4.4: Plates and Plate Motions

The idea of plate tectonics became widely accepted around 1965 as more and more geologists started thinking in these terms. By the end of 1967, Earth’s surface had been mapped into a series of plates (Figure \(\PageIndex{1}\)). The major plates are Eurasia, Pacific, India, Australia, North America, South America, Africa, and Antarctic. There are also numerous small plates (e.g., Juan de Fuca, Nazca, Scotia, Philippine, Caribbean), and many very small plates or sub-plates. For example the Juan de Fuca Plate is actually three separate plates (Gorda, Juan de Fuca, and Explorer) that all move in the same general direction but at slightly different rates.

The fact that the plates include both crustal material and lithospheric mantle material makes it possible for a single plate to be made up of both oceanic and continental crust. For example, the North American Plate includes most of North America, plus half of the northern Atlantic Ocean. Similarly the South American Plate extends across the western part of the southern Atlantic Ocean, while the European and African plates each include part of the eastern Atlantic Ocean. The Pacific Plate is almost entirely oceanic, but it does include the part of California west of the San Andreas Fault.

Rates of motions of the major plates range from less than 1 cm/year to over 10 cm/year (for comparison, human fingernails grow at around 6 cm/year). The Pacific Plate is the fastest at over 10 cm/year in some areas, followed by the Australian and Nazca Plates. The North American Plate is one of the slowest, averaging around 1 cm/year in the south up to almost 4 cm/year in the north. Plates move as rigid bodies, so it may seem surprising that the North American Plate can be moving at different rates in different places. The explanation is that plates move in a rotational manner. The North American Plate, for example, rotates counter-clockwise; the Eurasian Plate rotates clockwise.
As originally described by Wegener in 1915, the present continents were once all part of the supercontinent Pangaea. More recent studies of continental match-ups and the magnetic ages of ocean-floor rocks have enabled us to reconstruct the history of the break-up of Pangaea.

Pangaea began to rift apart along a line between Africa and Asia and between North America and South America at around 200 Ma (Figure 1). During the same period, the Atlantic Ocean began to open up between northern Africa and North America, and India broke away from Antarctica. At this stage, Pangaea was divided into Laurasia (now Europe, Asia and North America) and Gondwanaland (the southern continents; South America, Africa, India, Australia, and Antarctica). Between 200 and 150 Ma, rifting started between South America and Africa and between North America and Europe, and India separated from Antarctica and moved north toward Asia. By 80 Ma, Africa had separated from South America, and most of Europe had separated from North America. By 50 Ma, Australia had separated from Antarctica, and shortly after that, India collided with Asia.
Within the past few million years, rifting has taken place in the Gulf of Aden and the Red Sea, and also within the Gulf of California. Incipient rifting has begun along the Great Rift Valley of eastern Africa, extending from Ethiopia and Djibouti on the Gulf of Aden (Red Sea) all the way south to Malawi.

Over the next 50 million years, it is likely that there will be full development of the east African rift and creation of new ocean floor. Eventually Africa will split apart. There will also be continued northerly movement of Australia and Indonesia. The western part of California (including Los Angeles and part of San Francisco) will split away from the rest of North America, and eventually sail right by the west coast of Vancouver Island, en route to Alaska. Because the oceanic crust formed by spreading on the mid-Atlantic ridge is not currently being subducted (except in the Caribbean), the Atlantic Ocean is slowly getting bigger, and the Pacific Ocean is getting smaller. If this continues without changing for another couple hundred million years, we will be back to where we started, with one supercontinent.

Pangaea, which existed from about 350 to 200 Ma, was not the first supercontinent. In 1966, Tuzo Wilson proposed that there has been a continuous series of cycles of continental rifting and collision; that is, break-up of supercontinents, drifting, collision, and formation of other supercontinents. Pangaea was preceded by Pannotia (600 to 540 Ma), by Rodinia (1,100 to 750 Ma), and by other supercontinents before that.

With all of these plates constantly on the move, they inevitably end up interacting with each other at their plate boundaries. Plates can interact in three ways: they can move apart (divergent boundary), they can move towards each other (convergent boundary), or they can slide past each other (transform boundary).
boundary), or they can slide past each other (transform boundary). The following sections will examine each of these types of plate boundaries, and the geological features they create.

Additional links for more information:

- An interactive animation of plate motion over the past 550 million years: [http://barabus.tru.ca/geol1031/plates.html](http://barabus.tru.ca/geol1031/plates.html)