Deep Earth Academy
CONSORTIUM FOR OCEAN LEADERSHIP

Activity of the Month – February, 2008

It's Not Just The Core That Tells The Hole Story: An Introduction to Downhole Logging Technology

Summary

Students read about "down-hole logging" technology, in which instruments are lowered from the drilling ship into the hole after cores have been removed to measure physical properties that reveal more about seafloor sediments and rocks. They then examine sample logs to note patterns and interpret the data.

Learning Objectives

Students will be able to:

- explain "downhole logging" technologies used on the *JOIDES Resolution*
- interpret data from three ODP drill sites
- explain what the patterns reveal about sub-seafloor sediment and rock layers

National Science Education Standards

- Content Standard A: Science as Inquiry
- Content Standard B: Physical Science
- Content Standard D: Earth and Space Science
- Content Standard E: Science and Technology
- Content Standard F: Science in Personal and Social Perspectives
- Content Standard G: History and Nature of Science

Ocean Literacy Essential Principles

- Principle 1: Earth has one big ocean with many features.
- Principle 2: The ocean and life in the ocean shape the features of Earth.
- Principle 7: The ocean is largely unexplored.

Target Age: Grades 7-12

Time: 1 class period

Materials

- Copies of the student pages of this activity

Background

After cores have been brought up on the *JOIDES Resolution*, scientists often learn more about what lies beneath the seafloor by lowering special instruments into the **borehole** to measure **physical properties** of the sediments and rocks. This process is called **logging** and the records are called **logs**.

Data from logging add more knowledge about Earth's history because some of the seafloor materials will not be recovered by drilling. Some substances are too hard or too weak for complete recovery. This creates gaps in the core. But logs provide continuous records that give information about the missing layers.

Also, when the cores are brought to the surface, temperature and pressure conditions are very different from where materials originally lay, and so the cores may expand or be altered in the process. Logging measurements, by contrast, are made **in situ** (in the place where the layers are located), so they help correct core properties that were disturbed or changed.

Strings of instruments attached together are lowered by an electrical wireline into the borehole to measure sediment and rock properties, as represented by Figure 1. This operation allows scientists to study such variables as **stratigraphy** (what kinds of rock and sediment layers are down there); **mineral composition**; **porosity** (amount of space between the particles); location of **fractures** and **faults**; and **cycles** in the stratigraphy that may reveal patterns of climate change or other events in Earth's history.

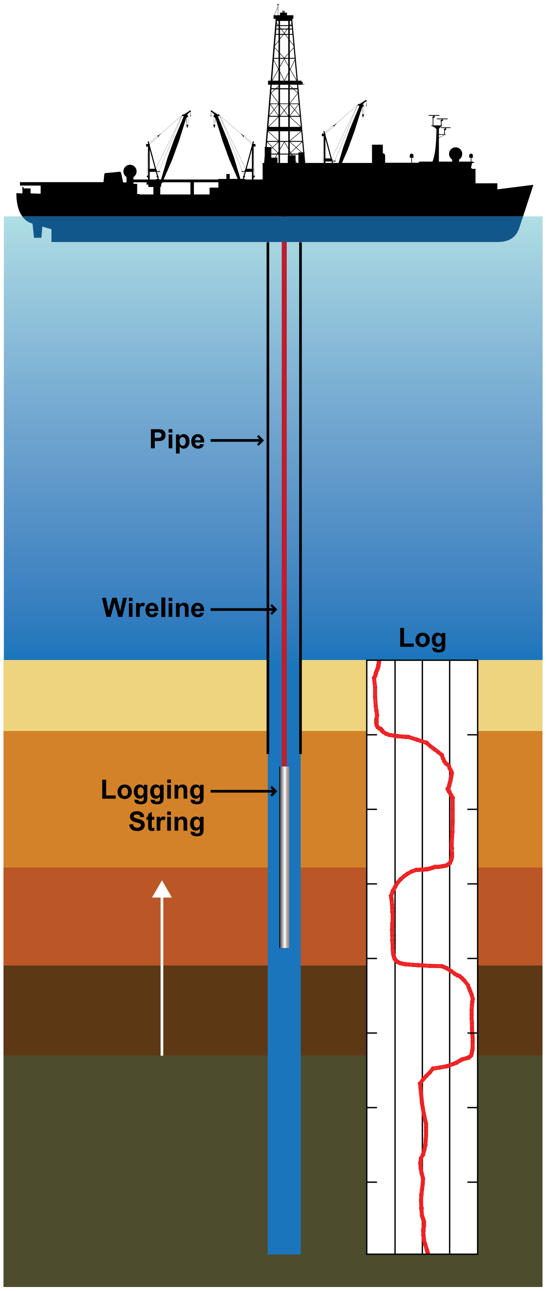

Figure 1. The "JOIDES Resolution" lowers a string of instruments to learn more about the sediment and rock layers of the ocean floor. As the instruments go across different layers, the physical properties measured (logs) change.

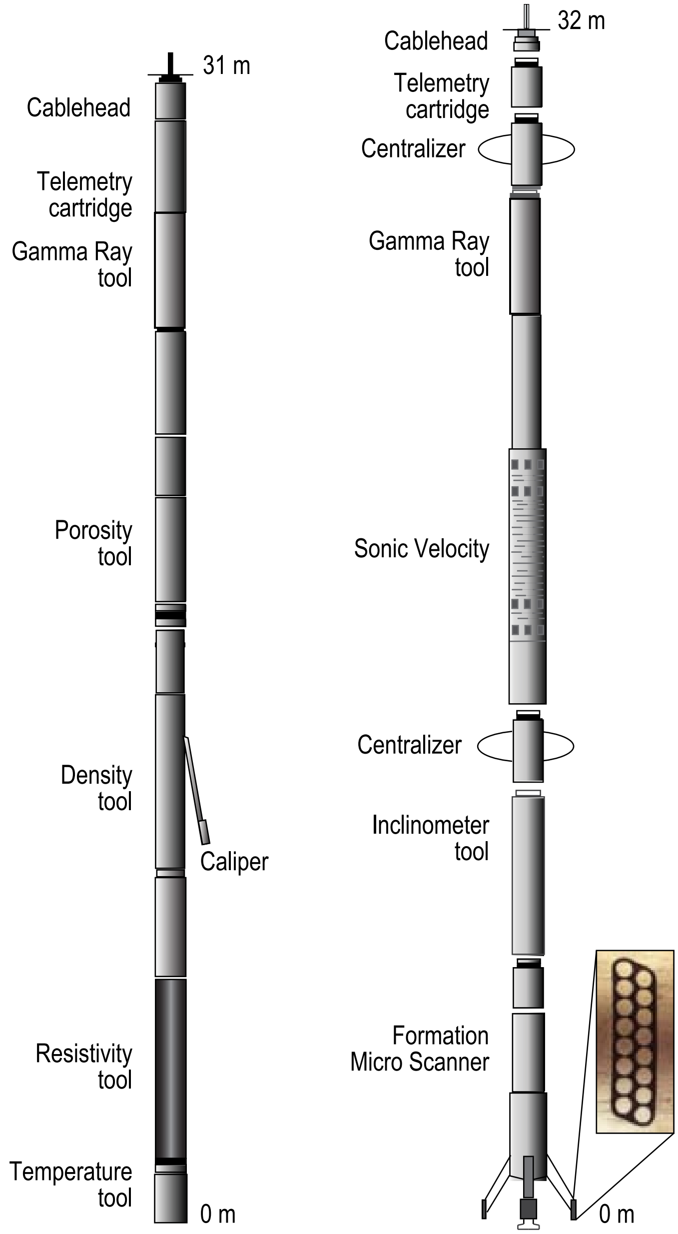

Figure 2. Logging string configurations.

Figure 2 shows some of the instruments that could be included in a string. (Note: You can learn more about what each does by viewing the "Logging 101" Powerpoint created by Gilles Guerin for School of Rock 2007 (*www.ldeo.columbia.edu/BRG/outreach/projects/index.html; scroll down to "Logging 101" Powerpoint*) or other Suggested Resources listed at the end of this lesson.)

Data collected by these instruments consist of vast sets of numbers collected about each property at **intervals** (distances apart) ranging from 2.5 mm to 15 cm. The physics behind the measurements is quite complex, but **geophysicists** have created methods to convert these numbers into graphs and interpret the patterns.

Usually, scientists will examine many sets of measurements to create a log for a site. In this activity, students will learn to use examples of logging data from three ocean drilling sites to understand how scientists study ocean floors through these technologies.

What to do

1. Explain to students that they will be investigating what is called "downhole logging" and the data that this process gathers from drill sites.
2. Divide students into groups of 2-3 and hand out the student pages.
3. Take some time to go over the background information and answer any questions the students may have.
4. Give groups ample time to work through the exercises.
5. When everyone is done, bring the class back together to go through the answers to their work and discuss what they found.

Suggested Resources

"Logging 101" PowerPoint presentation for School of Rock 2007 by Gilles Guerin *www.ldeo.columbia.edu/BRG/outreach/projects/index.html*

Borehole Research Group, Lamont-Doherty Earth Observatory of Columbia University *http://www.ldeo.columbia.edu/BRG/tools_technology/tools/index.html*

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Student Page

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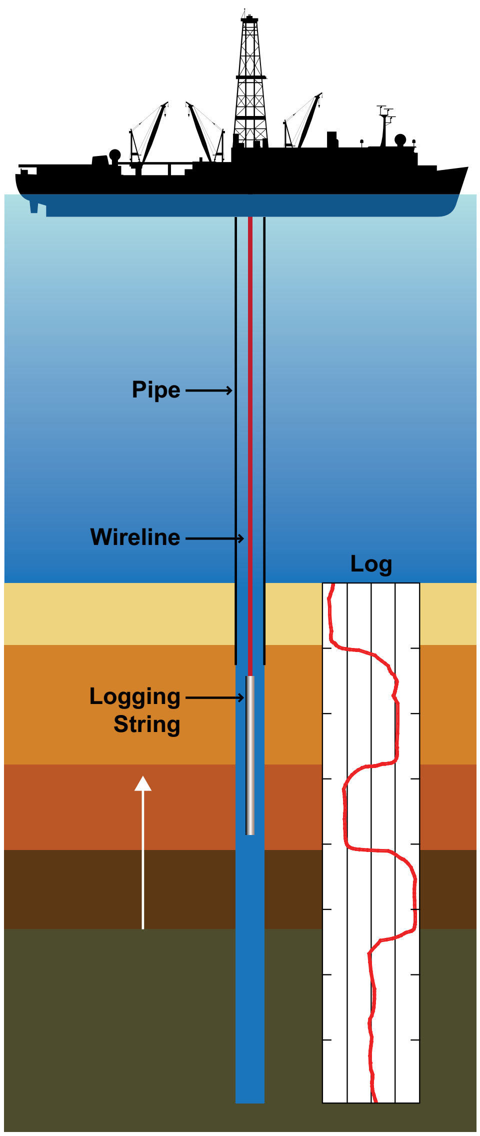

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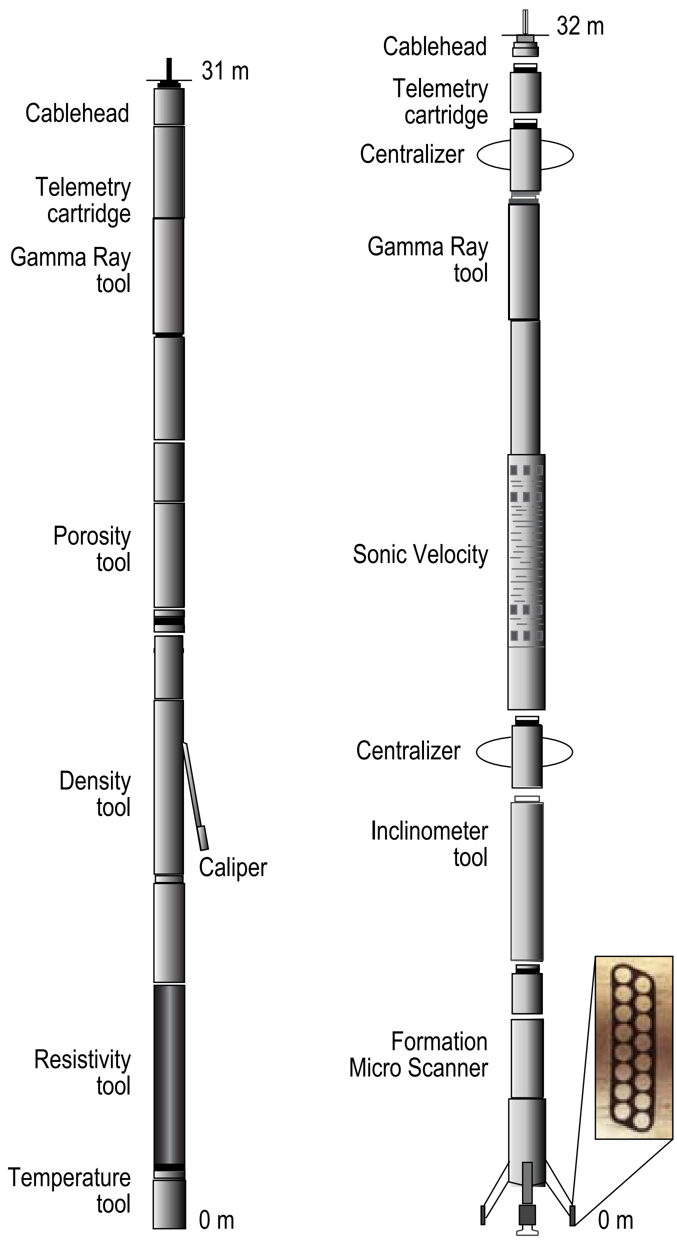

***Figure 2.** Logging string configurations.*

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Gamma ray logs measure the natural radioactivity in the formation. Radioactivity is usually higher in **clay minerals** that form **shales** and lower in **sands** or other sediments and rocks. These logs help identify the types of material in a layer. They can show cyclic patterns in the deposits which may result from global climate changes. They also help scientists match cores and logs at different locations.

Resistivity logs measure how well an electrical current can flow through rocks and sediments. Electricity runs most easily through **fluids** (liquid) present in cracks and spaces between the mineral grains. Highest resistivity values are found in **basalts** and other hard rocks with very little porosity, or space between grains.

Table 1 shows typical ranges for these properties. You'll need this information to complete the activities.

Other variables used in this activity include:

- **Core Recovery:** how much rock and sediment material was physically brought up by drilling. Black in the column indicates that material was retrieved, and white means material was missing from that core section. Notice that logging data are always continuous.
- **Hole Size (diameter):** an important indicator of how firm the material was around the drilled hole. A very large hole can degrade the quality of the logs.
- **Density:** provides information about the **mass** (weight) of the grains and fluids in a given **volume** of material. This helps identify types of sediments or rocks.
- **Porosity:** describes how much space exists between the grains. High porosity usually means larger spaces between them, typical of sands and sandstones.
- **Sound Velocity:** depends on how hard the material is, and usually will be faster in solid rock than in sediments.

With this background information, you are ready to look at three examples of logs from ODP drill sites (Figure 3), and then answer questions to gain more understanding of how scientists interpret them. Each set of data is identified by its drilling number. Hole 1228A was drilled near the South American coast, and receives sediments that were eroded into the ocean. Hole U1326D lies off the Washington-British Columbia coast, an area with a very interesting geologic history. Hole 1256D lies off Central America in a region where the sea floor moves at a very fast rate (by plate-tectonics standards).

Material (sediment/rock)	Gamma Ray units	Resistivity (Ω.m)
Sand	20 - 80	0.1 - 2.0
Shale	50 - 180	0.1 - 2.0
Hard Rock (ex., basalt)	<20	10 - 50,000

Table 1. *Property ranges*

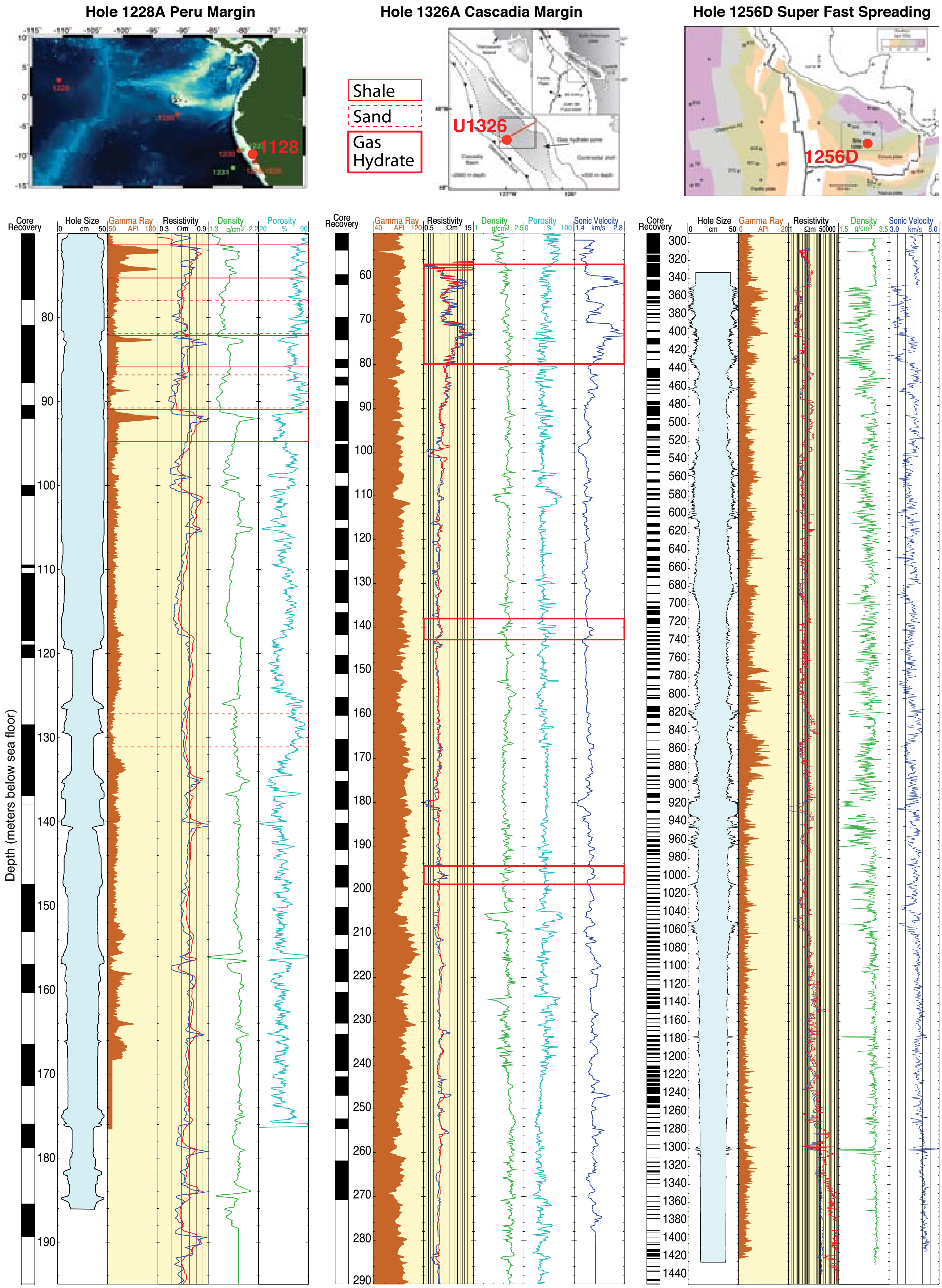

Figure 3. *Three Examples of Down-hole Logging and Other Data*

As you examine the logs, pay special attention to the **range of values** at the top of the Gamma Ray and Resistivity columns. Because they are different in each log, the differences will help you identify the types of sea floor materials at each location.

1. The maps show where each site is located. Look closely at the latitude and longitude markings or landforms shown. Then complete Table 2 to show you understand in which ocean and in which hemisphere (northern or southern) these holes were drilled.

Hole Number	Ocean	Hemisphere
Hole 1228A		
Hole U1326A		
Hole 1256D		

Table 2. *Location of the Drill Sites*

2. As you first examine these logs, you may feel confused by all the squiggles. But in a short time, you should begin to notice patterns and features that stick out. Write down your observations in Table 3. For holes 1228A and U1326A, pay special attention to the sections enclosed in boxes. The key shows that each box represents a different kind of material.

Hole	Observed Features and Patterns
Hole 1228A	
Hole U1326A	
Hole 1256D	

Table 3. *Your own observations about the logs*

3. In the Hole 1228A log, use the gamma ray and resistivity information to identify the most common type of sediment or rock found within the boxes outlined by the **solid** lines. Explain the logging data that provides evidence for your decision.

4. Try to determine what type of sediment or rock is in the boxes outlined by the **dashed** lines. Explain the evidence from the log for your decision.

5. Look next at the Density and Porosity logs for Hole 1228A. How do the patterns in these logs confirm any differences you found between sediments in the solid-line boxes and dashed-line boxes?

Gas hydrates are a widespread ice-like structure found in many seafloor sediments and elsewhere. Gas hydrates may have played an important role in global climate changes over Earth's history. (You can learn more about gas hydrates at: *www.oceanleadership.org/classroom/all_caged_up*) They have received a lot of interest in recent years because of their potential use as energy resources.

Gas hydrates can be identified in logs by high values of Resistivity. This happens because they replace pore water, which easily **conducts** electrical currents, with an ice-like solid, which acts as an electrical **insulator**. They can also be identified by higher sound velocities, since a liquid is replaced by a solid that makes sonic waves propagate (travel) more rapidly.

6. Look at Hole U1326A log. First, you should learn to recognize the characteristics that identify gas hydrates within the solid-line box located between 60 and 80 m from the top of the core. Then examine the rest of the log, and identify at least two more zones where gas hydrates were found.

Location in core	Reason for your decision
Between ____ m and ____ m	
Between ____ m and ____ m	

7. You probably noticed that no boxes have been drawn for Hole 1256D. What kind of material was probably recovered by drilling at this location? What evidence can you provide for your interpretation?

8. For Hole 1256D, why do you think that porosity was not one of the variables displayed? How much space do you think exists between the grains in this material, compared with the other cores?

Bonus questions

1. Until about fifty years ago, people knew very little about the ocean floor. They did not even know the answer to the question, "Are the materials making up the seafloor the same everywhere or different?" How has down-hole logging provided evidence to answer this question and expand our knowledge of our planet? Explain your response.

2. As the drill string goes deeper in the borehole, does it pass through rocks and sediments that are older or younger than the materials near the surface?

3. In Holes 1228A and U1326A, you see there are different sediments at different depths. What geologic processes might create these changes?