Deep Earth Academy
CONSORTIUM FOR OCEAN LEADERSHIP

IODP
INTERNATIONAL OCEAN DISCOVERY PROGRAM

Core Stories Episode 1:
Recognizing Patterns In Earth's Climate History
Teacher's Guide

Overview

In this exercise your students will be asked to make observations about marine sediments. Cores of sediment are obtained by drilling into the seafloor by a scientific ocean drilling research vessel, the *JOIDES Resolution*. Students will examine a series of photographs of sediment cores in this activity. The photographs range from a close-up of a particular interval of one core, to the whole core, and then to the whole sequence of cores from a single drilling location. Moving across this range of scales will allow students to expand their observations and recognize patterns. The last task asks students to compare their core observations to relevant global climate data and develop hypotheses on how the patterns they observed in the cores may have been driven by cyclic global climate change.

Learning Objective

Students will demonstrate the ability to use observational-based evidence to infer patterns in Earth's climate history.

Next Generation Science Standards:

- ESS1.C The History of Planet Earth; ESS2.D Weather and Climate
- CCM Patterns; CCM Scale, Proportion, and Quantity; CCM Stability and Change
- SEP Analyzing and Interpreting Data; SEP Constructing Explanations

Target Audience

Grades 6-8, 9-12 and undergraduate

Time Required

Approximately 1 hour

Materials Required (included in the student worksheet):

- Drillhole Location Map
- Image of Core Section 303-1308A-6H-1
- Image of Core 303-1308A-6H
- Composite image of cores retrieved from Hole 1308A [need to find image source file]
- Glacial-Interglacial figure (source, image): Use this to guide the synthesis discussion of this exercise; it reflects the global climate evolution of the last 5 million years, as it is a measure of changes in global ice volume and deep-water temperature.

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Materials Recommended:

- Introduction to core nomenclature exercise
- Mini-Core Replica of Exp 303-1308A-6H-1 Glacial/Interglacial through Ocean Leadership
- Online interactive core (CoreRef)

Science Background for Instructor

The main goal of Integrated Ocean Drilling Program (IODP) Expeditions 303 and 306 was to generate a continuous high-resolution chronology spanning the last 5 million years (late Neogene-Quaternary), using North Atlantic climate proxies collected from layers of ocean sediments. Using a range of stratigraphic tools, including stable isotopes and relative (geomagnetic) paleointensities, these records will be correlated at scales much smaller than Milankovitch cycles of eccentricity (100,000 years), obliquity (41,000 years), and precession (23,000 years), which are known to externally govern climate changes. For this specific research program nine holes were drilled to a depth of several hundred meters below the seafloor at three sites in the central North Atlantic between 40 degrees and 56 degrees N in water depths between 2800 and 3400 meters, using advanced piston coring (APC) system. **Note**: This brief background (source) corresponds to the text label on the Mini-Core Replica.

Summary describing the sediment core and comparing it to the Mini-Core Replica.

Summary of the expedition goals and research results.

Summary of changes in North Atlantic climate and ocean conditions for the last 5 millions years.

Summary of glacial cycles and sediments in the North Atlantic.

Activity:

1. Provide students with the Drillhole Location Map (Figure1) and tell them they will be examining sediment that was cored at location U1308. Note: Hole 1308A = location U1308. Ask them to describe this location.

2. Using either the Mini-Core replica, a color photo, or the online photo (Figure 2) students individually examine and make written observations of the sediment core. If using the online photo, students can zoom in on and scroll across the image, noting particular points of interest in their description.

3. In small groups, students compare their written descriptions and formulate questions about the sediment in this core section. Based on student team discussion, groups create a hypothesis about what they believe has happened over time to produce the changes they see in the sediment.

Possible guiding questions to ask students:

- ➔ What other data could be used to interpret the sediment?
- ➔ Can you create a hypothesis about any distinguishing features found in the sediment core section?

4. Each student group is given a color photo of the whole core (Figure 3), or they can access the online equivalent. Note that the core section that they were describing in questions 2 and 3, is part of this whole core image. Students expand their observations to now include the rest of the sediment in this core. Teams share their observations and questions raised with the rest of the class. Note that the core is ~9.5 m long and is cut into sections labeled 1 to CC. CC stands for core catcher. These sections are laid out from left to right in the image of the whole core. For a 1-page introduction to core nomenclature go here (exercise).

   Suggestion: Make color copies that each team can cut apart into numbered sections and lay out end to end in sequential order to understand the orientation of the entire core.
   Possible guiding questions to ask students:
   - ➔ How does what you see in the core section fit into the longer record of the core?
   - ➔ What observations can be made about the connections between the two photos?
   - ➔ Is there evidence of a pattern?
   - ➔ What other information (data) would you like to have to explain (make a hypothesis about) what you see in the photos?
   - ➔ What do the patterns in this sediment core possibly indicate about changes in Earth's history?

4. Each student group is given a composite photo of all of the cores collected at Hole A (Figure 4) or they can access the online equivalent to complete observations of the changes they see in the sediment across three scales of observation. Students can make further observations and pose additional questions about what they see in this longer sediment core sequence, and about how Figure 2, 3, and 4 are related.

   Possible guiding questions to ask students:
   - ➔ What do you notice about the patterns found among the three photos?

5. From these three photos, students use the pattern they identified in Figure 2 to determine the placement of Figure 2 within Figure 3. Subsequently, students will determine the placement of Figure 3 within Figure 4. Students outline with pencil where they believe Figure 3 is located within Figure 4 and share their findings with the class. The teacher can use Figure 6 (teacher copy only) to reveal the location.

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The composite core sequence shown in Figure 4, extends from the seafloor down to a depth of ~350 meters below the seafloor. Scientists have used fossils in these same cores to convert sub-seafloor depth to geologic age. Based on these data we know that the sediments in Hole 1308A extend from today back to ~5.6 million years ago. Other data on changes in global ice volume and related global average temperatures for this same time span are shown in Figure 5.

6. Teams are given the Glacial and Interglacial diagram (Figure 5) or they can access the online equivalent. Students share observations and ideas to make connections between the core photos and the data in Figure 5. In particular, ask the students: *How might the observations you made about the changes in marine sediments (Figure 4) relate to the changes in ice volume and temperature shown in Figure 5? List your ideas.*

Background for Instructor:
The color patterns in the sediment cores are controlled by changes in sedimentation, which in turn are controlled by changes in climate. In Figure 5 we see what some of those climate changes may be: changes in ice volume and temperature. Furthermore, we see that these changes are cyclic.

Students may further be able to correlate particular colors in the core to climate states. Notice that the oldest part of the core (deepest portion of the core) is largely white. In Figure 5, we see that is a time of relatively warm climate and lower ice volume. In fact, this is before the onset of Northern Hemisphere glaciation.

Following that logic, students may be able to predict after the onset of Northern Hemisphere glaciation, light-colored sediments (= calcareous ooze, a biogenic-rich sediment composed of tiny microfossils with shells made of calcium carbonate [$CaCO_3$]) were deposited at location 1308 during warmer times with reduced ice volume, and dark-colored sediments (terrigenous-dominated, and carbonate-poor) were deposited during cooler times (and expanded ice sheets). These warm and cool times are called **interglacial** and **glacial periods**, respectively.

Glacial-interglacial cycles were a dominant characteristic of global climate change during the last ~3 million years and are controlled by cyclic changes (Milankovitch cycles) in Earth's orbit around the Sun.

Brief information regarding glacial and interglacial periods and how these relate to the composition of sediment at location U1308 are found on the mini core replica label. In sum:

- Glacial-Exp. 303-1308A-6H-1 is characterized by clay and diatom-rich, dark-colored clayey nannofossil oozes or nannofossil clays. Transitions may be sharp or gradational.

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- Interglacial-Exp. 303-1308A-6H-1 is characterized by carbonate-rich, light-colored nannofossil ooze with clay.

7. Students are next asked to mark on Figure 4, where they think the onset of Northern Hemisphere glaciation is recorded in this sediment record. They are also asked to explain their reasoning. Students should focus in on the major color shift that occurs within cores 24- 25. Note that according to the fossil age data this interval is ~3 million years old.

Possible Extensions:

1. Demonstrate the length of a core: Give students 9 pieces of string, each 1.5 meters in length. Ask students to lay them out end-to-end to determine a representation of the total length (9.5m) and orientation of a core sample. Orientation of the core: younger age-top of the core, older age-bottom of the core.

2. Discuss scale as it pertains to Figures 2, 3, and 4 in this activity.

3. Assessment of Core Prediction: During Step 5 of this activity, write 1- 35 on a board to represent the segments shown in Figure 4. Students place their initials under one number or between two numbers to predict the location of Figure 3 within Figure 4 (Example: student initials could be placed under segment 10, or between 9-10, or 10 and 11). The end result is to show distribution of predictions within the class.

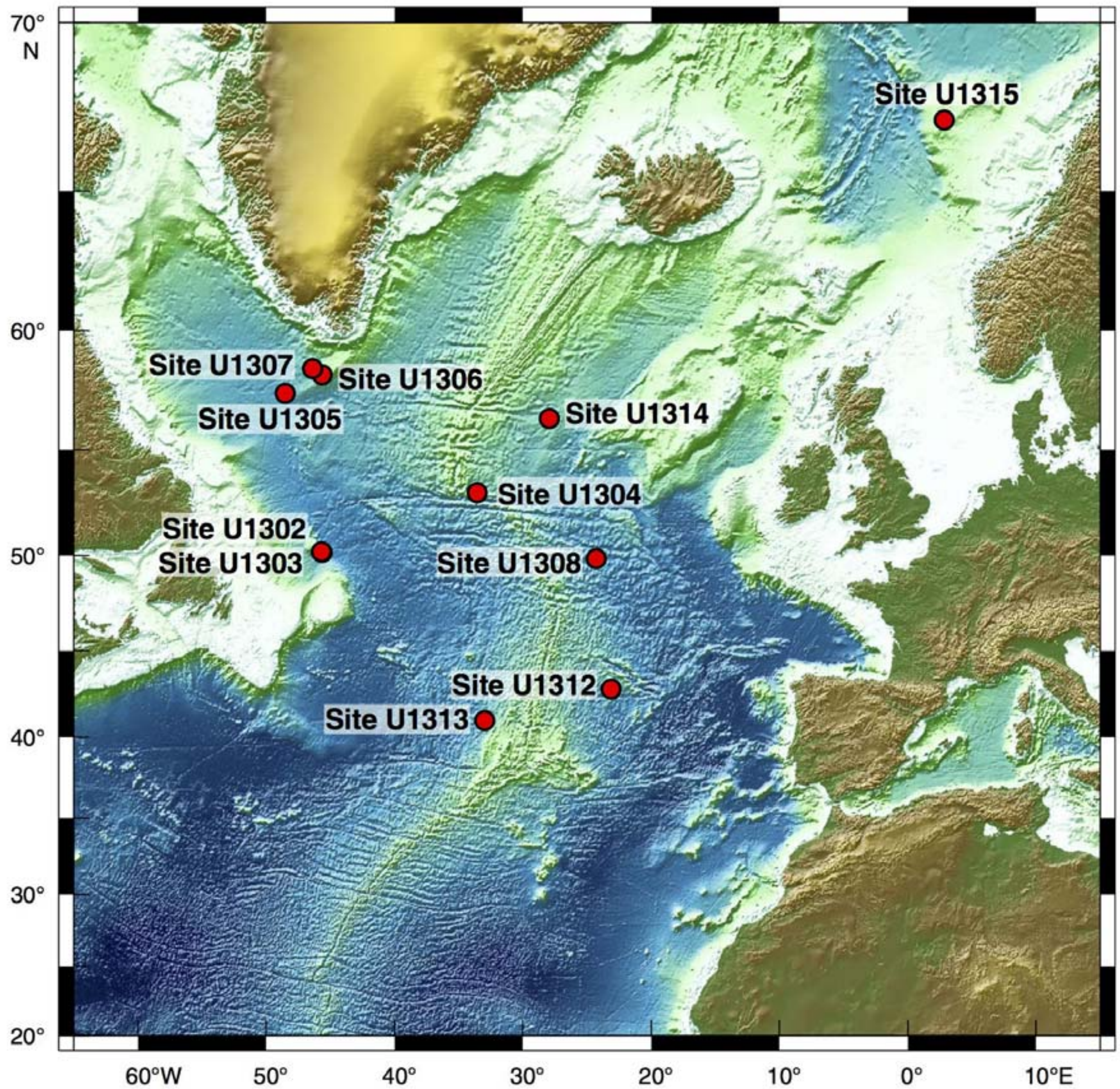

Figure 1: Map depicting the location of drilling location from the IODP Expedition 303/306 (source).

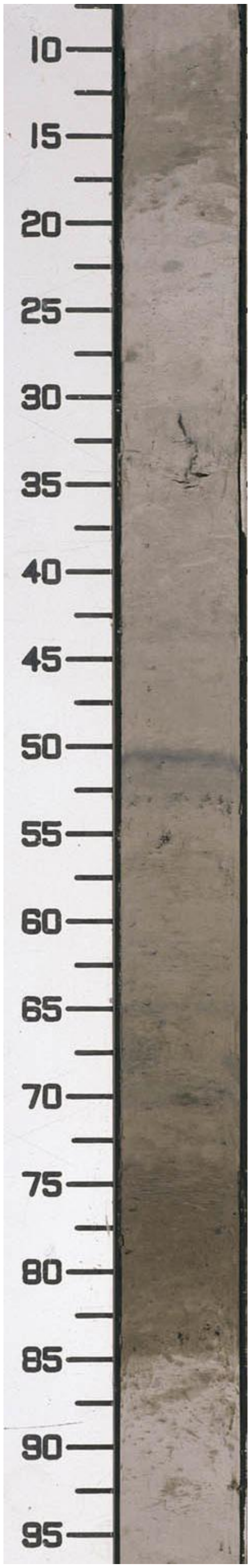

Figure 2: Photo showing part of a marine sediment core recovered from ~50 meters below the North Atlantic Ocean seafloor (source). For an online interactive core, please visit here.

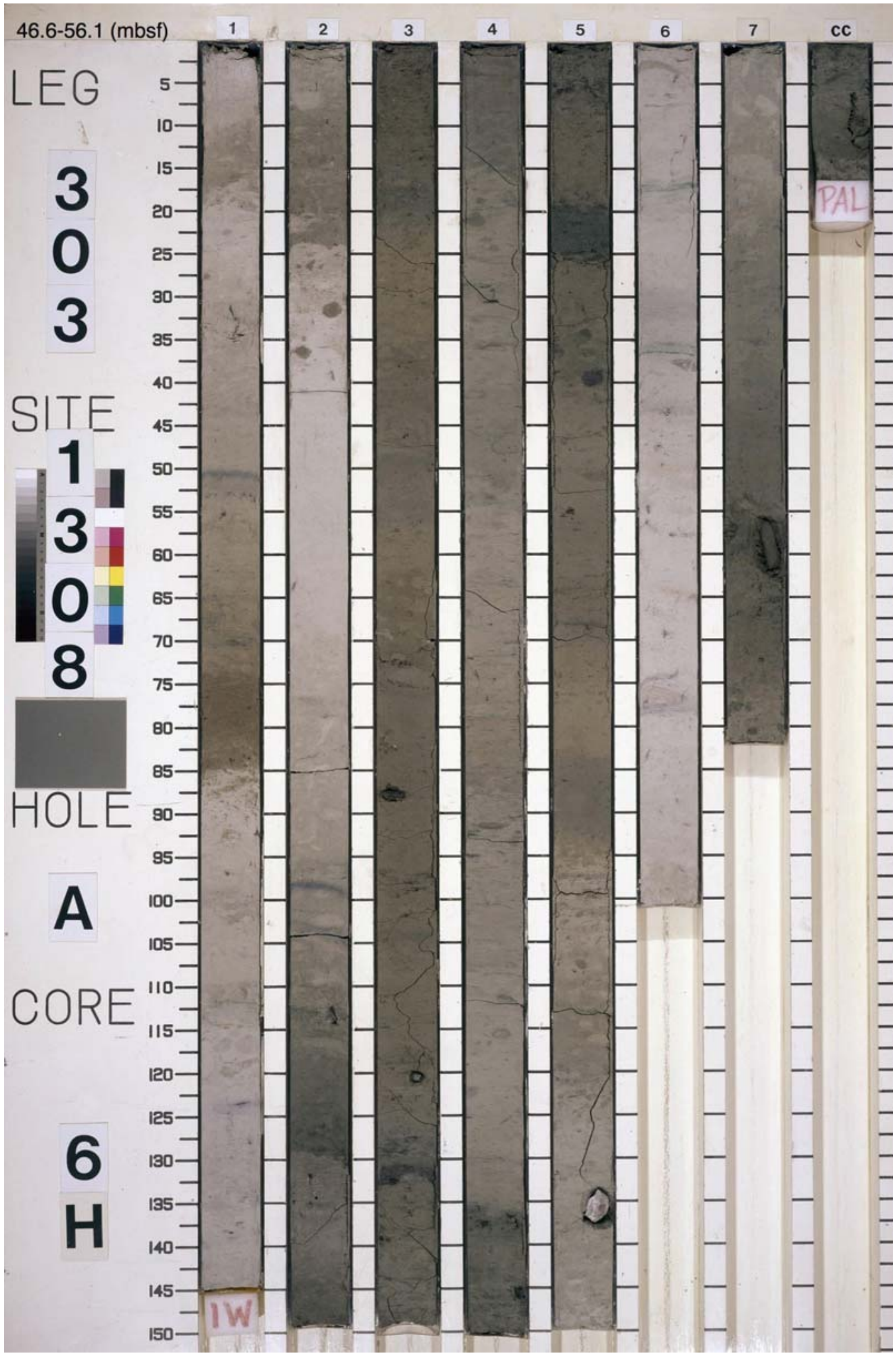

Figure 3: A composite image of 1.5 meter sections of sediment collected from 303-1308A-6H ([source]()). Each 9.5 meter of core is cut into these 1.5 meter sections to facilitate research efforts and storage. For more information on core nomenclature please review [this]() exercise. **Note**: The first section in this image (6H-1) is the same section provided in Figure 2.

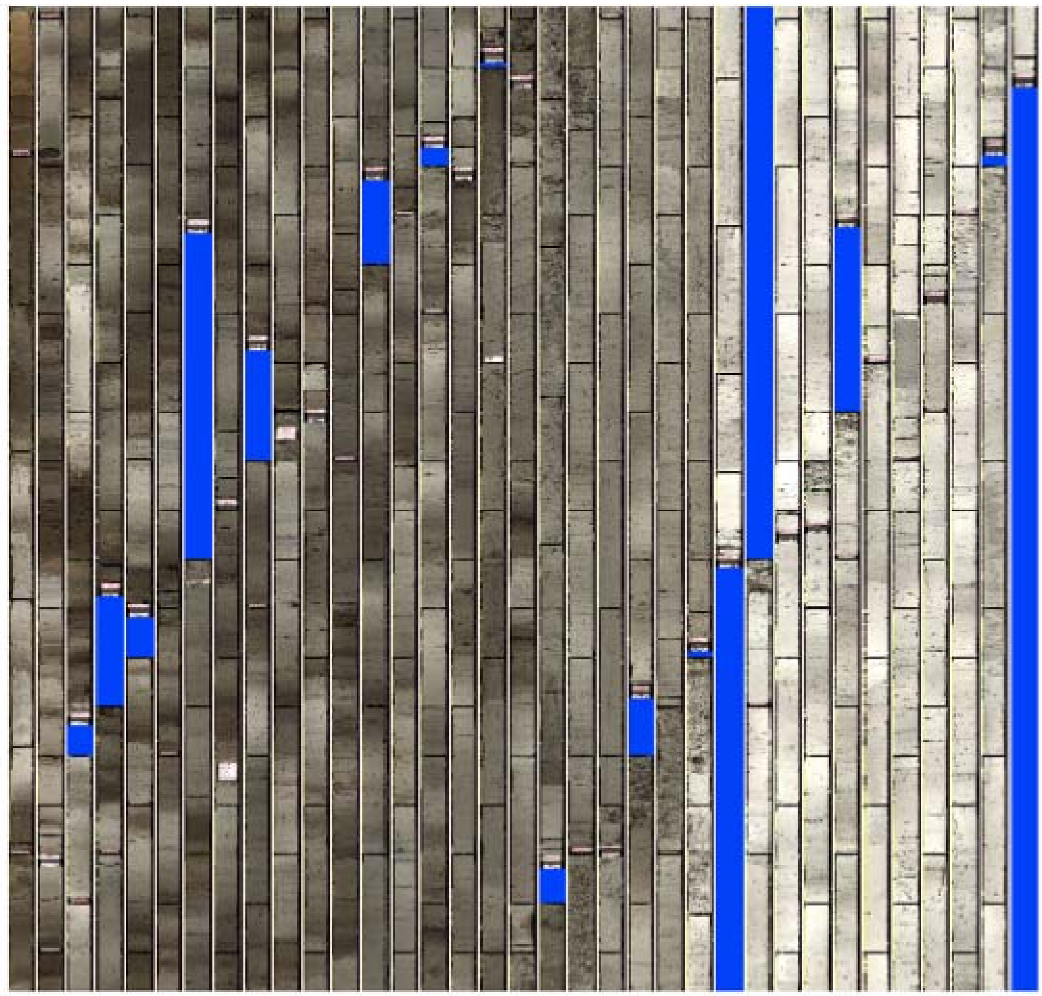

Figure 4: A composite image of all cores collected from 303-1308A-6H (source).

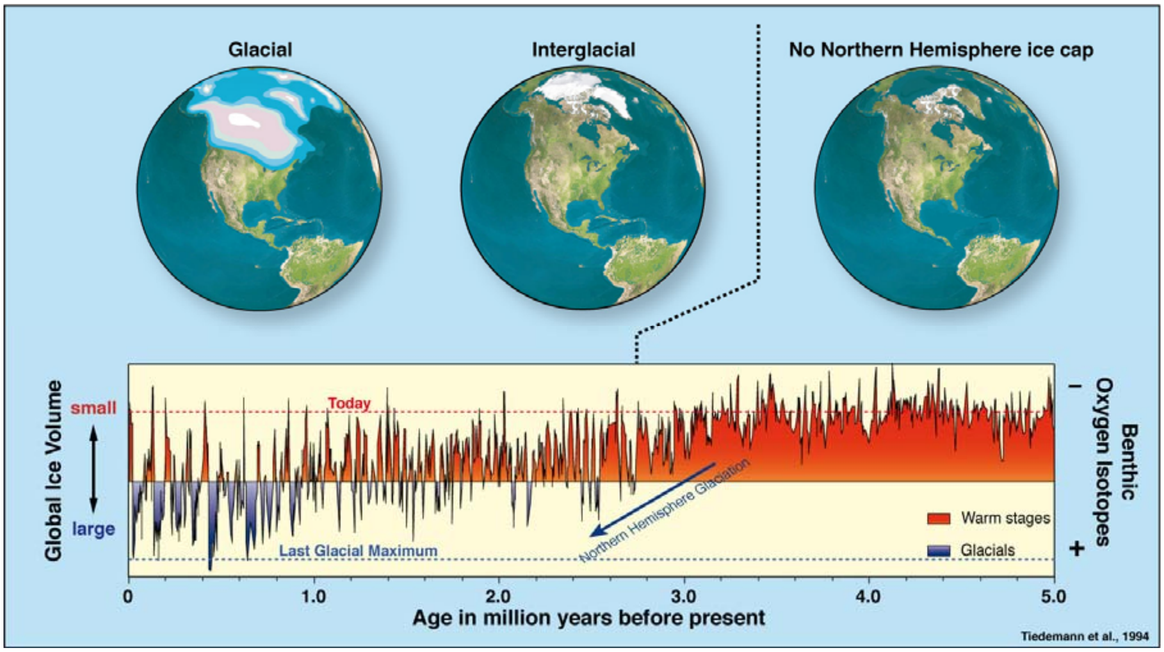

Figure 5: The benthic oxygen isotope curve reflects the global climate evolution of the last 5 million years, as it is a measure of changes in global ice volume and deep-water temperature. The Pliocene warm period from ~5 to ~3 million years ago is believed to hold clues for assessing future climate change. This time interval, with atmospheric CO2-concentrations close to modern ones, was significantly warmer than today. High-latitude sea surface temperatures were up to 7°C higher, the modern Northern Hemisphere ice cap over Greenland was absent, and the sea level was about 30 m higher than today. Hence, it represents a possible future climate scenario predicted by numerical models. The long-term increase in oxygen isotope values from ~3–2.5 million years ago marks the development of a permanent Northern Hemisphere ice cap with varying size. The last 3 million years are characterized by alternating glacial and interglacial climate stages, while glacial ice sheets reached their largest size during the last 700.000 years (source).

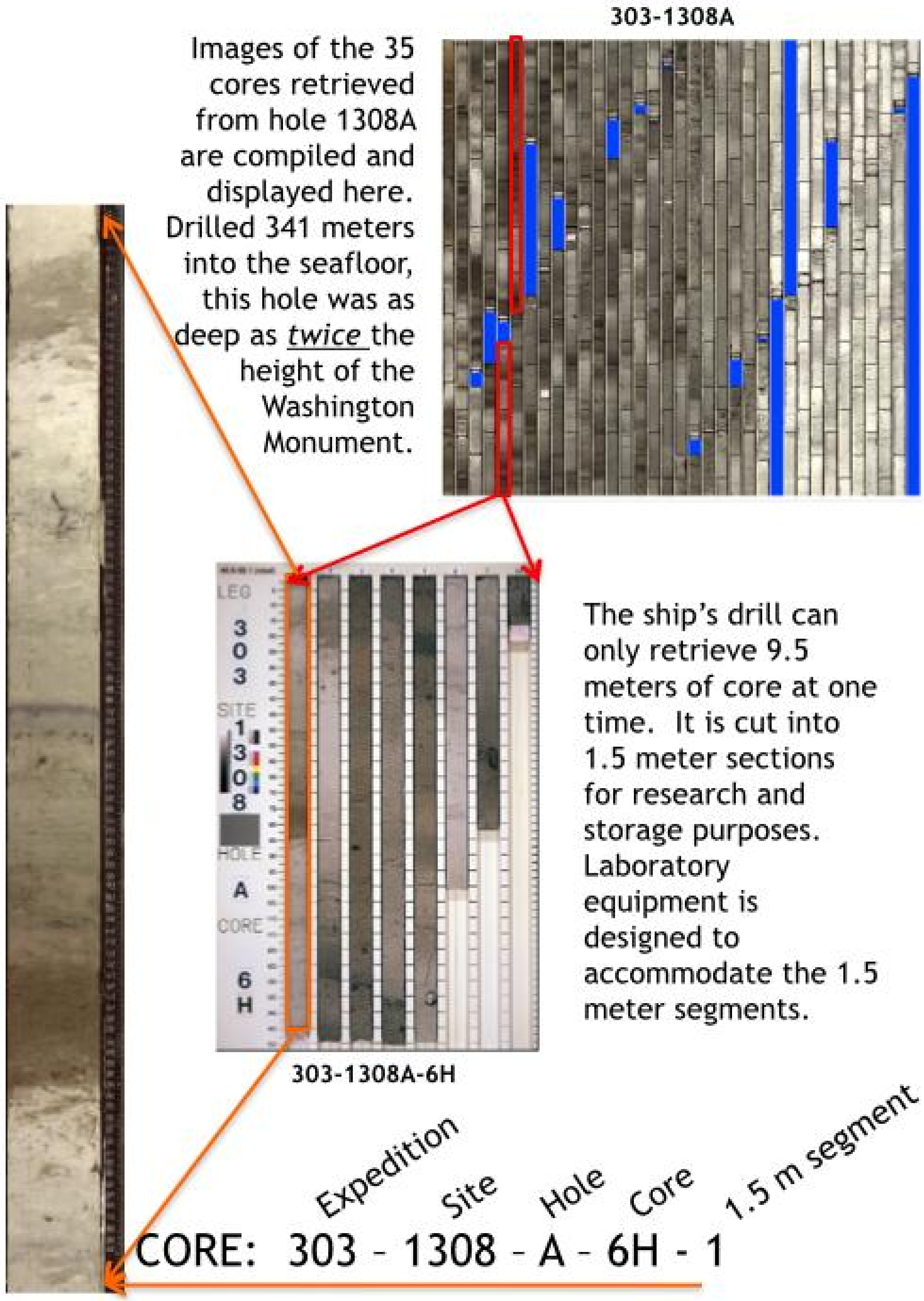

Figure 6: Illustration demonstrating the link between figures 1, 2 and 3. (Provided by tesserazoa@gmail.com).

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