The Evidence is Piling Up … On the Seafloor

STUDENT NAME: .....

STUDENT ACTIVITY

SCIENTIFIC OCEAN DRILLING

Objective(s)/Outcome(s)

Students will be able to:

1. explain the origin of sediments due to erosion and sediment transport from terrestrial to marine environments.
2. analyze data on radioactive decay in zircon to assess the age of turbidite-forming events.

Materials

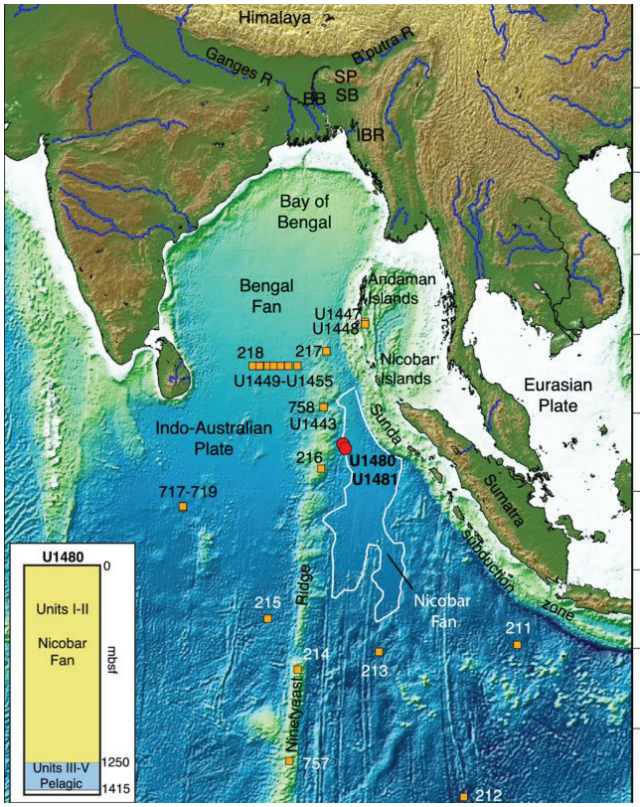
Per Group:

- color copies of cores and smear slide images
- copy of zircon age plots
- computer with internet access
- microscope, slides, and sediment samples (optional)

Background

In 2004, a magnitude >9 earthquake struck North Sumatra and the Andaman-Nicobar islands leading to a huge tsunami. In order to find an explanation for this event, Expedition 362 of the International Ocean Discovery Program (August– September 2016) drilled sites to collect **ocean sediment cores** (see Figure 1). Site U1480 (1432 m into the seafloor) and U1481 (1500 m into the seafloor) were where cores were taken from the seafloor, approximately 200 km west of Sumatra, before the Indian Plate reaches the Sunda **subduction zone** (see Figure 2). What makes this subduction zone offshore Northern Sumatra quite unusual is the amount of sediment on the subducting oceanic plate (up to 5 km thick just before subduction).

FIGURE 1. BATHYMETRIC MAP OF THE INDIAN OCEAN, INDICATING CORING SITES.



Credit: McNeill et al, 2017

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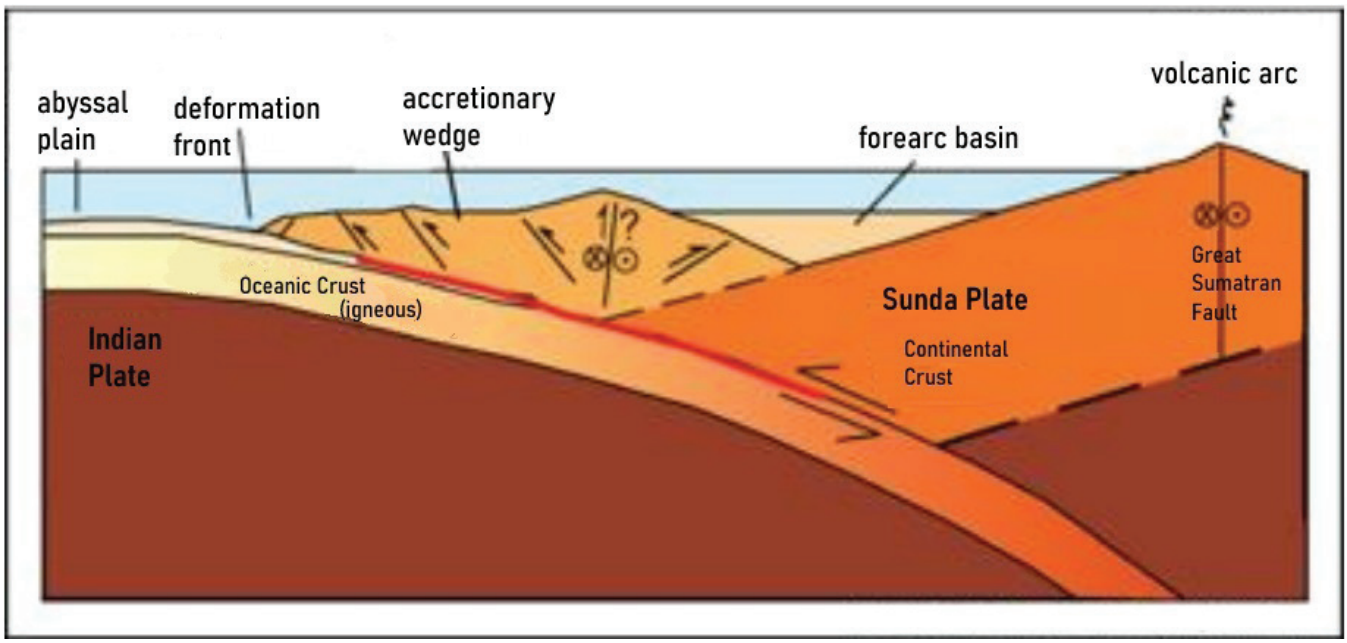
FIGURE 2. TECTONIC SETTING OF THE 2004 SUMATRA-ADAMAN ISLANDS EARTHQUAKE



Credit: Lisa McNeill, with permission

Geologists have determined that the sedimentary materials being incorporated into the North Sumatra subduction zone are related to the Bengal-Nicobar Fan system (indicated on Figure 1). This fan is the largest **submarine fan** currently on the planet. This sedimentary system originates from **erosion** of the Himalayan mountains, more than 3000 km away from the drilling sites! Rivers carry eroded material to the coast. If most of the sediment (~80%) is deposited onshore and offshore quite close to the coastline, a huge amount still makes its way along deep-sea canyons to the deep-sea portion of the Indian and even Australian plate. During Expedition 362, a lot of **turbidites** coming from the erosion of the Himalaya mountains have been described in the cores.

Activity
Part 1

1. Follow your teacher's instructions to identify turbidites within sediment cores collected from Nicobar Fan on the floor of the Indian Ocean.

2. Follow your teacher's instructions to share about the turbidites within your assigned segment of ocean sediment core.

3. Within ocean sediment, scientists identify specific types of minerals to determine the source and age of each sediment layer.

    a. Study Figure 3, which shows four minerals found within seafloor sediment, as they appear under a microscope.

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b. Read the figure caption and make observations of each of the images, comparing what the two types of light reveal about each mineral type.

4. Zircon (Figure 3g and 3h) is of particular interest when it is found in turbidites.

a. Zircon has a very high melting temperature and hardness, which makes it resistant to many geologic processes, especially erosion. Consider how this property is beneficial for scientists.

b. Zircon contains Uranium (and sometimes Thorium), a radioactive isotope. Uranium decays over time to form stable Lead atoms. Scientists determine the ratio of Uranium to Lead within zircon to determine its age. Consider how this property is beneficial for scientists.

c. Study Figure 4, which shows age plots for samples taken from cores collected from the Nicobar Fan sediment, which indicates the age(s) of zircon samples found within the cores. Note: this does NOT indicate when the sediment was deposited, but rather the age of the parent rock from which it was derived.

d. For each age plot from the Expedition, compare the peaks of different ages to the sources of sediment to determine where the sediment originated before it was eroded and washed into the Bay of Bengal. Reference a **map of the rivers in this area** (**alternative map of the area**) that transport sediment from various parts of the Himalayas to the Bay of Bengal.

e. Record data in the provided table that indicates the origin and transport of each sediment.

Analysis

1. Explain how you identified turbidites within the ocean sediment cores. Refer to two specific core images, one with few turbidites, and one with many turbidites. Describe the occurrence of turbidites in each of these cores.

2. Use your observations from Figure 3 to describe properties that can help identify the four minerals with seafloor sediment samples. Which of the four minerals do you think is easiest to identify using this method? Explain your reasoning.

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Synthesis

1. Summarize the zircon age plot data to explain the most likely source of sediments found in the core samples.

2. Re-read the background information on page 1. Recall that expedition 362 was proposed and conducted to investigate sea floor sediment after earthquakes occurred, leading to a tsunami event.

   a. Explain how the occurrence of turbidites in sea floor sediment could be evidence of similar events in this area in the past. (Note: not all turbidites are caused by seismic events.)

   b. Revisit the core images that you referenced in analysis question 1. Do you think seismic events (especially those that lead to tsunamis) are more likely to cause the formation of thin or thick turbidites? Explain your answer.

Extensions

1. Research where there are other sediment fans on the ocean floor. How are turbidity currents involved in their formation? What other processes are also involved in creating these fans?

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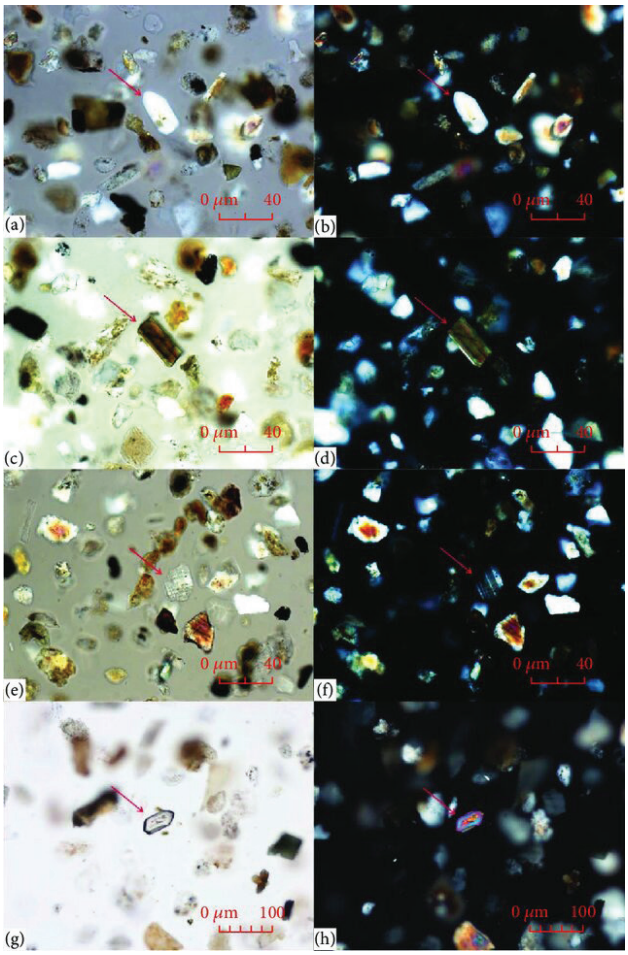
HANDOUTS

FIGURE 3. MINERALS FROM THE SEAFLOOR, AS VIEWED UNDER A MICROSCOPE



Credit: Wu et al, 2022, CC BY 4.0

The minerals within these images were sampled from seafloor sediment and placed on microscope slides to produce what is called a smear slide, with a very thin layer of material. This allows scientists to study grain size, shape, and color to identify minerals. Images a, c, e, and g were taken under plane polarized light. Polarizing light allows for it to be focused, allowing scientists to view the minerals more clearly. Images b, d, f, and h were taken under cross polarized light. Cross-polarization uses two filters to not only focus the light, but to help reveal patterns and textures on and in the minerals that cannot be seen under regular light, but which also help in mineral identification. Note that images g and h are under a higher magnification.

The red arrows indicate specific minerals of interest:

- a/b: quartz
- c/d: muscovite mica
- e/f: plagioclase feldspar
- g/h: zircon

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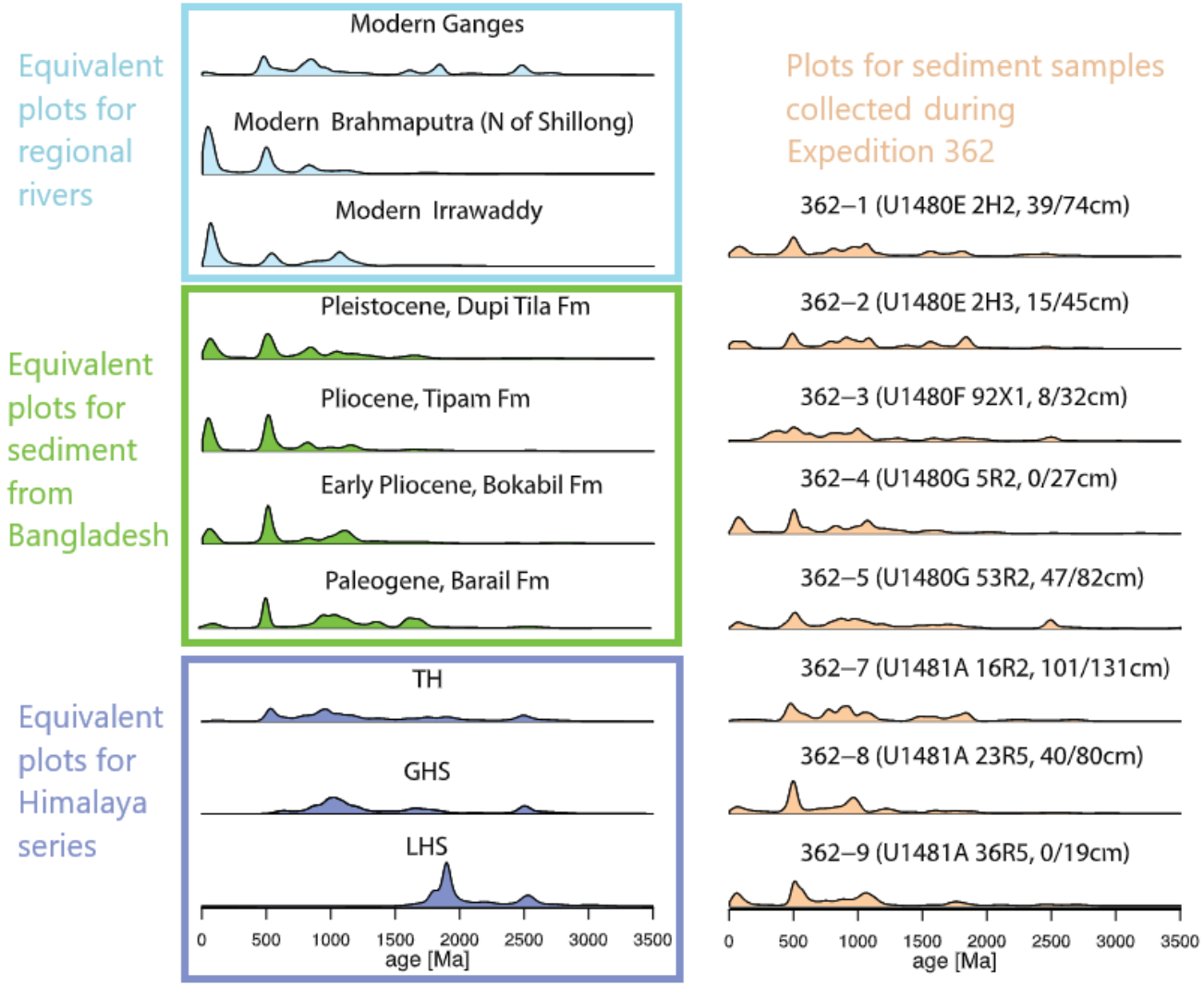
FIGURE 4. DETRITAL ZIRCON AGE PLOTS FOR CORING SITE U1480E AND EQUIVALENT RIVERS AND FORMATIONS



Credit: Modified from McNeill et al., 2017

For the Himalayan regions, TH = Tethys Himalayas, GH = Greater Himalayas, LHS = Lesser Himalayas. Use **this map** as a reference for these areas.

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SOURCES OF ZIRCON SEDIMENT WITHIN CORES FROM SITES U1480 AND U1481
EXPEDITION 362

Core from which sample was collected	Data from the sample that indicates origins in the Himalayas	Data from the sample that indicates origins in Bangladesh
U1480E 2H 2		
U1480E 2H3		
U1480F 92X1		
U1480G 5R2		
U1480G 53R2		
U1481A 16R2		
U1481A 23R5		
U1481A 36R5		