Investigation 4A

Plate Tectonics in Action

Objectives

The theory of continental drift, later expanded into plate tectonics, transformed our understanding of Earth's surface. These theories explain how the movement of tectonic plates shapes features like mid-ocean ridges, deep trenches, and underwater mountain chains, reflecting the movement and interaction of tectonic plates over time.

In this investigation, we will:

- Identify major bathymetric features and explain their relationship to tectonic plate boundaries
- Interpret maps to describe how seafloor spreading and subduction influence the distribution of earthquakes, volcanic eruptions, and the age and structure of the oceanic crust
- Distinguish between divergent, convergent, and transform plate boundaries by matching each type to its characteristic geological features

Evidence of Continental Drift

Earth's topography and bathymetry, along with other evidence, led to the hypothesis of continental drift. In the early 20th century, the **continental drift** hypothesis posited that Earth's continents have moved over geologic time, appearing to drift across the ocean floor. **Figure 2A-1** shows the bathymetry and topography of Earth. Bathymetry is depicted in shades of blue, with shallower areas represented by lighter shades of blue and deeper areas by darker shades of blue. Topography is shown with low elevations in green and yellow and higher elevations in brown and white.

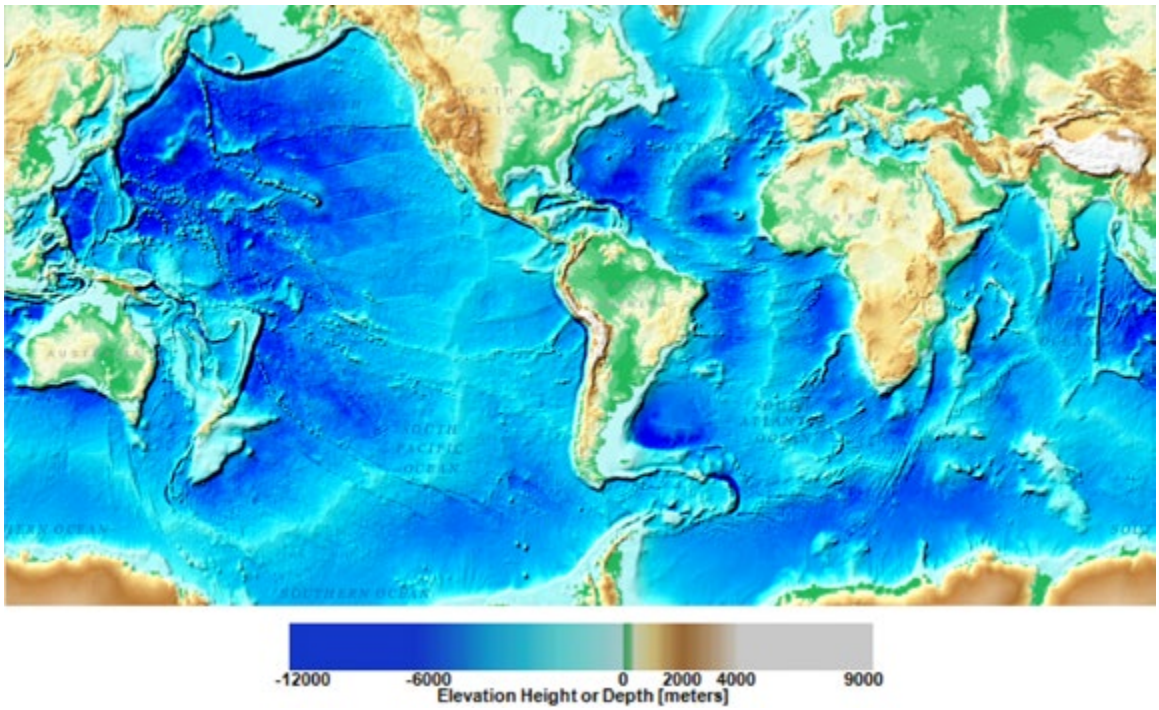

Figure 4A-1. The topography and bathymetry of Earth from satellite measurements. [ESRI, 2025]

1. Study the bathymetry in Figure 4A-1. **Oceanic ridges**, underwater mountain ranges, are shown in lighter shades of blue and are found primarily _____ of the ocean basins. In contrast, o**ceanic trenches**, deep, narrow depressions shown in dark blue, are mainly located _____ of the ocean basins.

    a. in the centers ... along the edges
    b. along the edges ... in the centers

Tectonic processes are responsible for shaping these bathymetric features. At mid-ocean ridges, **seafloor spreading** occurs as tectonic plates move apart and new oceanic crust forms. In contrast, **subduction** occurs at oceanic trenches, where one plate is forced beneath another and descends into Earth's mantle.

2. Next to subduction zones, there are _____.

    a. mountains or island chains
    b. rolling hills
    c. flat abyssal plains
    d. wide, gradually sloping continental shelves

Geological processes associated with tectonic movements include earthquakes, volcanism, and mountain building. Seafloor spreading and subduction are the primary causes of most earthquakes and volcanic eruptions. **Figure 4A-2** displays global earthquakes from 2015 to 2025, color-coded by depth: shallow earthquakes appear in blue, while deeper ones are shown in red. Earthquake strength is represented using the *Moment Intensity Scale*, with larger circles indicating more intense seismic events.

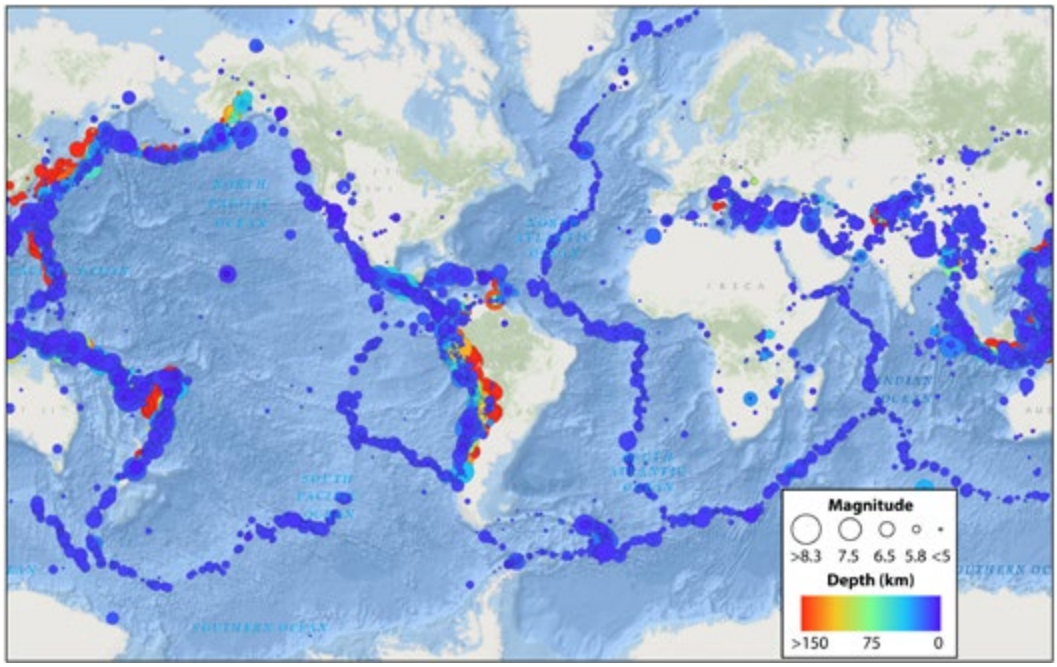

Figure 4A-2. Earthquakes that occurred from 2015 to 2025 with the symbols color-coded by depth and sized by magnitude. [Data from USGS, 2025]

3. Compare Figure 4A-1 and Figure 4A-2. Mid-ocean ridges have mainly _____ earthquakes, while _____ earthquakes occur mainly near ocean trenches.

   a. shallow ... deep
   b. deep ... shallow

4. Examine the western coast of South America. Deeper earthquakes generally occur under the _____ side of the subduction zone.

   a. oceanic
   b. continental

Volcanic eruptions, like earthquakes, are closely linked to tectonic processes. They commonly occur near subduction zones, where melting of the descending plate into the mantle generates magma that rises to the surface. **Figure 4A-3** displays recorded volcanic eruptions from 1850 to 2025, represented by red triangles. The size of each triangle indicates the eruption's magnitude.

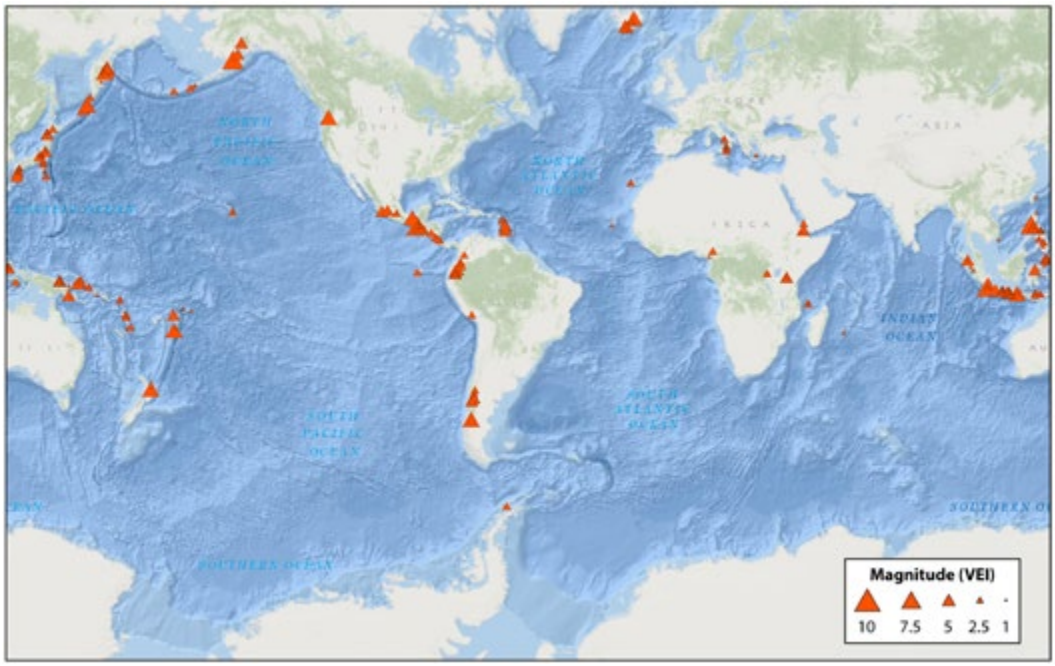

Figure 4A-3. Volcanic eruptions recorded from 1850 to 2025. Red triangles represent eruption locations, with triangle size indicating the Volcanic Explosivity Index. [Data from NCEI, 2025]

5. Most of the large volcanic eruptions occur along the edges of the _____ Ocean, leading this area to be commonly called “the ring of fire”.

    a. Atlantic
    b. Indian
    c. Pacific
    d. Southern

6. A large number of volcanoes occur along mid-ocean ridges. However, most documented eruptions occur on land rather than underwater. This is likely because _____.

    a. most volcanoes are found on continents
    b. it is very difficult to explore the deep ocean
    c. eruptions on land are generally stronger than underwater eruptions

Figure 4A-4 displays the seafloor age, or the age of the oceanic crust, with the youngest seafloor in red and the oldest seafloor in blue. We know the age of the seafloor through a combination of direct sampling and magnetic data. Scientists analyze the magnetic patterns preserved in oceanic crust, which record Earth’s magnetic field and its reversal over time. By comparing these patterns with a well-dated geomagnetic timeline, we can determine the age of seafloor rocks relative to their distance from mid-ocean ridges.

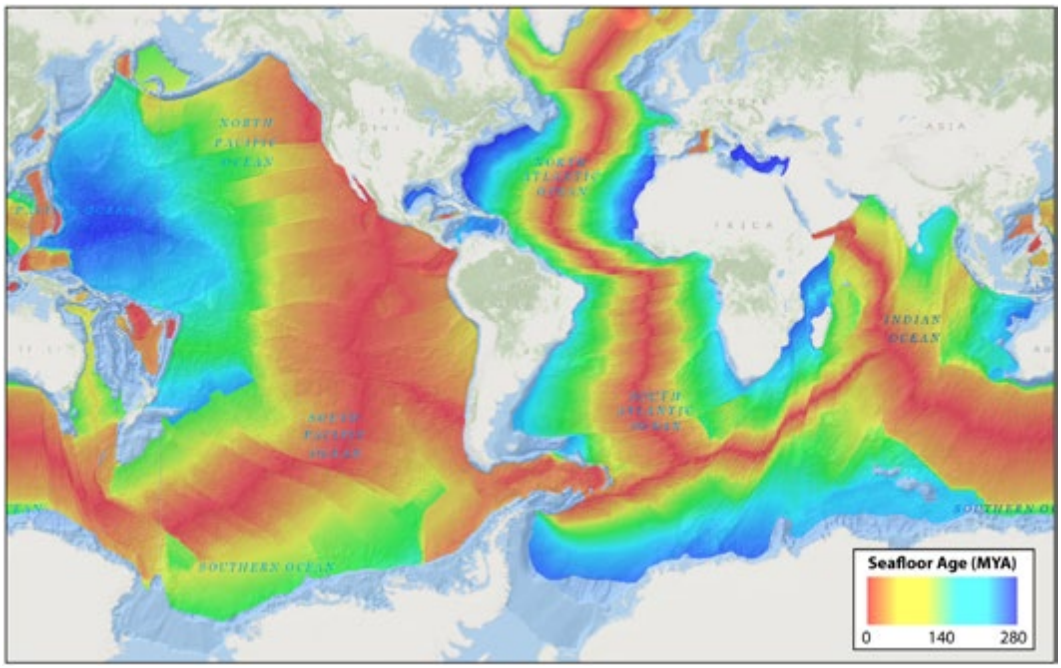

Figure 4A-4. This map shows the age of the seafloor, with red indicating the youngest crust near mid-ocean ridges and blue representing the oldest crust farther away. [Data from Müller, R.D. et al., 2008]

7. New oceanic crust is continuously formed at mid-ocean ridges, which would _____ the size of ocean basins over time if subduction did not _____ crust at a similar rate.

   a. increase ... create
   b. increase ... destroy
   c. decrease ... create
   d. decrease ... destroy

8. The _____ Ocean contains the largest area of old oceanic crust, suggesting that subduction on that side of the basin is very slow.

   a. Atlantic
   b. Indian
   c. Pacific
   d. Southern

9. In addition to these four variables (bathymetry and topography, depth and magnitude of earthquakes, volcanic eruption locations and intensity, and seafloor age), the presence of _____ offers further evidence that all the continents were once connected as part of a supercontinent.

   a. differences in mountain height
   b. symmetrical areas of active subduction
   c. similar jigsaw-like shapes

The theory of continental drift, along with additional evidence, led to the development of the theory of **plate tectonics**, which posits that the Earth's outer shell is divided into rigid plates that move over the

semi-fluid mantle beneath them, and the delineation of the current tectonic plates.

Tectonic Plates

Figure 4A-5 shows the major tectonic plates covering Earth's surface with red arrows for the direction each plate is moving. Earth's lithosphere is broken into a dozen major plates, and many smaller microplates, moving slowly across the surface of the planet. Plates moving apart form **divergent boundaries**, plates moving together form **convergent boundaries**, and plates sliding past one another form **transform plate boundaries**. Along plate boundaries, crustal materials are created, destroyed, or displaced.

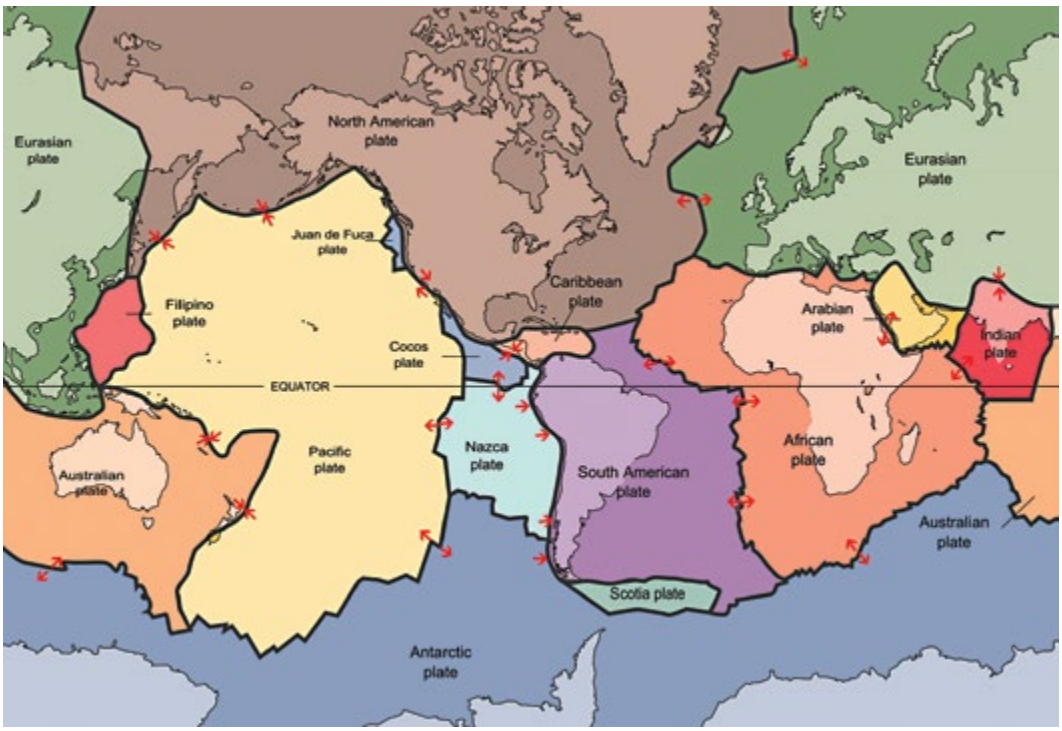

Figure 4A-4. Major tectonic plates that compose Earth's crust and upper mantle. Arrows show general plate movements. [Adapted from USGS]

Oceanic ridges, like the mid-Atlantic Ridge, form along spreading tectonic plate boundaries. Landmasses on either side of the Atlantic Ocean were once joined together in the supercontinent Pangaea. At the beginning of the current spreading cycle, the Atlantic Ocean began to spread, breaking up part of Pangaea.

10. The Mid-Atlantic Ridge features a narrow rift valley following a central axis. Magma seeps upward along the rift and adheres to the edge of either side of the ridge. The new material pushes each plate away from the central axis, as denoted by the red arrows. The Mid-Atlantic Ridge is a _____ boundary and most likely has _____.

    a. convergent ... volcanoes
    b. convergent ... strong, deep earthquakes
    c. divergent ... volcanoes
    d. divergent ... strong, deep earthquakes

11. Along the western edge of South America, there is an oceanic trench, the Peru-Chile trench, shown

in dark blue in Figure 4A-1. The trench is formed from a _____ boundary between the South American and _____ plates.

a. convergent ... Nazca
b. divergent ... Caribbean
c. transform ... Scotia

12. Transform boundaries occur at intervals along mid-ocean ridges where the spreading rates are slightly different and, notably, along the San Andreas fault in California, where the North American Plate slides along the _____ Plate.

a. Juan de Fuca
b. Pacific
c. Cocos
d. Nazca

13. Making the theory of plate tectonics difficult to study, nearly all plate boundaries occur _____.

a. in the oceans
b. on the continents

Summary

Plate tectonics provides the foundation for understanding the dynamic nature of Earth's surface, especially the formation and evolution of the oceans, from the creation of new crust at mid-ocean ridges to its destruction at subduction zones. These movements are responsible for the creation of mid-ocean ridges, deep-sea trenches, seafloor spreading, and subduction zones. Over millions of years, plate interactions have opened and closed ocean basins, recycled oceanic crust, and generated much of the seafloor topography observed today.

References

Figure 4A-1 – ESRI, 2025: TopoBathy. Accessed 21 July 2025, https://www.arcgis.com/home/item.html?id=c753e5bfadb54d46b69c3e68922483bc.

Figure 4A-2 – USGS, 2025: Earthquake interactive map. Accessed 21 July 2025, https://earthquake.usgs.gov/earthquakes/map/.

Figure 4A-3 – NCEI/WDS, 2025: Global significant volcanic eruptions database. Accessed 21 July 2025, https://doi.org/10.7289/V5JW8BSH.

Figure 4A-4 – Müller, R.D., M. Sdrolias, C. Gaina, and W.R. Roest, 2008: Age, spreading rates and spreading symmetry of the world's ocean crust. Geochem. *Geophys. Geosyst.*, **9**, Q04006, https://doi.org/10.1029/2007GC001743.

Figure 4A-5 – USGS, 2011: Moving slabs. Accessed 31 December 2024, https://pubs.usgs.gov/gip/dynamic/slabs.html.