

OCN 201 L – Fall 2009

Plate Tectonics

This laboratory supports the material covered in OCN 201 lectures on Seafloor Spreading and Plate Tectonics.

KEY WORDS: Continental drift, Seafloor spreading, Plate tectonics, Mid ocean ridge (MOR) system, Spreading center, Divergent plate boundary, Convergent plate boundary, Subduction zone, Suture zone, Deep ocean trench, Conservative plate boundary, Transform fault, Strike slip fault, Fracture zone, Earthquakes, Oceanic crust, Continental crust, Upwelling, Convection.

Introduction

Geologists have hypothesized that the outer 60-100 km of the Earth are composed of approximately seven principal slabs of rigid lithospheric (rock) material. These slabs, known as **plates**, account for most of the dynamic features of the crust of the Earth. These include earthquakes, mountain chain building, and volcanic eruptions. The hypotheses developed to explain the presence of and interactions between these plates have been widely tested and are generally accepted today. They were, however, quite controversial when they were first proposed some thirty-five years ago. The concepts behind these hypotheses are now collectively known as **plate tectonics** and have been advanced from hypotheses to the level of a theory.

The theory of plate tectonics evolved from the hypothesis of **continental drift**, proposed by Alfred Wegener in the early part of the 20th century. Wegener hypothesized that continental masses plow through oceanic rock. Because oceanic rock is more rigid than continental rock, and because he failed to provide an acceptable mechanism to account for the way continents could have drifted great distances (not to mention the fact that Wegener was a meteorologist) his ideas were widely rejected. In the subsequently developed hypotheses of seafloor spreading and plate tectonics, however, there was no problem of continents plowing through oceanic rock. Instead, rigid plates, including those with continents, simply move about relative to one another. Much evidence acquired in the early 1960's and subsequently, provided strong support for the new hypothesis, and plate tectonics enjoyed wide-ranging support from earth scientists. It is now regarded as a theory.

The boundaries between lithospheric plates are zones of considerable deformation caused by the motions of the plates. These zones are characterized by abundant earthquakes, which, more than any other characteristic, define clearly the different types of plate boundaries.

Boundaries between crustal plates

The first type of plate boundary is found on the **mid ocean ridge (MOR) system** (e.g., the Mid Atlantic Ridge, the East Pacific Rise), where lava of basaltic composition upwells from mantle and flows out onto the ocean floor where it cools and solidifies to create new **oceanic crust**. The young crust is then pulled apart as additional lava comes up and newer crust is formed along the center of the ridge. As a result of this process, oceanic crust moves outward (horizontally) on both sides of an oceanic ridge, and new crust is continually added to older oceanic crust. This type of plate boundary is known as a **divergent plate boundary**, ridge, or rise where the dominant force is tension (i.e., PULLING apart).

Creation of new crust along ridges must be balanced by consumption (or destruction) of existing crust elsewhere. Many plates are bound by zones where rigid crust descends deep into the mantle and the crust is ultimately reabsorbed. These plate boundaries are known as **subduction zones**. The dominant force is compression (i.e., PUSHING together). There are three types of **convergent boundaries**:

- 1) **Oceanic vs. Continental convergent plate boundaries**, where dense oceanic crust converges with less dense continental crust. The denser oceanic crust descends below the continental crust.
- 2) **Oceanic vs. Oceanic convergent plate boundaries**, where oceanic crust collides with oceanic crust from another plate. The older (cooler and denser) plate descends and the younger (warmer and less dense) plate overrides.
- 3) **Continental vs. Continental convergent plate boundaries**, where two continental slabs encounter each other, a more complex convergent plate boundary occurs. The interaction between these slabs causes intense deformation and mountain building, leading to the formation of a **suture zone**.

The third type of plate boundary occurs where compensating motion takes place without creating or consuming crust and plates slide past each other. These **conservative plate boundaries** are characterized by long faults between the adjoining plates that are known as **transform faults** (i.e., one feature is “transformed” into another). They occur where new crust zones (i.e., ridges or rises) abruptly end. These plate boundaries are called **transform plate boundaries**. The physiographic features formed by the transform faults and their extensions beyond the region connecting two sections of ridge are called **fracture zones**. Note that the extensions of the fracture zones beyond the active ridge segments DO NOT separate different plates but are embedded within a single plate.

Major lithospheric plates of the Earth

There are seven major lithospheric plates on the rigid outer surface of the Earth. Several smaller plates, as well as regions of extremely complex tectonic morphology exist and complete the puzzle of the Earth’s plate tectonic structure. The latter will not be considered in this laboratory exercise. In the attached diagram of the Earth’s plates and that showing the location of major earthquake epicenters (Fig. 1), note that the zones of earthquakes coincide with plate

boundaries. There is, however, a major distinction between the various zones in terms of the depth of occurrence of the earthquakes. Shallow earthquakes occur at the MOR and along transform faults, whereas deeper earthquakes occur at subduction zones, with the deepest ones located at substantial distances beyond where the descending slab begins to be subducted. For example, the deepest earthquakes associated with the Peru-Chile trench occur well eastward of the Andes mountains of South America (see Fig. 1).

Figure 1: Major lithospheric plates and locations of epicenters of earthquakes throughout the world.

