

The Race Is On... with Seafloor Spreading!

Background

Seafloor spreading is one component of the theory of plate tectonics. At mid-ocean ridges in many of the world's oceans, new seafloor rock is added to the edges of plates on either side of the ridge. We find the youngest seafloor rocks near these ridges, where new seafloor is constantly added. As you move away from a ridge, seafloor rocks become increasingly older. One way geologists recognize the strips of seafloor rock created at, and subsequently moved away from, ridges is by collecting and determining the magnetic properties and ages of rocks from the ocean floor. In this activity, students will calculate rates of seafloor spreading from this kind of data. For more information, visit these websites: <http://pubs.usgs.gov/of/1999/ofr-99-0132/>, <http://www.pbs.org/wgbh/aso/tryit/tectonics/divergent.html>

Summary

Students explore average rates of seafloor spreading where the Pacific, Cocos and Nazca plates meet off the coast of Central America. Cores and data were recovered during the Ocean Drilling Program (ODP) Leg 206 to Site 1256 located in the eastern equatorial Pacific Ocean.

Learning Objectives

Students will be able to:

- Read and interpret a map of lithospheric plates
- Calculate seafloor spreading rates based on map data
- Explain the significance of different spreading rates

National Science Education Standards

Standard A: Science as Inquiry

Standard D: Earth and Space Sciences

Ocean Literacy Essential Principles

1. Earth has one big ocean with many features.
2. The ocean and life in the ocean shape the features of Earth.

Target Age: Grades 9-12

Time: One class period

What To Do

1. Introduce students to the concept of seafloor spreading rates, paleomagnetic anomalies, and plate boundaries (convergent, divergent and transform faults.)
2. Distribute student pages giving students ample time to do the exercise, either alone or in groups.
3. When everyone has finished, discuss their answers. What interesting conclusions can they draw from the data they have examined?

Acknowledgements

This activity is based on research conducted by the Integrated Ocean Drilling Program. Information is listed below along with the URL for the paper and research results.

Wilson, D.S., Teagle, D.A.H., Acton, G.D., An In Situ Section of Upper Oceanic Crust Formed by Superfast Seafloor Spreading at Site 1256. *Proc. ODP, Init. Repts., 206* [CD-ROM], College Station, TX (Ocean Drilling Program), 2003. Also published online December 2003. Available at: http://www-odp.tamu.edu/publications/206_IR/chap_03/chap_03.htm

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Student Page

Directions

Notice the three lithospheric plates on the map below: Pacific plate, Cocos plate, and Nazca plate. Locate these on a world map of the lithospheric plates (http://geology.about.com/library/bl/maps/n_map_crystalplates.htm). The black double lines shown in the diagram indicate the East Pacific Rise (EPR). The colored areas represent the paleomagnetic anomalies (“stripes”). The ages of these anomalies are shown in the key at the top of the diagram and a scale of 500 kilometers is shown at the bottom of the diagram.

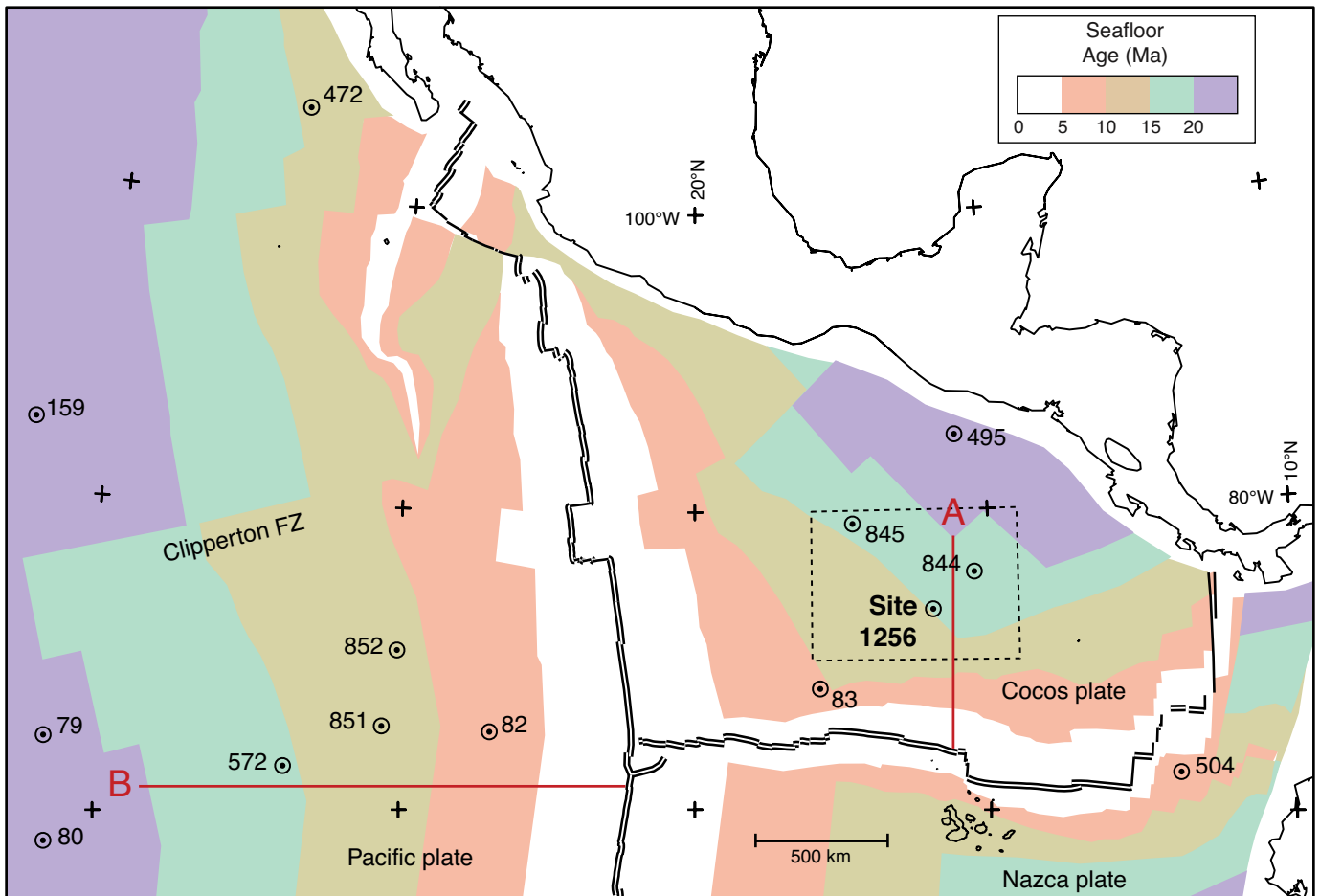


Figure: http://publications.iodp.org/proceedings/309_312/101/101_f2.htm#1002541

Questions

1. Are areas of seafloor spreading along a divergent or a convergent plate boundary? Why?
2. What color anomaly represents the youngest seafloor? What is its age range?

What color anomaly represents the oldest seafloor? What is its age range?

3. Using the tables below, calculate the spreading rates in centimeters/year (cm/yr) for the magnetic anomalies (“stripes”) of the Cocos plate and the Nazca plate using line “A.” Use line “B” for the Pacific-Nazca plates. (Hint: How many **centimeters are in a kilometer?** _____) Remember, age is in millions of years before present (Ma). Use the oldest value given in the key for each anomaly’s age. For example, for the green anomaly use 15 Ma.

Cocos-Nazca Plates Use Line A	White Anomaly	Orange Anomaly	Green Anomaly	Gray Anomaly
Distance from EPR across anomaly (km)				
In centimeters (cm)				
Age (years)				
Average Seafloor Spreading Half Rate (cm/yr)				

Pacific-Nazca Plates Use Line B	White Anomaly	Orange Anomaly	Green Anomaly	Gray Anomaly
Distance from EPR across anomaly (km)				
In centimeters (cm)				
Age (years)				
Average Seafloor Spreading Half Rate (cm/yr)				

4. Why is the purple anomaly not included in your calculations?
5. Explain what has happened to the magnetic anomalies located at the Clipperton FZ (fracture zone).
6. Between which two plates is the rate of seafloor spreading greater?
7. As these plates continue to form, what tectonic process must be occurring along the Mexico and Central American coasts?
8. Are the spreading rates uniform along a plate-to-plate boundary? Does your data support your answer?

Teacher's Guide

Students should be able to convert kilometers to centimeters using dimensional analysis:

$$1 \text{ km} \times \frac{1000 \text{ m}}{\text{kilometer}} \times \frac{100 \text{ cm}}{\text{meter}} = 100,000 \text{ cm}$$

Using a ruler or the edge of a piece of paper, students will mark off the distance from the EPR (spreading center) across each magnetic anomaly to its oldest edge along line A or B. To determine the actual distance, use the scale of 500 km on the diagram. Answers will be multiplied by 100,000 cm/km to convert to centimeters. Use the seafloor ages for each anomaly according to the age chart in millions of years before present (Ma) at the top of the diagram. Use the oldest age for each anomaly (e.g., use 15 Ma for the green anomaly). Note that crust that formed 15 Ma, has

been around for 15 million years (m.y.). Using the formula of distance/time, students will calculate the average half rates of seafloor spreading.

Example: White Anomaly for Cocos-Nazca Plate:
 $150 \text{ km} / 5 \text{ m.y.} = 30/\text{km per m.y} = 3.0 \text{ cm/year}$

The half rate gives the rate at which one plate moves relative to the ridge axis. To get a full rate, which tells us how fast the Pacific and Nazca plates are moving relative to each other, measure the distance from the old edge of one colored interval all the way across the ridge axis to the old edge on the opposite side of the ridge axis. The full rate will be about twice the rate calculated between a plate and the ridge axis for anywhere in the world, because seafloor spreading is mainly symmetric about the seafloor spreading centers.

*Cocos-Nazca Plates Using Line A	White Anomaly	Orange Anomaly	Green Anomaly	Gray Anomaly
Distance from EPR across anomaly (km)	150 km	300 km	425 km	950 km
In centimeters (cm)	15,000,000 cm	30,000,000 cm	42,500,000 cm	95,000,000 cm
Age (years)	5,000,000 yrs	10,000,000 yrs	15,000,000 yrs	20,000,000 yrs
Average Seafloor Spreading Half Rate (cm/yr)	3.0 cm/yr	3.0 cm/yr	2.8 cm/yr	4.8 cm/yr

*Pacific-Nazca Plates Using Line B	White Anomaly	Orange Anomaly	Green Anomaly	Gray Anomaly
Distance from EPR across anomaly (km)	370 km	700 km	1200 km	1760 km
In centimeters (cm)	37,000,000 cm	70,000,000 cm	120,000,000 cm	176,000,000 cm
Age (years)	5,000,000 yrs	10,000,000 yrs	15,000,000 yrs	20,000,000 yrs
Average Seafloor Spreading Half Rate (cm/yr)	7.4 cm/yr	7.0 cm/yr	8.0 cm/yr	8.8 cm/yr

** Answers are approximations and will vary among students as estimations of distances will not all be the same.*

Answers

1. Areas of seafloor spreading are along a divergent plate boundary because the plates are being pushed apart by the rising magma.
2. White represents the youngest seafloor. Its age range is 0 to 5 Ma.
Purple represents the oldest seafloor shown with an age range of 20 to 25 Ma.
3. See charts on page 4.
4. Purple magnetic anomalies are not included because the width of the anomaly can not be determined.
5. This area represents a fracture zone, an extension of a transform fault, which offsets the spreading zones.
6. The average spreading rates are greater for the Pacific-Nazca plates than the Cocos-Nazca plates. This area represents an area of fast seafloor spreading.
7. Subduction is occurring along the Mexico-Central American coasts.
8. Spreading rates are not uniform along a ridge axis. The constant motion of any object on a sphere can be described by a rotation about a vertical axis or pole. For example, for a north-south ridge like the mid-Atlantic ridge, imagine a ladybug walking due east along the equator. The rotation pole for the ladybug would be the North or South pole. If a tight string from the rotation pole was attached to the ladybug, the lady bug could keep walking without loosening or tightening the rope if she stayed on her path due east. Her path would be a great circle. The string would be along a meridian of longitude at all times. The same rotation pole would work for the motion of any other object as long as that motion was along a constant latitude line. For example, consider a second ladybug at 30 degrees North latitude walking due east. She would have the same rotation pole as the ladybug on the equator, but her path would be a small circle on the sphere. She wouldn't have to walk as fast, however, to keep on the same meridian of longitude as the equatorial ladybug. This process is the same for the relative motion of two plates. Their motion can be described by the rotation about a pole, which is referred to as an Euler pole (named after a famous mathematician). The spreading rate decreases in the direction of the Euler pole.