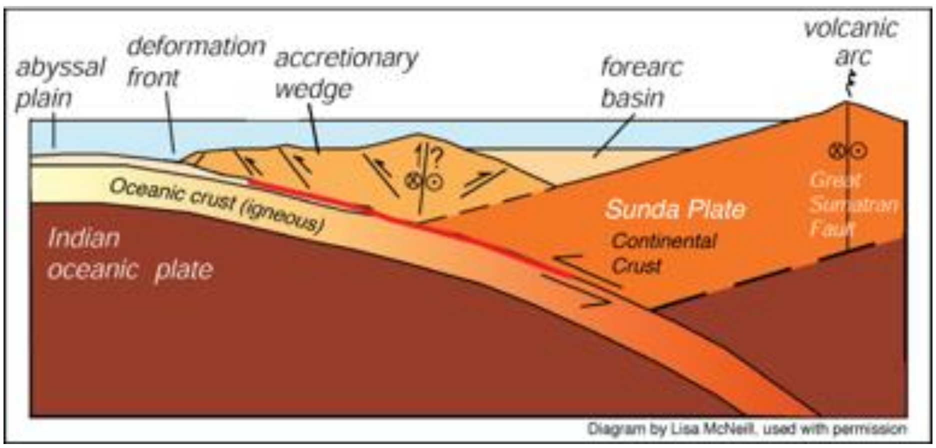
From the mountains to the ocean

Using Google Earth and Ocean Cores to discover the concept of erosion and sediment transportation

Background

In 2004, a magnitude >9 earthquake struck North Sumatra and the Andaman-Nicobar islands leading to a huge tsunami. In order to find some explanation for this event, **Expedition 362** (August- September 2016) drilled sites U1480 (1432 m below the seafloor) and U1481 (1500 m below the seafloor) on a section of the seafloor ~200 km west of Sumatra, before the Indian Plate reaches the Sunda subduction zone. What makes the 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).



Tectonic setting of the 2004 Sumatra-Adaman Islands earthquake (Diagram by Lisa McNeill, personal communication)

Geologists have determined that the sedimentary materials being incorporated into the North Sumatra subduction zone are related to the Bengal-Nicobar Fan system, which originates more than 3000 km away from our drilling site! This fan is the largest submarine fan currently on the planet.

This sedimentary system originates from erosion of the Himalayan mountains. Rivers carry the 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.

A **turbidite** is deposited by a turbidity current driven by gravity.
https://en.wikipedia.org/wiki/Turbidity_current

In the cores, they are units starting with sand levels fining up to clay levels and reflect an avalanche style deposit.

Summary

The propose classroom activity use the unusual tectonic setting of Expedition 362 to highlight the concept of erosion and transport of sediments in deep sea environments.

National Science Education Standards

Standard A
Standard B
Standard C
Etc...

Ocean Literacy Essential Principles

1. Understand the concept of erosion and sediment transportation from the mountains to deep marine environments along rivers and marine canyons

2. Learn to scientifically determine the origin of sediments (radioactive isotopes dating)

3. Use scientific literature in class and work with real data

Target Audience

Grades 11th to 12th

Time Required

Approximately 3 hours with the preparation and analyze of the smear slide

Contents and/or Materials

- Mixture of granitic sand and clay
- Google Earth Pro
- Coffee and chocolate powder
- Cores photos of Expedition 362

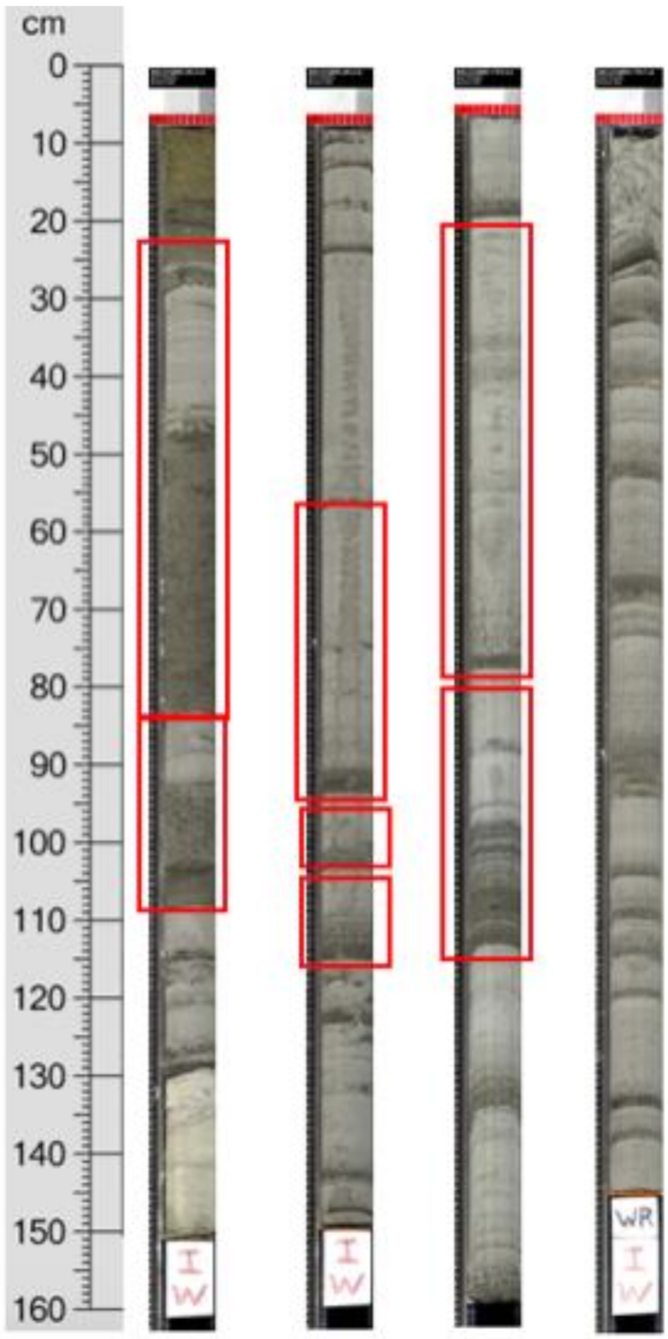
Credits:
Activity submitted by Agnès Pointu (Education Officer during Expedition 362, Louis de Broglie High School) and Hugo Pouderoux, sedimentologist onboard Expedition 362

What to do:

1. **Find the turbidite levels in some cores of Expedition 362**

Notice the localization of the holes of Expedition 362 by using Google Earth Pro (the kmz file is available on line: https://www.iodp.org/resources/maps-and-kml-tools)

Students work on photos of the cores to find by themselves some turbidites levels.

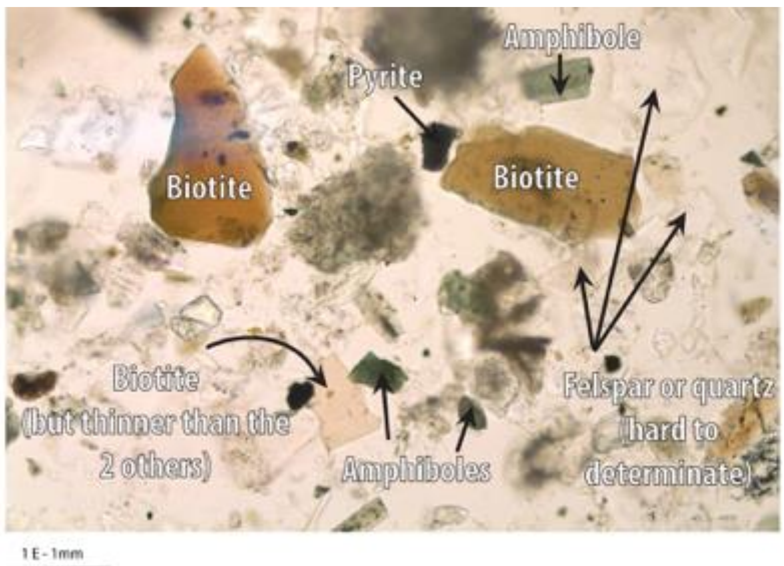


Examples of turbidites found in some cores of Expedition 362 (From left to right: cores 362 U1480 E 2H 2A, Cores 362 U1480 E 4H 2A, Cores 362 U1480 E 11H 3A, Cores 362 U1480 E 2H 1A). Full resolution images available on line

2. **What are these sediments made off?**

The preliminary question to answer is “what are these sediments made off?” because their composition is a key to discover their origin.

Like sedimentologists on board, students can realize a smear-slide using analogic sediments such as those described on board (a mixture with granitic sand and clays).
The recipe for a smear slide is here:
https://www.youtube.com/watch?v=2sDejrpwxD4
They also can study some pictures of the smear slides made on board (for example smear-slide 362U1480E-7H-1-SED-99039601).
It is quite easy to recognize that some minerals are characteristic of plutonic and metamorphic rocks (such as biotite for example).

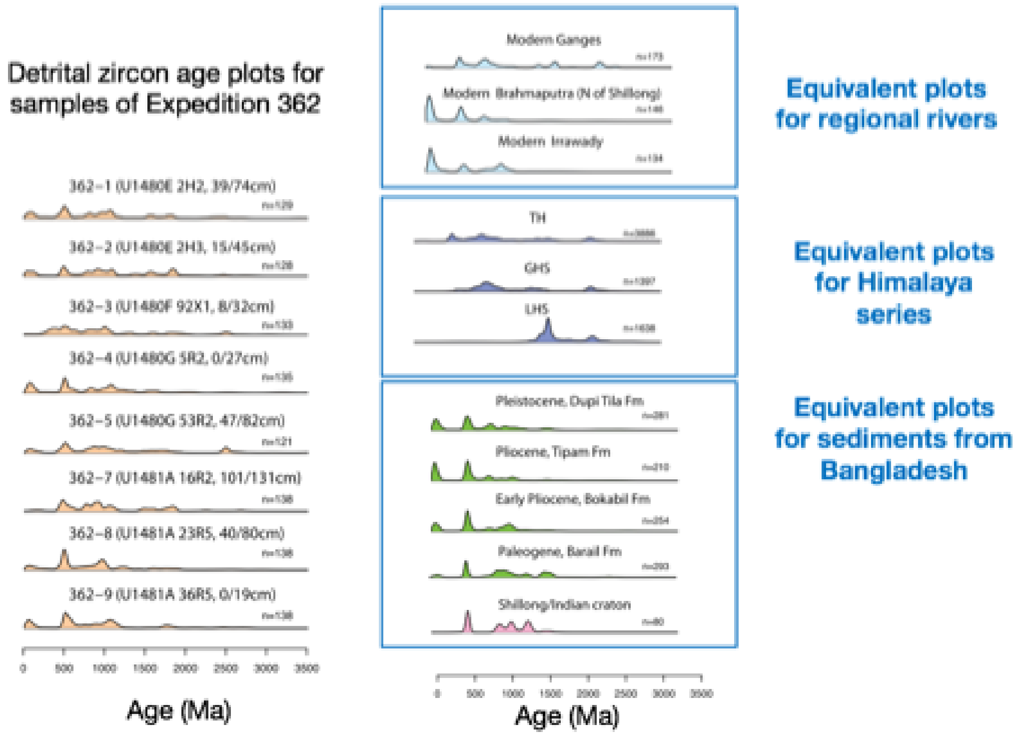


Example of a smear slide made on board during Expedition 362 showing typical minerals of plutonic rocks (Smear-slide 362U1480E-7H-1-SED-99039601)

3. **Where do these sediments come from?**

To find out where do these sediments come from, scientists of Expedition 362 have analyzed the age of the zircons found in the sand levels of the turbidites by using U/Pb meth. Ages of the zircons are linked to the age of eroded rocks so they are a good indicator of the localization of the sources of sediments.
Ages of zircons found in the sediments are been plotted and compared to:
• regional rivers (Brahmaputra, Ganges and Irrawaddy which are currently carry products of erosion of the Himalaya mountains),
• the Himalaya series (TH: Tethyan Himalaya; GHS: Greater Himalaya Series; LHS: Lesser Himalaya Series*)*
• and regional formations of Bangladesh (Dupi Tila, Tipam, Bokabil, Barail formations) and India (Shillong formation).
The results are published in an article of 2017 * available on line an in free access:
https://www.sciencedirect.com/science/article/pii/S0012821X17303977

** “Understanding Himalayan erosion and the significance of the Nicobar Fan”, McNeill & al., Earth and Planetary Science Letters, Volume 475, p 134-142*



Detrital zircon age plots for samples of Expedition 362 and equivalent plots of regional rivers and formations
TH = Tethyan Himalaya; GHS = Greater Himalaya Series; LHS = Lesser Himalaya Series
(modified from Mc Neill & al., 2017)

- The peak of zircons around 500 Ma are found in the modern Ganges, Brahmaputra and Irraddawy and come from the erosion of the TH series in Himalaya.
- There is a particular form of the repartition of the ages of the zircons around 1000 Ma (sort of dome). We can find the same repartition in the actual Ganges and Brahmaputra and are the signature of the GHS series of Himalaya.
- There is another peak between 0 and 100 Ma. We can find an equivalent repartition in modern Brahmaputra and Irradaway and but not in Ganges which indicates that these zircons have probably a Bangladesh origin and are not coming from Himalaya

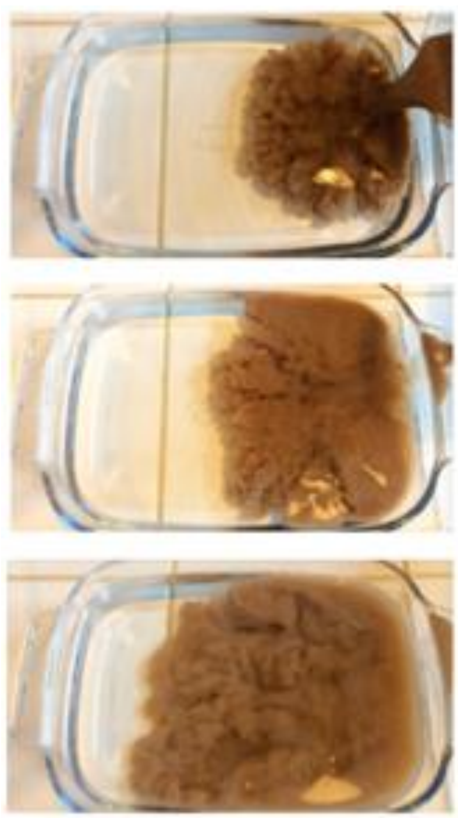
By working on this figure, students can find out that the origin of the zircons found in holes U1580 and U1481 is complex but that some of them have clearly a Himalayan origin!

4. **How did these sediments travel from the Himalaya mountains to holes U1480 and U1481?**

By using the tool Ruler of Google Earth Pro (Tool: Ruler, then Line), students can find out that the sediments have travelled more than 3000 km from the Himalaya mountains to sites U1480 and 1481 in a deep-sea environment!

A long travel for the sediments from the Himalaya mountains to holes of Expedition 362…

In order to understand how sediments can be carried on such a long way, an analogic modelling of a turbidite flow can be realized in class. The sediments can easily be replaced by a mixture of coffee and chocolate powder.



Analogic modelling of a turbidity current using a mixture of coffee and chocolate powder