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2005 Lost City Expedition

Massif Mystery

Focus

Structure and origin of the Atlantis Massif

Grade Level

9-12 (Earth Science)

Focus Question

What do recent research data suggest about the structure and origin of the Atlantis Massif?

Learning Objectives

Students will be able to compare and contrast basalt, gabbro, and peridotite, and explain what the presence of these rocks may suggest about the origin of formations where they are found.

Students will be able to describe and interpret research data that suggest possible origins of the Atlantis Massif.

Materials

❒ Copies of "Massif Mystery Worksheet," one copy for each student

Audio/Visual Materials

❒ (Optional) equipment for viewing online or downloaded video of vent communities

Teaching Time

One or two 45-minute class periods, plus time for student research

Seating Arrangement

Classroom style

Maximum Number of Students

30

Key Words

Atlantis Massif
Gabbro
Harzburgite
Serpentinization
Peridotite

Background Information

In 1977, scientists in the deep-diving submersible Alvin made the first visit to an oceanic spreading ridge near the Galapagos Islands, and made one of the most exciting discoveries in 20th century biology. In the middle of deep, cold ocean waters, they found hot springs and observed black smoke-like clouds billowing from chimneys of rock; and nearby were communities of animals that no one had ever seen before.

These hot springs came to be known as hydrothermal vents, and since that first discovery, more than 200 similar vent fields have been documented in the world's ocean. These systems are formed when seawater flowing through cracks in the seafloor crust enters magma-containing chambers beneath a spreading ridge. Intense heat from the molten rock causes a variety of chemical changes and many substances from the rocks become dissolved in the fluid. The heated fluid becomes less dense, rises upward, and emerges onto the sea floor to form a hydrothermal vent. When the heated fluid is cooled by cold water of the deep ocean, many of the dissolved materials precipitate, creating black clouds and chimneys of rock-like deposits. The hydrothermal fluid emerging from the vents is rich in sulfide, which is used as an energy source by chemosynthetic bacteria to produce essential organic substances. These autotrophic bacteria are the base of a diverse food web that includes large tubeworms (vestimentiferans), clams, mussels, limpets, polychaete worms, shrimp, and crabs.

In 2000, a different sort of vent field was serendipitously discovered on an underwater mountain called the Atlantis Massif near the Mid-Atlantic Ridge. This new field also had hot fluids venting from rocky chimneys. But these chimneys towered as much as 200 feet above the seafloor, much larger than chimneys found in other vent fields. In fact, the vent field was located 15 kilometers away from the spreading axis of the Mid-Atlantic Ridge and the chimneys looked so much like towers and spires of a fantastic city that the new vent field was named "Lost City." And the fluids emerging from the chimneys, as well as the surrounding biological communities, were unlike any other known hydrothermal system. Subsequent investigations have shown that the newly-discovered hydrothermal fields are not formed by seawater reacting with molten magma. Instead, these fields are formed when seawater reacts with solid mantle rocks. These rocks, called peridotites, are formed deep inside the Earth, but a unique type of faulting can bring them close to the seafloor. Cracks in the seafloor can allow seawater to percolate down to the up-lifted peridotites. When this happens, numerous chemical reactions occur between seawater and minerals in the rock (a process called serpentinization). These reactions produce a large amount of heat that causes the fluids to rise and eventually vent at the surface of the seafloor. Mixing between the heated fluids and cold surrounding seawater causes additional reactions that include precipitation of calcium carbonate (limestone), which forms the towering chimneys of Lost City. Because the reactions of seawater with peridotites are essential to these formations, the Lost City is called a "peridotite-hosted ecosystem."

Discovery of the LCHF is a good example of how serendipity often enters scientific investigations. Scientists who made the discovery were studying the Atlantis Massif, a formation unusual enough to justify its own investigation. Discovered in 1996 by Donna Blackman of the Scripps Institution of Oceanography and Joe Cann of the University of Leeds, this underwater mountain is unusually large. Its peak is 1,700 m (5,000') higher than the nearby spreading ridge crest and its width is 4-6 times greater than that of most abyssal hills. When scientists discovered the Lost City, they were attempting to find out why and how the Atlantis Massif was formed. In this lesson, students will examine some of the clues to this question that have emerged from recent research.

Learning Procedure

1. To prepare for this lesson, visit the Lost City expedition's Web pages (http://oceanexplorer.noaa.gov/explorations/05lostcity/welcome.html; http://www.lostcity.washington.edu/; and http://www.immersionpresents.org) for an overview of the expedition and background essays.

2. Briefly review:
   - The concepts of plate tectonics, being sure that students understand the processes that take place at convergent and divergent boundaries, and why these boundaries are often the site of volcanic activity;
   - The discovery of the Atlantis Massif in 1996; and
   - The discovery of Lost City Hydrothermal Field in 2000

   You may want to show video clips from some of the sites referenced in Step 1 to supplement this discussion.

3. Provide each student with a "Massif Mystery Worksheet," and tell students that their assign-

ment is to examine some results of recent research that provide answers to questions on the worksheet. You may want to provide addresses for the Web sites listed in Step 1, or allow students to find these (and other) resources for themselves. Caution students that some older articles written about the Atlantis Massif and Lost City may contain hypotheses that are not supported by results of more recent expeditions. Emphasize that investigation of the structure and origin of the Atlantis Massif is only beginning, and much remains to be discovered.

4. Lead a discussion of students' answers to questions on the worksheet. The following points should be included:

   - Peridotites are rocks formed in the Earth's mantle and are composed of several minerals of which olivine is the most common. Peridotites are "ultramafic," meaning that they have a very low silica content (less than 45%) and high concentrations (usually greater than 90%) of magnesium and iron.

   - Harzburgites are a type of peridotite that contains olivine, enstatite, small amounts of chromite, and trace amounts of other minerals.

   - Basalt is a fine-textured extrusive igneous rock that contains relatively high concentrations of magnesium and iron. The crust of oceanic tectonic plates is predominantly made of basalt.

   - Gabbro is a coarse-textured intrusive rock that has the same composition as basalt. Gabbros form when molten rock slowly cools in magma chambers without reaching the surface of the Earth's crust.

   - Serpentinization is a process in which peridotite rock is changed to serpentinite rock. This process occurs when peridotites are exposed to water. Olivine (and other peridotite minerals) is unstable at temperatures below about 425°C and reacts with seawater to form the mineral serpentine.

   - The predominance of harzburgites in rock samples collected in 2000 suggests that the Atlantis Massif may be composed of rock formed deep within the Earth's mantle (instead of basalt which is much more common in the oceanic crust) that was somehow uplifted to the surface of the crust. One theory that has been proposed to account for the presence of harzburgites is that basalts were originally on top of the peridotites, but were stripped off by faulting or other processes. One such process is a gradual stretching of the crust caused by motion of the tectonic plates, causing cracks in the crust that gradually tilt surface rocks to form mountains (similar to the process that formed the Basin and Range Province in the southwestern United States). Another possibility is that deep faulting may expose peridotites to seawater, resulting in serpentinization. Because the process causes the rock to swell and become less dense, the newly-formed serpentinite would tend to rise towards the seafloor, resulting in a high massif.

   - The predominance of gabbroic rocks and absence of peridotite in cores drilled through the top of the Atlantis Massif complicates the question of how the massif was formed. The discrepancy in the composition of rocks in core samples compared to those collected by submersibles shows that the Massif is not composed solely of a single type of rock. It is possible that the southern ridge sampled by submersible has a fundamentally different structure and composition than the dome area sampled by coring. It is also possible that the Atlantis Massif is the result of more than one structuring event or process, that may include an event that uplifted gabbro from a cooled magma chamber, and another event (or series of events) that exposed peridotites in the Lost City area to seawater, resulting in the hydrothermal activity observed at the site.

The Bridge Connection

www.vims.edu/bridge/ – In the "Site Navigation" menu on the left, click "Ocean Science Topics," then "Habitats," then "Deep Sea" for links to resources about hydrothermal vents.

The "Me" Connection

Have students write a brief essay describing how knowledge of the origin of the Atlantis Massif might be of personal importance. If they have trouble with this, you may want to suggest that they consider the nature of processes that might result in this type of formation (i.e., very powerful tectonic forces) and whether these processes are known to affect humans in any way (earthquakes, volcanoes, tsunamis…).

Connections to Other Subjects

English/Language Arts, Chemistry

Evaluation

Written answers to worksheet questions and group discussions provide opportunities for assessment.

Extensions

1. Have students visit http://oceanexplorer.noaa.gov/explorations/05lostcity/welcome.html to keep up to date with the latest Lost City Expedition discoveries.

2. Visit http://www.iodp-usio.org/Education/Educ.html for activities related to the Integrated Ocean Drilling Program, including examination of rock types in core samples.

Resources

http://oceanexplorer.noaa.gov/explorations/05lostcity/welcome.html – Web site for the 2005 Lost City expedition.

http://www.lostcity.washington.edu – Web site for earlier Lost City expeditions

http://www.iodp-usio.org/Education/Educ.html – Integrated Ocean Drilling Program Curriculum Enrichment Web page

http://www.iodp-usio.org/Education/Curriculum_Activities/TES_Summer05.pdf – The Earth Scientist, Summer 2005; special issue on Integrated Ocean Drilling Program, including classroom activities (co-published by the National Earth Science Teachers Association and the Joint Oceanographic Institutions)

National Science Education Standards

Content Standard A: Science as Inquiry
- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard B: Physical Science
- Motions and forces

Content Standard D: Earth and Space Science
- Energy in the Earth system
- Geochemical cycles

Content Standard E: Science and Technology
- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives
- Natural resources
- Science and technology in local, national, and global challenges

Content Standard G: History and Nature of Science
- Nature of scientific knowledge

For More Information

Paula Keener-Chavis, Director, Education Programs
NOAA Office of Ocean Exploration
Hollings Marine Laboratory
331 Fort Johnson Road, Charleston SC 29412
843.762.8818
843.762.8737 (fax)
paula.keener-chavis@noaa.gov

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http://oceanexplorer.noaa.gov

Massif Mystery Worksheet

The Atlantis Massif is an underwater mountain near the mid-Atlantic spreading ridge, discovered in 1996 by Donna Blackman of the Scripps Institution of Oceanography and Joe Cann of the University of Leeds. The mountain is unusually large, with a peak 1,700 m (5,000′) higher than the nearby spreading ridge crest and a width that is 4-6 times greater than that of most abyssal hills. Since its discovery, several scientific expeditions have been undertaken to investigate why and how the Atlantis Massif was formed. Your task is to examine some of the resulting data and possible answers that have been proposed to this question.

1. What is:

   Peridotite

   Harzburgite

   Basalt

   Gabbro

   Serpentinization

2. In 2000, scientists used the submersible Alvin to collect more than 200 rock samples from a small area on the Atlantis Massif. Most of these rocks were harzburgites. What does this suggest about the structure and origin of the Atlantis Massif? What are some theories that have been proposed to account for the presence of harzburgites at the surface of the Atlantis Massif?

3. One of the obvious questions about the Atlantis Massif is "Why is it so big?" Part of the answer may involve serpentinization. How might serpentinization contribute to the size of the mountain?

4. In the spring of 2005, Integrated Ocean Drilling Program Expeditions 304 and 305 drilled a series of cores through the top of the Atlantis Massif. Rock samples from these cores consisted primarily of gabbroic rocks. Fresh mantle peridotite was not found, even though the cores reached a depth of approximately 1.4 km. What does this suggest about the formation of the Atlantis Massif?