What Causes Earthquakes?

The Earth and its Interior

Long time ago, a large collection of material masses coalesced to form the Earth. Large amount of heat was generated by this fusion, and slowly as the Earth cooled down, the heavier and denser materials sank to the center and the lighter ones rose to the top. The differentiated Earth consists of the *Inner Core* (radius ~1290*km*), the *Outer Core* (thickness ~2200*km*), the *Mantle* (thickness ~2900*km*) and the *Crust* (thickness ~5 to 40*km*). Figure 1 shows these layers. The Inner Core is solid and consists of heavy metals (*e.g.*, nickel and iron), while the Crust consists of light materials (*e.g.*, basalts and granites). The Outer Core is liquid in form and the Mantle has the ability to flow. At the Core, the temperature is estimated to be ~2500°C, the pressure ~4 million *atmospheres* and density ~13.5 *gm/cc*; this is in contrast to ~25°C, 1 *atmosphere* and 1.5 *gm/cc* on the surface of the Earth.

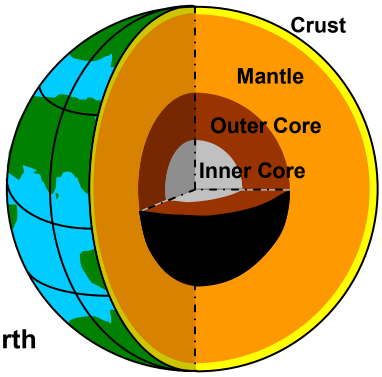

Figure 1: Inside the Earth

The Circulations

Convection currents develop in the viscous Mantle, because of prevailing high temperature and pressure gradients between the Crust and the Core, like the convective flow of water when heated in a beaker (Figure 2). The energy for the above circulations is derived from the heat produced from the incessant decay of radioactive elements in the rocks throughout the Earth's interior. These convection currents result in a *circulation* of the earth's mass; hot molten lava comes out and the cold rock mass goes into the Earth. The mass absorbed eventually melts under high temperature and pressure and becomes a part of the Mantle, only to come out again from another location, someday. Many such local circulations are taking place at different regions underneath the Earth's surface, leading to different portions of the Earth undergoing different directions of movements along the surface.

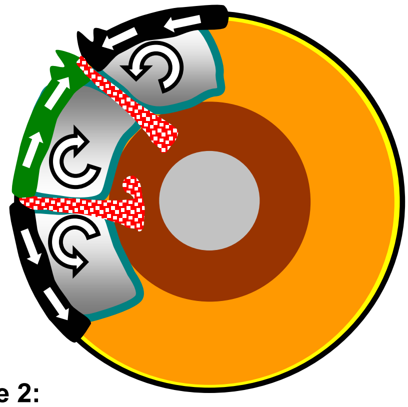

Figure 2: Local Convective Currents in the Mantle

Plate Tectonics

The convective flows of Mantle material cause the Crust and some portion of the Mantle, to slide on the hot molten outer core. This sliding of Earth's mass takes place in pieces called *Tectonic Plates*. The surface of the Earth consists of seven major tectonic plates and many smaller ones (Figure 3). These plates move in different directions and at different speeds from those of the neighbouring ones. Sometimes, the plate in the front is slower; then, the plate behind it comes and collides (and *mountains* are formed). On the other hand, sometimes two plates move away from one another (and *rifts* are created). In another case, two plates move side-by-side, along the same direction or in opposite directions. These three types of inter-plate interactions are the *convergent*, *divergent* and *transform* boundaries (Figure 4), respectively. The convergent boundary has a peculiarity (like at the Himalayas) that sometimes neither of the colliding plates wants to sink. The relative movement of these plate boundaries varies across the Earth; on an average, it is of the order of a couple to tens of *centimeters per year*.

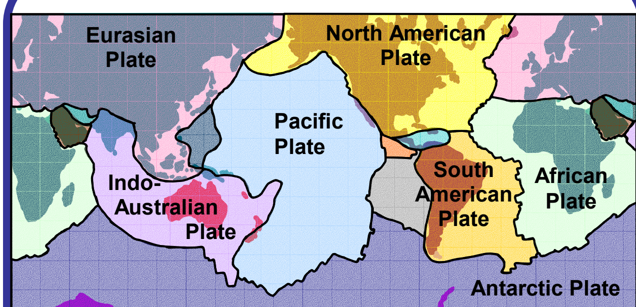

Figure 3: Major Tectonic Plates on the Earth's surface

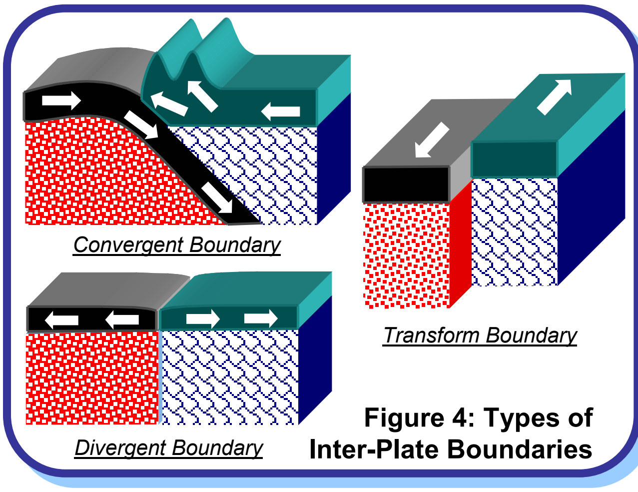

Figure 4: Types of Inter-Plate Boundaries

The Earthquake

Rocks are made of elastic material, and so elastic strain energy is stored in them during the deformations that occur due to the gigantic tectonic plate actions that occur in the Earth. But, the material contained in rocks is also very brittle. Thus, when the rocks along a weak region in the Earth's Crust reach their strength, a sudden movement takes place there (Figure 5); opposite sides of the *fault* (a crack in the rocks where movement has taken place) suddenly *slip* and release the large elastic strain energy stored in the interface rocks. For example, the energy released during the 2001 Bhuj (India) earthquake is about 400 times (or more) that released by the *1945 Atom Bomb* dropped on Hiroshima!!

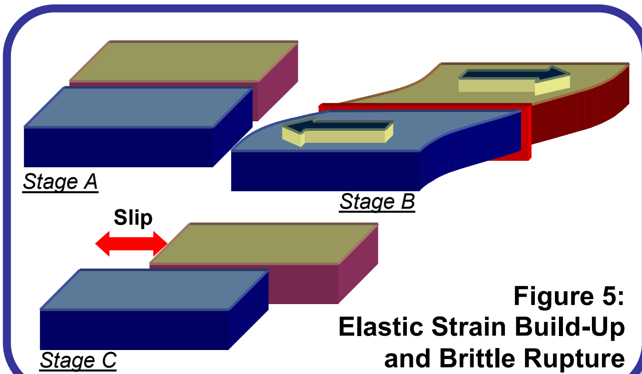

Figure 5: Elastic Strain Build-Up and Brittle Rupture

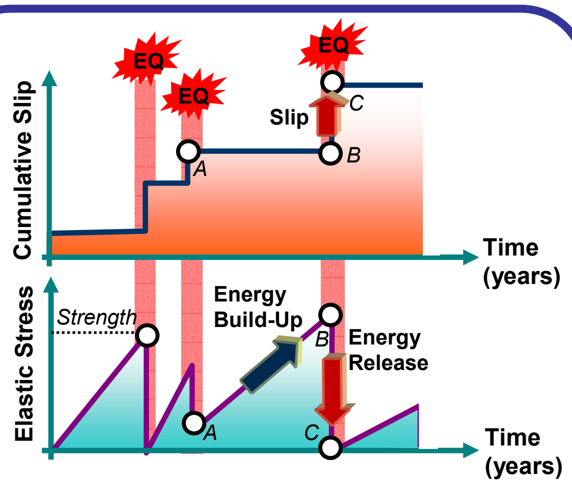

Figure 6: Elastic Rebound Theory

The sudden slip at the fault causes *the earthquake*…. a violent shaking of the Earth when large elastic strain energy released spreads out through seismic waves that travel through the body and along the surface of the Earth. And, after the earthquake is over, the process of strain build-up at this modified interface between the rocks starts all over again (Figure 6). Earth scientists know this as the *Elastic Rebound Theory*. The material points at the fault over which slip occurs usually constitute an oblong three-dimensional volume, with its long dimension often running into tens of kilometers.

Types of Earthquakes and Faults

Most earthquakes in the world occur along the boundaries of the tectonic plates and are called *Inter-plate Earthquakes* (*e.g.*, 1897 Assam (India) earthquake). A number of earthquakes also occur within the plate itself away from the plate boundaries (*e.g.*, 1993 Latur (India) earthquake); these are called *Intra-plate Earthquakes*. In both types of earthquakes, the slip generated at the fault during earthquakes is along both vertical and horizontal directions (called *Dip Slip*) and lateral directions (called *Strike Slip*) (Figure 7), with one of them dominating sometimes.

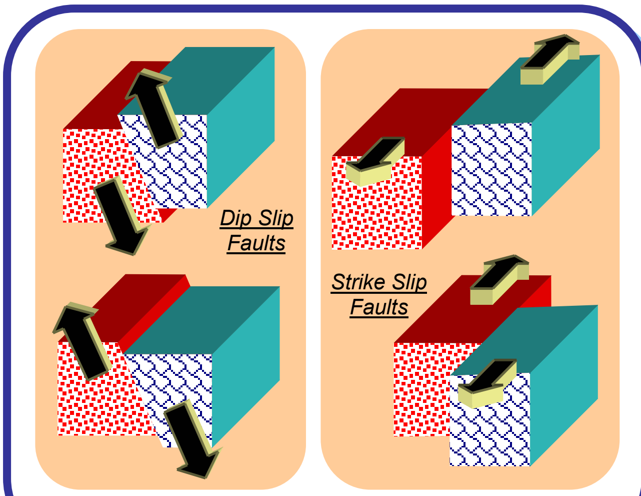

Figure 7: Type of Faults

Reading Material

Bolt,B.A., (1999), *Earthquakes*, Fourth Edition, W. H. Freeman and Company, New York, USA
http://earthquake.usgs.gov/faq/
http://neic.usgs.gov/neis/general/handouts/general_seismicity.html
http://www.fema.gov/kids/quake.htm

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