Sea Level Change and Historical Earthquakes of Sumatra from Coral Growth Rings—Introductory Version

The Sumatra region is prone to earthquakes because it lies at the boundary of two of Earth's shifting tectonic plates. The Indian Ocean crust is creeping steadily northeast and subducting beneath Sumatra. The steady horizontal movements, and pulses of faster horizontal motion that occur during earthquakes, are recorded by GPS stations on the islands. But GPS has only been recording horizontal land motion since the 1980s, so it can't tell us about earthquakes that happened long ago. GPS measurements of vertical motions are imprecise, and instruments can't be installed underwater, so GPS data are lacking for underwater regions of subduction zones.

In order to figure out how often large earthquakes happen in the Sumatra region, scientists have turned to coral micro-atolls. They also use coral records to reconstruct progressive sea-level changes. In this lab, you will use data from real corals collected in Sumatra to track the sea-level and earthquake record of the region over the past century.

TOOLS

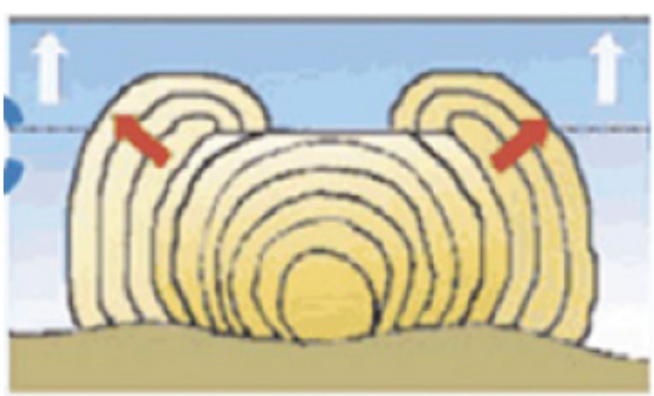
1) Figures 1–4 (including a location map) are included with this lab. You will refer to and annotate the coral figures to answer the following questions. For photos, illustrations, and animations related to coral growth and stranding, and for news coverage related to the Sumatra earthquakes and tsunami, visit: **http://www.tectonics.caltech.edu/outreach/highlights/sumatra**
2) Colored pencils, ruler, and calculator

OBJECTIVES

When studying earthquakes, scientists often concentrate on **coseismic** displacement of land along faults. In recent years, we have learned that there are also **interseismic** land-level shifts in earthquake-prone regions. In this assignment, you will use coral **microatolls** to measure both **coseismic** and **interseismic** land-level changes. You will learn that corals provide precise data on

1) *how* land level changes
2) *when* a historic earthquake happened

Time to complete whole assignment: 2 hours



Part I—Definitions and Context: In-class lesson

1) Atoll—a ring-shaped coral reef or a string of closely spaced small coral islands, enclosing or nearly enclosing a shallow lagoon.

Coral heads from Sumatra are considered "microatolls" because each head is a small, circular "island." (The outer ring is alive but the inner area is submerged and inactive.)

Referring to this website,
http://www.tectonics.caltech.edu/outreach/highlights/sumatra/coral.html
explain how coral grows, and what each growth band represents.

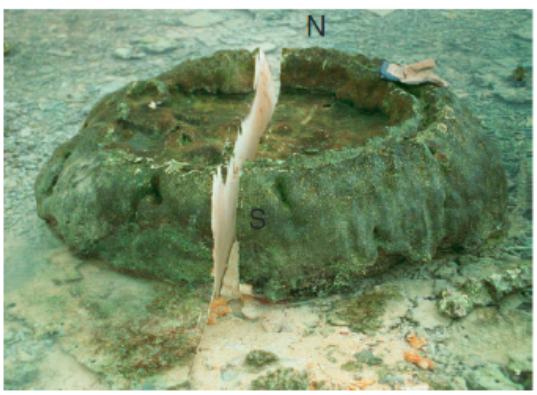
2) **Coseismic—**the time of the earthquake

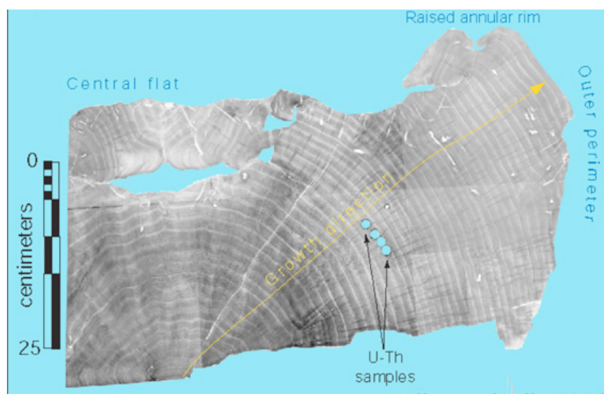
How long is a typical coseismic period? Instantaneous: seconds to minutes

3) **Interseismic—**time between earthquakes

How long can an interseismic period be? (Give an estimate of the range—shortest and longest)
Years to thousands of years

4) **Unconformity** (general definition)—missing time in the geologic record





Part II—Data Analysis

1) The upper part of Figure 2 is a vertical cross section through a coral microatoll from Bai (see map of Figure 1 for location). This cross section shows how the coral grew by adding a band each year, expanding outwards over time from right to left in the sketch. Each two-digit number indicates the year that band grew (all years in the 20th century). The last one grew in 1997, the year the slab was cut. The outer edge is the living part of the coral.

a) Using the scale bar, estimate the growth rate of the coral (measure the distance between several bands and give the average).

b) What does the top of each growth ring (HLS = "highest level of survival") represent in terms of water/tidal level?

c) Make a list of HLS over time, starting in 1964. (Use the scale at the left of the sketch.) Then plot your data on the graph below the coral cross section (or use Excel to plot).

NOTE: some bands are incomplete, so you will need to exercise your scientific judgment to either trace these lines to completion, or eliminate them from your analysis.

2) The coral section with colored lines on Figure 3 should guide your understanding of coral growth-ring unconformities. The left half of this coral, from 1925–1962, is marked with bold, colored lines that show growth-ring unconformities.

a) Based on your understanding of an unconformity, do you agree that there are unconformities in the remainder of this coral record?

b) What does an unconformity look like in the coral cross section?

c) What does an unconformity represent in the growth pattern of a coral?

d) Fill out the remainder of the coral head in Figure 3 with colored lines showing clear unconformities.

e) Are there unconformities in the coral head from Bai (Figure 2)? Mark each clear unconformity on the coral-head sketch with a color (they are already indicated with a bolder line).

f) For what time period (give the years) is the record from coral head Bai incomplete because of erosion? How can you tell?

g) Fill out the rest of the graph under the coral head in Figure 3, marking the HLS with time until 2002.

Part III—Interpretation

Use your plots and the sketches of the coral slabs to answer the following questions:

1) **Figure 2**—the first coral you looked at:

a) From 1964–1997, has this coral been emerging, submerging, or both? How can you tell?

b) Calculate the coral's **average** rate of movement during each emergence and/or submergence period over the 40 years that you graphed.

c) During this period, global sea level has been rising by about 2 mm/y. Use this record to correct the answer(s) from 3b to determine the site's **actual average** tectonic uplift or subsidence rate(s).

d) Do you think your result indicates coseismic or interseismic motion? Why?

e) Is there an unconformity every year? Why or why not?

2) **Figure 3**—the second coral slab

a) From 1925–2002, has this coral been emerging, submerging, both, or neither? If both, what has been the predominant trend?

b) Calculate the average rate(s) of emergence or submergence during this time. Is there any suggestion of sudden events within this period? How can you tell?

c) Correct for global sea-level rise to obtain the site's actual tectonic uplift or subsidence history during this time period.

d) Is there any suggestion of a change in uplift or subsidence rate over time? Would you call your results in (c) coseismic or interseismic? Why?

5) Comparing corals from Bendera (**Figure 6**)
Based on *in situ* surveying of heads TB1 and TB2 from Bendera Island (see Figure 1 for location), we know that the highest point on microatoll Tb2 is 55 cm higher than the highest level of growth on Tb1 (year 2000 growth ring).

a) What do you think caused the change in elevation between the two adjacent corals?

b) What was the vertical uplift experienced by coral TB2?

Optional end discussion:

Find tidal-gauge data for the past century from various places around the world. What is the global trend in sea level? How does this compare to **relative** sea level changes in tectonically active regions? For example, compare the Gulf coast with Alaska.

Optional extra credit or "Task #1" for this assignment:

Ask students to use GeoMapApp, a free mapping tool provided by MARGINS:
http://www.geomapapp.org
to zoom in on Sumatra and mark the locations of the coral heads used in this exercise. They should print out a map to hand in with the rest of the assignment.