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Northwestern Hawaiian Islands Exploration

Mapping Deep-Sea Habitats

Focus

Bathymetric mapping of deep-sea habitats

Grade Level

5-6, 7-8 (Earth Science)

Focus Question

How can deep-sea areas of the Northwest Hawaiian Islands be mapped to facilitate their exploration with a manned submersible?

Learning Objectives

Students will be able to create a two-dimensional topographic map given bathymetric survey data.

Students will be able to create a three-dimensional model of landforms from a two-dimensional topographic map.

Students will be able to interpret two- and three-dimensional topographic data.

Additional Information for Teachers of Deaf Students

In addition to the words listed as key words, the following words should be part of the vocabulary list.

Atoll
Nautical
SCUBA
Exploration
Constraint
Nautical chart
Multibeam swath bathymetry
Topography
Transducer
Backscatter
GPS
Topographic

The key words are integral to the unit but will be very difficult to introduce prior to the activity. They are really the material of the lesson. There are no formal signs in American Sign Language for any of these words and many are difficult to lipread. Having the vocabulary list on the board as a reference during the lesson will be extremely helpful. Also give the list as a handout to the students to refer to after the lesson.

If these topics have not already been covered in your class you will need to add an additional class period to cover all the material. This activity is a bit involved and may require an additional period as well. List all the steps required for the activity on the board so that students can follow step-by-step and you can easily refer to the steps to be sure activity is on track.

Materials

- ❒ Copies of "Loihi Submarine Volcano Bathymetric Data;" one for each student group
- ❒ Copies of "Bathymetric Data Reduction Sheet;" one for each student group
- ❒ (Optional) Copies of "Appendix A Supplemental Data Sets;" one for each student group
- ❒ Tracing paper
- ❒ Pieces of foamcore display board, seven for each student group; 8-1/2" x 11" x 5/32" thick or 11" x 17" x 1/4" thick if students'

maps are enlarged 200% (see Learning Procedure, Step #2; these thicknesses will approximate the correct vertical scale)

- ❒ Glue, preferably spray type used for mounting photographs
- ❒ Sharp scissors or X-Acto knives for cutting cardboard

Audio/Visual Materials

None

Teaching Time

Two 45-minute class periods

Seating Arrangement

Groups of four students

Maximum Number of Students

32

Key Words

Seamount
Bathymetry
Transducer
Backscatter
Topographic contour

Background Information

Nearly 70% of all coral reefs in U.S. waters are found around the Northwestern Hawaiian Islands, a chain of small islands and atolls that stretches for more than 1,000 nautical miles (nm) northwest of the main Hawaiian Islands. While scientists have studied shallow portions of the area for many years, almost nothing is known about deeper ocean habitats below the range of SCUBA divers. Only a few explorations have been made with deep-diving submersibles and remotely-operated vehicles (ROVs), and these explorations have yielded discoveries of new species and species previously unreported in Hawaiian waters. Northwestern Hawaiian Islands are regularly visited by Hawaiian monk seals, one of only two species of monk seals remaining in the world (the Caribbean monk seal was declared extinct in 1994). Waters around the North-western Islands may be an important feeding area for the seals, which appear to feed on fishes that find shelter among colonies of deep-water corals. These corals are also of interest, because they include several species that are commercially valuable for jewelry. The possibility of discovering new species also has commercial importance as well as scientific interest, since some of these species may produce materials of importance to medicine or industry.

A major constraint to exploration of deep-water regions around the Northwestern Hawaiian Islands is the absence of accurate maps of the area. In fact, recent expeditions have found that some islands are not where they are supposed to be according to official nautical charts. Since underwater exploration time in submersibles is severely limited, every dive must be carefully planned to ensure that the submersible can go directly to places that are most likely to provide the information the scientists need. For this reason, underwater mapping is a top priority for the Ocean Exploration 2002 Northwestern Hawaiian Islands Expedition.

Scientists aboard the University of Hawaii's research vessel Kilo Moana will use multibeam swath bathymetry to create detailed pictures of the underwater topography around the Northwestern Hawaiian Islands. Multibeam swath bathymetry (also called "high-resolution multibeam mapping") uses a transducer (a sort of combination microphone/loudspeaker) mounted on the ship's hull to send out pulses of sound in a fan-shaped pattern below the ship, and then records sound reflected from the seafloor through a set of narrow receivers aimed at different angles on either side of the ship. This system collects high resolution water-depth data that can distinguish differences of less than a meter. The system also measures the amount of sound energy returned from the seafloor (called "backscatter"), which can help identify different materials (such as rock, sand, or mud) on the seafloor. The multibeam system is coupled to a global positioning system (GPS) that can pinpoint sea-floor locations within one meter. All data are collected in digital form, which allows them to be processed by computer to produce maps, three dimensional models, or even "fly-by" videos that simulate a trip across the area being mapped in a high-speed submersible! Topographic maps are one of the most common outputs from these systems. On these maps, areas with the same depth are connected by lines, so that mountains (or valleys) are shown as a series of concentric, irregular closed curves. Curves that are close together indicate steep topography, while curves that are farther apart show more gentle slopes.

This activity focuses on how topographic maps are created from multibeam bathymetric data. Students will construct a three-dimensional model of the Loihi submarine volcano from their topographic maps to help visualize the actual form of the seamount.

Learning Procedure

1. Introduce the location of the Northwestern Hawaiian Islands, and point out some of the features that make this area important (discussed above). Discuss the need for accurate maps in planning diving expeditions to deep-sea regions, and explain the general concept of multibeam swath bathymetry. You may need to review the basic idea of topographic maps if students are unfamiliar with these.

2. Distribute copies of "Loihi Volcano Bathymetric Data" and "Bathymetric Data Reduction Sheet" to each student group. Tell the students that the bathymetric data are part of a data set that was produced by a research vessel using multibeam bathymetry. Be sure students understand that each data point represents the depth of water below the research vessel when the vessel was at the location described by the grid coordinates. If you want to relate the grid to an actual map location, the lower left corner of grid cell 1,1 corresponds to latitude 18°-45'N, longitude 155°-20'W. Each grid cell interval corresponds to one minute of latitude or longitude. Note that for the purposes of this exercise, we are not dealing with all of the side-scan data, which would include more than a hundred additional depth readings in each grid cell, and would be much more difficult to process without computer analysis.

   Have each group enter the depth readings from the bathymetric data sheet into the corresponding grid cells on the "Bathymetric Data Reduction Sheet." Next, have the students draw contour lines on the Data Reduction Sheet for depths of 1,000 m, 2,000 m, 3,000 m, and 4,000 m. Tell the students to assume that the depth reading was taken at the center of each grid cell (indicated on the Data Reduction Sheet by the light crossed diagonal lines). In most cases, students will have to interpolate the position of the contour lines; for example, if one grid cell has a depth reading of 2,800 m and an adjacent cell has a depth reading of 3,200 m, students should assume that the 3,000 m contour line passes halfway between the center points of the two cells. Once these three contour lines are drawn, have students draw intermediate contour lines at 500 m intervals (i.e., 1,500 m, 2,500 m, and 3,500 m). When students have completed their contour maps, have them make a master tracing, and seven photocopies. If you want them to make larger models, they can enlarge their master tracing on the photocopier.

3. Have the students mount each copy of their contour map onto a piece of cardboard. Be sure to use enough glue to cover the entire surface of the cardboard. Next, students should prepare the seven layers of their

three dimensional model by cutting along the 4,000 m contour line on one mounted map, then cutting along the 3,500 m contour on the next mounted map, and so on until three layers have been cut out corresponding to each of the seven contour lines constructed on the Data Reduction Sheet. If students are using X-Acto knives, be sure to have a suitable backing (heavy cardboard, cutting board, etc.) to protect work surfaces.

4. Starting with the 4,000 m contour, carefully glue successive contours together to build the three-dimensional model of the volcano.

5. Using the models the students have produced, discuss the advantages of various locations on the volcano for diving missions. Flat regions are more likely to have accumulations of sediment, and will provide different habitats than very steep areas. On the other hand, steep areas obviously have a greater range of depths within a short distance, so these are better sites to study how depth influences the distribution of various species. Identify areas that are likely to offer a variety of habitat types within a short distance. These offer some of the best opportunities to get the most out of limited diving time.

Have the students compare their models with the bathymetric image of the Loihi volcano at http://www.oar.noaa.gov/spotlite/archive/spot_loihi.html. This image provides much more detail than the students' topographic maps because it includes thousands more data points. This sort of detailed mapping is only possible when computer analysis is available.

The BRIDGE Connection

www.vims.edu/BRIDGE/pacific.html

The "Me" Connection

Have students write a first-hand account of an exploratory mission to the Loihi volcano, referring to topographic features revealed by their model.

Connections to Other Subjects

English/Language Arts, Mathematics

Evaluation

Have students write a description of the Loihi volcano based on their model. Have them include geographic location (north-south-east-west directions and/or latitude and longitude), topography (steepness), and depth. Ask them to discuss the advantages and disadvantages of two-dimensional and three-dimensional topographic maps.

Extensions

Have students visit http://oceanexplorer.noaa.gov to follow the progress of deep-sea mapping in the vicinity of the Northwestern Hawaiian Islands. Additional data sets for topographic map construction may be posted here as the Expedition proceeds.

Resources

http://oceanexplorer.noaa.gov – Follow the Northwestern Hawaiian Islands Expedition daily as documentaries and discoveries are posted each day for your classroom use.

http://pubs.usgs.gov/fs/2000/fs013-00.pdf – Fact sheet on multi-beam mapping

http://www.oar.noaa.gov/spotlite/archive/spot_loihi.html – Short article on the Loihi volcano

http://www.soest.hawaii.edu/GG/HCV/loihi.html – More extensive website with information on Loihi and other volcanoes in Hawaii

http://www.sciencegems.com/earth2.html – Science education resources http://www.martindalecenter.com/ – References on just about everything

National Science Education Standards

Content Standard A: Science As Inquiry

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Content Standard D: Earth and Space Science

- Structure of the Earth system

For More Information

Paula Keener-Chavis, National Education Coordinator/Marine Biologist
NOAA Office of 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

Student Handout

Loihi Submarine Volcano Bathymetric Data

Grid Cell (row, column)	Depth (m)	Grid Cell (row, column)	Depth (m)	Grid Cell (row, column)	Depth (m)	Grid Cell (row, column)	Depth (m)
1,1	no data	3,10	2400	6,4	4000	8,13	3200
1,2	no data	3,11	2000	6,5	3400	8,14	3200
1,3	no data	3,12	1900	6,6	2700	8,15	2800
1,4	4600	3,13	2000	6,7	2000	9,1	4400
1,5	4400	3,14	21	6,8	1800	9,2	4000
1,6	4400	3,15	2200	6,9	1600	9,3	3600
1,7	4000	4,1	no data	6,10	1300	9,4	3400
1,8	3800	4,2	no data	6,11	1200	9,5	3900
1,9	3600	4,3	4400	6,12	1700	9,6	4000
1,10	3300	4,4	3800	6,13	2000	9,7	3800
1,11	2700	4,5	3500	6,14	2200	9,8	3700
1,12	2400	4,6	3200	6,15	2000	9,9	3600
1,13	2500	4,7	2800	7,1	4500	9,10	3800
1,14	2600	4,8	2800	7,2	4400	9,11	3600
1,15	2800	4,9	2300	7,3	4000	9,12	3500
2,1	no data	4,10	1800	7,4	3800	9,13	3400
2,2	no data	4,11	1400	7,5	3000	9,14	3300
2,3	no data	4,12	1500	7,6	2400	9,15	3200
2,4	4200	4,13	1600	7,7	2400	10,1	4500
2,5	4100	4,14	1800	7,8	2300	10,2	4200
2,6	4100	4,15	1900	7,9	2300	10,3	4200
2,7	3900	5,1	no data	7,10	2500	10,4	4700
2,8	3400	5,2	no data	7,11	2500	10,5 - 10,15	no data
2,9	3200	5,3	4600	7,12	2700	11,1	4700
2,10	2800	5,4	4000	7,13	2900	11,2	4500
2,11	2400	5,5	3400	7,14	3000	11,3	4700
2,12	2200	5,6	2900	7,15	2500	11,4 - 11,15	no data
2,13	2300	5,7	2300	8,1	4500		
2,14	2300	5,8	1800	8,2	4000		
2,15	2400	5,9	1600	8,3	3600		
3, 1	no data	5,10	1000	8,4	3100		
3,2	no data	5,11	1100	8,5	3000		
3,3	no data	5,12	1200	8,6	3200		
3,4	4000	5,13	1400	8,7	3200		
3,5	3800	5,14	1600	8,8	3100		
3,6	3800	5,15	1800	8,9	3000		
3,7	3700	6,1	no data	8,10	3100		
3,8	3300	6,2	no data	8,11	3100		
3,9	2800	6,3	4500	8,12	3200		

Student Handout
Bathymetric Data Reduction Sheet

	1	2	3	4	5	6	7	8	9	10	11
16											
15											
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Appendix A
Supplemental Data Sets

Two data sets are provided to give students additional opportunities to create two-dimensional topographic maps and three-dimensional models of seafloor features from bathymetric survey data. These data sets include bathymetry for the Blake Ridge (a ridge/bank feature), and Hudson Canyon (a submarine canyon). Bathymetric data for these locations were obtained from NOAA's National Geophysical Data Center using the GEODAS (GEOphysical DAta System) Design-a-Grid tool (*http://www.ngdc.noaa.gov/mgg/gdas/gd_designagrid.html*).

These data sets may be used with the original Mapping Deep-Sea Habitats lesson created for the 2002 Northwestern Hawaiian Islands Expedition (*http://oceanexplorer.noaa.gov/explorations/02hawaii/background/education/media/nwhi_mapping.pdf*), as well as with the Mapping Deep-Sea Features lesson included in the "Learning Ocean Science Through Ocean Exploration" curriculum (*http://www.oceanexplorer.noaa.gov/edu/curriculum/*). Because the latter lesson involves coloring grid cells according to depth, recommended color keys are included with the supplemental data.

The basic procedure for creating three-dimensional models from these data is described in Learning Procedure Steps 2 through 4 of the Mapping Deep-Sea Habitats lesson. Separate Data Reduction Sheets are provided for each data set. Bathymetric data for Data Reduction Sheet grid cells are given in columns beginning with the lower left grid cell. Because these supplemental data cover much larger areas than the Loihi volcano which was the subject of the original lesson, please note the following:

Blake Ridge (Bank)
There are 300 cells in the Data Reduction Sheet grid, each cell representing 4 minutes of latitude and longitude. The entire grid represents an area of 80 nautical miles x 60 nautical miles; about 145 km x 109 km. So the approximate scale of the grid is 1 inch = 19.3 km.

Have students construct contour lines in 200 meter intervals, from 2,000 meters to 4,000 meters. This will result in a model with eleven layers. If the layers are cut from foamcore 0.25 in thick, each layer will represent a vertical dimension of 200 meters and the vertical scale will be 1 inch = 800 m. Be sure students realize that the vertical scale of their model is exaggerated by a factor of about 24 compared to the horizontal scale. There is nothing wrong with this; such exaggeration is often used when constructing models of large features where variations in vertical distance (such as height or depth) are much smaller than variations in horizontal distance.

For bathymetric maps and images of the Blake Ridge (Bank), see
http://oceanexplorer.noaa.gov/explorations/deepeast01/logs/sep23/media/bathy.html;
http://oceanexplorer.noaa.gov/explorations/03windows/logs/jul24/media/d1fig1.html;
http://oceanexplorer.noaa.gov/explorations/deepeast01/logs/sep25/media/area_a.html; and
http://oceanexplorer.noaa.gov/explorations/03windows/logs/jul26/media/bdiapir.html.

Hudson Canyon

There are 240 cells in the Data Reduction Sheet grid, each cell representing 2 minutes of latitude and longitude. The entire grid represents an area of 80 nautical miles x 60 nautical miles; about 145 km x 109 km. So the approximate scale of the grid is 1 inch = 9.6 km.

Because the canyon is very steep, the procedure for constructing contour lines needs to be a little different. Have students construct contour lines at 50 meter intervals from depths of 50 meters to 200 meters, then at 200 meter intervals from depths of 201 meters to 1,143 meters. This will result in a model with seven layers. To maintain a uniform vertical scale, contours for depths below 200 meters should be cut from four thicknesses of foamcore (since the interval for these depths is four times greater than the interval for shallower depths).

If the layers are cut from foamcore 0.25 in thick, the vertical scale will be 1 inch = 200 m. This will cause the vertical scale to be exaggerated by a factor of about 48 compared to the horizontal scale, as discussed above.

For bathymetric maps and images of Hudson Canyon, see
http://oceanexplorer.noaa.gov/explorations/02hudson/background/plan/media/hudson_poster.html;
http://oceanexplorer.noaa.gov/explorations/02hudson/background/mapping/mapping.html;
http://oceanexplorer.noaa.gov/explorations/02hudson/logs/sep08/media/3dview.html; and
http://oceanexplorer.noaa.gov/explorations/02hudson/logs/sep12/sep12.html.

Table 1
Blake Ridge (Bank) Bathymetric Data

Lat	Lon	Depth (m)	Lat	Lon	Depth (m)	Lat	Lon	Depth (m)
31° 36′	75° 44′	3056	32° 24′	75° 36′	3309	32° 12′	75° 24′	3513
31° 40′	75° 44′	2919	32° 28′	75° 36′	3326	32° 16′	75° 24′	3566
31° 44′	75° 44′	2790	32° 32′	75° 36′	3344	32° 20′	75° 24′	3543
31° 48′	75° 44′	2687	31° 36′	75° 32′	3072	32° 24′	75° 24′	3543
31° 52′	75° 44′	2613	31° 40′	75° 32′	3041	32° 28′	75° 24′	3573
31° 56′	75° 44′	2646	31° 44′	75° 32′	2934	32° 32′	75° 24′	3622
32° 0′	75° 44′	2663	31° 48′	75° 32′	2789	31° 36′	75° 20′	3102
32° 4′	75° 44′	2608	31° 52′	75° 32′	2692	31° 40′	75° 20′	3043
32° 8′	75° 44′	2644	31° 56′	75° 32′	2691	31° 44′	75° 20′	2908
32° 12′	75° 44′	2684	32° 0′	75° 32′	2777	31° 48′	75° 20′	2822
32° 16′	75° 44′	2810	32° 4′	75° 32′	2901	31° 52′	75° 20′	2896
32° 20′	75° 44′	2965	32° 8′	75° 32′	3066	31° 56′	75° 20′	3026
32° 24′	75° 44′	3035	32° 12′	75° 32′	3132	32° 0′	75° 20′	3141
32° 28′	75° 44′	3042	32° 16′	75° 32′	3337	32° 4′	75° 20′	3299
32° 32′	75° 44′	3103	32° 20′	75° 32′	3400	32° 8′	75° 20′	3501
31° 36′	75° 40′	3077	32° 24′	75° 32′	3376	32° 12′	75° 20′	3621
31° 40′	75° 40′	2989	32° 28′	75° 32′	3388	32° 16′	75° 20′	3685
31° 44′	75° 40′	2839	32° 32′	75° 32′	3410	32° 20′	75° 20′	3664
31° 48′	75° 40′	2708	31° 36′	75° 28′	3081	32° 24′	75° 20′	3601
31° 52′	75° 40′	2661	31° 40′	75° 28′	3014	32° 28′	75° 20′	3625
31° 56′	75° 40′	2696	31° 44′	75° 28′	2951	32° 32′	75° 20′	3747
32° 0′	75° 40′	2638	31° 48′	75° 28′	2814	31° 36′	75° 16′	3054
32° 4′	75° 40′	2652	31° 52′	75° 28′	2744	31° 40′	75° 16′	3004
32° 8′	75° 40′	2735	31° 56′	75° 28′	2785	31° 44′	75° 16′	2913
32° 12′	75° 40′	2839	32° 0′	75° 28′	2877	31° 48′	75° 16′	2891
32° 16′	75° 40′	2875	32° 4′	75° 28′	3036	31° 52′	75° 16′	3007
32° 20′	75° 40′	3094	32° 8′	75° 28′	3162	31° 56′	75° 16′	3181
32° 24′	75° 40′	3192	32° 12′	75° 28′	3261	32° 0′	75° 16′	3250
32° 28′	75° 40′	3223	32° 16′	75° 28′	3461	32° 4′	75° 16′	3386
32° 32′	75° 40′	3233	32° 20′	75° 28′	3462	32° 8′	75° 16′	3654
31° 36′	75° 36′	3093	32° 24′	75° 28′	3431	32° 12′	75° 16′	3746
31° 40′	75° 36′	3037	32° 28′	75° 28′	3467	32° 16′	75° 16′	3783
31° 44′	75° 36′	2891	32° 32′	75° 28′	3515	32° 20′	75° 16′	3810
31° 48′	75° 36′	2779	31° 36′	75° 24′	3077	32° 24′	75° 16′	3766
31° 52′	75° 36′	2658	31° 40′	75° 24′	3015	32° 28′	75° 16′	3747
31° 56′	75° 36′	2694	31° 44′	75° 24′	2953	32° 32′	75° 16′	3836
32° 0′	75° 36′	2714	31° 48′	75° 24′	2819	31° 36′	75° 44′	3056
32° 4′	75° 36′	2769	31° 52′	75° 24′	2797	31° 40′	75° 44′	2919
32° 8′	75° 36′	2922	31° 56′	75° 24′	2871	31° 44′	75° 44′	2790
32° 12′	75° 36′	3032	32° 0′	75° 24′	3033	31° 48′	75° 44′	2687
32° 16′	75° 36′	3185	32° 4′	75° 24′	3188	31° 52′	75° 44′	2613
32° 20′	75° 36′	3299	32° 8′	75° 24′	3334	31° 56′	75° 44′	2646

Table 1(continued)
Blake Ridge (Bank) Bathymetric Data

Lat	Lon	Depth (m)	Lat	Lon	Depth (m)	Lat	Lon	Depth (m)
32° 0′	75° 44′	2663	31° 48′	75° 32′	2789	31° 36′	75° 20′	3102
32° 4′	75° 44′	2608	31° 52′	75° 32′	2692	31° 40′	75° 20′	3043
32° 8′	75° 44′	2644	31° 56′	75° 32′	2691	31° 44′	75° 20′	2908
32° 12′	75° 44′	2684	32° 0′	75° 32′	2777	31° 48′	75° 20′	2822
32° 16′	75° 44′	2810	32° 4′	75° 32′	2901	31° 52′	75° 20′	2896
32° 20′	75° 44′	2965	32° 8′	75° 32′	3066	31° 56′	75° 20′	3026
32° 24′	75° 44′	3035	32° 12′	75° 32′	3132	32° 0′	75° 20′	3141
32° 28′	75° 44′	3042	32° 16′	75° 32′	3337	32° 4′	75° 20′	3299
32° 32′	75° 44′	3103	32° 20′	75° 32′	3400	32° 8′	75° 20′	3501
31° 36′	75° 40′	3077	32° 24′	75° 32′	3376	32° 12′	75° 20′	3621
31° 40′	75° 40′	2989	32° 28′	75° 32′	3388	32° 16′	75° 20′	3685
31° 44′	75° 40′	2839	32° 32′	75° 32′	3410	32° 20′	75° 20′	3664
31° 48′	75° 40′	2708	31° 36′	75° 28′	3081	32° 24′	75° 20′	3601
31° 52′	75° 40′	2661	31° 40′	75° 28′	3014	32° 28′	75° 20′	3625
31° 56′	75° 40′	2696	31° 44′	75° 28′	2951	32° 32′	75° 20′	3747
32° 0′	75° 40′	2638	31° 48′	75° 28′	2814	31° 36′	75° 16′	3054
32° 4′	75° 40′	2652	31° 52′	75° 28′	2744	31° 40′	75° 16′	3004
32° 8′	75° 40′	2735	31° 56′	75° 28′	2785	31° 44′	75° 16′	2913
32° 12′	75° 40′	2839	32° 0′	75° 28′	2877	31° 48′	75° 16′	2891
32° 16′	75° 40′	2875	32° 4′	75° 28′	3036	31° 52′	75° 16′	3007
32° 20′	75° 40′	3094	32° 8′	75° 28′	3162	31° 56′	75° 16′	3181
32° 24′	75° 40′	3192	32° 12′	75° 28′	3261	32° 0′	75° 16′	3250
32° 28′	75° 40′	3223	32° 16′	75° 28′	3461	32° 4′	75° 16′	3386
32° 32′	75° 40′	3233	32° 20′	75° 28′	3462	32° 8′	75° 16′	3654
31° 36′	75° 36′	3093	32° 24′	75° 28′	3431	32° 12′	75° 16′	3746
31° 40′	75° 36′	3037	32° 28′	75° 28′	3467	32° 16′	75° 16′	3783
31° 44′	75° 36′	2891	32° 32′	75° 28′	3515	32° 20′	75° 16′	3810
31° 48′	75° 36′	2779	31° 36′	75° 24′	3077	32° 24′	75° 16′	3766
31° 52′	75° 36′	2658	31° 40′	75° 24′	3015	32° 28′	75° 16′	3747
31° 56′	75° 36′	2694	31° 44′	75° 24′	2953	32° 32′	75° 16′	3836
32° 0′	75° 36′	2714	31° 48′	75° 24′	2819	31° 36	75° 12′	3011
32° 4′	75° 36′	2769	31° 52′	75° 24′	2797	31° 40′	75° 12′	2979
32° 8′	75° 36′	2922	31° 56′	75° 24′	2871	31° 44′	75° 12′	3049
32° 12′	75° 36′	3032	32° 0′	75° 24′	3033	31° 48′	75° 12′	3056
32° 16′	75° 36′	3185	32° 4′	75° 24′	3188	31° 52′	75° 12′	3156
32° 20′	75° 36′	3299	32° 8′	75° 24′	3334	31° 56′	75° 12′	3350
32° 24′	75° 36′	3309	32° 12′	75° 24′	3513	32° 0′	75° 12′	3369
32° 28′	75° 36′	3326	32° 16′	75° 24′	3566	32° 4′	75° 12′	3464
32° 32′	75° 36′	3344	32° 20′	75° 24′	3543	32° 8′	75° 12′	3781
31° 36′	75° 32′	3072	32° 24′	75° 24′	3543	32° 12′	75° 12′	3833
31° 40′	75° 32′	3041	32° 28′	75° 24′	3573	32° 16′	75° 12′	3848
31° 44′	75° 32′	2934	32° 32′	75° 24′	3622	32° 20′	75° 12′	3880

Table 1(continued)
Blake Ridge (Bank) Bathymetric Data

Lat	Lon	Depth (m)	Lat	Lon	Depth (m)	Lat	Lon	Depth (m)
32° 24′	75° 12′	3918	31° 40′	75° 4′	3123	31° 56′	75° 0′	3802
32° 28′	75° 12′	3934	31° 44′	75° 4′	3253	32° 0′	75° 0′	3874
32° 32′	75° 12′	3915	31° 48′	75° 4′	3401	32° 4′	75° 0′	3951
31° 36′	75° 8′	3009	31° 52′	75° 4′	3515	32° 8′	75° 0′	4058
31° 40′	75° 8′	2999	31° 56′	75° 4′	3656	32° 12′	75° 0′	4098
31° 44′	75° 8′	3113	32° 0′	75° 4′	3777	32° 16′	75° 0′	4231
31° 48′	75° 8′	3206	32° 4′	75° 4′	3867	32° 20′	75° 0′	4242
31° 52′	75° 8′	3346	32° 8′	75° 4′	3952	32° 24′	75° 0′	4230
31° 56′	75° 8′	3502	32° 12′	75° 4′	4032	32° 28′	75° 0′	4286
32° 0′	75° 8′	3565	32° 16′	75° 4′	4070	32° 32′	75° 0′	4144
32° 4′	75° 8′	3660	32° 20′	75° 4′	4106			
32° 8′	75° 8′	3831	32° 24′	75° 4′	4107			
32° 12′	75° 8′	3920	32° 28′	75° 4′	4093			
32° 16′	75° 8′	3962	32° 32′	75° 4′	4084			
32° 20′	75° 8′	4008	31° 36′	75° 0′	3227			
32° 24′	75° 8′	3995	31° 40′	75° 0′	3312			
32° 28′	75° 8′	3998	31° 44′	75° 0′	3451			
32° 32′	75° 8′	4018	31° 48′	75° 0′	3578			
31° 36′	75° 4′	3089	31° 52′	75° 0′	3694			

Use Colored Pencils, Markers, or Crayons for Data Ranges:

2,000-2,200 m - red
2,201-2,400 m - red orange
2,401-2,600 m - orange
2,601-2,800 m - yellow orange
2,801-3,000 m - yellow
3,001-3,200 m - yellow green
3,201-3,400 m - green
3,401-3,600 m - blue green
3,601-3,800 m - blue
3,801-4,000 m - blue violet
4,001-4,200 m - purple
4,201-4,400 m - black

Blake Ridge (Bank) Bathymetric Data Reduction Sheet

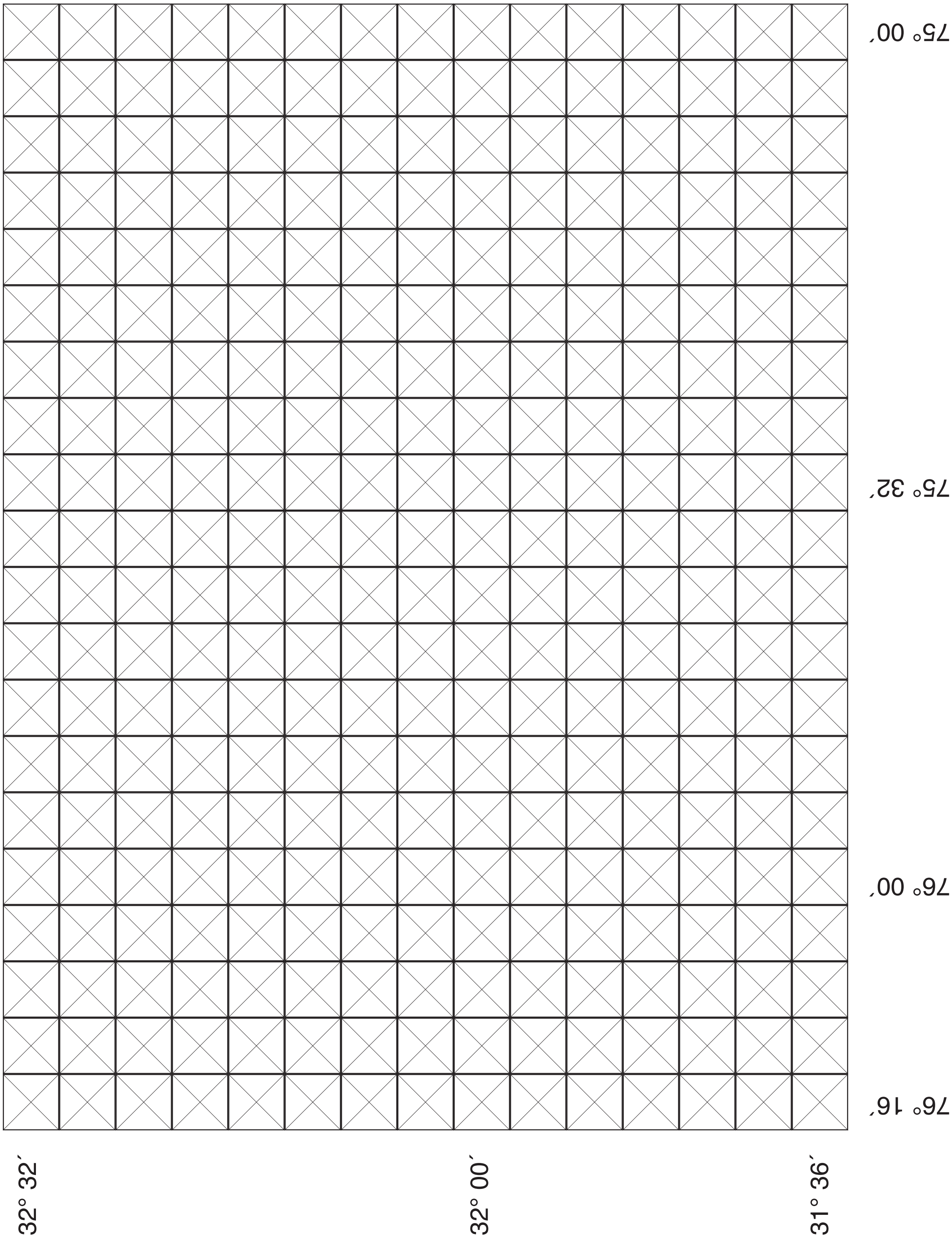

Table 2
Hudson Canyon Bathymetric Data

Lat	Lon	Depth (m)	Lat	Lon	Depth (m)	Lat	Lon	Depth (m)
72° 36′	39° 14′	134	72° 32′	39° 38′	81	72° 26′	39° 32′	116
72° 36′	39° 16′	129	72° 32′	39° 40′	80	72° 26′	39° 34′	110
72° 36′	39° 18′	126	72° 32′	39° 42′	78	72° 26′	39° 36′	99
72° 36′	39° 20′	120	72° 30′	39° 14′	177	72° 26′	39° 38′	204
72° 36′	39° 22′	117	72° 30′	39° 16′	139	72° 26′	39° 40′	149
72° 36′	39° 24′	108	72° 30′	39° 18′	139	72° 26′	39° 42′	92
72° 36′	39° 26′	102	72° 30′	39° 20′	134	72° 24′	39° 14′	316
72° 36′	39° 28′	93	72° 30′	39° 22′	131	72° 24′	39° 16′	197
72° 36′	39° 30′	87	72° 30′	39° 24′	127	72° 24′	39° 18′	164
72° 36′	39° 32′	79	72° 30′	39° 26′	121	72° 24′	39° 20′	143
72° 36′	39° 34′	81	72° 30′	39° 28′	114	72° 24′	39° 22′	138
72° 36′	39° 36′	78	72° 30′	39° 30′	105	72° 24′	39° 24′	133
72° 36′	39° 38′	74	72° 30′	39° 32′	92	72° 24′	39° 26′	130
72° 36′	39° 40′	77	72° 30′	39° 34′	90	72° 24′	39° 28′	125
72° 36′	39° 42′	76	72° 30′	39° 36′	89	72° 24′	39° 30′	121
72° 34′	39° 14′	140	72° 30′	39° 38′	86	72° 24′	39° 32′	219
72° 34′	39° 16′	134	72° 30′	39° 40′	88	72° 24′	39° 34′	262
72° 34′	39° 18′	132	72° 30′	39° 42′	81	72° 24′	39° 36′	143
72° 34′	39° 20′	126	72° 28′	39° 14′	219	72° 24′	39° 38′	296
72° 34′	39° 22′	123	72° 28′	39° 16′	144	72° 24′	39° 40′	165
72° 34′	39° 24′	119	72° 28′	39° 18′	142	72° 24′	39° 42′	93
72° 34′	39° 26′	109	72° 28′	39° 20′	139	72° 22′	39° 14′	346
72° 34′	39° 28′	99	72° 28′	39° 22′	134	72° 22′	39° 16′	228
72° 34′	39° 30′	91	72° 28′	39° 24′	130	72° 22′	39° 18′	188
72° 34′	39° 32′	87	72° 28′	39° 26′	126	72° 22′	39° 20′	157
72° 34′	39° 34′	83	72° 28′	39° 28′	120	72° 22′	39° 22′	144
72° 34′	39° 36′	78	72° 28′	39° 30′	110	72° 22′	39° 24′	139
72° 34′	39° 38′	79	72° 28′	39° 32′	99	72° 22′	39° 26′	130
72° 34′	39° 40′	78	72° 28′	39° 34′	94	72° 22′	39° 28′	127
72° 34′	39° 42′	76	72° 28′	39° 36′	94	72° 22′	39° 30′	150
72° 32′	39° 14′	151	72° 28′	39° 38′	93	72° 22′	39° 32′	394
72° 32′	39° 16′	138	72° 28′	39° 40′	107	72° 22′	39° 34′	289
72° 32′	39° 18′	137	72° 28′	39° 42′	91	72° 22′	39° 36′	147
72° 32′	39° 20′	129	72° 26′	39° 14′	268	72° 22′	39° 38′	190
72° 32′	39° 22′	127	72° 26′	39° 16′	170	72° 22′	39° 40′	141
72° 32′	39° 24′	124	72° 26′	39° 18′	145	72° 22′	39° 42′	103
72° 32′	39° 26′	115	72° 26′	39° 20′	139	72° 20′	39° 14′	391
72° 32′	39° 28′	106	72° 26′	39° 22′	136	72° 20′	39° 16′	278
72° 32′	39° 30′	102	72° 26′	39° 24′	131	72° 20′	39° 18′	218
72° 32′	39° 32′	92	72° 26′	39° 26′	129	72° 20′	39° 20′	176
72° 32′	39° 34′	84	72° 26′	39° 28′	122	72° 20′	39° 22′	154
72° 32′	39° 36′	82	72° 26′	39° 30′	117	72° 20′	39° 24′	146

Table 2
Hudson Canyon Bathymetric Data

Lat	Lon	Depth (m)	Lat	Lon	Depth (m)	Lat	Lon	Depth (m)
72° 20′	39° 26′	137	72° 14′	39° 20′	303	72° 8′	39° 14′	914
72° 20′	39° 28′	129	72° 14′	39° 22′	232	72° 8′	39° 16′	762
72° 20′	39° 30′	239	72° 14′	39° 24′	218	72° 8′	39° 18′	661
72° 20′	39° 32′	475	72° 14′	39° 26′	260	72° 8′	39° 20′	598
72° 20′	39° 34′	186	72° 14′	39° 28′	451	72° 8′	39° 22′	748
72° 20′	39° 36′	107	72° 14′	39° 30′	657	72° 8′	39° 24′	954
72° 20′	39° 38′	103	72° 14′	39° 32′	330	72° 8′	39° 26′	1006
72° 20′	39° 40′	119	72° 14′	39° 34′	128	72° 8′	39° 28′	662
72° 20′	39° 42′	105	72° 14′	39° 36′	125	72° 8′	39° 30′	484
72° 18′	39° 14′	497	72° 14′	39° 38′	121	72° 8′	39° 32′	315
72° 18′	39° 16′	353	72° 14′	39° 40′	121	72° 8′	39° 34′	150
72° 18′	39° 18′	258	72° 14′	39° 42′	121	72° 8′	39° 36′	142
72° 18′	39° 20′	204	72° 12′	39° 14′	821	72° 8′	39° 38′	130
72° 18′	39° 22′	174	72° 12′	39° 16′	606	72° 8′	39° 40′	125
72° 18′	39° 24′	155	72° 12′	39° 18′	433	72° 8′	39° 42′	126
72° 18′	39° 26′	149	72° 12′	39° 20′	362	72° 6′	39° 14′	988
72° 18′	39° 28′	143	72° 12′	39° 22′	307	72° 6′	39° 16′	908
72° 18′	39° 30′	394	72° 12′	39° 24′	310	72° 6′	39° 18′	786
72° 18′	39° 32′	430	72° 12′	39° 26′	444	72° 6′	39° 20′	794
72° 18′	39° 34′	160	72° 12′	39° 28′	675	72° 6′	39° 22′	1143
72° 18′	39° 36′	109	72° 12′	39° 30′	548	72° 6′	39° 24′	639
72° 18′	39° 38′	111	72° 12′	39° 32′	195	72° 6′	39° 26′	730
72° 18′	39° 40′	111	72° 12′	39° 34′	136	72° 6′	39° 28′	549
72° 18′	39° 42′	110	72° 12′	39° 36′	132	72° 6′	39° 30′	398
72° 16′	39° 14′	606	72° 12′	39° 38′	123	72° 6′	39° 32′	360
72° 16′	39° 16′	451	72° 12′	39° 40′	125	72° 6′	39° 34′	180
72° 16′	39° 18′	317	72° 12′	39° 42′	123	72° 6′	39° 36′	150
72° 16′	39° 20′	252	72° 10′	39° 14′	876	72° 6′	39° 38′	138
72° 16′	39° 22′	197	72° 10′	39° 16′	660	72° 6′	39° 40′	135
72° 16′	39° 24′	174	72° 10′	39° 18′	523	72° 6′	39° 42′	129
72° 16′	39° 26′	162	72° 10′	39° 20′	434			
72° 16′	39° 28′	241	72° 10′	39° 22′	422			
72° 16′	39° 30′	583	72° 10′	39° 24′	584			
72° 16′	39° 32′	403	72° 10′	39° 26′	709			
72° 16′	39° 34′	127	72° 10′	39° 28′	756			
72° 16′	39° 36′	119	72° 10′	39° 30′	498			
72° 16′	39° 38′	119	72° 10′	39° 32′	223			
72° 16′	39° 40′	116	72° 10′	39° 34′	147			
72° 16′	39° 42′	118	72° 10′	39° 36′	138			
72° 14′	39° 14′	721	72° 10′	39° 38′	129			
72° 14′	39° 16′	542	72° 10′	39° 40′	124			
72° 14′	39° 18′	383	72° 10′	39° 42′	124			

Use Colored Pencils, Markers, or Crayons for Data Ranges:

50-100 m – red
101-150 m – orange
151-200 m – yellow
201-400 m – green
401-600 m – blue
601-800 m – blue violet
801-1,143 m – purple

Hudson Canyon Bathymetric Data Reduction Sheet