

Expedition Objectives

- Learn about the types of plate boundaries and their key characteristics
- The vast majority of these plate boundaries are located beneath the oceans, and along several of the seafloor features that we identified on our transects of the ocean basins in a previous expedition.
- Remember to answer the questions below and take notes
- Required learning group discussion instructions at the end of this worksheet

Many of the figures in this worksheet and the expedition are derived from "This Dynamic Earth" by Jacqueline Kious and Robert Tilling of the U.S. Geological Survey. (<http://pubs.usgs.gov/publications/text/dynamic.html>)

Remember to use the worksheet to take notes just as if you were listening to a lecture!

This expedition has 45 minutes of video, so with taking notes, should take about an 80 minutes to complete. Begin at:

http://oceansjsu.com/105d/exped_boundaries/1.html

1. Introduction to Plate Boundaries

What types of events occur along plate boundaries? (see photos)

2. Plate Boundary Types

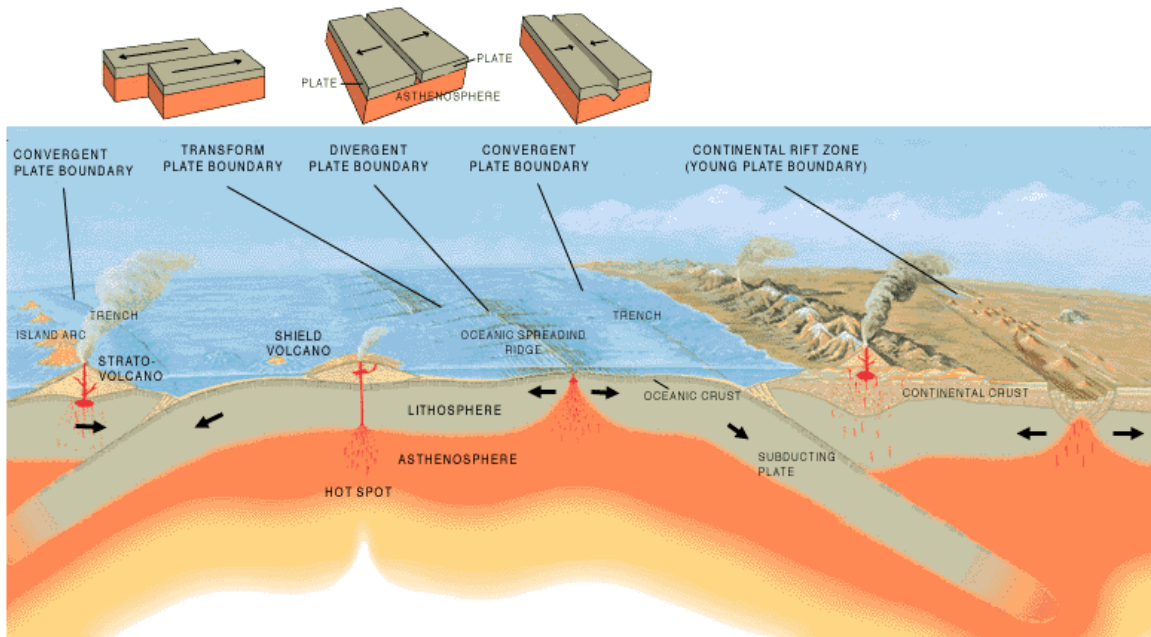
What are the three types of plate boundaries and describe the type of plate motion relative to the position of the plate boundary?

1. _____

2. _____

3. _____

From "This Dynamic Earth" by Jacqueline Kious and Robert Tilling of the U.S. Geological Survey.



This diagram illustrates how the seafloor is created at a divergent plate boundary by seafloor spreading and recycled by subduction at convergent plate boundaries

3. Divergent Boundaries

As the plates spread apart, hot portions of the mantle rise up beneath mid-ocean ridges
 - The divergent plate boundary at a mid-ocean ridge is often called a **spreading center** (where plates spread apart)

List the characteristics of a divergent plate boundary

What are the general locations of divergent plate boundary in the global ocean basins?

What is the age of the oceanic lithosphere at Point A and how far is A away from the plate boundary?

4. Calculating the Rate of Spreading

Show your calculation of (full) rate of seafloor spreading (both sides)

5. Forming Oceanic Lithosphere

What is magma?

How is magma formed at divergent plate boundaries?

How does magma form oceanic lithosphere at divergent plate boundaries?

What happens to the oceanic lithosphere after it is formed at a divergent plate boundary?

6. Age and Water Depth of Oceanic Lithosphere

Is there a relationship between water depth and age of the underlying oceanic lithosphere after it has formed by seafloor spreading?

7. Seafloor Profile Across a Mid-Ocean Ridge

View the seafloor profile across a mid-ocean ridge, collected with an echo profiler.

We have measured the water depths at a number of distances away from the divergent plate boundary and listed these data in the table on the webpage.

What is the range of water depths of the oceanic lithosphere (shallowest to deepest)?

Notice how the water depth increases with distance from the divergent plate boundary that is located in the rift valley of the mid-ocean ridge shown in your profile above.

8. Relationship of Water Depth to Age of Oceanic Crust and Lithosphere

The patterns of seafloor magnetism can be compared to the magnetic polarity time scale to assign ages to the oceanic crust and lithosphere with distance from the divergent plate boundaries and the water depth measured at each distance. These are given in the table on the webpage.

How does the age of the ocean crust change with distance away from the rift valley?

9. Water Depth Versus Age of Oceanic Lithosphere Relationship - The Equation

Does the water depth of the sea floor increase or decrease with increasing age of the oceanic crust and lithosphere? _____

Based on the square root of the age versus water depth plot, an empirical relationship can be developed between the water depth to the top of the oceanic crust (sea floor in this case) and the age of the crust at that location.

This relationship, developed from basic statistics, called a regression line, is:

$$D = 2500 + 350 T^{1/2}$$

where D = water depth in meters *and*
T = Age of the oceanic crust in Million Years

Remember $T^{1/2}$ means T raised to the 1/2 power or the square root of T

Science is often about making predictions, then testing these predictions with independent data.

Let's make a prediction using this age versus water depth relationship:

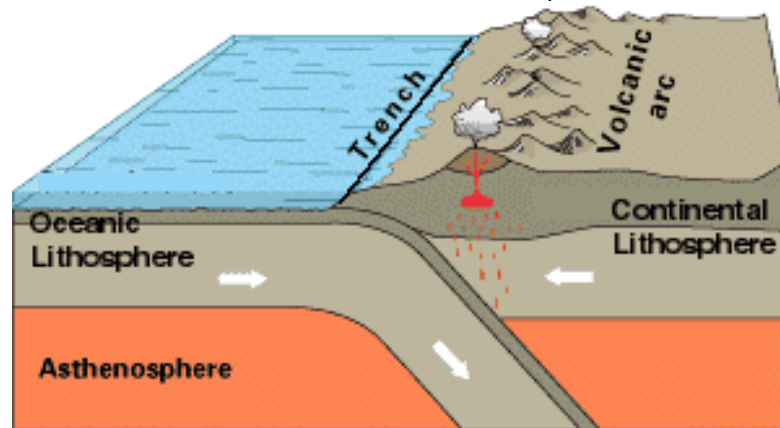
Predict the water depth you would expect to find above 16 million year-old oceanic crust?

$$D = 2500 + 350 (16)^{1/2} \Rightarrow D = 2500 + 350 (4)$$

$D = 2500 + 1400 = 3900$ meters -- this would be the water depth 16 million years after the crust formed by seafloor spreading

10. Convergent Plate Boundaries

Subduction is the process of recycling of the seafloor and oceanic lithosphere as the latter sinks back into the earth at deep-sea trenches.

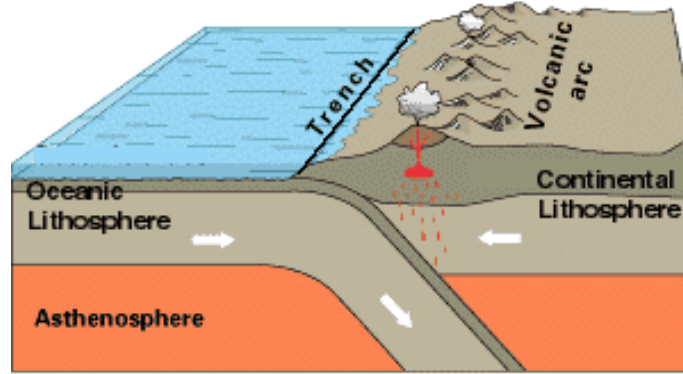


Oceanic-continental convergence

From "This Dynamic Earth" by Jacqueline Kious and Robert Tilling of the U.S. Geological Survey.

Why does the lithosphere sink back into the earth at trenches, which form the surface trace of subduction zones? (think about this one)

Where an oceanic plate meets a continental Plate at a convergent plate boundary, the oceanic plate (when old) descends back into the earth's mantle due to its high density (related to rock chemistry and temperature)

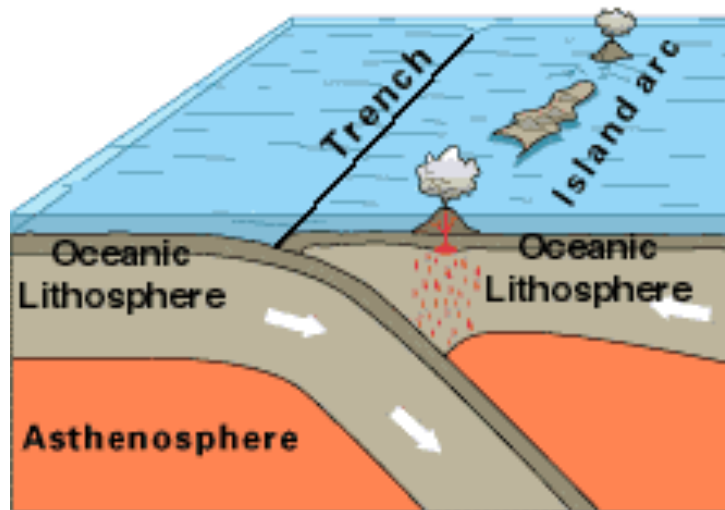


Oceanic-continental convergence

From "This Dynamic Earth" by Jacqueline Kious and Robert Tilling of the U.S. Geological Survey.

Where ocean lithosphere subducts beneath a continental lithosphere, a volcanic arc is built on the overriding continental plate - For example, Mount St. Helens, an active volcano in the Pacific Northwest, lies within a volcanic arc extending from Washington, through Oregon and into northern California.

Oceanic lithosphere can also subduct beneath oceanic lithosphere.



Oceanic-oceanic convergence

From "This Dynamic Earth" by Jacqueline Kious and Robert Tilling of the U.S. Geological Survey.

Oceanic Plate and Oceanic Plate - the older, colder plate sinks beneath the younger, warmer plate forming an island arc. U.S. scientists played a pivotal role in predicting the major eruption at Mount Pinatubo in the Philippines thereby saving many lives and preventing damage to U.S. equipment.

What two features are formed on the seafloor by subduction?

1. _____
2. _____

List the characteristics of a convergent plate boundary

11. Convergent Plate Boundary Earthquakes

Why do very large earthquakes occur at convergent plate boundaries?

12. Transform Plate Boundaries

Note that the orientation of a transform plate boundary is parallel to motion between the plates

Transforms form staircase-like steps in divergent plate boundaries at the mid-ocean ridges (such as shown at the Juan de Fuca and East Pacific Rise in the diagram on the next page)

Draw a picture of a transform boundary where it offsets a mid-ocean ridge



Understand direction of plate movement across transform plate boundary

Transform faults are very important to the people of California, since we live along the San Andreas fault system - our very own transform. This transform exerts a fundamental control on the shape of our coastline and life in California! You should understand that it runs along much of the length of coastal California from a divergent plate boundary in the Gulf of California in the south to Cape Mendocino in the north, which we will study in one of subsequent expeditions.

Draw the outline of the state of California on the map!

Notice the position of Mendocino Fracture Zone, the Juan de Fuca Ridge and the subduction zone marking the convergent plate boundary (more on this in a subsequent expedition)

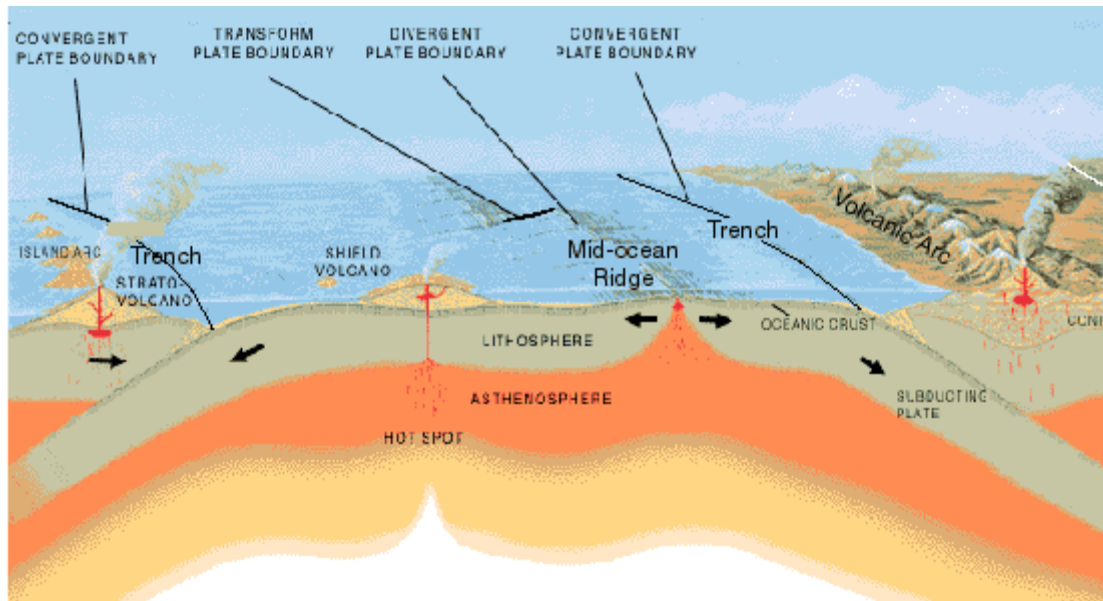
Very Important!



From "This Dynamic Earth" by Jacqueline Kious and Robert Tilling of the U.S. Geological Survey.

You should know about the plates on the surface of the Earth, their movements and the types of plate boundaries. You now also know how the plates under the ocean are formed and recycled back into the Earth.

13. Time to Review - Sometimes Scientists Need to Sit at Their desk and Review the Evidence



From "This Dynamic Earth" by Jacqueline Kious and Robert Tilling of the U.S. Geological Survey.

From the last two expeditions, you learned each of the following points about the Earth:

- The earth is a dynamic planet
- Several lines of evidence suggest that the modern continents were once part of a super-continent, Pangea, more 180,000,000 years ago
- After WWII, seafloor mapping by oceanographers showed the existence of a global network of mid-ocean ridges
- Later work showed that the ridges were formed by long chains of active undersea volcanoes, literally thousands of them -- forming a continuous feature on the seafloor from one ocean basin to the next
- Harry Hess proposed the concept of seafloor spreading that suggested that the Earth's crust under the oceans, and the uppermost part of its mantle, which together compose the lithosphere, was formed at the mid-ocean ridges by volcanism and that this layer spreads laterally away from the ridge on each side, thereby forming the seafloor
- Oceanographers next recognized an amazing, striped pattern of magnetism within the rocks (crust) below the seafloor in all of the ocean basins
- These magnetic patterns were mirror-images across the line of volcanism within the rift valleys of the mid-ocean ridges
- At the same time, scientists, working on land, showed that the directions of Earth's magnetic field had a history of flipping back and forth, i.e. the north magnetic pole became the south magnetic pole and vice versa (only the magnetic poles reversed position -- NOT the rotational or geographic poles!)

- Vine and Matthews took the record of magnetic reversals identified in volcanic rocks on land and matched it to the pattern of marine magnetic properties (striped pattern) - which supported Hess' seafloor spreading hypothesis -- it therefore appeared that the oceanic lithosphere should be older with greater distance from the center of the mid-ocean ridge where it first formed
- By matching the reversal history to the magnetic patterns under the sea, and assuming seafloor spreading, the age of a particular piece of oceanic lithosphere could be determined
- The rigid, strong surface layer of the Earth is composed of the lithosphere (between 80 and 300 kilometers-thick), which includes the crust and the uppermost part of the mantle
- The lithosphere forms the tectonic plates that ride over top the hot, mobile asthenosphere, which moves by convection (mantle convection) due to the great amount of heat stored within the Earth
- The boundaries between the moving plates include three varieties, depending on the plate motion, divergent, convergent and transform
- Plates move away from divergent plate boundaries, allowing molten rock to rise to fill the gap between the plates -- the cooling of the molten rock forms the lithosphere (plate) beneath the ocean.
- The rate of plate motion away from the divergent plate boundary can be determined by using the age of the oceanic lithosphere, from the marine magnetic anomalies, and the distance between the divergent plate boundary and the location of the marine magnetic anomaly
- Plates move towards convergent plate boundaries, allowing one of the plates to sink back into the Earth by a process called subduction -- thus the lithosphere beneath the ocean, known as oceanic lithosphere, is recycled
- The process of subduction also produces deep-sea trenches, which mark the deepest areas in the ocean, and highly explosive volcanoes that form volcanic arcs on continents and island arcs in the ocean along convergent plate boundaries (we will study the undersea earthquakes next week)
- The third type of plate boundary is the transform, where one plate slides horizontally by the other plate (motion is parallel to the plate boundary). Lithosphere is neither created or recycled, but is instead conserved. Examples of transforms include the offsets (steps) in mid-ocean ridges and the San Andreas fault along California

Check Canvas for any required reading assignments for this expedition that are posted online

Required Learning Group Discussion Assignment

- After completing this expedition, go to your learning group discussion and then post two multiple-choice questions, each with 5 potential answers (a, b, c, d, and e), on **the scientific material** covered in this expedition dealing with the characteristics of plate boundaries and what happens to the lithosphere at plate boundaries; do not highlight the correct answers to your questions.
- Scoring on required posting will be based on the clarity (ability to communicate in writing) and quality (scientific insight) of the posted questions and the listings of potential answers.
- Ambiguous questions or answers, or error in writing quality, will receive point deductions - be clear and precise.
- Do not repeat a question posted previously by another student in your learning group, which will consist of 7-8 other students.
- Students will then provide feedback on the clarity and quality of the questions posted by the student immediately above their own posting in their assigned discussion and then answer the questions.
- First student to post in a learning group receives an extra 48 hours, after deadline, to answer the posting of the last student to post in the group by the deadline.
- After your questions have been answered, provide the feedback on the accuracy of the answers and review the work in your other learning group members to compile a list of the top six questions covering the breadth of material in this expedition.