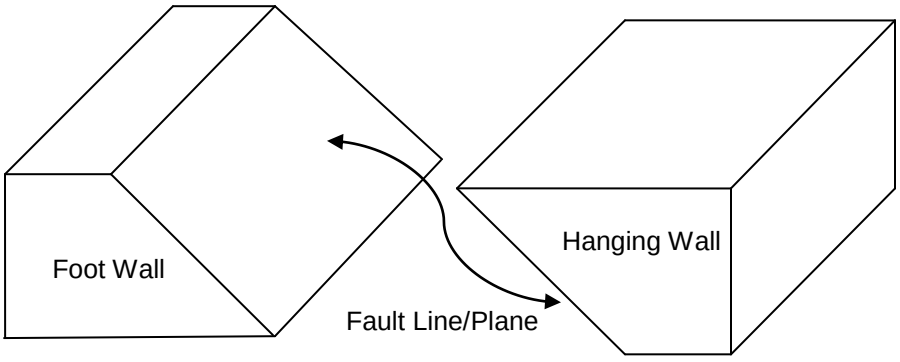

Fig. 1.4 Foot Wall, Hanging Wall Definitions

Fault movements are categorized as strike slip and dip slip. At a strike slip fault (Fig 1.5), the blocks on either side of the fault (hanging wall and foot wall) move horizontally relative to each other. A strike slip fault is classified as either *left lateral* or *right lateral.* In a left lateral fault, an observer standing on one block will see the other block moving to the left.

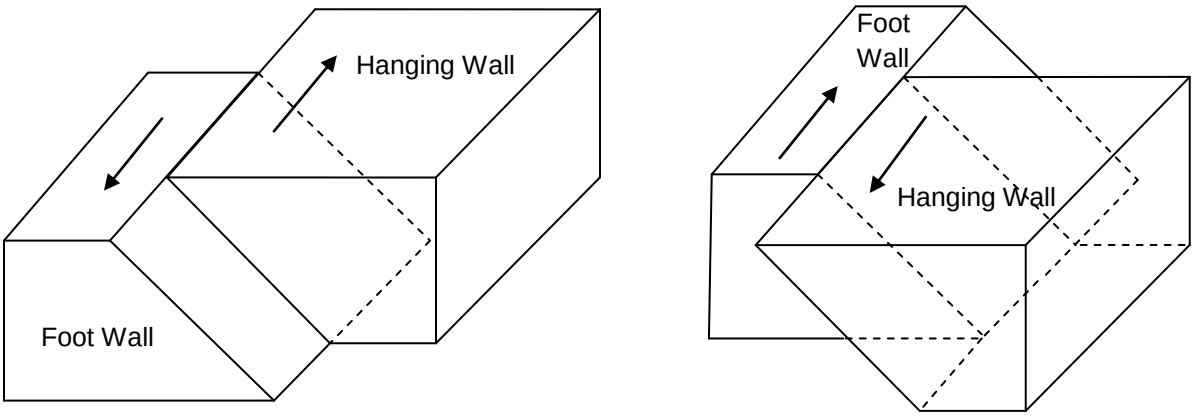

Fig. 1.5 Strike Slip Fault Movements

At a dip slip fault, the blocks on either side of the fault will move vertically relative to each other. See Figure 1.6. A dip slip fault may be classified as either *normal* (aka *detachment*) fault or *reverse* (aka *thrust*) fault. At normal fault movement, the hanging wall will move down relative to the foot wall. In a reverse fault, the hanging wall moves up relative to the foot wall.

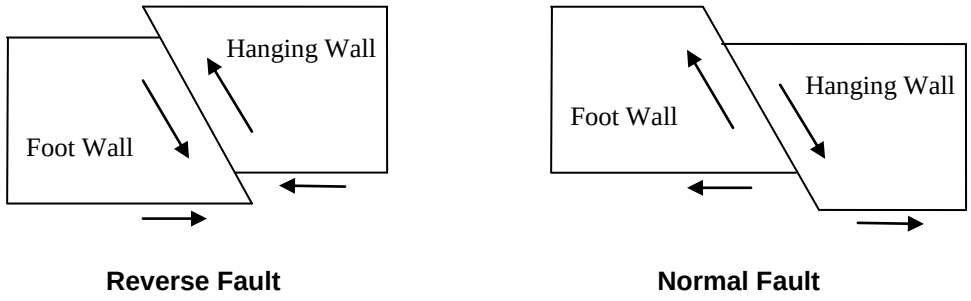

Fig. 1.6 Dip Slip Fault Movements

A combination of strike slip and dip slip may also occur and are referred to as *Oblique* fault. Figure 1.7 shows a left lateral reverse fault movement.

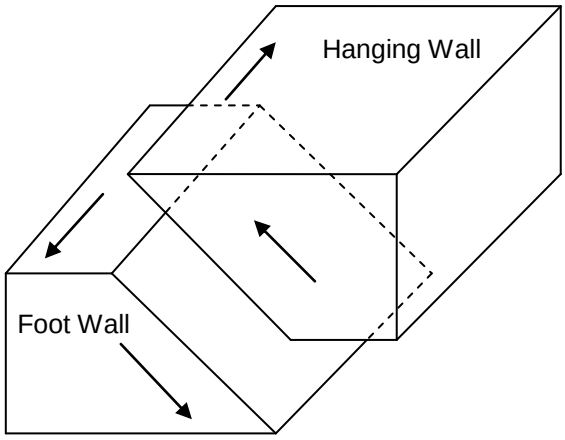

Fig. 1.7 Left Lateral Reverse Fault Movements

FAULT CREEP

Movement along the fault can occur by sudden displacement (slip) of the crust (**Fault rupture**), or by a continuous and intermittent slow movement without noticeable earthquake (**Fault Creep**).

CALIFORNIA FAULTS

California is the most earthquake prone area in the United States with many active faults and fault systems during the past 200 years. The San Andreas Fault (600 mile long, 20 mile deep) is the major fault in a system of faults that cuts through the rocks of the coastal region (Fig. 1.8). Another fault system is the one separating the Sierra Nevada from the Great Basin. There are also many smaller faults branch off and join the major and larger faults as can be seen in Fig 1.8.

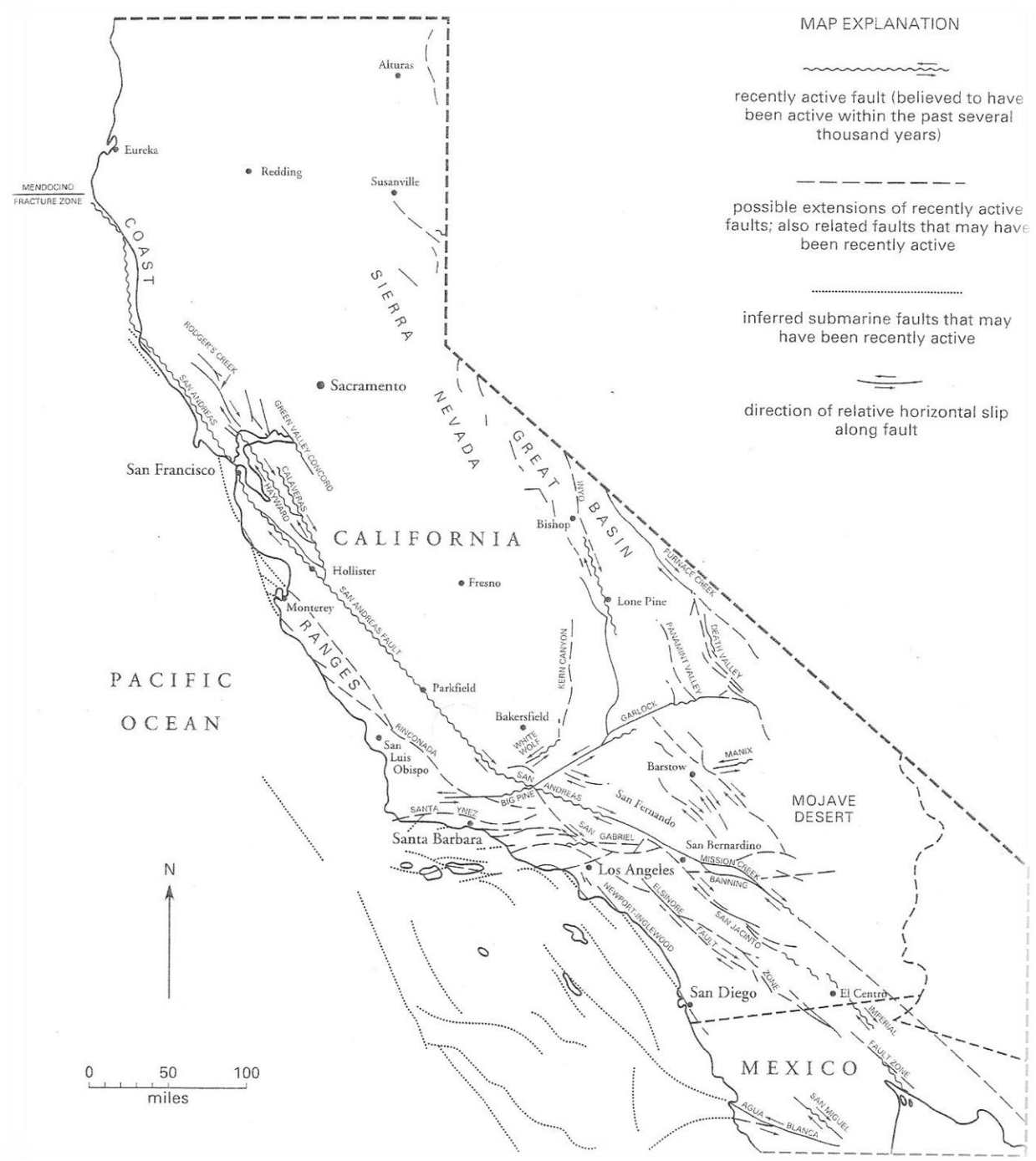

Fig. 1.8 California Faults and Fault Systems (Ref. 2)

Most of California faults are strike slip movement. **San Andreas Fault system is a right lateral movement.**

EARTHQUAKE TERMINIOLOGY

- The point on the earth crust, where the earthquake energy suddenly released, is referred to as the ***focus*** of an earthquake, also known as the ***hypocenter***.
- Earthquake energy release (slip or snap of the rock formation) propagates from the focus (hypocenter) along the ***fault plane***.
- The point on the earth surface directly above the earthquake focus is known as the ***epicenter***.
- The ***focal depth*** of an earthquake is the depth from the earth surface to the point where energy is released (distance from epicenter to hypocenter).
- Geographic position of an earthquake is described by its ***epicenter*** and its ***focal depth***.

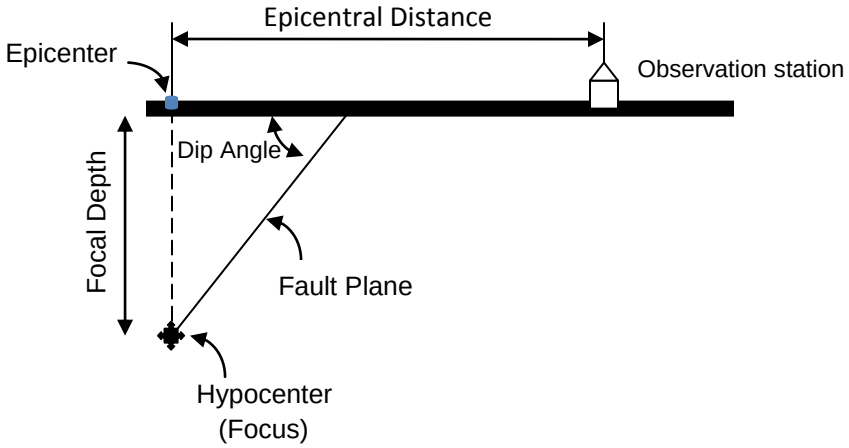

Fig 1.9 Earthquake Terminology

- Earthquakes with focal depth less than 40 miles are classified as shallow earthquakes. From 40 miles to 140 miles are classified as intermediate. Up to 450 miles are classified as deep earthquakes.

SEISMIC WAVES

The sudden release of energy from the earthquake focus (hypocenter) causes seismic waves to propagate through the earth crust producing vibration on the earth surface. Two principal types of seismic waves may be generated: ***Body Waves***, which travel from the focus directly through the earth crust; and ***Surface Waves*** which travel from the focus along the surface of the earth.

Figure 1.10 shows the two types of Body Waves: the ***Primary Wave*** (also known as ***Compression Wave***, or ***P-Wave***), and the ***Secondary Wave*** (also known as ***Shear Wave***, or ***S-Wave***).

- P-wave moves in an alternate compression and expansion pattern along the direction of propagation.
- S-Wave produces a shearing effect in the earth crust transverse to the direction of propagation.

P Wave is the faster and reaches the ground surface first producing a perceptible jolt, followed by the rolling motion produced by the S Wave. Shear waves are the ones responsible for the greatest damage to structures like high rise buildings and bridges that are near the epicenter.

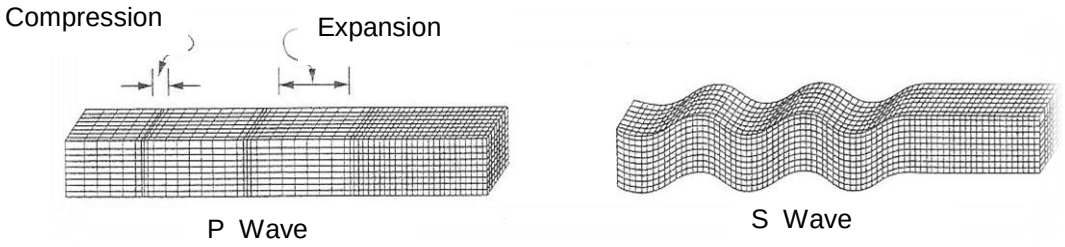

Fig. 1.10 Body Waves: P-wave (Compression wave) and S-wave (Shear wave) (Ref. 3)

There are two types of Surface waves: the Love Wave, and Rayleigh Wave.

- The Love Wave produces a horizontal motion effect in the earth surface transverse to the direction of propagation.
- The Rayleigh Wave produces a rotary wave like motion in the vertical plane.

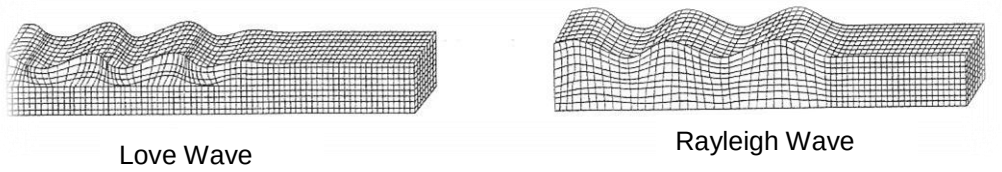

Fig. 1.11 Surface Waves: Love Wave and Rayleigh Wave (Ref. 3)

Surface Waves are the slowest of the seismic waves and may or may not develop. Surface Waves damp out much more slower than body waves and thought to cause the greatest damage far from the epicenter.

Figure 1.12 summarizes the different types of seismic waves and their effects.

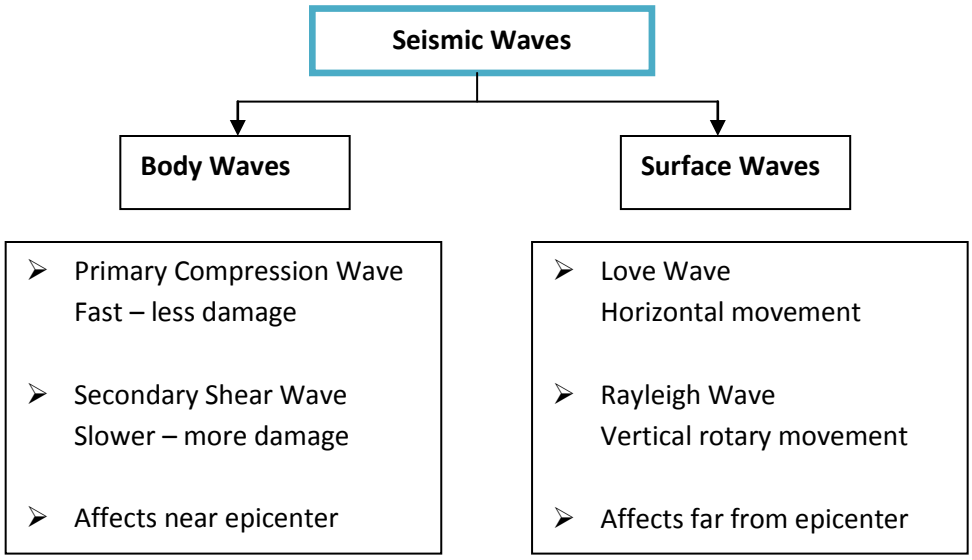

Fig 1.12 Types of Seismic Waves

SEISMIC SEA WAVES

During a great earthquake, the seafloor rises up, and the sea water rises up with it (surges) then rushes away to find a level surface. This motion creates seismic sea waves (also known as ***Tsunami, Surface Sea wave, or Tidal Wave***). Seismic sea waves can also result if the seafloor drops. Water rushes in an enormous amount and a complex sloshing occurs back and forth.

- In deep ocean, the seismic sea waves travels at a speed of about 500 miles/hour with a shallow wave height (can be about only 1 ft).
- As the waves approach seashores (land), wave velocity decreases, and wave height increases dramatically (can be up to 30 ft)

Only dip slip fault movements (Normal and Reverse) produces ***Tsunami***.

MULITPLE CHOICE QUESTIONS

1.1 When two earth plates moves apart from each other, the earth movement creates:

A blind fault

B trench

C slide

D ridge

1.2 When a hanging wall moves down the foot wall during an earth shaking along the fault plane, the fault movement is classified as:

A strike slip

B reverse

C normal

D left lateral

1.3 Earthquake origination point on the earth surface is designated as:

A the focal depth

B the epicenter

C the focus

D the dip angle

1.4 When an earth plate slides beneath another plate, the movement is known as:

A subduction

B slip dip

C sea floor ridge

D strike slip

1.5 California San Andreas fault movement is classified as:

A right lateral

B normal

C oblique

D left-lateral

1.6 Which of the following is incorrect for seismic waves?

A Rayleigh waves produce motion in the vertical plane

B shear waves are at right angles to compression waves

C S-waves displace materials just ahead and behind the wave direction of travel

D compression, shear and surface waves are seismic waves

1.7 When a Tsunami wave approaches land, ….

A wave velocity increases

B wave height decreases

C both wave velocity and height increase

D wave velocity decreases and wave height increases

1.8 Which of the following is incorrect for S-waves?

A S-waves travel more slowly than P-waves

B S-waves transmit more energy than P-waves

C S-waves cause less damage to structures than P-waves

D S-wave cause damage near earthquake epicenter

1.9 A Tsunami can be best described as:

A seismic waves

B seismic water waves

C Japanese nomenclature

D wide-spread damage due to seismic activities

1.10 Earthquakes are generated by which of the following?

A volcanic eruption

B deep artificially induced explosion

C snap of rock formation within the earth crust

D all of the above