



WATCHING IN 3D

Exploring with Multibeam Sonar

Educator Guide

TOPIC:	Bathymetric Mapping/Deep-sea Discoveries
GRADE LEVEL:	9-12 (Technology/Physical Sciences/Life Sciences)
TIME NEEDED:	Two or three 45-minute class periods (to allow students to fully explore each Tool in their Case Study)
FOCUS:	Students will utilize authentic ocean exploration tools to understand how they contribute to understanding our unexplored ocean.

DRIVING QUESTION:	How are bathymetric maps and multibeam sonar data used to support ocean exploration?
--------------------------	--------------------------------------------------------------------------------------

OBJECTIVES/ LEARNING OUTCOMES:	<p>Students will learn:</p> <ul style="list-style-type: none">• how multibeam sonar is used to explore and study the shape and composition of the ocean floor (bathymetry)• how to analyze and interpret maps of specific seafloor features using multibeam sonar data.
-------------------------------------------	------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

MATERIALS:	Copies of student Case Study worksheets; five Fledermaus demonstration videos (1 introductory video and 4 Case Studies)
-------------------	-------------------------------------------------------------------------------------------------------------------------

EQUIPMENT:	Computer(s) - number depends on choice of instructional approach; high speed internet
-------------------	---------------------------------------------------------------------------------------

SET-UP INSTRUCTIONS:	<ul style="list-style-type: none">• Explore this guide and get comfortable with the Digital Atlas, the Case Study videos, and the Student Case Study Worksheets.• Possible lesson set-up approaches:<ul style="list-style-type: none">• Instruct as a jigsaw, with each student group doing a single Case Study.• Do one Case Study as a class and then assign student groups to the remaining 3 Case Studies.
-----------------------------	--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

Note: Be sure to consider quiet spaces if multiple groups will be watching different videos simultaneously.

ba·thym·e·try

noun

The study of the "beds" or "floors" of water bodies, including the ocean, rivers, streams, and lakes; "submarine topography," or the depths and shapes of underwater terrain.

In the same way that topographic maps represent the three-dimensional features (or relief) of overland terrain, bathymetric maps illustrate the land that lies underwater.

Performance Expectations (PEs): HS-PS4-5; HS-LS2-6
HS-LS2-4

Disciplinary Core Ideas (DCIs)
PS4.C Information Technologies and Instrumentation

LS2.C Ecosystem Dynamics, Functioning and Resilience

Crosscutting Concepts (CCs)
System and System Models
Stability and Change

Science & Engineering Practices (SEPs)

Obtaining, Evaluating, and Communicating Information
Engaging in Argument from Evidence

COMMON CORE CONNECTIONS
ELA/Literacy - RST.11-12.1, WHST.9-12.1

OCEAN LITERACY ESSENTIAL PRINCIPLES AND FUNDAMENTAL CONCEPTS

Principle 1: FC b, Principle 5: FCs e, f, g
Principle 7: FCs a, b, d, e, f



Educator Guide cont.

Background

The NOAA Ship *Okeanos Explorer* was commissioned as “America’s Ship for Ocean Exploration,” the only U.S. federal vessel dedicated to exploration of our largely unknown ocean. Similar ships are operated by the Schmidt Ocean Institute (R/V *Falkor* (too) and the Ocean Exploration Trust (E/V *Nautilus*).

While specific activities aboard these ships vary from mission to mission, they all employ a similar overall strategy for exploring Earth’s ocean with a goal of developing baseline information about the biological, geological and water chemistry features of unexplored areas to provide a foundation for future exploration and research.

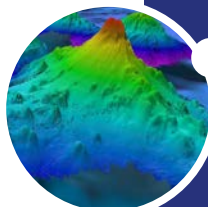
Baseline information includes:

- High resolution maps of the area being explored, as well as areas that the ship crosses while underway from one location to the next (underway reconnaissance);
- Data about water column chemistry and other features; and
- High definition video of biological and geological features in the exploration area (site characterization), as well as additional data about water chemistry, living organisms, and geologic features.

For more on these three ships, their exploration technologies and where and what they are exploring, check out the Vessels page of the Deep Ocean Education Project website.

► <https://deepoceaneducation.org/vessels/>

Four key technologies are used to gather baseline information on areas of ocean exploration:



1 Listen

Multibeam sonar mapping system and other types of sonar that can detect specific features in the water column and on the seafloor.



2 Test

Conductivity, Temperature and Depth profilers (CTDs) and other electronic sensors to measure chemical and physical seawater properties.



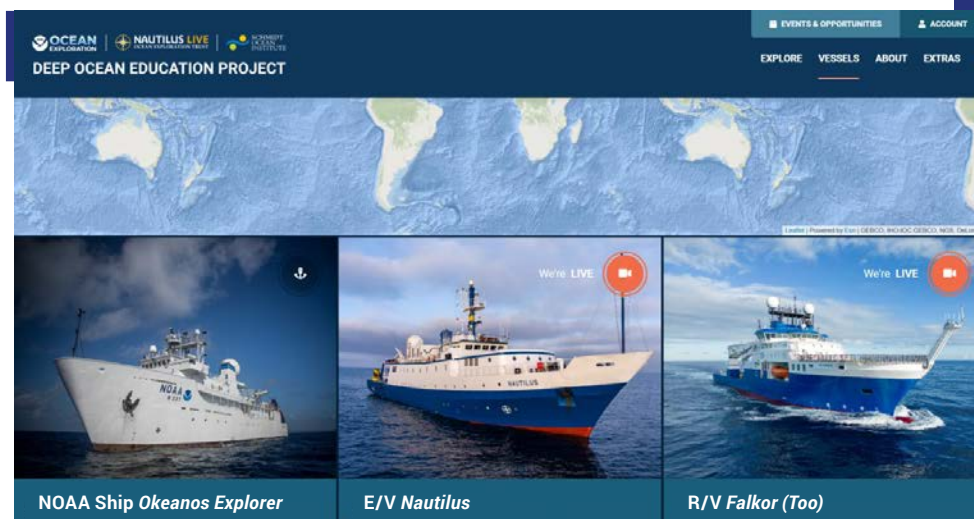
3 Photograph

A **Remotely Operated Vehicle (ROV)** capable of obtaining high-quality imagery and samples in depths as great as 6,000 meters.



4 Share

Telepresence technologies that allow scientists with many different areas of expertise to observe and interact with exploration activities, though they may be thousands of miles from the ship.



Educator Guide cont.

Introduction

THIS EDUCATOR GUIDE PROVIDES:

1. An overview of **multibeam sonar**.
2. Links to four specific ocean exploration Case Studies and associated student worksheets and demonstration videos.
3. The Learning Procedure, including a Tool Guide with step by step instructions to familiarize educators with using the NOAA Ocean Exploration Data Atlas (a searchable, interactive expedition data map) to explore key Case Study regions; Fledermaus software, an interactive mapping data visualization tool used by ocean explorers; and the oceanexplorer.noaa.gov website.
4. Links to additional support information and teaching resources.

Each Case Study provides engaging ways for students to explore a specific underwater feature while combining multiple interactive tools like maps, videos, and expedition logs. These real scientific expedition data and resources are used to expose students to authentic ocean exploration and research and allows them to practice their observation and critical thinking skills.

The background information for students provided in each Case Study is in the form of readings, videos, and fact sheets to give them context and understanding needed to discuss and think about the questions presented. This information is part of each case and can be assigned as homework before students begin the lesson. Be sure to review each case beforehand to see if any additional key vocabulary words should be defined or clarified based on student need.

- **Fledermaus Software:** [Introduction Video](#)
- **Case Study 1:** [Exploring an Underwater Volcano \(Kawio Barat\)](#)
[Fledermaus Video: Underwater Volcano \(Kawio Barat\)](#)
- **Case Study 2:** [Exploring Cold Seeps](#)
[Fledermaus Video: Cold Seeps](#)
- **Case Study 3:** [Exploring a Northeast U.S. Seamount \(Mytilus\)](#)
[Fledermaus Video: Northeast U.S. Seamount \(Mytilus\)](#)
- **Case Study 4:** [Exploring a Hotspot Volcano \(Vailulu'u\)](#)
[Fledermaus Video: Hotspot Volcano \(Vailulu'u\)](#)



For more images, videos, and teaching resources on these topics, visit the NOAA Ocean Exploration **Theme pages**.

<https://oceanexplorer.noaa.gov/discover/educators/>



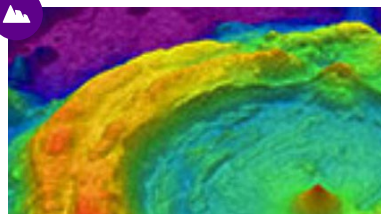
UNDERWATER VOLCANOES/ HOTSPOT VOLCANOES

Most of the active volcanoes on Earth are located underwater, formed when magma from deep within the crust rises to the seafloor. Cooling of the magma can create hydrothermal vents, where superheated and chemical-rich water spews upward, similar to geysers on land.



COLD SEEPS

Cold seeps are locations where hydrocarbon-rich fluid seeps up from below the seafloor, often as methane gas or hydrogen sulfide. Cold seeps have been found to support significant chemosynthetic communities, in which chemical energy is used to produce food in the absence of sunlight.



SEAMOUNTS

Seamounts are often remnants of extinct volcanoes and come in a variety of shapes and sizes. They can be found in every world ocean basin. By definition, seamounts are geological structures that rise at least 1,000 meters (3,300 feet) above the surrounding the seafloor.

Educator Guide cont.

What is Multibeam Sonar?

Multibeam sonar is one of the most powerful tools available for modern deep-sea exploration, and can create high-resolution maps, three dimensional models, or even “fly-through” videos that simulate a trip across an area being mapped.

SOund NAVigation and Ranging (SONAR) systems consist of a transmitter that sends pulses of sound energy through the water and a receiver that detects return signals (echoes) that are reflected back from the seafloor or other objects, including living organisms. In use, an acoustic signal or pulse of sound (often called a ping) is transmitted into the water by a sort of underwater speaker known as a transducer. The transducer may be mounted in a variety of ways including on the hull of a ship, on a pole, on underwater vehicles, or towed in a container called a towfish. If the seafloor or another object is in the path of the sound pulse, the sound bounces off the object and returns an echo to the sonar transducer. The time elapsed between the emission of the sound pulse and the reception of the echo is used to calculate the distance of the object.

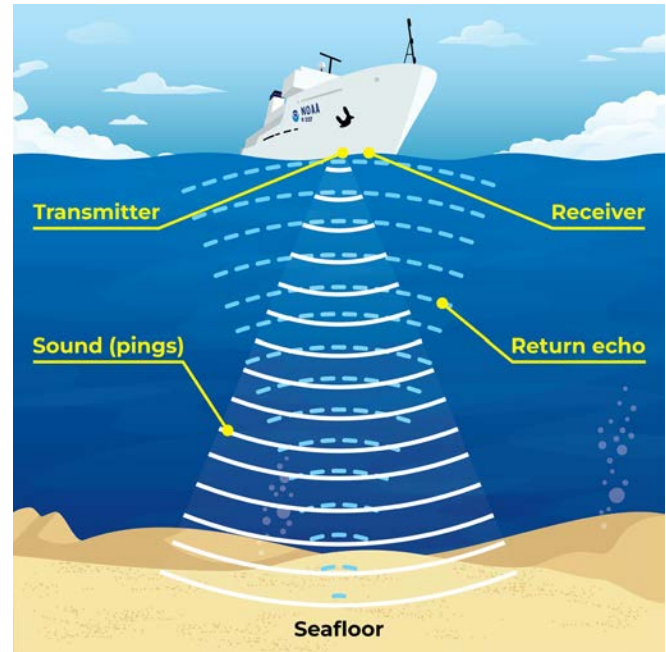
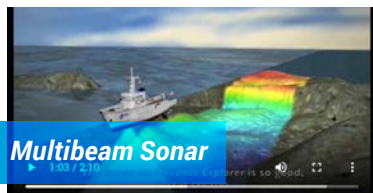
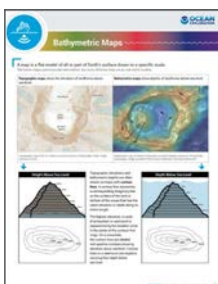


Illustration courtesy of NOAA Ocean Exploration.

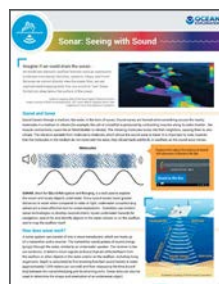


Video courtesy of
 NOAA Ocean
 Exploration.

FOR MORE INFORMATION:



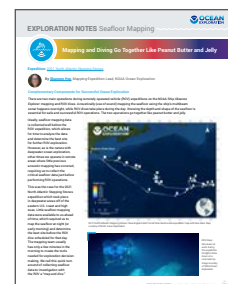
► [Bathymetric Maps](#)
 Fact Sheet



► [Sonar: Seeing with Sound](#)
 Fact Sheet



► [Multibeam Sonar](#)
 Fact Sheet



► [Mapping and Diving Go Together Like Peanut Butter and Jelly](#)
 Exploration Note



Educator Guide cont.

Learning Procedure

- Provide a brief presentation to introduce the lesson and expectations, to answer any clarifying questions, and to provide guidance for using the Tools in the sections below.
- Start by asking students to think about and discuss the following questions as a class.
 - Why do we map the ocean floor?
 - How do we map the ocean floor?
 - What features exist on the ocean floor?
 - Why do you think it important to understand these features?

This Mapping StoryMap will provide you with additional background.



Tool Guide

Use this step-by-step Tool Guide either to orient yourself or as a demonstration example to show students how to use the NOAA Ocean Exploration Data Atlas, the Case Study videos and the Ocean Explorer website to dive into their case and become familiar with these authentic science tools and ocean exploration discoveries.

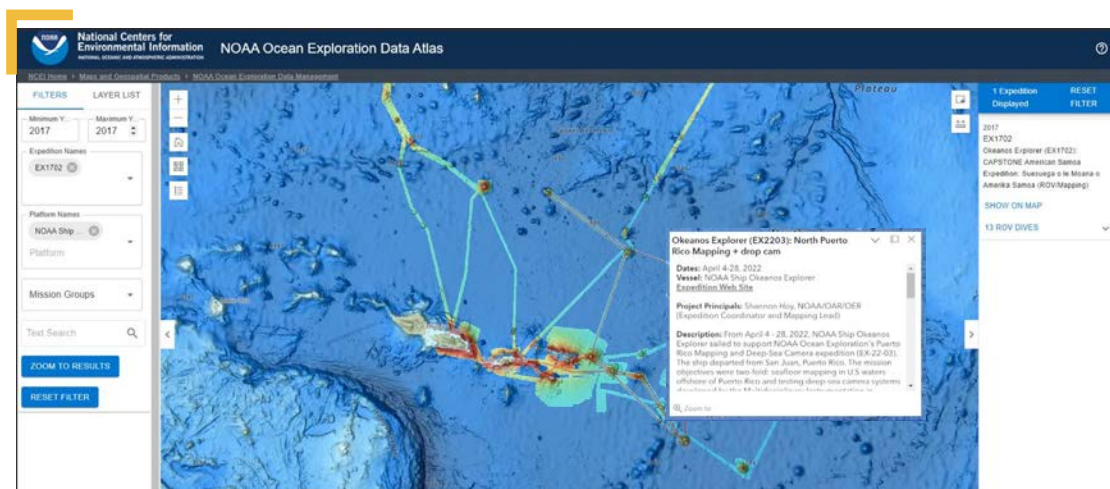
TOOL 1: The NOAA Ocean Exploration Data Atlas

Students will explore the NOAA Ocean Exploration Data Atlas to learn how scientists use this powerful tool to document incredible seafloor features. This map-based, interactive online tool provided by NOAA's National Centers for Environmental Information (NCEI) links to data and information about past NOAA Ocean Exploration expeditions since they began in 2001. The atlas orients users to expedition locations and provides experiences exploring data and associated discoveries from specific expeditions.

Note: For the purpose of this example, we will be referencing the CAPSTONE American Samoa Expedition: *Suesuega o le Moana o Amerika Samoa (ROV/Mapping) EX1702*.

1. OPEN THE NOAA OCEAN EXPLORATION DATA ATLAS

► <https://www.ncei.noaa.gov/maps/ocean-exploration-data-atlas/>



EX1702: "EX" is used as an abbreviation for the NOAA Ship *Okeanos Explorer*, the last two digits of the year of the cruise (17) and the number of the cruise (second-02 cruise for 2017).

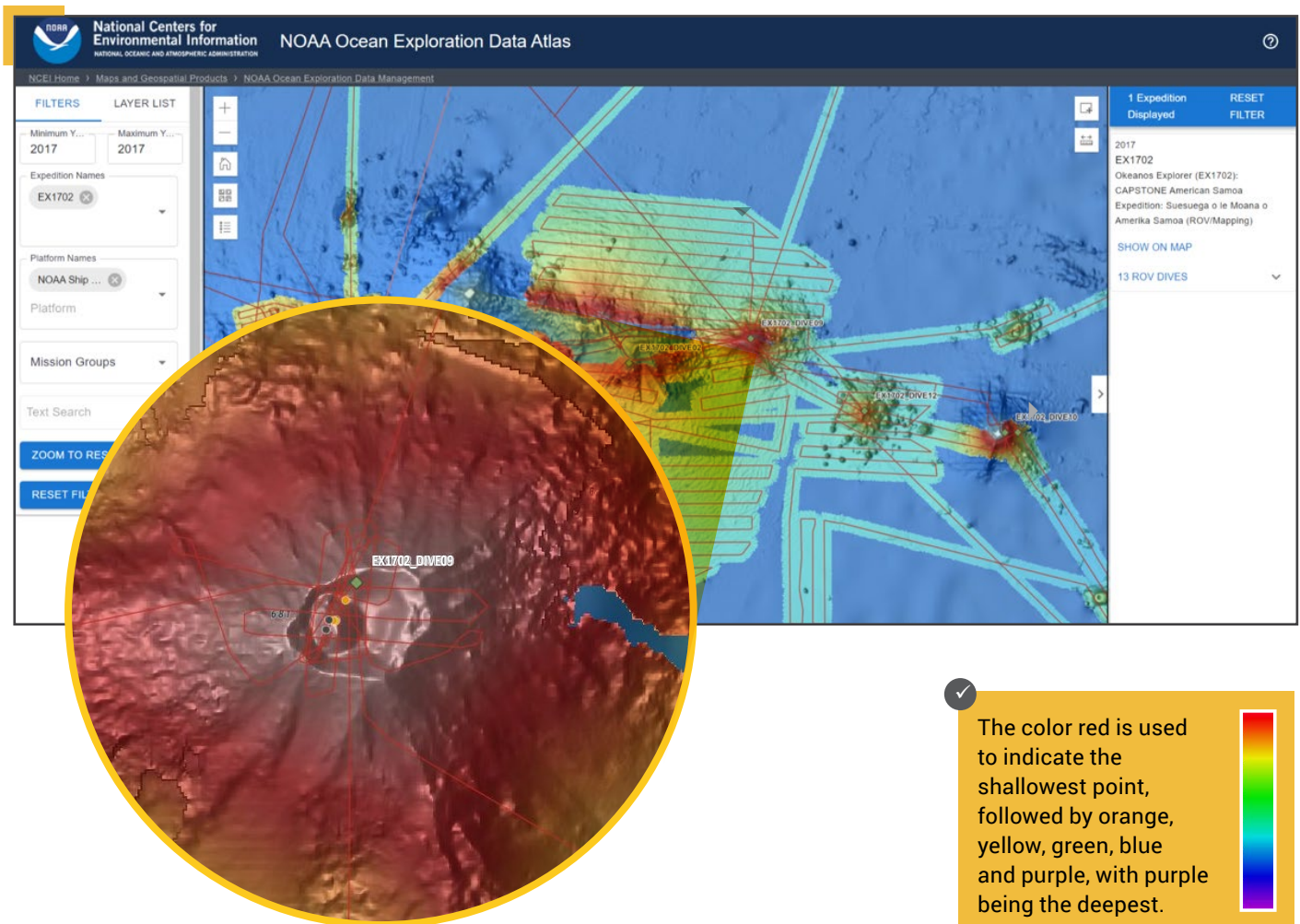
2. CHOOSE YEAR, EXPEDITION, AND VESSEL:

On the left, select the year (2017) of the expedition as both the Minimum Y(ear) and Maximum Y(ear). Then, select the Expedition Code (EX1702) and Platform Name (NOAA Ship *Okeanos Explorer*). The expedition name will pop up on the righthand side bar.

3. CLICK ZOOM TO RESULTS.



Educator Guide cont.



- PLOT ON MAP:** Use your center mouse button to zoom in until the names of the ROV dives appear.

TEACHER NOTE

Part of the student observations are to note that the lines displayed illustrate where the ship tracked back and forth “mowing the lawn” as the multibeam sonar mapped the seafloor.

- LOOK CLOSER:** Holding the left mouse button down, shift the map and zoom in to find Remotely Operated Vehicle (ROV) Dives 9 (EX1702_DIVE09). This is atop Vailulu’u Seamount.
- DIVE IN:** Zoom in to get a closer look at Vailulu’u.
- ZOOM OUT:** Zoom out farther to see where this hotspot volcano sits on the globe.

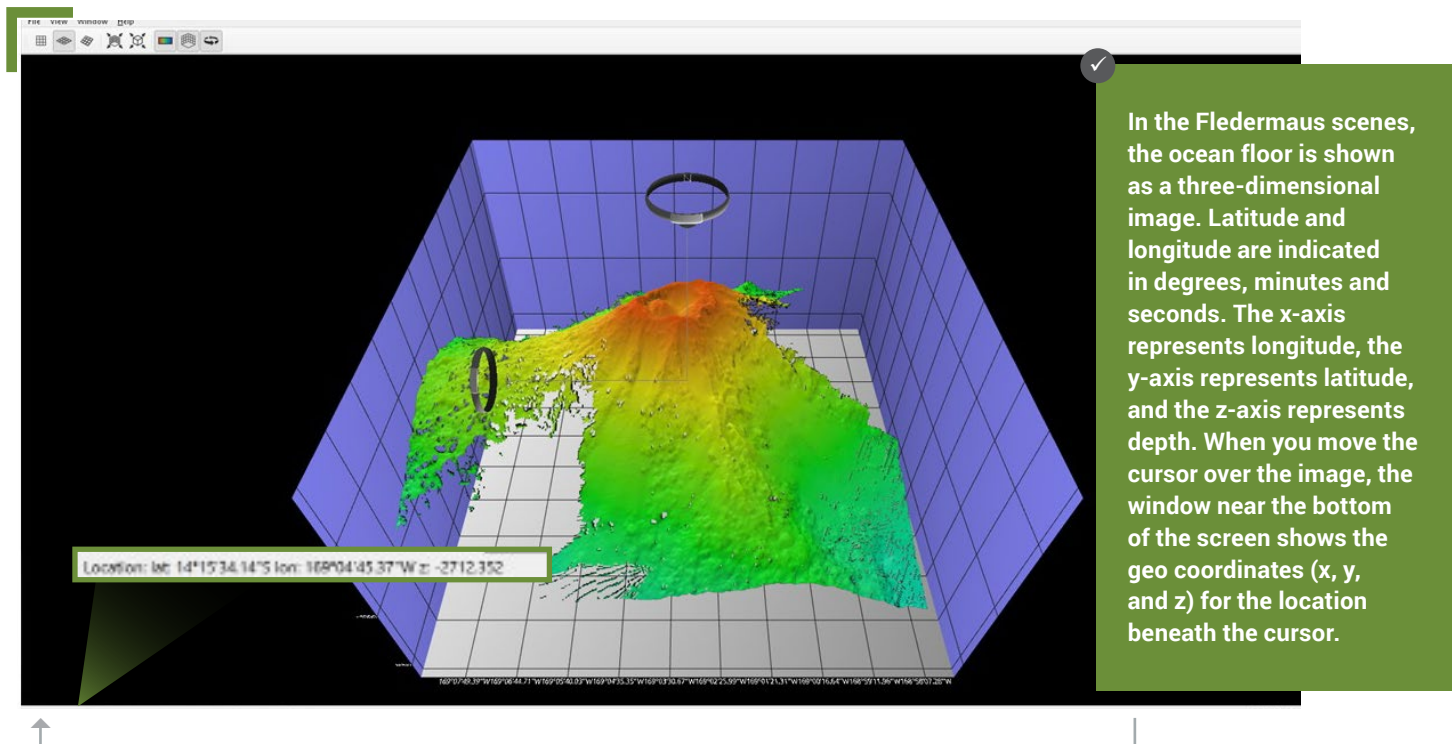


Educator Guide cont.

TOOL 2: Exploring with Fledermaus (Demonstration Videos)

Once students have found the targeted expedition on the Atlas, they will explore a highlighted structure in 3D. One 3D data visualization system used by ocean explorers is called Fledermaus. This software allows the user to view and manipulate 3D models of seafloor features, providing insight into the geological structure of an area and helping to pinpoint ideal locations for further exploration. Students will explore a demonstration video using this software within each of the case studies.

Fledermaus, pronounced "FLEE-der-mouse," is the German word for bat.



This image is of Vailulu'u Seamount/Volcano within the Samoan archipelago (Case Study 4). Each Case Study has a video that walks through a 3D image created using multibeam sonar data in order for students to explore a feature and answer questions.

TOOL 3: Expedition Web Pages

Each expedition has specific web pages on the [NOAA Ocean Exploration website](https://oceanexplorer.noaa.gov/). Within their assigned Case Studies, students will be instructed to explore the details and discoveries of specific associated expeditions. For example, you can explore the 2017 American Samoa Expedition here: <https://archive.oceanexplorer.noaa.gov/oceanos/explorations/ex1702/welcome.html>

(The expedition webpages can also accessed by clicking on SHOW ON MAP on the right side of the NOAA Ocean Exploration Data Atlas - Tool 1).





Educator Guide cont.

Learning Procedure cont.

For a jigsaw instructional approach:

- Hand out the assigned Case Study to each student group with a worksheet for each student.
- Have each group work together to investigate their exploration site using the NOAA Ocean Exploration Data Atlas, the video of the 3D map of their key seafloor feature and the associated discoveries described on the ocean explorer website. As the students work, they should each fill out their Case Study Worksheet.

Putting the Pieces Together

Once student groups have explored their Case Studies and completed their worksheets:

1. Have each group report out on their findings being sure to include:
 - Where their site was located.
 - What they learned about their site.
 - What they learned about the tools used to explore the site.
 - What questions their team has that they would like to see ocean explorers look into in the future.
2. Once all groups have reported out, ask the class to compare and contrast their expeditions. What was the same about them? What was different? What is particularly special about these exploration tools? How do these tools support efficient ocean exploration? How could these tools be improved?

Assessment

The following summative assessments can be used to evaluate student's comprehension of lesson material. Groups can choose or be assigned one of the following options below and create a project using the knowledge and insight gained from their Case Study.

Options

- Write a newspaper article summarizing the key discoveries from the expedition.
- Create a 3-4 minute video documentary showcasing the expedition highlights.
- Develop a visual infographic displaying the key geographical, biological, and chemical findings from the expedition.
- Construct a concept map linking terms related to the underwater feature including type, characteristics, exploration tools, habitat flora/fauna, and importance.
- Design a science station museum display for the public.

LOOK FORS

At minimum, all projects should include:

- the name and type of underwater feature highlighted
- how/what tools were used to explore this feature
- two key things about the geography, biology, and chemistry of the area in their Case Study
- key findings of the expedition
- one or two thoughts on further exploration of the site.



Educator Guide URLs/Links

- Page 2:**
- ▶ Vessels: Deep Ocean Education Project website: <https://deepoceaneducation.org/vessels/>
 - ▶ Listen: <https://oceanexplorer.noaa.gov/edu/materials/multibeam-sonar-fact-sheet.pdf>
 - ▶ Test: <https://oceanexplorer.noaa.gov/technology/ctd/>
 - ▶ Photograph: <https://oceanexplorer.noaa.gov/edu/materials/rov-fact-sheet.pdf>
 - ▶ Share: <https://oceanexplorer.noaa.gov/technology/telepresence/>
- Page 3:**
- ▶ Theme pages: <https://oceanexplorer.noaa.gov/edu/themes>
 - ▶ Fledermaus software introduction (video): https://oceanexplorer.noaa.gov/edu/materials/Win3D_Fledermaus.mp4
 - ▶ CS 1: Exploring an Underwater Volcano (Kawio Barat)(PDF): https://oceanexplorer.noaa.gov/edu/materials/CaseStudy1_KawioBarat_Volcano.pdf
 - ▶ Fledermaus Video: Underwater Volcano (Kawio Barat): https://oceanexplorer.noaa.gov/edu/materials/CaseStudy1_KawioBarat_Volcano.mp4
 - ▶ CS 2: Exploring Cold Seeps (PDF): https://oceanexplorer.noaa.gov/edu/materials/CaseStudy2_ColdSeeps.pdf
 - ▶ Fledermaus Video: Cold Seeps: https://oceanexplorer.noaa.gov/edu/materials/CaseStudy2_ColdSeeps.mp4
 - ▶ CS 3: Exploring a Northeast U.S. Seamount (Mytilus)(PDF): https://oceanexplorer.noaa.gov/edu/materials/CaseStudy3_Mytilus_Seamount.pdf
 - ▶ Fledermaus Video: Northeast U.S. Seamount (Mytilus): https://oceanexplorer.noaa.gov/edu/materials/CaseStudy3_Mytilus_Seamount.mp4
 - ▶ CS 4: Exploring a Hotspot Volcano (Vailulu'u)(PDF): https://oceanexplorer.noaa.gov/edu/materials/CaseStudy4_Vailuluu_HotSpot.pdf
 - ▶ Fledermaus Video: Hotspot Volcano (Vailulu'u): https://oceanexplorer.noaa.gov/edu/materials/CaseStudy4_Vailuluu_HotSpot.mp4
 - ▶ Underwater Volcanoes: <https://oceanexplorer.noaa.gov/education/hydrothermal-vents-volcanoes/>
 - ▶ Cold Seeps: <https://oceanexplorer.noaa.gov/education/cold-seeps-educators/>
 - ▶ Seamounts: <https://oceanexplorer.noaa.gov/education/seamounts/>
- Page 4:**
- ▶ Multibeam Sonar Fact Sheet (PDF): <https://oceanexplorer.noaa.gov/edu/materials/multibeam-sonar-fact-sheet.pdf>
 - ▶ Flythrough videos: https://archive.oceanexplorer.noaa.gov/explorations/12_ire/background/laubasin/laubasin.html
 - ▶ *Okeanos Explorer* Multibeam Animation: <https://oceanexplorer.noaa.gov/technology/sonar-multibeam.html>
 - ▶ Sonar: Seeing with Sound Fact Sheet (PDF): <https://oceanexplorer.noaa.gov/edu/materials/sonar-fact-sheet.pdf>
 - ▶ Sonar Illustration: <https://oceanexplorer.noaa.gov/edu/materials/sonar-pings-illustration.png>
 - ▶ Bathymetric Maps Fact Sheet (PDF): <https://oceanexplorer.noaa.gov/edu/materials/bathymetric-mapping-fact-sheet.pdf>
 - ▶ Sonar: Seeing with Sound Fact Sheet (PDF): <https://oceanexplorer.noaa.gov/edu/materials/sonar-fact-sheet.pdf>
 - ▶ Multibeam Sonar Fact Sheet (PDF): <https://oceanexplorer.noaa.gov/edu/materials/multibeam-sonar-fact-sheet.pdf>
 - ▶ Mapping and Diving Go Together Like Peanut Butter and Jelly Exploration Note (PDF): <https://oceanexplorer.noaa.gov/edu/materials/map-dive-exploration-note.pdf>
- Page 5:**
- ▶ Mapping Story Map (image): <https://archive.oceanexplorer.noaa.gov/world-oceans-day-2015/mapping-the-seafloor-one-ping-at-a-time.html>
 - ▶ NOAA Ocean Exploration Data Atlas: <https://www.ncei.noaa.gov/maps/ocean-exploration-data-atlas/>
- Page 7:**
- ▶ NOAA Ocean Exploration website: <https://oceanexplorer.noaa.gov/>
 - ▶ American Samoa Expedition Web Page: <https://archive.oceanexplorer.noaa.gov/okeanos/explorations/ex1702/welcome.html>

Information and Feedback



We value your feedback on this activity package, including how you use it in your formal/informal education settings. Please send your comments to: oceaneducation@noaa.gov. If reproducing this lesson, please cite NOAA as the source, and provide the following URL: <https://oceanexplorer.noaa.gov>.