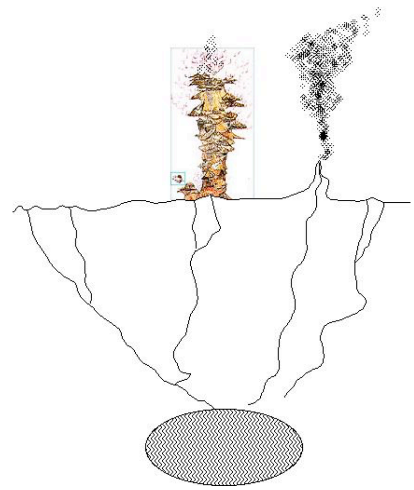
Hot Water - Hydrothermal Vent Plumes and Fluid Dynamics Analysis

(created by Ardi Kveven, Snohomish High School, Snohomish, WA and Veronique Robigou, University of Washington)

Key Concepts

1) Material leaving a hydrothermal vent rises in a plume because its high temperature makes it less dense than the surrounding very cold ocean water.
2) It is possible to locate hydrothermal vent fields by looking for slight changes in temperature and salinity at the ocean's surface.



Background

When geologists first set out to find and study hydrothermal vent fields, they made predictions about where a vent site might be based on their understanding of an area's geology and then went looking with submersibles and cameras.

Today, new vent fields are found using a CTD cast or Conductivity, Temperature and Depth study. A set of probes is lowered from a surface ship. The probes take readings on water salinity and temperature and other parameters at a variety of depths. Though hydrothermal vents generally are about 2000 meters deep, the plumes of hot, highly saline water they emit are so powerful that these surface probes can detect a change in temperature and salinity. The changes seem small to a novice, less than 1 degree C. temperature change and less than 1 part per thousand salinity change, but to scientists accustomed to looking for anomalies, these changes pinpoint vent fields.

In this demonstration, students observe a simple plume created by heating cold water submerged in a larger container of water. They then review all they have learned about the physics and chemistry of hydrothermal vents in the Fluid Dynamics Analysis.

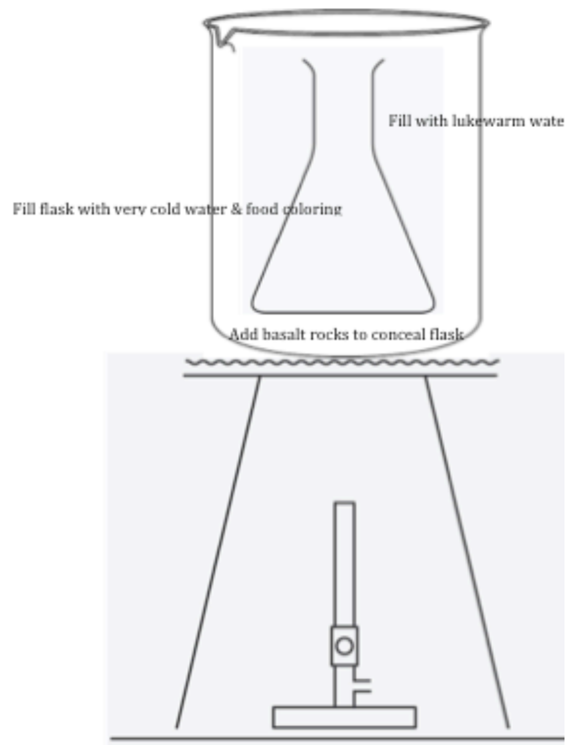
Materials

Per demonstration:
Large Pyrex beaker or any heat resistant large, clear container

Lukewarm water
Stand to hold the large container over a bunsen burner
Bunsen burner
Flask small enough to fit submerged in the large beaker
Cold water
Food coloring
Basalt rocks to camouflage flask

<u>Follow-up- per student or student team:</u>
Copy of Fluid Dynamics Analysis questions
Copy of Godzilla Profile

Demonstration Directions



Set up the demonstration as follows:

1. Fill the large container with lukewarm water.
2. Set the container on a stand over a bunsen burner.
3. Fill the flask with very cold water and add food coloring to the water.
4. Submerge the flask in the large container. The cold water is more dense than the lukewarm water in the container, so it will stay in the flask and not mix with the contents of the large container.
5. Place basalt rocks around the flask to camouflage it.

Lead the demonstration as follows:

6. Tell the students that the large container models the the sea floor. Ask them to watch what happens in t heated, modeling the heating of water in the sea flo
7. Heat the flask with the bunsen burner. In a few mir flask will have heated up enough to begin to rise ou container.
8. Ask the students to describe verbally, in writing anc develops and diffuses. Ask them to explain in their happened.
9. Explain that scientists can detect these plumes at th temperature and salinity. Have them notice how high in the big container the plume has traveled. Has it reached the surface? How diffuse is it? Would scientists on the surface ship looking for signs of a plume be looking for large or small changes in sea surface temperature and salinity?

Follow-up:

10. Give the students a copy of the profile of the smoker called Godzilla and the Fluid Dynamics Analysis questions. Have them answer the questions and label the diagram as directed.

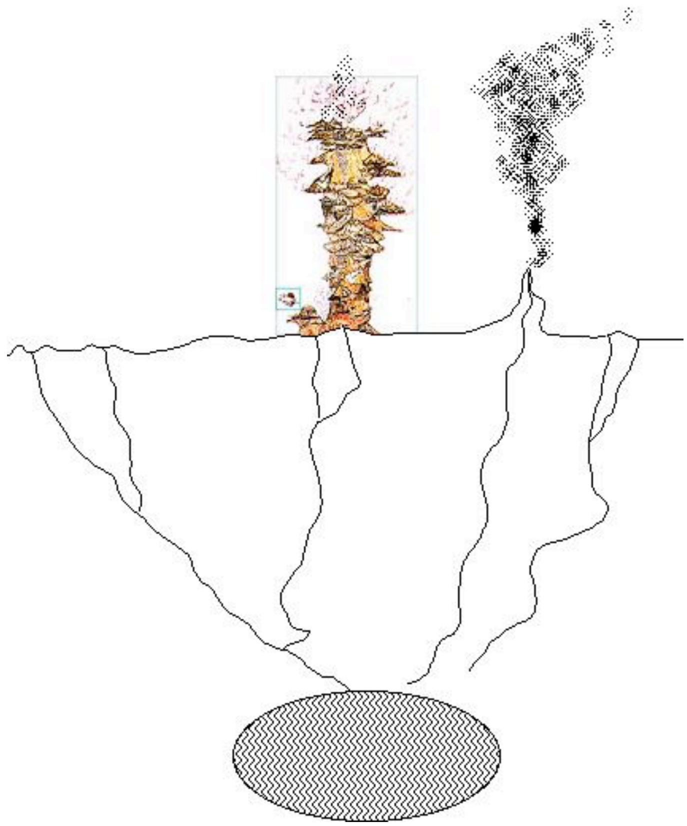
Answer Key

Fluid Dynamics Analysis Questions

1. Seawater seeps through cracks in the sea floor created by the volcanic activity along the ridge.
2. The water temperature increases as the water gets closer to the magma chambers.
3. The water rises because it is now superheated and, therefore, has a low density.
4. The water comes in contact with very cool ambient seawater and therefore cools rapidly. This causes materials to precipitate out of the seawater. A cloudy plume forms that becomes gradually more diffuse as it rises above the vent opening.
6. Different vent plumes are different colors because they contain different combinations of solutes. Temperature and the composition of the seafloor rocks both determine what materials will dissolve into the vent fluids.
7. Some vents do not have chimneys because the fluids there do not have enough material dissolved in them to form precipitates upon leaving the vent.
8. It would be dangerous for a submersible to get close to a black smoker orifice because the fluids there are very hot, perhaps with a temperature as high as 350°C. Visibility would be very low close to a vent as well. Also, the temperature gradients between the plume and the surrounding seawater create currents that might buffet the sub and send it in directions it doesn’t want to go.
9. The upside-down pools are very hot, around 200°C. This hot fluid rises until it runs into a flange or overhang and cannot rise any higher. The density of this fluid is so different from the surrounding seawater that light rays hitting the surface of the pool reflect off, creating the shimmering mirror effect.

Hot Water - Hydrothermal Vent Plumes

Fluid Dynamics Analysis



You will need a copy of the Godzilla Profile to answer the following questions. Godzilla is a hydrothermal vent chimney extensively studied by geologists. It reached an amazing height of 55 meters!. On a return visit, scientists were stunned to see that this giant tower had collapsed.

Use the drawing of this magnificent chimney to review what you have learned so far about hydrothermal vent formations.

1. a) How does water get into and through the rocks that form the sea floor?

   b) Find a likely spot on the diagram where water might penetrate through the rocks and label it #1.

   c) What kind of water is seeping down through the sea floor?

2, a) What happens to the temperature of the water as it gets closer to the magma?

b) Label as #2 on the diagram an area where water is nearing magma chambers.

3. a) Eventually, water rises back up out of a vent. Label a vent site as #3.

   b) What might cause the water to stop its downward path and return back to the surface?

4. a) What happens to the water as it leaves the vent?

   b) Label the hydrothermal vent plume as #4.

5. Now, use markers or colored pencils and highlight the path of the water through this hydrothermal vent system.

6. Hydrothermal vent plumes can be different colors. For example, some are black and others white. Why do you think different plumes are different colors?

7. Some vents do not have chimneys. Why do you think a chimney would not form at a vent?

8. Why might it be dangerous for a submersible to get too close to a black smoker orifice?

9. Upside-down pools of hydrothermal vent fluid form on chimneys. These are pools of liquid that form underneath flanges or extensions on the chimney. The surface of the fluid reflects light and so the pools look shiny, like mirrors. What temperature do you think these pools would have compared to the surrounding sea water? Try to explain how these pools might form.


Courtesy of V. Robigou, Ocean et Terra Studio