Navigating Deep Sea Vents
ALVIN Dive Log, Part 1

Lesson by Ardi Kveven, Snohomish High School, Snohomish, WA and
Veronique Robiqou University of Washington.

Key Concepts

1. Though hydrothermal vents are located in very deep and very dark water, scientists are able to navigate back to identified vent fields using maps made from data from initial visits to the site.

2. Navigators can determine where they are in the middle of a dive by using permanent markers placed by previous expeditions and by triangulating their positions using signals from transponders.

Background

Most activities on the water, from whale watching to oceanographic sampling, require exact knowledge of the position of the boat. It is no easy task to navigate a surface ship to just the right location above the sea floor and then launch a submersible and pilot it with pinpoint accuracy to a specific vent field. The target is two thousand meters below the ocean surface and in deep darkness. However, scientists must be able to locate their study sites accurately. Each dive with a submersible is expensive, of limited duration and hard to schedule since many projects compete for the use of submersibles.

Traditionally, the knowledge gained from reading nautical charts, combined with information from a compass and the techniques of triangulation, has been used to establish the general location of the boat. Determining position by triangulation is a basic oceanographic procedure that should be learned by any one who spends time working on the ocean.

Triangulation relies on the ability to determine exact directions. Successful triangulation has depended upon the ability to read a chart, on the use of a compass, and on the visibility of at least two fixed reference points. The FOR SEA Grades 7 activity “Hmmmm... .Where Did You Say We Were?” provides an introduction to triangulation. A description of the activity may be found at forsea.org/FSTOC7

Since the introduction of radio beacons in 1921 and satellites in the 1970s, the fixed reference points” have changed from those that can be seen by eye, to those that can be electronically sensed. Global Positioning System (GPS) receivers determine exact position latitude, longitude, and altitude - by comparing radio signals from at least three satellites. The network of satellites is such that at least four satellites can be accessed from any position on the surface of the globe at any time, day or night. The GPS system has been a boon to ocean navigation. RV Atlantis, mother-ship to the ALVIN, uses such GPS navigation to locate its position.

Unfortunately, GPS navigation works at the ocean's surface but not beneath the surface. Researchers aboard the ALVIN must use an alternate method for locating their position. The method of choice is sonar (originally SONAR for SOund Navigation And Ranging), a method of using sound waves and their returning echoes. The waves are generated and detected by a "transducer or track point", a device that converts electrical eneiy to sound waves and vice versa. The RV Atlantis sends a sound wave, or "ping", out from its transducer aboard ship. The waves are received by a transducer aboard ALVIN, which, in turn, sends out sound waves that are received by a track point onboard the RV Atlantis.

These complementary signals provide important data to help the boat to locate the position of the ALVIN as it navigates to a site. Sonar allows the boat and the research vehicle to measure the depth to the bottom. Using the lattitude and longitude of the boat, the depth and angle to the ALVIN, and the compass direction to the research vehicle, scientists aboard the RV Atlantis can determine the exact position of the ALVIN as it navigates the waters.

Materials

Per team of three students

- "Endeavor Vent Field Map" (preferably in color- consider laminating a set of these for classroom use only)
- "Endeavour Ridge Bathymetric Map" (black and white- students will write on this)
- "Navigating Deep Sea Vents - ALVIN Dive Log, Part 1" student pages
- overhead markers or other washable marker (for writing on laminated maps)
- compass (for drawing circles)
- ruler or straight edge (for measuring distances on the "Vent Field Map")

Teaching Hints

In "Navigating Deep Sea Vents - ALVIN Dive Log, Part 1", students act as pilots of a deep sea submersible. They use a map of a real vent field located off the coast of Oregon and practice using latitude and longitude and transponder readings to find their way.
If your students have not worked with latitude and longitude or need a refresher, consider doing all or part of the lesson Ocean Floor Features. That lesson explains how to find latitude and longitude and practices other map reading skills.

Key Words

bathymetric map - a map portraying the shape of a water body using equal depth contours (isobaths)

chimney - roughly conical deposits of minerals formed at hydrothermal vents

hydrothermal vents - natural springs which release warm or hot water on the sea floor.

mid-ocean ridge - underwater mountain ranges found at spreading centers

seamount - an underwater mountain standing alone

subduction - the process of one tectonic plate descending beneath another

subduction zone - the place where two tectonic plates come together, one riding over the other

transducer - a device that converts electrical energy to sound waves and vice versa, also called a "track point"

transponder - sonar device that automatically sensed out a signal when it receives an incoming signal

trench - long, narrow, deep depressions in the sea floor associated with zones of abduction of tectonic plates and which parallel the continental margins

vent field - a portion of the ocean bottom in which hydrothermal vents are concentrated

Answer Key

Getting Oriented

2. The Juan de Fuca plate is subducting.

ALVIN Dive Log

2. The depth at the launch site is about 2200 meters.

3. It would take Alvin, traveling 1 knot, 1.24 hours, or 1 hour and 14 minutes, to reach the sea floor at a depth of 2300 meters.

   (i.e., Depth = Speed x Time
   2300 meters = 1 knot x Time
   2300 meters = 1 nautical mile/hour x Time
   2300 meters = 1,852 meters/hour x Time
   1.24 hours = Time to reach the sea floor
   Time to reach sea floor = 1 hr + 0.24 hours x 60 minutes/hour = 1 hour 14 minutes)

4. The colors on the ENDEAVOUR VENT FIELD MAP show types of rock. The purple indicates talus. Talus is basalt rubble, the most common igneous rock on the sea floor. In this lesson, the students will be most interested in the inactive sulfide structures colored yellow and the active chimneys colored orange.

5. Dudley's position is approximately:
   X (east-west) = 6125 m . Y (north-south) = 5010 m .

7. The heading to HULK is due west, or 270°. The distance is about 50 meters.

8. It will take the sub between 3 and 4 minutes to get to HULK.
   (i.e., Speed of Alvin = 0.5 knots = 0.5 nautical miles/hour
   To calculate the speed in meters per hour:
   1,852 meters/nautical mile x 0.5 nautical mile/hour = 926 meters/hour
   Time to reach HULK = 0.06 hours
   Time to reach HULK = 0.06 hours x 60 minutes/hour = 3.6 minutes)

9. Accept reasonable and creative ideas for how the sub might get out of its predicament. One possibility would be for the sub to release some ballast to achieve positive buoyancy so it could move above the plume.

10. The distance to each transponder is approximately:
    Dl=about105 m D2=about 225 m D3=about195 m
    Distance to transponder = Speed of sound in water x Time for sound to travel from transponder to sub
    Distance to transponder = 1500 meters/sec x 0.14 seconds/2 Distance to transponder = 1500 meters/sec x 0.7 seconds Distance to Transponder =105 meters)

11. The sub is located at the following coordinates:
    X=4900 m, Y=6250 m
12. The sub is now located along a talus slope. The pilot and scientists would not see any vent chimneys, but rather would see a rocky slope.
13. Accept students' reasonable and creative stories about what dangers the sub could encounter on a dive.

Navigating Deep Sea Vents

ALVIN Dive Log, Part 1

You and two team members have been selected to conduct a dive to a hydrothermal vent field in the Pacific Ocean, near the coast of Oregon. This particular vent field was discovered in 1981 and has been named the Main Endeavour Hydrothermal Vent Field.

The vents are over 2,000 meters below the ocean's surface and surrounded by total darkness. How will you know you are diving at the right location? How will you find your way? Fortunately, the expeditions ahead of you have prepared a map of the area and have left permanent markers at the vent field. In addition, your surface support ship will lower devices called transponders, which will help you, find out where you are. More about those later.

Procedure

Part One: Getting Oriented

Let's begin by looking at the bigger picture.

1. Obtain a copy of the ENDEAVOUR RIDGE BATHYMETRIC MAP. Map 1 shows the general area where you will be working. Label or color code Washington, Oregon and California.

2. The line edged with triangles shows a subduction zone. A subduction zone is an area where one crustal plate is sliding beneath another. The unattached point of the triangles show the direction of movement of the plate edge.

On Map 1, what is the name of the plate that is subducting at this subduction zone.

3. Map 2 takes a closer look at the area where you will be diving. The solid, heavy line shows a ridge system where magma is erupting and new crust is being formed. On your dive, you will be visiting the Endeavor Ridge section of this ridge system.

On Map 2, circle or color code the Endeavour Ridge.

4. Finally, look at Map 3, the largest map on the page, located on the right- hand side. Map 3 shows a detail of the Endeavour Ridge shown on Map 2. (Map 2, of course, is a detail of Map 1.) This bathymetric map provides a lot of information. Bathymetric maps show the shape of the ocean bottom using equal depth contours. For example, find a place on the map labeled 2500. That number tells you the sea floor is 2500 meters deep at that location.

On Map 3, using a colored pencil, trace the line where 2500 is written; everywhere along that line, the sea floor is 2500 meters deep.

Preparing for the Dive

Now it is time to prepare for the dive.

Assemble your dive team. On ALVIN dives, each dive team consists of a pilot and two scientists. Determine who on your team will be the pilot, who will be the scientist observing out the port (or left) window and who will be the scientist observing out the starboard (or right) window.

Obtain a “Dive Preparation Sheet”. Record the names of the dive team members. Once you’re registered, proceed with the rest of your dive plan.

ALVIN DIVE LOG

DIVE PREPARATION SHEET
Date:

Dive #3194

Pilot Name:

Port Observer Name:

Starboard Observer Name:

1. Your dive will launch at 47° 57N, 129° 05.75W. (This can also be read, "47° 57N latitude and 129° 05.75W longitude".) Find these latitude and longitude coordinates along the sides of the Endeavour Ridge Bathymetric Map (Map 3). Place a dot at the launch site where these two coordinates intersect.
   (Hint: For latitude, draw a straight line from 47° 57N on the right to 47° 57N on the left side of the map. Repeat with longitude. Where the lines meet (their intersection) marks the launch site.)

2. Find the contour line closest to your launch point. Read the depth of that point on the map Record that depth here: Z= meters.

3. Knowing the depth is important because it will tell you how long it will take to reach the bottom. The ALVIN drifts down from the surface at a speed of 1 knot. ("Knots" is a sailor's way of saying nautical miles per hour. There are 1,852 meters in a nautical mile.)

4. Calculate how long it will take to get you to the seafloor. Show your work in the space below. Record that depth here: T= hours minutes
   (Hint: Depth = Speed x Time.)

Scientists working in 1988, 1991 and 1995 mapped the Main Endeavour Vent Field. The results of their work are shown in the ENDEAVOUR VENT FIELD MAP (Map 4). Obtain a copy of this precise geological map. You will use this map to orient yourself when "flying" the submersible around the sulfide vents. Note that the coordinates of the map are in meters.

Take a few minutes to look at the map and familiarize yourself with it.

Note that each sulfide structure mapped has a name. Researchers have also placed permanent markers (called, "bench marks" and "flotation markers" in the map key) on the sea floor. The flotation markers are labeled 8A, 8B etc... and help new divers working in the area to find their way on the seafloor. The bench marks provide information about the elevation of the sulfide structures above the sea floor. Some bathymetric contour lines, indicating the depth of the area where you will work, are also included.

4. If you have a color map, what do the different colors represent? If you have black and white map, what do the different patterns represent?

Look at the edges of the map. Unlike the other maps you've used so far, there are no latitude or longitude markings. The numbers are in meters and reflect positions on a “grid”, a network of evenly spaced north-south and east-west lines. Just like with latitude and longitude, you can use these numbers to determine locations.

5. Find the “Dudley” sulfide structure on your map. Use the numbers in meters to define its location.
Record the Dudley’s position here:
X (east-west) = , Y (north-south) = .

Launching

Now, it is launch time. Your team is onboard and settles in while the lines holding ALVIN to the boom on the R/V Atlantis are checked. All is satisfactory and the submersible is lowered to the surface of the Pacific Ocean. Scuba divers check the outside and secure the hatch. You accelerate away from the mother-ship and tilt the controls slightly. ALVIN noses under the waves and you’re on your way.

Underway

Everything is going smoothly. There is no major current during your descent. This is good news because currents can move ALVIN about and also cloud the water at landing. You touch ground gently without creating a huge cloud of mud around the sub. You are ready to start orienting yourself inside the vent field and start working.

6. The submersible touched ground at X= 5100 m and Y= 6250 m. (Recall that the X coordinates runs east-west, across the page, and the Y coordinates run north-south, up and down the page.)
Plot the sub’s position on the ENDEAVOUR VENT FIELD MAP (Map 4).

The pilot needs to know where the scientists want to go. The pilot tells the scientists that right now the sub is heading 20° east, or 020E. The pilot asks the heading and the distance to the first work station.

7. The scientists have a long list of things they want to visit. They want to check out HULK first and see how active the smokers are on top of this structure. Look at the compass rose on the map. Which direction should the sub go to get to HULK? This will be the sub’s heading. How many meters will it be to HULK?

Heading=................ Distance=..............

8. The pilot is ready and starts flying the sub. When working in a dangerous area like a vent field, the pilot will fly the sub at a speed of 0.5 knot so she does not run into some unknown feature that might not be on the map (Maps are never perfect! They only show as much as is known at the time the map is drawn).
How long will it take the sub to get to HULK? Show your calculations:

Time to HULK=.................

The pilot knows HULK very well because she has worked there before and she notices that the smokers located at 15 m elevation on the east side of the structure are much more active than the last time he saw them in 1991. So she recommends that the sub stay at the base of the structure to protect itself from currents and heat generated by the vent activity.

Well, this is no fun for the scientists; they want to go up to the top to check out the smokers and start measuring fluid temperatures and sample rocks. They convince the pilot to take the sub up and as soon as it reaches the top of HULK, the currents redirect all the black smoke from the smokers toward the sub. **The sub is now surrounded by a dark cloud of smoke! The pilot does not see anything through his porthole. The starboard scientist cannot see a thing either, but the port scientist had time to see a dangerously close smoker through the porthole before losing track of the sub's position.**

9. What can the pilot do to get out of this potentially dangerous situation? Explain his(her) choices.

During this experience everybody in the sub was too busy trying to look outside and make sure the sub was not running into a smoker and getting burnt by the hot hydrothermal fluids to pay attention to the movement of the sub. Now the sub is out of the smoke cloud, you are safe...**but you have lost track of where you are.** There is nothing out in the water landscape that you recognize. And during the few minutes of confusion on board ALVIN, the starboard scientist's elbow turned off the computer screen that gives the position of the sub every few seconds. So, the sub is lost. To figure out where you ended up, you are going to have to use triangulation before moving any further.

Before you got in the sub this morning, the chief scientist of the cruise gave you the location of the transponders that were deployed for navigating in the area. Transponders are devices lowered underwater. The sub can transmit a noise, called a “ping”. When the ping reaches a transponder, the device sends a ping back to the sub. If you measure how long it takes the sound to return to you, you will know how close you are to each transponder.

Plot the locations of the three transponders on your colored map:

T1	X= 4950m Y= 6350m
T2	X= 5100m Y= 6150m
T3	X= 4875m Y= 6050m

The sub sends out a “ping” and the transponders return the sound. The pilot gives you the travel times for the sounds from the 3 transponders as follows:

t1= 0.14 s
t2= 0.30 s
t3= 0.26 s

Now you should be able to calculate the distance between the sub and each of the transponders. The speed of sound in sea water is 1500 m/second. Remember that the travel times the pilot reads inside the sub correspond to the time an acoustic "ping" travels from the sub to a transponder and back from that transponder.

10. Record the distances to the transponders in the spaces below:

d1=...........m

d2=...........m

d3=...........m

11. When you have the distance to each transponder, use your compass to draw a circle around each transponder at the correct distance. Where do the circles intersect? That must be where the sub is located. Read the new coordinates of the sub:

X=............m

Y=............m

12. Using the map for real information and using your imagination, describe the geologic terrain the sub finds itself on.

13. Imagine what could have happened to the sub and write it down in your notes for the dive log. It should make for a great story this evening when the scientists on board ask you what happened during the dive.