DRILLING INTO GEOSCIENCE EDUCATION

SCIENTIFIC OCEAN DRILLING LESSONS BRING AUTHENTIC EXPERIENCES TO CLASSROOM LEARNING

Maya Pincus & Sharon Cooper, U.S. Science Support Program
Ed Robeck, Lindsay Mossa, Lauren Brase, & Sequoyah McGee, American Geosciences Institute

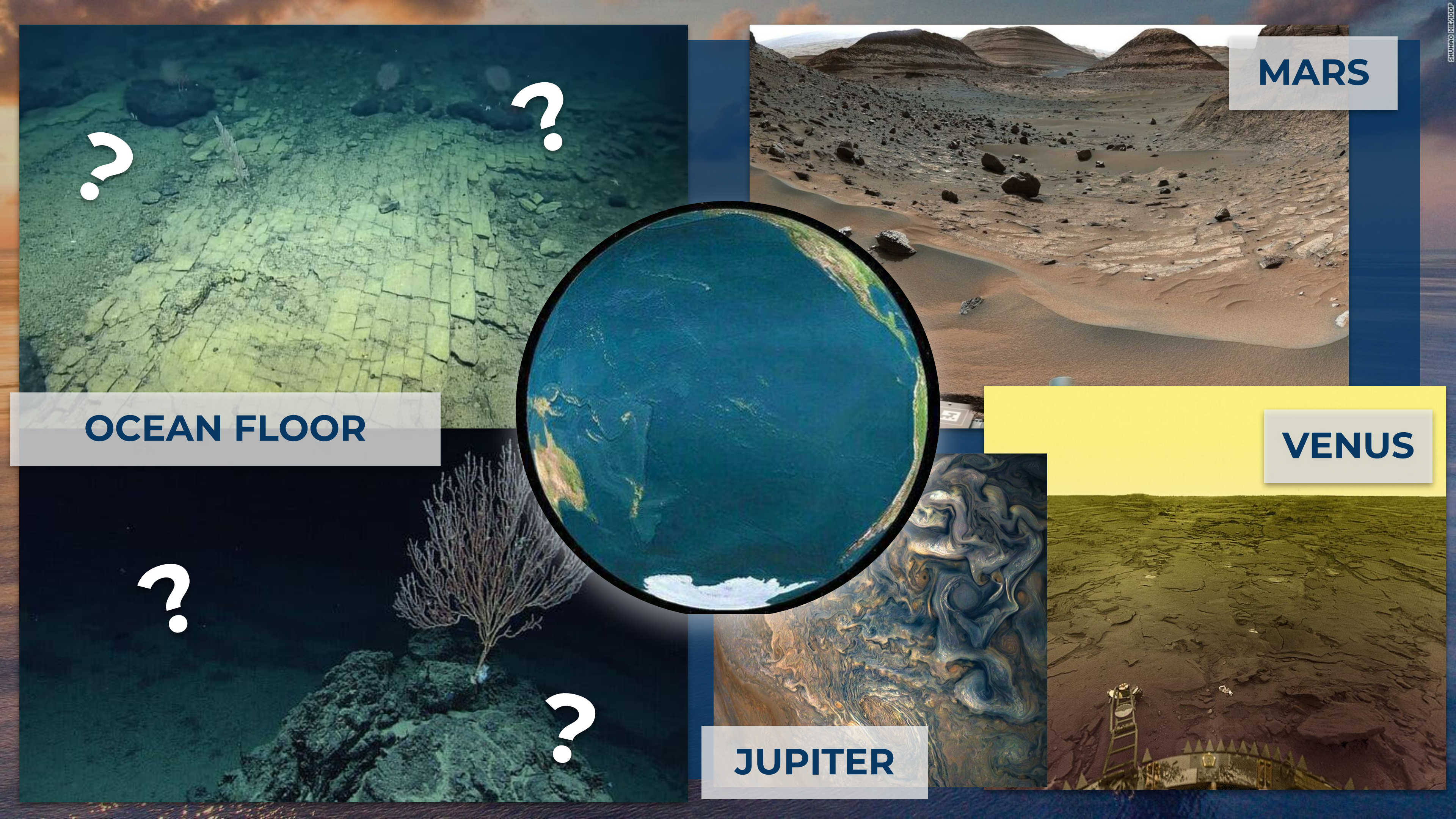
U.S. SCIENCE SUPPORT PROGRAM

american geosciences institute
connecting earth, science, and people

Who am I?

MAYA PINCUS

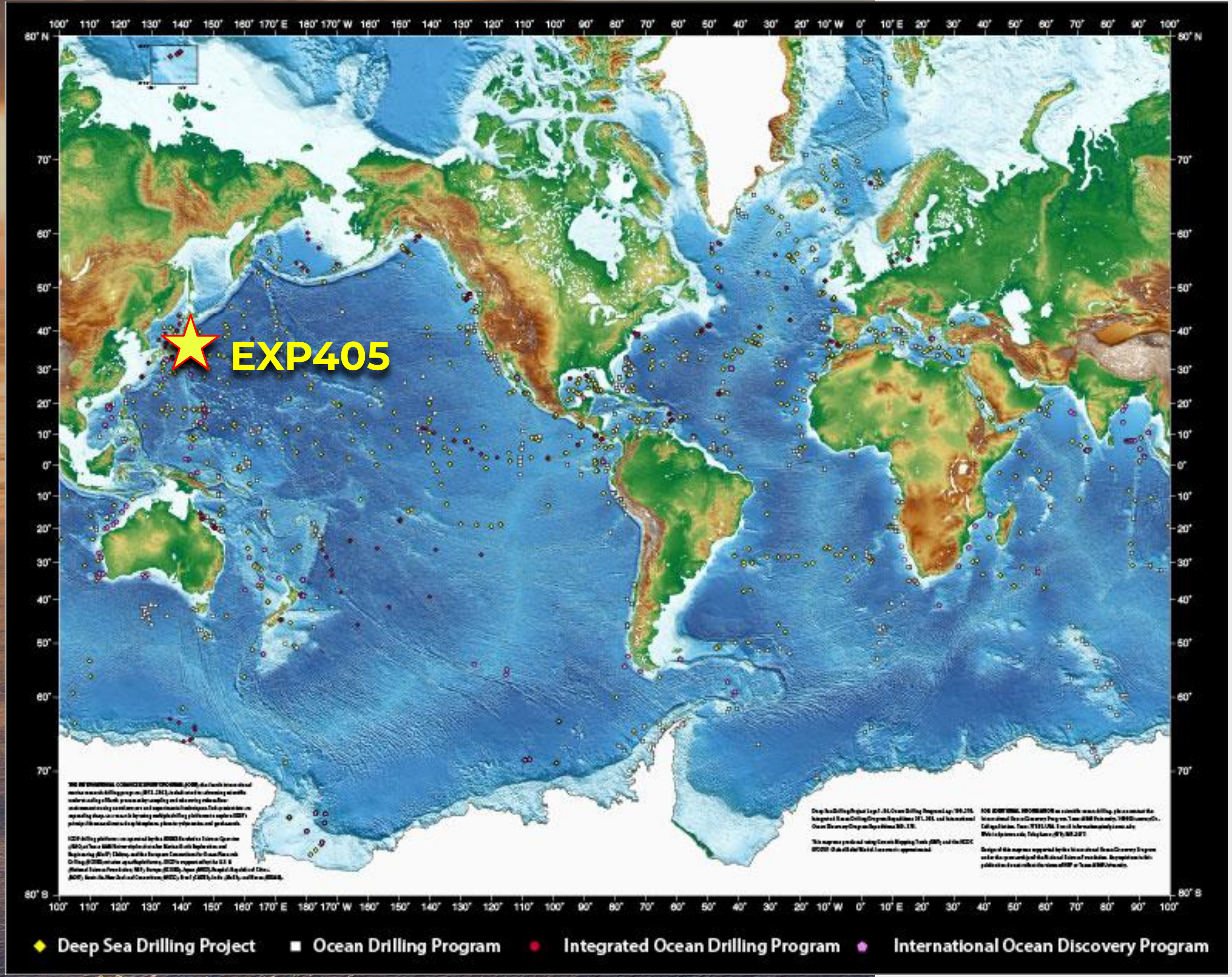
- ➢ Earth Science teacher in NYC (2015 - 2022)
- ➢ Onboard Outreach Officer for Expeditions 391 and 397T
- ➢ Science communicator for the International Ocean Discovery Program


OCEAN FLOOR
MARS
VENUS
JUPITER

International Ocean Discovery Program (IODP)

drilling into the ocean floor since 1961

"The most successful science program no one's ever heard of!"



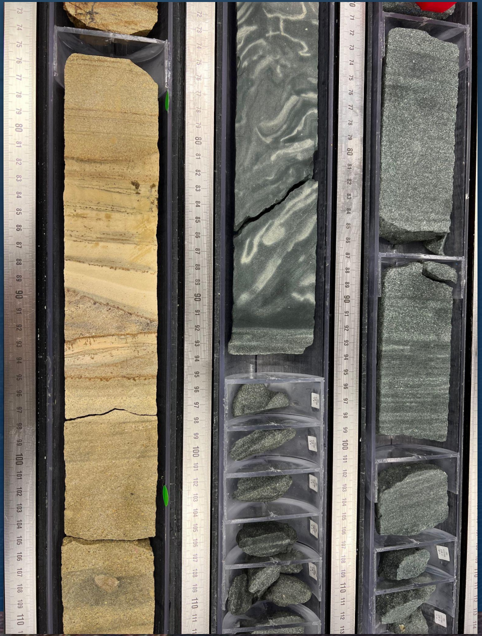
To date, IODP and its predecessor programs have carried out almost **400 expeditions**, with drilling sites in **every ocean on Earth.**

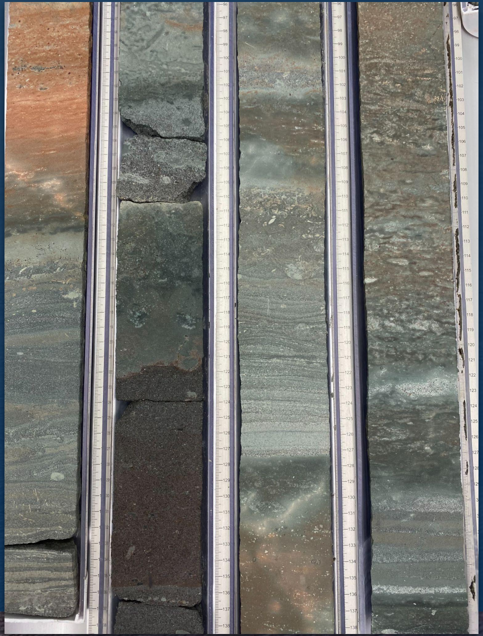
What is a "core"?

A 10 m (30 ft) long tube full of sediment and rock collected from the ocean floor.

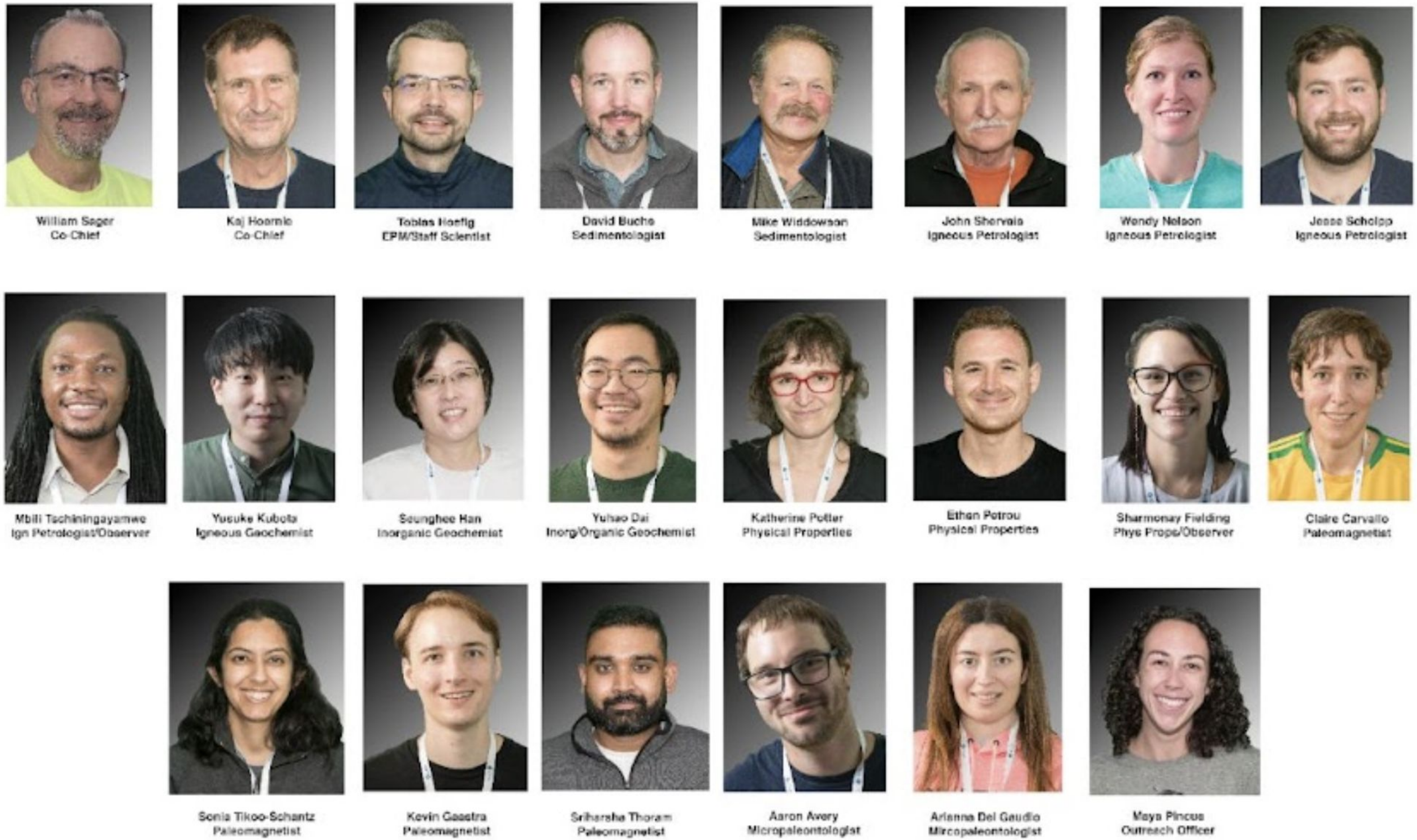
Collecting cores

We travel back in time by drilling into the Earth. It's like a time machine.





SCIENTISTS



SHUHAO XIE/IODP

TECHNICIANS

Steve Midgley
Operations Superintendent

Lisa Crowder
Laboratory Officer

Daniel Marone
Assistant Lab Officer

Beth Novak
Assistant Lab Officer

Carel Lewis
Curator

Doug Cummings
Publications Specialist

Sandra Herrmann
Imaging Specialist

James Zhao
Application Developer

Susan Boehm
Chemistry Lab Specialist

Aaron Mechler
Chemistry Lab Specialist

Fabricio Ferreira
Description Lab Specialist

Emily Britt
Marine Lab Specialist

Mark Higley
Paleomag Lab Specialist

Alejandro Avila Santis
Phys Props Lab Specialist

Brian Swilley
Thin section Lab Specialist

Myriam Kars
X-ray Lab Specialist

Randy Gjesvold
Marine Instrumentation Specialist

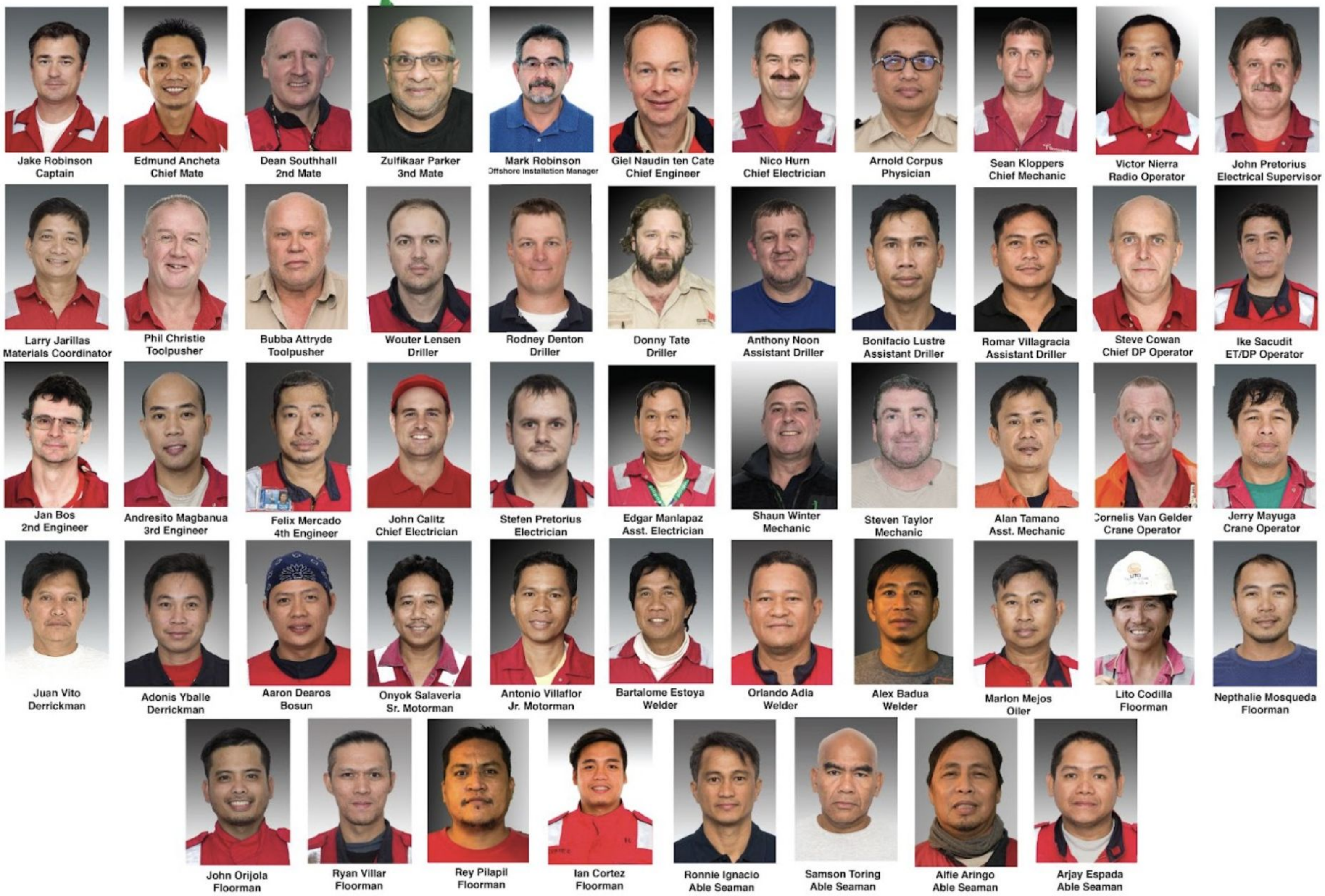
Chris Visser
Marine Instrumentation Specialist

Steve Thomas
Marine Computer Specialist

Mike Hodge
Marine Computer Specialist

Clayton Furman
Schlumberger Logging Engineer

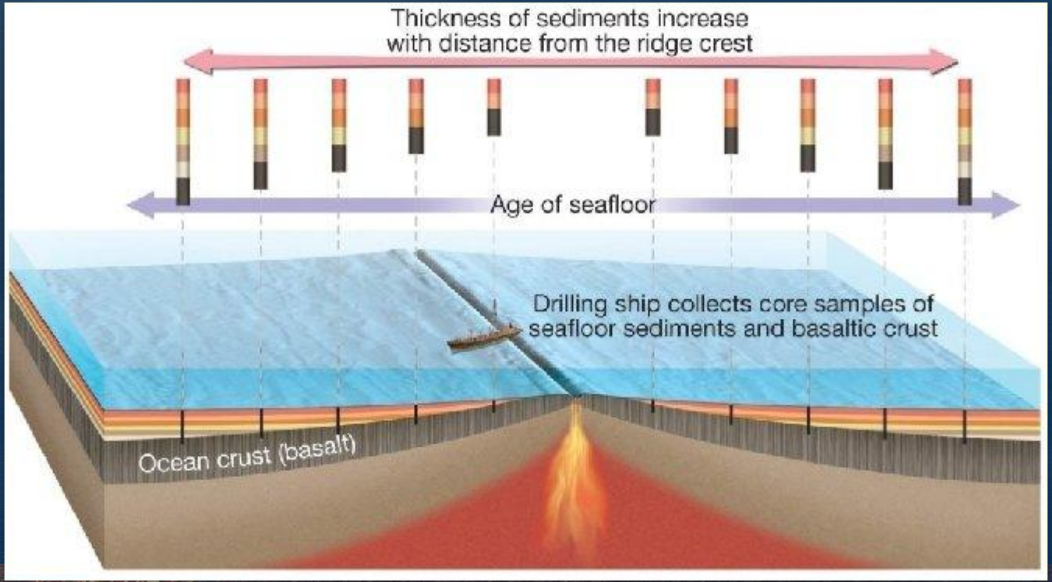
SHIP'S CREW

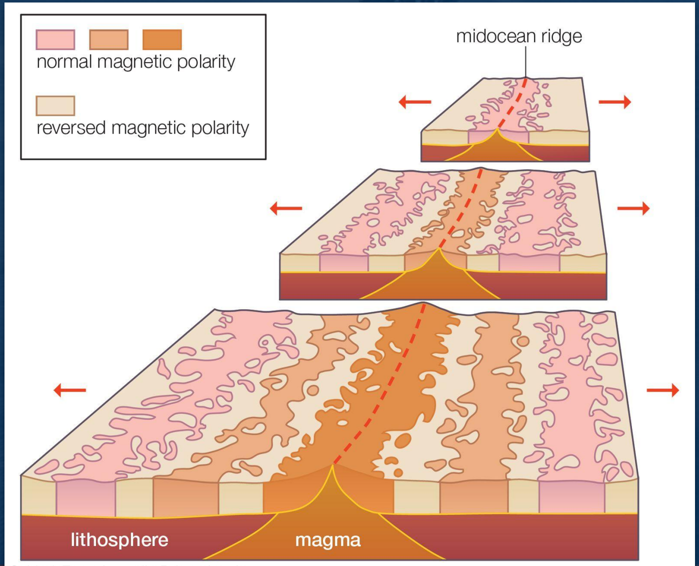

Jake Robinson Captain
Edmund Ancheta Chief Mate
Dean Southhall 2nd Mate
Zulfikaar Parker 3rd Mate
Mark Robinson Offshore Installation Manager
Giel Naudin ten Cate Chief Engineer
Nico Hurn Chief Electrician
Arnold Corpus Physician
Sean Kloppers Chief Mechanic
Victor Nierra Radio Operator
John Pretorius Electrical Supervisor
Larry Jarillas Materials Coordinator
Phil Christie Toolpusher
Bubba Attryde Toolpusher
Wouter Lensen Driller
Rodney Denton Driller
Donny Tate Driller
Anthony Noon Assistant Driller
Bonifacio Lustre Assistant Driller
Romar Villagracia Assistant Driller
Steve Cowan Chief DP Operator
Ike Sacudit ET/DP Operator
Jan Bos 2nd Engineer
Andresito Magbanua 3rd Engineer
Felix Mercado 4th Engineer
John Calitz Chief Electrician
Stefen Pretorius Electrician
Edgar Manlapaz Asst. Electrician
Shaun Winter Mechanic
Steven Taylor Mechanic
Alan Tamano Asst. Mechanic
Cornelis Van Gelder Crane Operator
Jerry Mayuga Crane Operator
Juan Vito Derrickman
Adonis Yballe Derrickman
Aaron Dearos Bosun
Onyok Salaveria Sr. Motorman
Antonio Villaflor Jr. Motorman
Bartalome Estoya Welder
Orlando Adia Welder
Alex Badua Welder
Marlon Mejos Oiler
Lito Codilla Floorman
Nepthalie Mosqueda Floorman
John Orijola Floorman
Ryan Villar Floorman
Rey Pilapil Floorman
Ian Cortez Floorman
Ronnie Ignacio Able Seaman
Samson Toring Able Seaman
Alfie Aringo Able Seaman
Arjay Espada Able Seaman

COOKING AND CLEANING

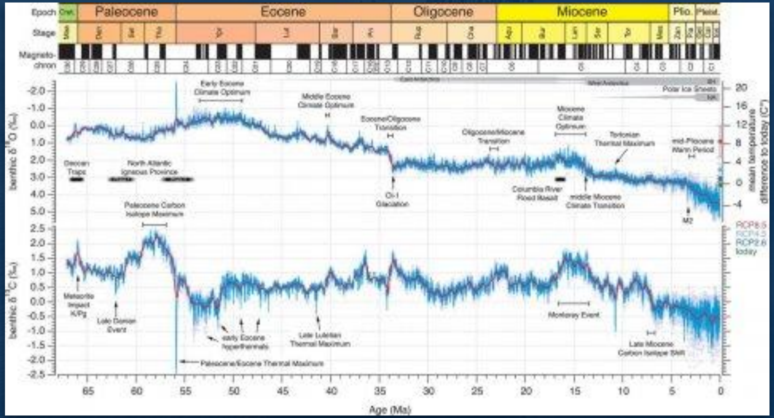
Scientific Ocean Drilling: plate tectonics

New ocean crust is created at mid-ocean ridges, preserving a mirror image of seafloor ages and magnetic anomalies on each side of the ridge.

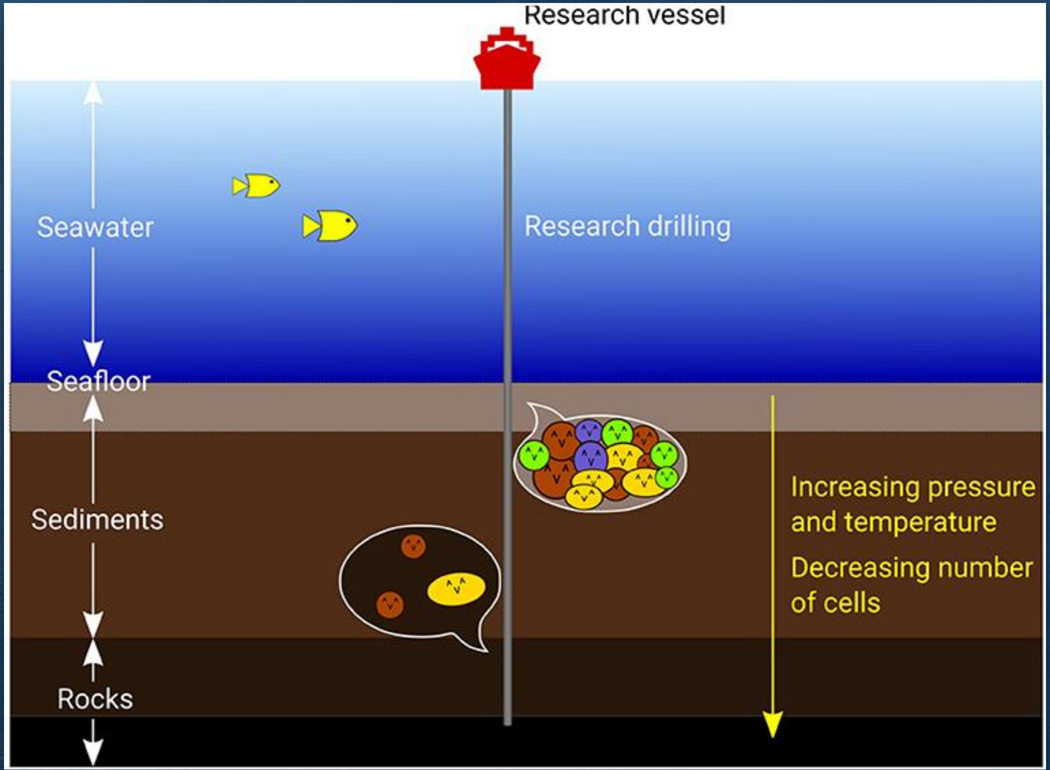


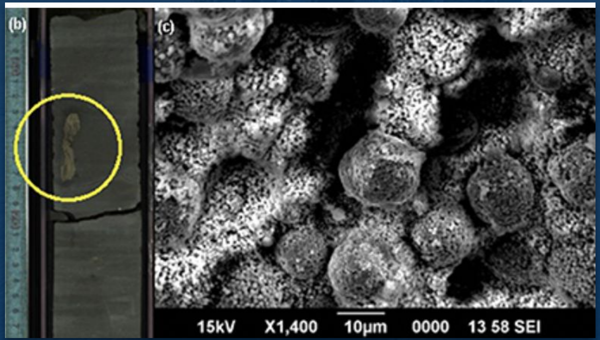


Scientific Ocean Drilling: climate



Scientific Ocean Drilling: extremes of life





School of Rock - Educator PD

- Educators come together to learn about scientific ocean drilling operations and research
- Teachers are immersed in the science so they can turn-key it in their communities
- They help create free resources available online

IODP Educational Resources

- Over 100 lessons developed over 15 years, located on the *JOIDES Resolution* website
- The existing materials are currently being revised
- Lessons include:
  - Data generated by scientists on the research ships
  - High-resolution images of the cores
  - Hands-on activities
- Grounded in pedagogical research and best practices
- Materials are aligned with:
  - A Framework for K-12 Science Education
  - NGSS Description of Phenomena
  - 2050 Science Framework
  - Ocean Literacy Principles

Revised Lessons - Teacher Version

Climate Diaries of the Deep: Research on Ancient Environments

LESSON SUMMARY

This lesson focuses on the use of data to study how Earth's climate has changed over time. Students use foraminifera species sampled from JR Expedition 342 to determine the age of the sediment and the climate conditions during the sample ages. This lesson could be used as part of a unit on geologic history and the types of evidence that can be studied to understand how Earth has changed over time.

Standards and Dimensions

NGSS: HS-ESS2-2, HS-ESS2-4
Science Engineering Practices: Analyzing and Interpreting Data
Cross-Cutting Concepts: Patterns
Disciplinary Core Ideas: ESS2.A: Earth Materials and Systems

Connections to 2050 Science Framework

Strategic Objectives: Earth's Climate System, Tipping Points in Earth's History
Flagship Initiatives: Ground Truthing Future Climate Change
Enabling Elements: Broader Impacts and Outreach

Ocean Literacy Principle(s)

OLP 5: The ocean supports a great diversity of life and ecosystems.

Suggested Time

45–60 minutes

Preparation of Materials

Per group:

- Print organism/fossil sorting cards (one set per group)
- Print foraminifera species cards (each person in the group receives a different foraminifera species card)

Per student:

- Handouts

Acknowledgments

Authors: Alyssa Weisenstein and Lindsay Mossa, based on an original lesson by Dr. Edward Cohen.

Scientific Acknowledgment

Expedition: One objective of **Expedition 342** was sampling in the North Atlantic was to study the climate transition from "greenhouse" to "icehouse" during the Eocene to Oligocene.
Data Source: Jones, M.M., Sageman, B.B., Selby, D., Jacobson, A.D., Batenburg, S.J., Riquier, L., MacLeod, K.G., Huber, B.T., Bogus, K.A., Tejada, M.L.G., Kuroda, J., & Hobbs, R.W. (2023). Abrupt episode of mid-Cretaceous ocean acidification triggered by massive volcanism. Nature Geoscience, 16(2), 169–174. **https://doi.org/10.1038/s41561-022-01115-w.**

BACKGROUND FOR THE INSTRUCTOR

Foraminifera (forams) have a critical role in aging sediment layers and determining environmental changes that have occurred throughout Earth's history. These microscopic marine organisms, abundant in ocean sediments, serve as invaluable time capsules, offering a detailed record of past environmental conditions. By examining the composition and distribution of forams within sediment cores, scientists can meticulously reconstruct Earth's climatic fluctuations over time.

IODP EXPEDITION 342

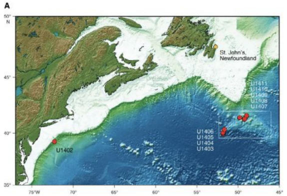


Figure TE-1. Drill sites where sediment cores were collected during Expedition 342.

JOIDES Resolution is a research vessel that has collected sediment cores from seafloors all over Earth. Expedition 342 (Figure TE-1) collected samples from the northwestern Atlantic Ocean. Study of these cores allows students to specifically delve into data that shows climatic changes throughout the Eocene and Oligocene epochs. This data is provided in the form of foram fossils and the measurements of oxygen isotopes within these fossil samples.

Supplemental Resources*

Oceanic Drilling

- **Introducing the International Ocean Discovery Program**
- **Holes in the Bottom of the Sea: History, Revolutions, and Future Opportunities**
- **Highlights of IODP Discoveries**

Lesson specific

- **What are foraminifera?**
- **Smithsonian Scientists Unearth Signs of an Ancient Climate Calamity Buried Beneath the Seafloor (Summary of Data Source Article)**

ANNOTATED STUDENT ACTIVITY

Objective(s)/Outcome(s)

Students will be able to analyze foraminifera LAD and FAD to describe patterns in climate fluctuations throughout Earth's history.

Materials

- organism/fossil sorting cards
- Foraminifera species cards
- *Lab Profile Micropaleontology* video

Background

JOIDES Resolution Expedition 342 traveled to the Newfoundland Ridges where core samples were collected from nine sites on the seafloor of the north Atlantic Ocean. One objective of this expedition was to study how Earth's climate has changed over time. Micropaleontologists are the first to get a sediment sample from the core. They looked for microfossils, especially forams, that provide clues to the age of sediment. The chemical makeup of a foram's test (shell) can give insights into climate, as they incorporate elements and compounds from ocean water directly into their tests. One element in particular is oxygen-18 (18O), an isotope whose concentration is known to change with ocean temperatures. Warmer waters have lower levels of 18O, while colder waters have higher levels of 18O. Forams that live in colder waters incorporate more 18O into their tests, and when they fossilize, this stable isotope can then help scientists to classify the climate in which the forams lived.

Activity

Teacher Note: Give each student one Foram Card to complete the data recording on the geologic time scale and graph as shown in Figure TE-2. Students can then form groups with classmates with the other Foram Cards to obtain the rest of the data or have them exchange cards to continue recording data. It is recommended you use *Guembelitrioides nuttali* as an example to demonstrate the procedure for students. When students are ready to interpret the graph, you may want to demonstrate how to read it using the same example species.

Revised Lessons - Student Version

Investigating Seafloor Spreading Using Nannofossils

STUDENT NAME: ....

STUDENT ACTIVITY

SCIENTIFIC OCEAN DRILLING

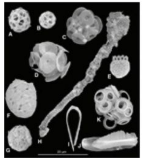
Objective(s)/Outcome(s)

Students will be able to:

1. analyze real-world data collected from the Deep-Sea Drilling Project to describe evidence of seafloor spreading.
2. graph and use slope analysis to determine the relationship between distance from the spreading center and age of the sediments.

Background

FIGURE 1. SEM IMAGES OF COMMON COCCOLITHOPHORES FROM CORE SAMPLES.



Credit: Betzler, Eberli, and Alvarez-Zarikian

Nannofossils (Figure 1) are the remains of tiny plankton, shelled animals that are 1-40 microns in size. Dead plankton and other sediments in the water sink down through the water column and are deposited on the sea floor (oceanic crust). Specific techniques are used to determine the age of nannofossils.

A divergent plate boundary (ridge) is where two tectonic plates meet. New oceanic crust is formed at ridges on the ocean floor. Seafloor spreading occurs as new crust forms and older crust is pushed away from the ridge, carrying with it any sediment that was deposited on top of the crust. The distance of the sediments from the ridge, plus the age of the sediments, can be used to determine the rate of seafloor spreading at a divergent boundary.

Activity

1. The data in Table 1 were collected by the Deep Sea Drilling Project (DSDP) in 1968, during which they drilled the seafloor sediment on either side of the Mid-Atlantic Ridge. Using data from Table 1, plot coordinates representing the age and distance from the ridge at each site (14-21).
   a. Choose a scale that allows your distance axis to go to 2200 km and your age axis to go to 100 m.y. (millions of years).
   b. Label each coordinate with the site number.

SCIENTIFIC OCEAN DRILLING

STUDENT NAME: ....

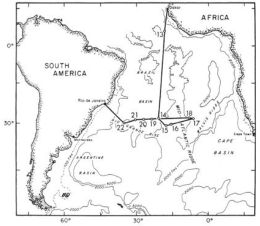
TABLE 1. DISTANCES AND AGES OF MID-ATLANTIC RIDGE SITES FROM THE AXIS

Site Number	Paleontological Age of Sediment (m.y.)	Distance From Ridge Axis (km)
14	40	745
15	24	422
16	11	221
17	33	718
18	26	506
19	49	1010
20	67	1303
21	76	1686
22	?	?

Credit: Modified from Maxwell et al., 1970. **https://bit.ly/DPSPLeg13**

2. Use the data in Table 1 to label the age of drill sites 14–21 on Figure 2, which shows each of the drill sites during leg 3.
3. Use your data to hypothesize where the Mid-Atlantic Ridge is located.
4. Sketch a line on the map to show which points the ridge is most likely located between.

FIGURE 2. MODIFIED FROM MAP OF JOURNEY AND DRILL SITES OF LEG 3.



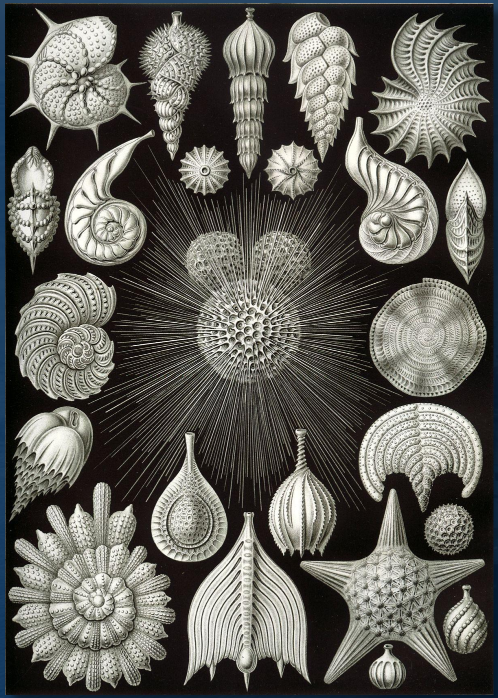
Credit: Maxwell et al., 1970, **https://bit.ly/DPSPLeg3Intro**

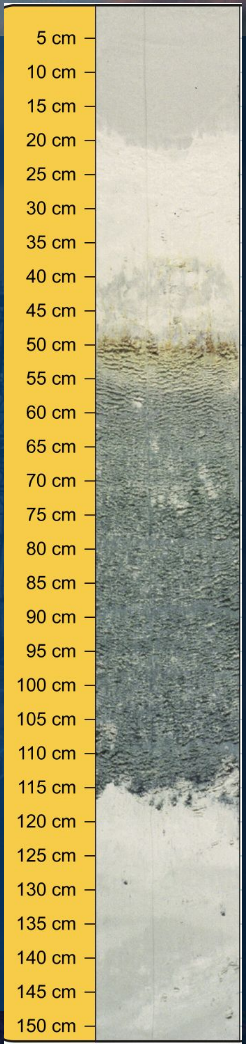
Student handouts contain:

- Objectives
- Background
- Step-by-step instructions
- Data analysis
- Synthesis
- Extension activity

Time Capsules of the Deep

Today you are a scientist investigating the day the dinosaurs died. Follow the instructions on your worksheet and work in teams to learn how a meteorite impact affects life on Earth.





Replica Cores

We lend replicas of our **5** most famous cores for classroom use.

CRETACEOUS IMPACT

GLACIAL / INTERGLACIAL

PALMER DEEP - GLACIAL RETREAT

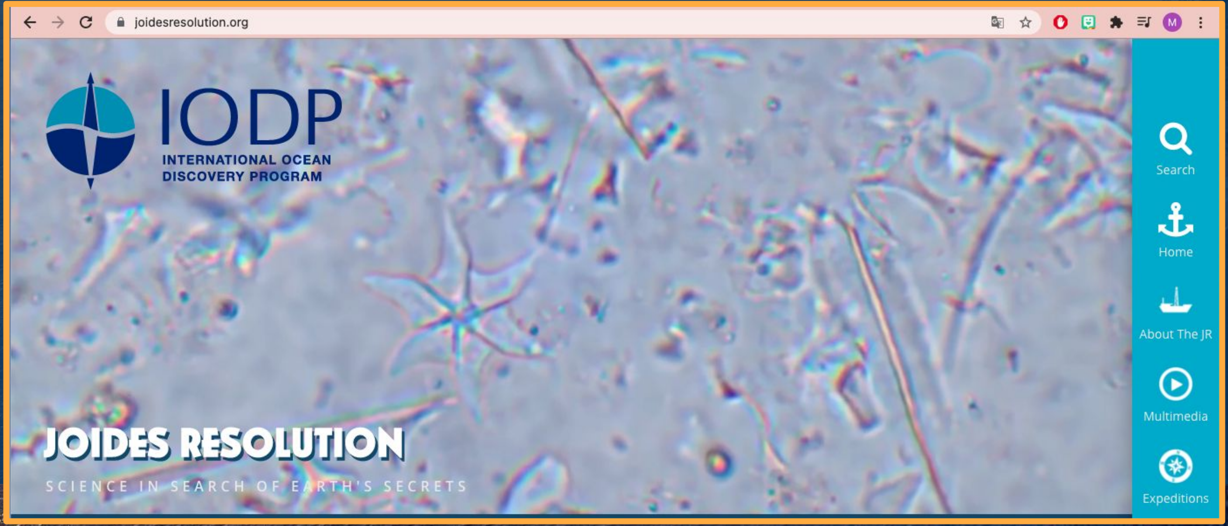
TAHITIAN SEA LEVEL CHANGE

SAANICH INLET - GLACIAL FLOODING

JOIDES Resolution FOR EDUCATORS

[Educational Materials and Resources]

[Educator Resource Inventory]



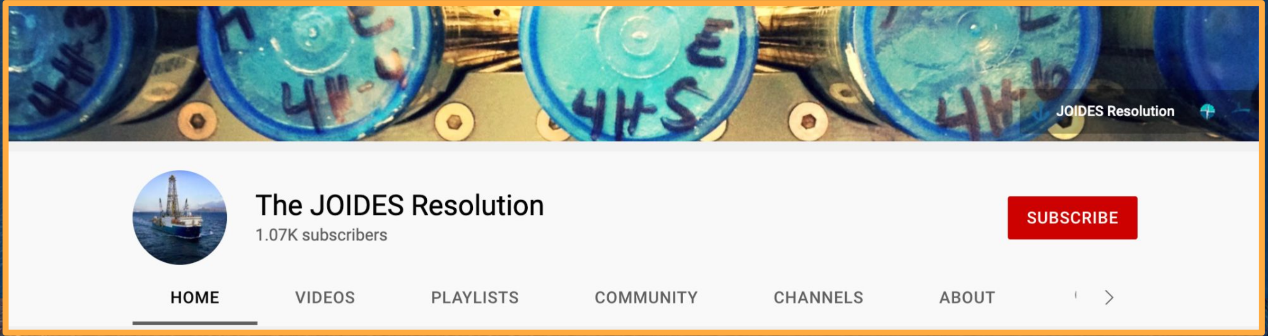
Additional Resources

- IODP Digital Photo Archive ("Guest access")
- StoryCorps: Tales from the Deep



Helpful Videos

- Introducing the International Discovery Program
- Special Report: Core on the Floor
- Ship-to-Shore Broadcasts
- And many more…



Questions?

What more do you want to know about scientific ocean drilling lessons?

JOIDES Resolution Science Operator

IODP
INTERNATIONAL OCEAN DISCOVERY PROGRAM

U.S. SCIENCE SUPPORT PROGRAM

NSF

mpincus@ldeo.columbia.edu

Stay in touch!!

We update our blog and social media often.

HTTPS://JOIDESRESOLUTION.ORG/

TheJR

joides_resolution

JOIDES Resolution

JOIDES Resolution