Digging into the Geologic Record of Environmentally Driven Changes in Coral Reef Development

NOTES FOR INSTRUCTOR

Advance Preparation

Activity 1 and Activity 2

The teacher should pre-print the images of the intervals recovered from each core for each time interval and each location, along with copies of the core materials key and core analysis grid for Activity 1 (Handout S1). We recommend laminating the images. The teacher should also print copies of the Student Activity Sheet.

Activity 3

The teacher will need to prepare separate containers for each time interval of the core for both Sr/Ca and Ba/Ca for each student pair. We recommend that the elements be represented with candies that have different masses (e.g., M&M®'s of different varieties to represent different elemental masses). Alternatively, the instructor can represent each element's mass using cardboard cutouts. For example Ca, which has a molecular weight of 40, can be represented with a cardboard cutout of a dime; Sr, which has a molecular weight of 87, can be represented with a cardboard cutout of a nickel; and Ba, which has molecular weight of 137, can be represented with a cardboard cutout of a quarter. Table S5A lists the counts for each element that should be prepared in advance. The table also lists the calculated ratios, which use the formulas provided in the lesson methodology. The teacher should be aware that the final time interval in Activity 3 is indicative of changes that facilitated recovery of the Panamanian coral reefs. The teacher should also be aware that this activity is designed to model the average trends in elemental ratios and that a true elemental analysis would have replicates and greater variability in the data.

TABLE S5A. A teacher's guide for preparing the elemental ratio containers used in Activity 3. For each student pair, the teacher will need an Sr/Ca and Ba/Ca container for each time interval (6 total per student pair).

RATIO	TIME INTERVAL	ELEMENTAL COUNTS (total per element)		CALCULATED RATIO (use formula provided)
Sr/Ca	1,500–1,000 yr BP	Sr = 10	Ca = 50	9.148
	4,000–3,500 yr BP	Sr = 8	Ca = 39	3.383
	5,000–4,500 yr BP	Sr = 9	Ca = 44	9.356
Ba/Ca	1,500–1,000 yr BP	Ba = 8	Ca = 55	4.245
	4,000–3,500 yr BP	Ba = 6	Ca = 31	5.649
	5,000–4,500 yr BP	Ba = 7	Ca = 42	4.864

Gravinese et al., 2020, https://doi.org/10.5670/oceanog.2020.113

Lesson Delivery

Pre-Lab Activity and Discussion

The instructor should provide students with an opportunity to conduct a comparison of the environmental conditions in the Gulf of Panamá (Table S1 in the Student Activity Sheet) during ENSO-neutral, El Niño, and La Niña years to help guide them toward formulating explanations for the differences they will observe in reef condition throughout the lesson. Student review of the pre-lab materials can be completed as a homework assignment prior to the lesson or as an introduction to the lesson at the beginning of class. During the discussion, the instructor should introduce the topic of ENSO and explain how El Niño and La Niña conditions affect the Gulf of Panamá; their differences, scaled up to long time intervals, are the primary reason for temporal patterns in reef condition and elemental geochemistry. At the end of the discussion, the instructor should guide the students toward creating a hypothesis to explain how different environmental conditions might impact the conditions of coral reefs over time.

Activities

The questions provided for each activity will prompt the instructor to discuss the relationship among the environmental changes and how those changes alter elemental ratios in the surrounding seawater during the life of the reef. After Activity 1 students should be aware that the composition of the reef framework and conditions of the corals that formed that framework changed during this region's geological history. After Activity 2, students should have learned that change in reef condition, an ecological attribute, is manifested as change in the rate of reef accretion, a geological attribute. The instructor should then challenge them to think about how specific environmental conditions during certain climatic events may have impacted their data. The instructor can then lead a discussion about the relationships between changes in climate and conditions that may or may not promote reef growth.

The temporal changes in species compositions and conditions in the core records indicate how well the reef grew through time, which is influenced by various environmental changes in the past. This concept should be used to transition into Activity 3, which challenges students to identify the changes in elemental ratios over similar time periods. The changes in elemental ratios correlate with environmental changes during the specified intervals. Students should be guided toward identifying these relationships using the data compiled during these activities.

If students are having difficulty coming to conclusions about how to relate the elemental ratios to the environmental conditions during the time intervals, the teacher can lead a brainstorming session that focuses on characterizing the optimal conditions that promote reef growth, using data collected in Activities 1 and 2. The instructor should make students aware that this lesson mimics the geochemical analyses involved in such a study and that the actual geochemical analyses require precise measurements using mass spectrometry and related geochemical techniques.

Extensions and Modifications

The teacher can also lead a discussion or link the geochemistry in this lesson to other chemistry lessons aimed at determining the composition of a sample (e.g., chromatography). The teacher can also briefly discuss potential sources of nutrients into coastal ecosystems that might affect coral growth (e.g., runoff from terrestrial sources).

In Activity 2, the teacher can opt to make classroom models of the cores by attaching meter sticks together to match the lengths of the cores used in the lesson. The teacher can tape together colored construction paper to match the length of each section of the core we provide in Figure S3 in the Student Activity Sheet. Student groups can then make their measurements, as described in the lesson, on the models of the cores. This modification would create a life-sized replica of each core that is to scale. This modification may also help to demonstrate how much a reef framework grows in 1,000 years and highlight how the different environmental conditions impact coral growth.

Gravinese et al., 2020, https://doi.org/10.5670/oceanog.2020.113

GLOSSARY OF TERMS

Calcification. The process of deposition of calcium carbonate ($CaCO_3$).
Cohen and Holcomb (2009) and http://www.aroundtheamericas.org/log/wp-content/uploads/2010/02/Teachers_GuideLess-1-CoralCO2Calcification.pdf

El Niño–Southern Oscillation (ENSO). A naturally occurring oceanic–atmospheric cycle of trade-wind circulation that results in the cyclical warming and cooling of the sea in the eastern Pacific Ocean.
Garrison (2013) and https://www.esrl.noaa.gov/psd/enso/education/

Geochemistry. The study of the chemical composition of and chemical changes in the solid matter of the Earth or a celestial body; the related chemical and geological properties of a substance.
https://www.merriam-webster.com

Paleoclimatology. The study of past climate.
https://www.merriam-webster.com

Taphonomy. The study of the biological, chemical, and physical processes that occur after the death of an organism as they become fossilized
https://www.merriam-webster.com

INTERNET RESOURCES

Florida Tech — Marine Paleoecology Laboratory
Website summarizing research in the eastern tropical Pacific being conducted by investigators at the Florida Institute of Technology.
http://research.fit.edu/marine-paleolab/

NASA — Global Seawater Oxygen-18 Database
US government database containing over 26,000 seawater oxygen-18 values since 1950 (Schmidt et al., 1999).
https://data.giss.nasa.gov/o18data/

NOAA Climate.gov — El Niño & La Niña (El Niño-Southern Oscillation)
US government website describing the climatic changes that occur during El Niño events.
https://www.climate.gov/enso

NOAA — El Niño
US government website providing educational materials about ENSO.
https://www.noaa.gov/education/resource-collections/weather-atmosphere-education-resources/el-nino

NOAA National Centers for Environmental Information — Paleoclimatology Data
US government website describing paleoclimatology data from tree rings, ice cores, corals and ocean and lake sediments. Other educational resources are also available.
https://www.ncdc.noaa.gov/data-access/paleoclimatology-data

NOAA National Ocean Service — What is Coral Bleaching?
US government website explaining coral bleaching.
https://oceanservice.noaa.gov/facts/coral_bleach.html

University of Exeter — Reef Budget
Provides additional resources and descriptions of methods used to calculate carbonate production in coral reefs.
http://geography.exeter.ac.uk/reefbudget/