Lecture 2: Early Engineering Seismology, Understanding of Earthquakes, Continental Drift and Major fault zones

Topics

- Introduction
- History of Earthquakes
- Causes of Earthquakes: Types of Plate Boundaries
- Elastic Rebound theory
- Continental Drift and Plate Tectonics
- Major Subduction zones in the world
- Major Spreading zones in the world
- Major Thrust Faults in the world
- Major Strike Slip Faults in the world
- Uncertain/Diffuse Boundaries in the World

Keywords: *Plate, Continental Drift, fault, Earthquake*

Topic 1

Introduction

- In Asian countries where earthquakes occur frequently, often with many casualties, an abundant folklore of legends and proverbs about earthquake precursor phenomena has grown up.

- Ancient cultural explanations of earthquakes were often along the lines of the mythical Japanese Namazu: A giant catfish with the islands of Japan on his back. A demigod, or daimyojin, holds a heavy stone over his head to keep him from moving. Once in a while the daimyojin is distracted so Namazu moves and the Earth trembles.

- The legends probably derive from the unusual behavior, violent jumping and twisting movements that have been observed in catfish before earthquakes.

- There are numerous legends about fogs, unusual cloud formations, lights, and unusual animal behavior before earthquakes.

- But the stories are not only legendary. Fogs, unusual cloud formations, lights, and unusual animal behavior, from a week to a few minutes before major earthquakes, have been widely reported in the modern world.

Topic 2

History of Earthquakes

- The study of earthquakes dates back many centuries. Written records of earthquakes in China dates back as far as 3000 years.
- Japanese records from the eastern Mediterranean region go back nearly 1600 years.
- In the United States the historical record of earthquakes is much shorter, about 350 years.
- On the seismically active west coast of the United States, earthquake records go back only about 200 years.
- Compared with the millions of years over which earthquakes have been occurring, humankind's experience with earthquakes is very brief.

Topic 3

Causes of Earthquakes: Types of Plate Boundaries

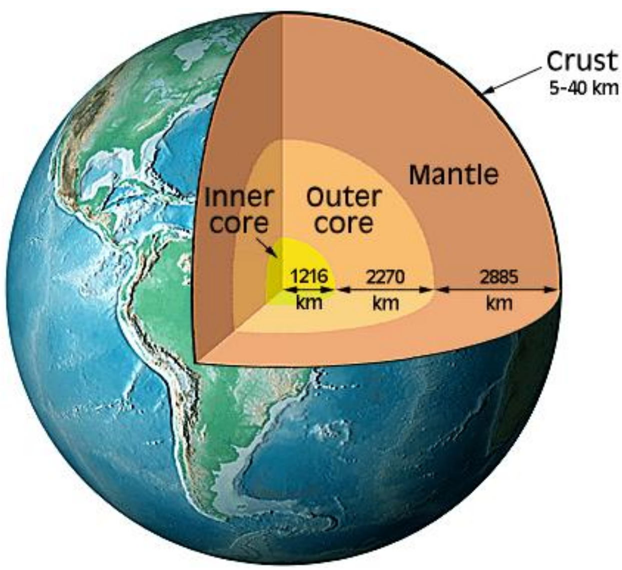

Fig 2.1: Internal Structure of Earth

- The interior of the Earth is divided into layers by their chemical or physical (rheological) properties (Fig 2.1). The outermost layer of the Earth is called crust, on which human beings live. Crust is underlain by a highly viscous solid mantle. The thickness of the crust ranges from about 25 to 40 km beneath the continents to as thin as 5 km or so beneath the oceans.

- The Mantle can be divided into upper mantle (less than 650 km) and the lower mantle. The mantle materials are in a viscous, semi molten state. Beneath the mantle, an extremely low viscosity liquid outer core lies above a solid inner core.

- The earth's crust is broken into about seven major plates Fig 2.2, each of which behaves for the most part as a rigid body that slides over the partially molten mantle, in which deformation occurs plastically.

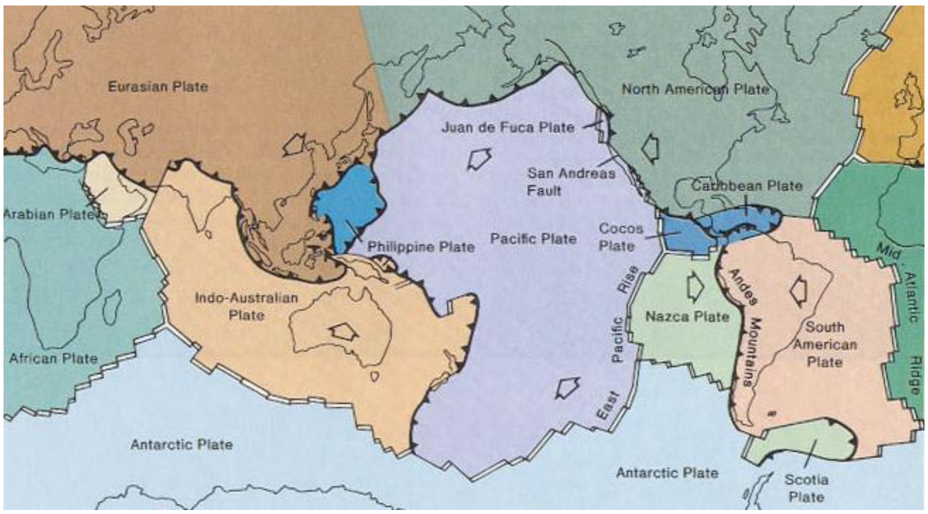

Fig 2.2: Crust Divided into number of Major and Minor Plates and its Plate Boundaries

- Tectonic earthquakes result from motion between these plates. The plates are driven by the convective motion of the material in the Earth's mantel, which in turn is driven by heat generated at the Earth's core.

- Three types of plate boundaries are defined according to their relative motion: zones of spreading, zones of relative lateral motion (transform faults), and zones of convergence, where plates collide. Figure 2.3 shows types of plate boundaries with associated land forms.

- In certain areas the plates move apart from each other at boundaries known as spreading ridges or spreading rifts. Molten rock from the underlying mantle rises to the surface where it cools and becomes part of the spreading plates.

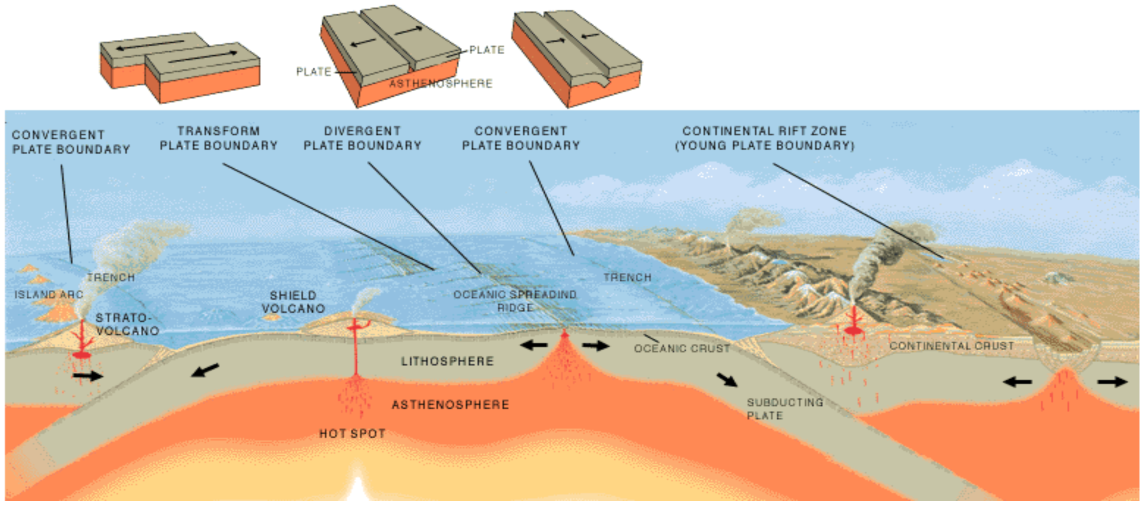

Fig 2.3: Convergent, Divergent and Transform Plate Boundary

- Subduction occurs when the relative movement of two plates is toward each other. When the rate of plate convergence is high, a trench is formed at the boundary between plates. Earthquakes are generated at the interface between the subducting and overriding plates.

- When plates move towards each other continental collisions can lead to the formation of mountain ranges. Example: Himalayas formed due to collision of Australia-Indian plate with Eurasian plate.

- Transform plate boundaries are unique, in that the plates move horizontally past each other on strike-slip faults. Lithosphere is neither created nor destroyed. Transform plate boundaries are shearing zones where plates move past each other without diverging or converging. In the shearing process, secondary features are created, including parallel ridges and valleys, pull-apart basins, and belts of folds. Compression and extension develop only in small areas.

- Relative plate motion at the fault interface is constrained by friction (areas of interlocking due to protrusions in the fault surfaces); strain energy accumulates in the plates, eventually overcomes any resistance, and causes slip between the two sides of the fault. This sudden slip, termed as elastic rebound, releases large amount of energy which constitutes **The Earthquake**.

Topic 4

Elastic Rebound Theory

- Following the great 1906 San Francisco earthquake, Henry Feilding Reid examined the displacement of the ground surface around the San Andreas Fault.

- From his observations he concluded that the earthquake must have been the result of the elastic rebound of previously stored elastic strain energy in the rocks on either side of the fault.

- The elastic rebound theory states that an earthquake is the sudden reaction of the earth's overly strained crust "snapping back" along the fault (Figure 2.4).

- Elastic rebound theory states that as tectonic plates move relative to each other, elastic strain energy builds up along their edges in the rocks along fault planes. Since fault planes are not usually very smooth, great amounts of energy can be stored (if the rock is strong enough) as movement is restricted due to interlock along the fault. When the shearing stresses induced in the rocks on the fault planes exceed the shear strength of the rock, rupture occurs.

- The elastic rebound theory is an explanation for how energy is spread during earthquakes. As plates on opposite sides of a fault are subjected to force and shift, they accumulate energy and slowly deform until their internal strength is exceeded. At that time, a sudden movement occurs along the fault, releasing the accumulated energy, and the rocks snap back to their original undeformed shape.

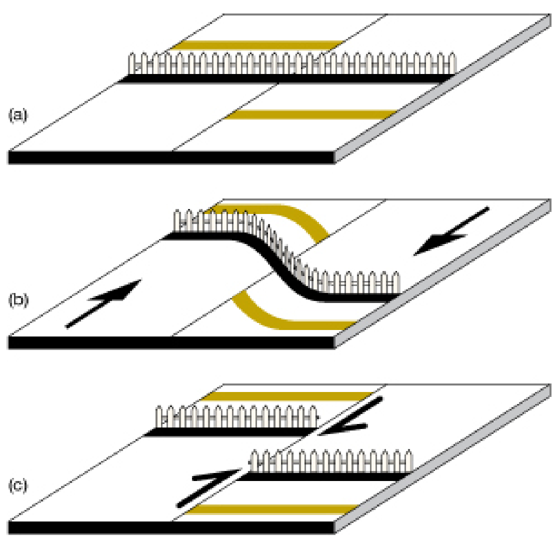

Fig 2.4: Elastic Rebound

(a) Initial Time- The fence is built straight across the fault trace.
(b) After Several Years- Tectonic movement occurs, but the edges of the crustal blocks are restrained by friction along the fault, and the ground and fence bend. Elastic strain energy builds up.
(c) Following Rupture- The edges of the blocks along the fault try to "catch up" with the middle as they release their strain energy during the rupture, but don't quite make it due to fault drag. Now the fence is offset and slightly curved.

Topic 5

Continental Drift and Plate Tectonics

- In geology, Rodinia (meaning "homeland") is the name of a super continent, a continent which contained most or all of Earth's landmass. According to plate tectonic reconstructions, Rodinia existed between 1100 and 750 million years ago, in the Neoproterozoic era.

- In 1915, the German geologist and meteorologist Alfred Wegener first proposed the theory of continental drift, which states that parts of the Earth's crust slowly drift atop a liquid core. The fossil record supports and gives credence to the theories of continental drift and plate tectonics.

- Wegener hypothesized that there was a gigantic super continent 200 million years ago, which he named Pangaea, meaning "All-earth" in Greek.

- Pangaea started to break up into two smaller super continents, called Laurasia and Gondwanaland, during the Jurassic period. By the end of the Cretaceous period, the continents were separating into land masses that look like our modern-day continents.

- The current continental and oceanic plates are mentioned below. These plates consist of smaller sub-plates.

Major Plates

- African Plate
- Antarctic Plate
- Eurasian Plate
- Indo-Australian Plate
- North American Plate
- Pacific Plate
- South American Plate

Minor Plates

These smaller plates are generally shown on major plate maps, but with the exception of the Arabian plate which do not comprise significant land area.

- Arabian Plate
- Caribbean Plate
- Cocos Plate
- Juan de Fuca Plate

- Nazca Plate
- Philippine Sea Plate
- Scotia Plate

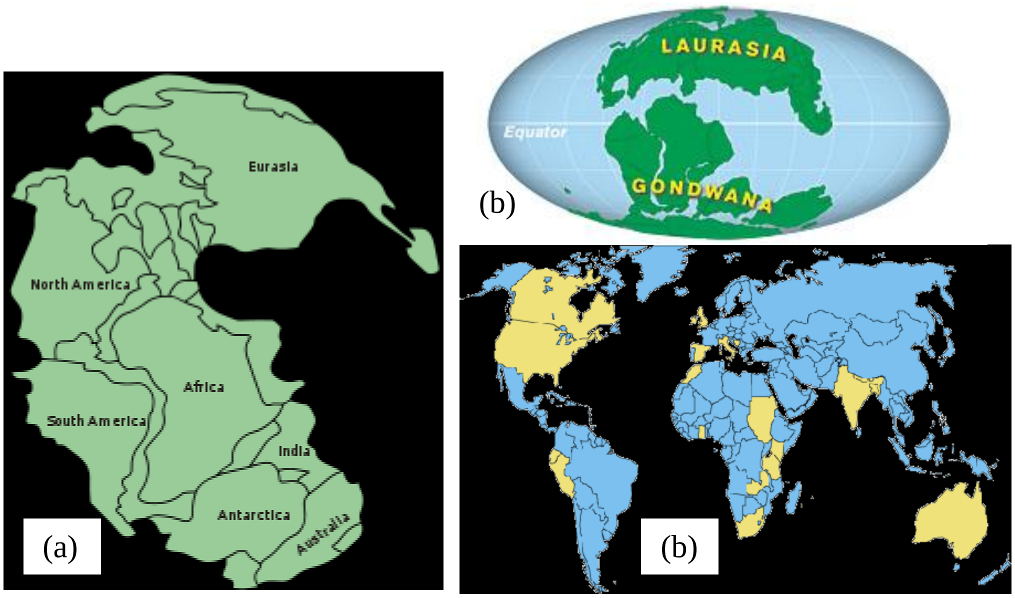

Fig 2.5: (a) Pangaea 200 million years ago, (b) Laurasia and Gondwana 150 million years ago, (c) Present day Earth (Clock wise)

http://en.wikipedia.org/wiki/File:Pangea_animation_03.gif

Topic 6

Major Subduction Zones in the World

- Long thin blades of magma rise to the surface along the mid-ocean ridges, where they cool and begin to subside as they get pushed away bilaterally as more oceanic crust is created.

- Millions of years after being created at a mid-ocean ridge, the crust encounters trenches along the ocean rim, where the crust then sinks, or subducts, descending back into the earth's mantle.

- At these places called subduction zones, the surface layers of rock plunge into the earth's interior. The Pacific Plate is getting smaller.

- As a plate bends downward at the ocean troughs, such as the Japan Trench, it fractures, generating shallow earthquakes. In the process of its downward movement, additional force is generated, causing further deformation, fracturing and mineral dehydration, thus giving rise to deep focus earthquakes (Fig.2.6).

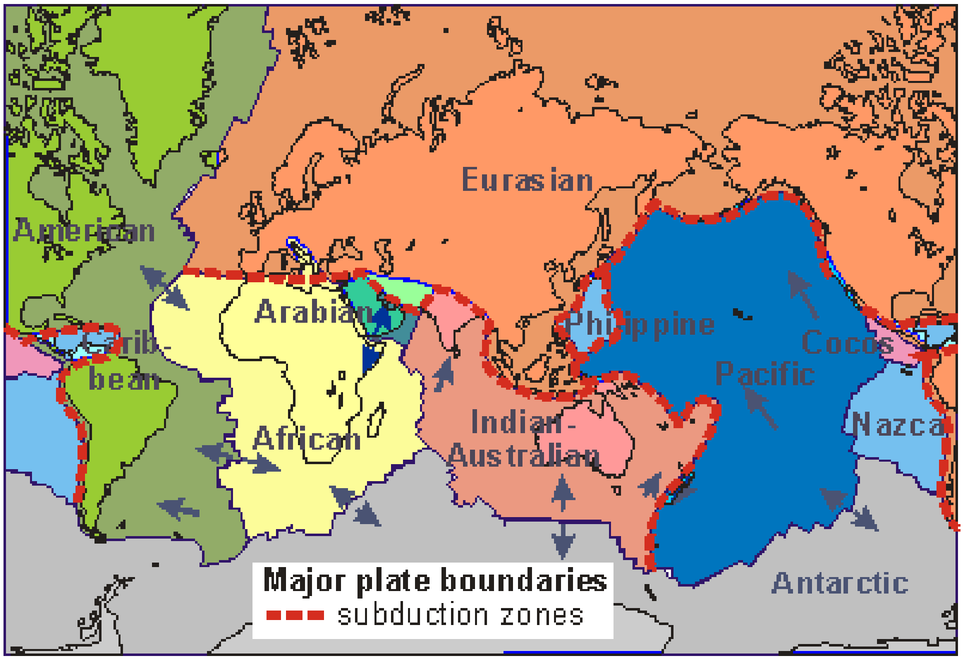

Fig 2.6: Major Subduction Zones in the World

Topic 7

Major Spreading zones in the world

- Magma is continually upwelling at the midoceanic ridges and rising as the seafloor spreads apart. This newly emplaced rock then moves slowly across the earth’s surface as new seafloor on either side of the ridge.
- In this way, plates extend and move at a uniform speed of a few to 10 centimeter per year across the planet’s surface, like great conveyor belts, cooling and aging as they get farther away from the ridges, hence midoceanic ridges and rises are called spreading zones.
- Figure 2.7 shows major spreading zones in the world
- At present the plates containing Africa, Antarctica, North America and South America are growing.

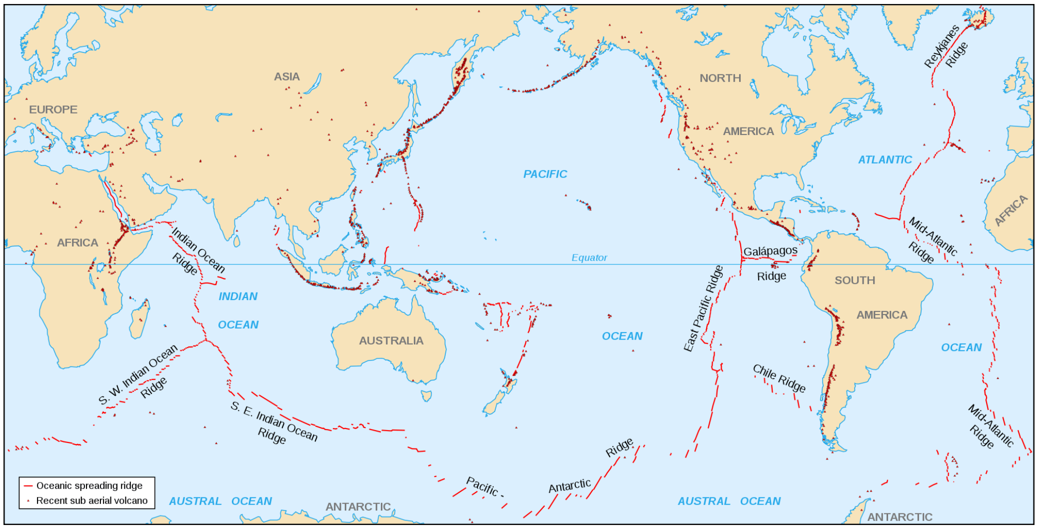

Fig 2.7: Major Spreading zones in the world

Topic 8

Major Thrust Faults in the world

- Faults are the physical expression of the boundaries between adjacent tectonic plates. Faults are typically classified according to their sense of motion. Basic terms include transform or strike slip, dip slip, normal, reverse and thrust faulting.

- A thrust fault is a special type of reverse fault which occurs when the fault plane has a small dip angle (less than 45°). Very large movements can be produced by thrust faulting; the European Alps are an excellent example of thrust structure.

- Figure 2.8 shows Major Thrust Faults in the world

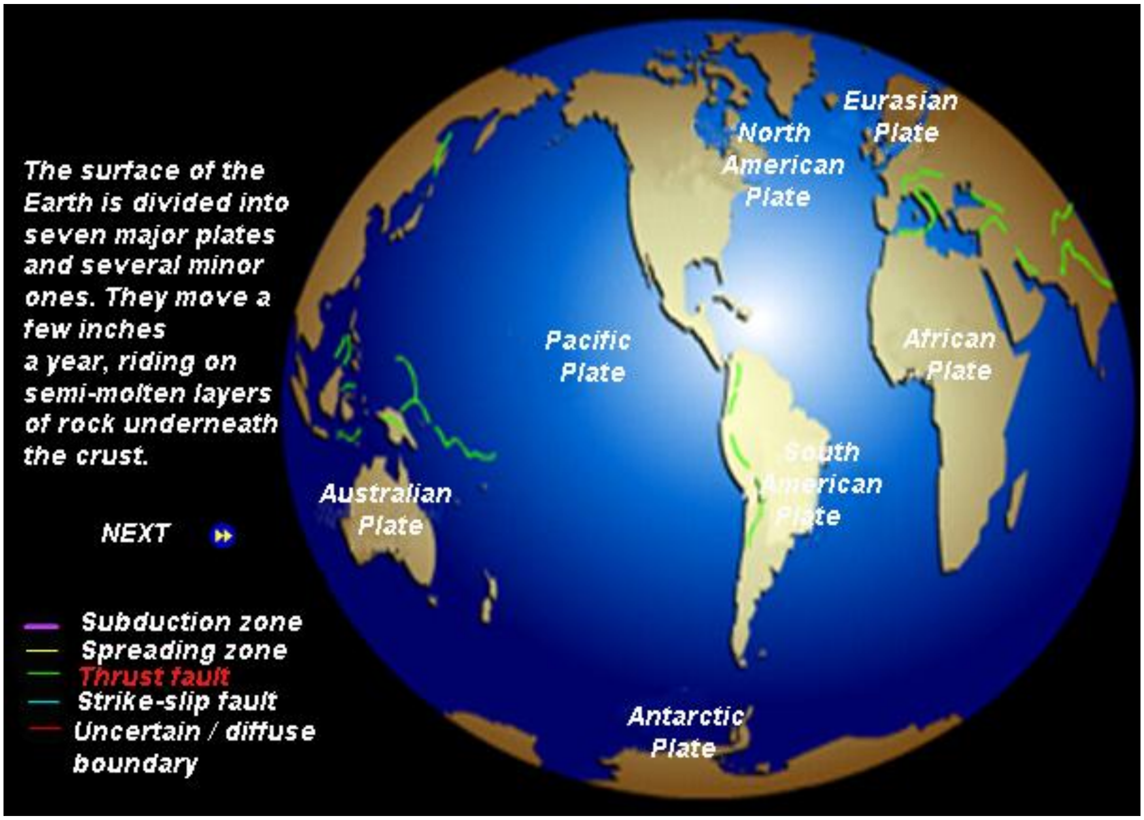

Fig 2.8: Major Thrust Faults in the world

Topic 9

Major Strike Slip Faults in the world

- Faulting that causes only horizontal displacements along the strike of the fault are called transcurrent, or strike-slip. Fault movement occurring parallel to the strike is called strike slip movement. Strike slip faults are usually nearly vertical and can produce large movements.
- Strike slip faults are further categorized by the relative direction of movement of the materials on either side of the fault. The San Andreas Fault in California is an excellent example of right lateral strike-slip faulting; in the 1906 San Francisco earthquake, several roads and fences north of San Francisco were offset by nearly 6 m.
- Figure 2.9 shows strike slip faults in the world

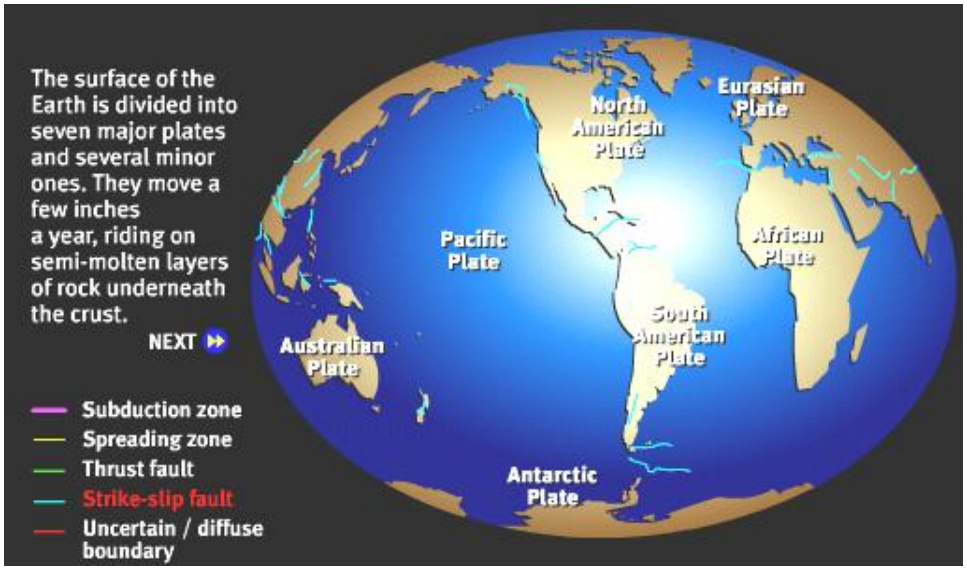

Fig 2.9: Major Strike Slip Faults in the world

Topic 10

Uncertain/Diffuse Boundaries in the World

- Although the plate tectonics theory is remarkably successful in explaining geological observations in most part of the world, the broad crustal deformation in the western North America, the Andes, and the Himalayan-Tibetan plateau accentuates the significance of diffuse plate boundary deformation.

- Attempts of understanding the geodynamics of diffuse plate boundary deformation in the past few decades have propelled modern geosciences to advance from the kinematic of plate tectonics theory towards a more integrated understanding of the dynamics of the Earth system [Molnar, 1988]. Continued studies are made more imperative by the fact that these diffuse plate boundaries are prone to geological hazards, whereas human densely populates many parts of these boundaries.

- The diffuse plate boundary deformation is the results of the relatively weak continents.

End of Lecture 2 in Early Engineering Seismology, Understanding of Earthquakes, Continental Drift and Major fault Zones.