










## WATCHING IN 3D

# Exploring with Multibeam Sonar

## Activity Package Introduction, Overview and Tool Guides

<b>THEME:</b>	Bathymetric mapping
<b>GRADE LEVEL:</b>	9-12 (Physical Sciences/Life Sciences)
<b>FOCUS QUESTION:</b>	What is multibeam sonar, and how is it used to explore Earth's deep ocean?
<b>LEARNING OBJECTIVES:</b>	Students will learn: <ul style="list-style-type: none"><li>• how multibeam sonar is used to explore and study the shape and composition of the ocean floor (<b>bathymetry</b>)</li><li>• how to analyze and interpret maps of specific seafloor features using multibeam sonar data.</li></ul>
<b>MATERIALS:</b>	Computer; high-speed internet
<b>TEACHING TIME:</b>	Two or three 45-minute class periods
<b>KEY WORDS/CONCEPTS:</b>	<ul style="list-style-type: none"><li>• Bathymetry</li><li>• Multibeam sonar</li></ul>
<b>GUIDING QUESTIONS:</b>	<ul style="list-style-type: none"><li>• Why do we map the ocean floor?</li><li>• How do we map the ocean floor?</li><li>• What features exist on the ocean floor?</li><li>• Why is it important to understand these features?</li></ul>
<b>PACKAGE LEGEND:</b>	<ul style="list-style-type: none"><li>✓ Check-in, definition, fun fact</li><li> Multibeam sonar</li><li> Ocean Exploration Digital Atlas</li><li> Fledermaus</li><li> Expedition Web Pages</li><li> Volcanoes and Hotspot Volcanoes</li><li> Cold Seeps</li><li> Seamounts</li></ul>
<b>NGSS:</b>	HS-PS4-5, HS-LS2-6. For more information, see page 9.



### 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.



# Introduction

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*) 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:

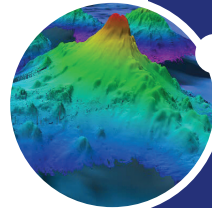
- High resolution maps of the area being explored, as well as areas that the ship crosses while underway from one location to the next (underway reconnaissance);
- Data about water column chemistry and other features; and
- High definition video of biological and geological features in the exploration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

For more on these three ships, their exploration technologies and the types of data they produce, please click below:

- ▶ [Introduction to Ships of Exploration and Their Strategy for Ocean Exploration](#)
- ▶ [Introduction to Sonar and Multibeam Mapping](#)
- ▶ [Introduction to Water Column Investigations](#)
- ▶ [Introduction to Remotely Operated Vehicles and Autonomous Underwater Vehicles](#)
- ▶ [Introduction to Telepresence](#)

The NOAA Ship *Okeanos Explorer* is the only federal U.S. ship whose sole assignment is to systematically explore our largely unknown ocean for the purposes of discovery and the advancement of knowledge.

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.



## Overview

### THIS ACTIVITY PACKAGE PROVIDES:

1. An overview of **multibeam sonar**.
2. Specific case studies with a variety of multibeam sonar 3D image files, and guides for student exploration.
3. Step-by-step usage tool guides for the **Ocean Exploration Digital Atlas** (a searchable, interactive expedition data map) and a free version of **Fledermaus**, a powerful interactive mapping data visualization software used by ocean explorers, so that students can have first-hand experience using these tools to explore multibeam sonar capabilities in 3D.
4. Specific **expedition website** links for more information and resources.
5. Resource links for further exploration.

### STUDENT ACTIVITIES INCLUDE:

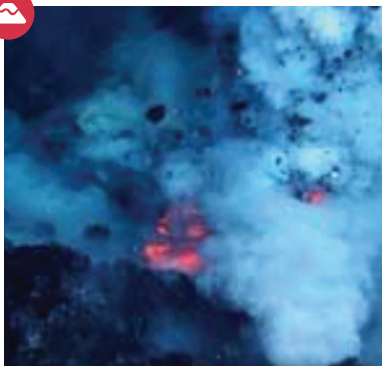
- **Case Study 1:** [Exploring an Underwater Volcano \(Kawio Barat\)](#)
- **Case Study 2:** [Exploring Cold Seeps](#)
- **Case Study 3:** [Exploring a Northeast U.S. Seamount \(Mytilus\)](#)
- **Case Study 4:** [Exploring a Hotspot Volcano \(Vailulu'u\)](#)

These case studies will explore three-dimensional multibeam sonar maps of three key seafloor structures:



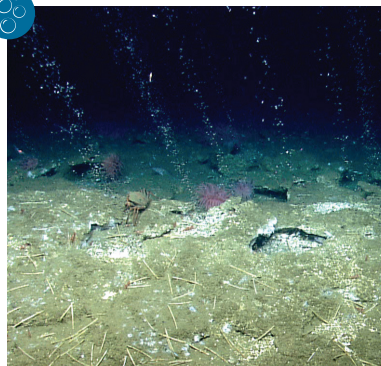
More details about these and other ocean exploration topics can be found on the NOAA OER **Theme pages**.

<https://oceanexplorer.noaa.gov/edu/themes>



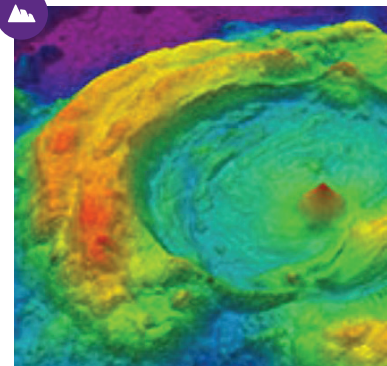
### UNDERWATER VOLCANOES/ HOTSPOT VOLCANOES

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, but most are much taller than that, rising upwards of 5,000 meters (16,400 feet), sometimes to within a few hundred meters of the ocean surface.

## Overview 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.

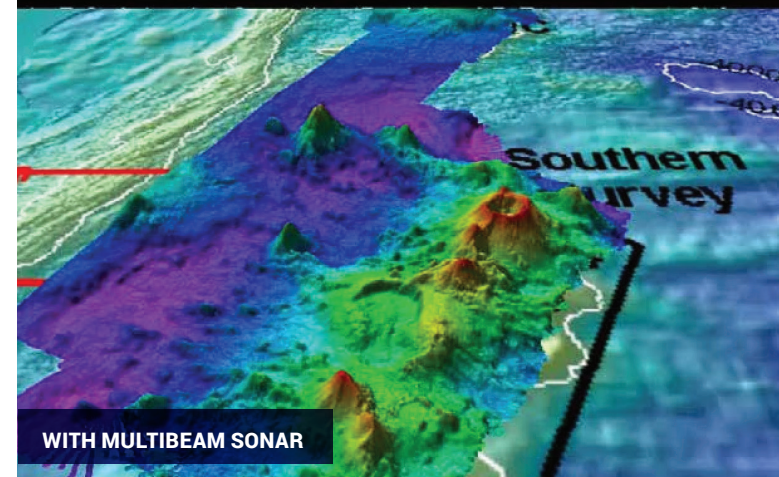
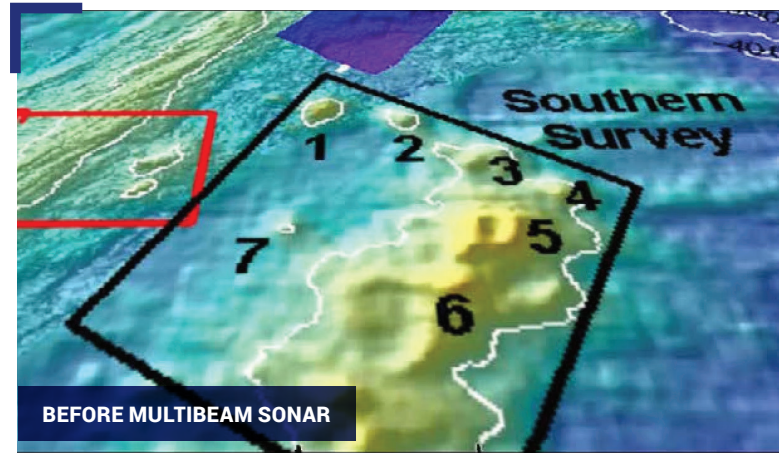
SOund NAVigation and Ranging (SONAR) systems consist of a transmitter that sends pulses of sound energy through the water and a receiver that detects return signals (echoes) that are reflected back from the seafloor or other objects, including living organisms. In use, an acoustic signal or pulse of 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.

### For more on sonar, click below:


- ▶ [Okeanos Explorer Multibeam Animation](#) (video)



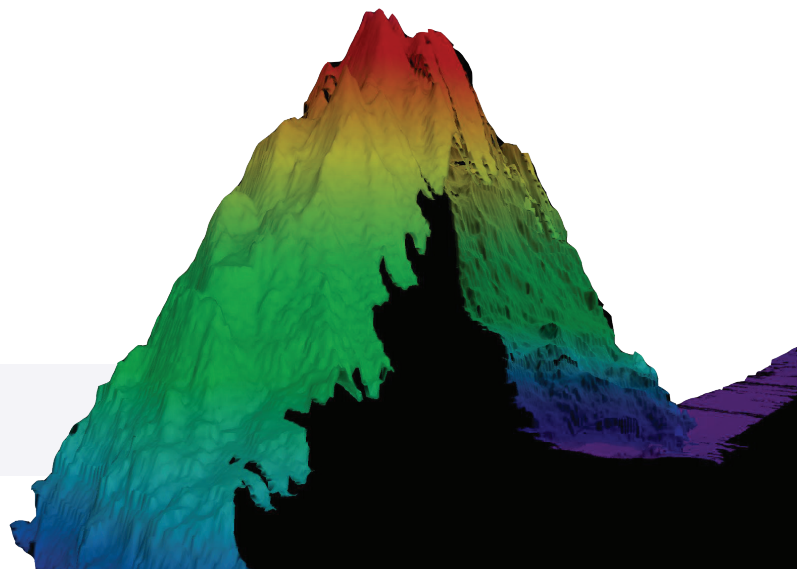
- ▶ [Ocean Mapping: An Essential Part of Ocean Exploration](#) (essay)



The top image shows what we previously knew about the seafloor terrain in the Southern Mariana region from satellite altimetry data. The bottom image includes an overlay of the information provided by *Okeanos Explorer's* EM302 Multibeam System. *Image courtesy of NOAA OER.*

Let's explore the **OCEAN EXPLORATION DIGITAL ATLAS** to learn how scientists use this powerful tool to document incredible seafloor features like this. 

Multibeam sonar image of a seamount mapped near Honolulu, Hawai'i. *Image courtesy of NOAA OER.*




# Tool Guides

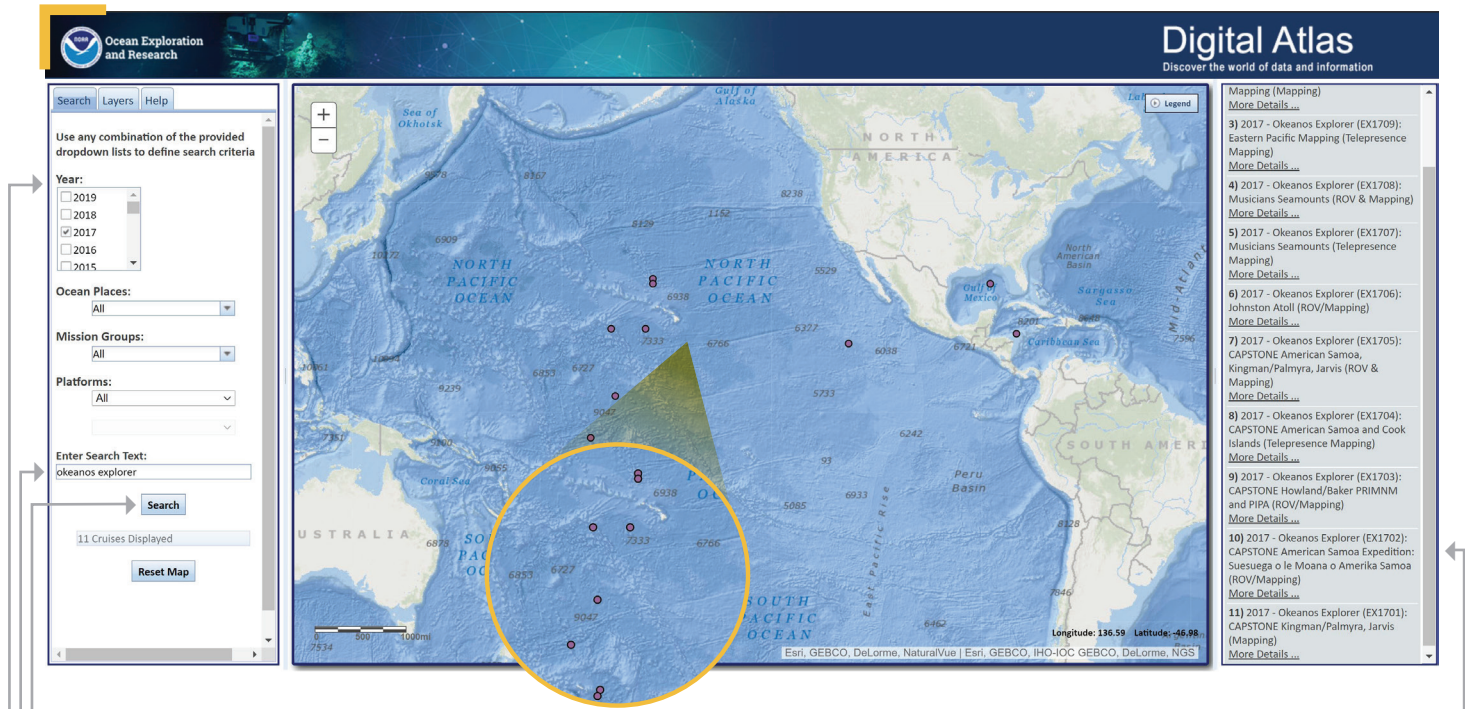
## TOOL 1: The Ocean Exploration Digital Atlas

The Ocean Exploration Digital Atlas is a map-based, interactive online atlas tool provided by NOAA's National Centers for Environmental Information (NCEI). The atlas links to information about past expeditions of NOAA's Office of Ocean Exploration and Research missions that began in 2001. This atlas orients users to expedition locations and provides experiences exploring data and associated discoveries from specific expeditions.

### HOW TO USE THE OCEAN EXPLORATION DIGITAL ATLAS

**Note:** For the purpose of this example, we will be referencing the 2017 Exploration of Vailulu'u Seamount in American Samoa (Case Study 4: Exploring a Pacific Seamount). 


- OPEN THE OCEAN EXPLORATION DIGITAL ATLAS:**
  - <https://www.ncei.noaa.gov/maps/oer-digital-atlas/mapsOE.htm>



- CHOOSE YEAR AND VESSEL:**

On the left, select the year 2017 and in the Enter Search Text, enter the vessel *Okeanos Explorer*. Click Search. The dots that appear are all the 2017 *Okeanos Explorer* expeditions.

- CHOOSE EXPEDITION:**

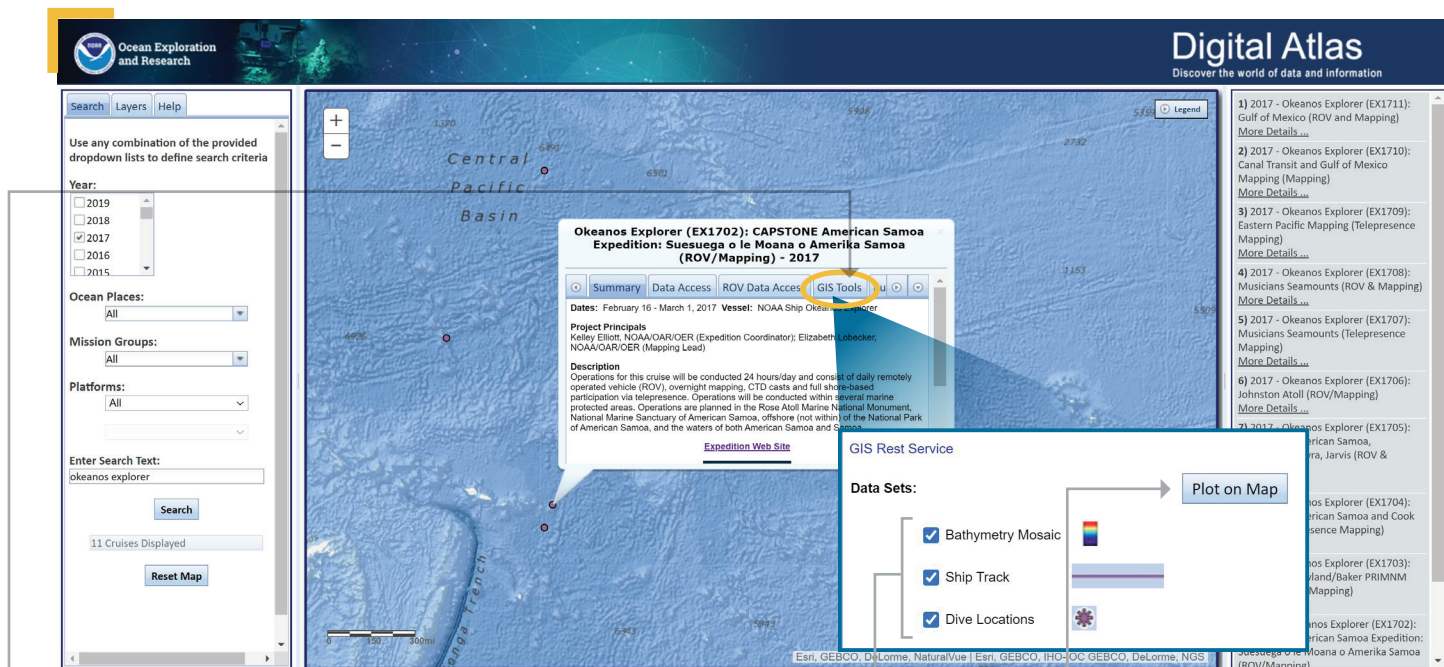
On the right, select your expedition: in this case, the 2017 *Okeanos Explorer* CAPSTONE American Samoa Expedition: Suesuega o le Moana o Amerika Samoa [EX1702]. Note that the summary box that pops up has a direct link to the **expedition website**. 



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



# Tool Guides cont.



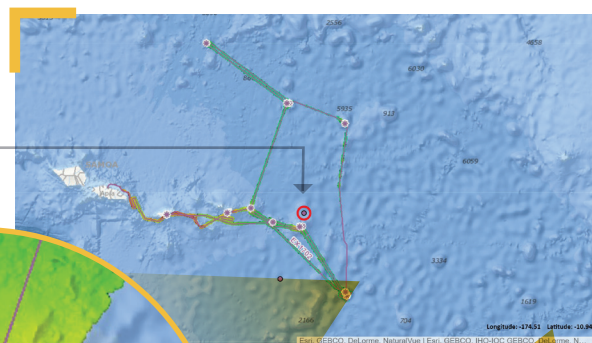
4. **PLOT ON MAP:** Click on the GIS Tools tab in the pop-up window, select the appropriate boxes (all three for this mission) and click Plot on Map.



GIS stands for Geographic Information Systems.

5. **LOOK CLOSER:** Click on the map and holding the left mouse button down, move the view to the right until the ship cruise tracks are in the center of the screen. Using the center mouse button, zoom in and you will see the entire cruise track for this mission and the bathymetric mapping work done throughout the expedition.

6. **DIVE IN:** Zoom in and look for the label for Dive 9. Zoom in more until you see the purple lines that indicate the track of the ship over the region of the dive.



Check longitude and latitude to make sure you are at Dive 9!

Longitude: -169.04 Latitude: -14.21

(provided in decimal format)



The color red is used to indicate the shallowest point, followed by orange, yellow, green, blue and purple, with purple being the deepest.



Now that you have found your dive, let's explore **FLEDERMAUS**, a system used by scientists to visualize seafloor features in three dimensions.



## Tool Guides cont.

## TOOL 2: Fledermaus

An important technique for studying multibeam images uses a three-dimensional data visualization system called Fledermaus. Fledermaus 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.



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

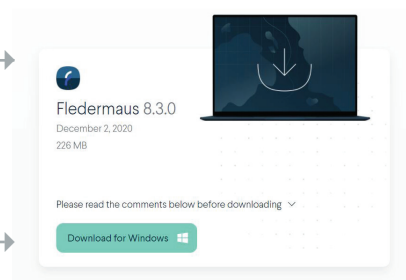
**Note:** For the purpose of this example, we will continue to reference the 2017 Exploration of Vailulu'u Seamount in American Samoa (Case Study 4: Exploring a Hotspot Volcano).

**1. DOWNLOAD THE (FREE) SOFTWARE (educators and/or students):**

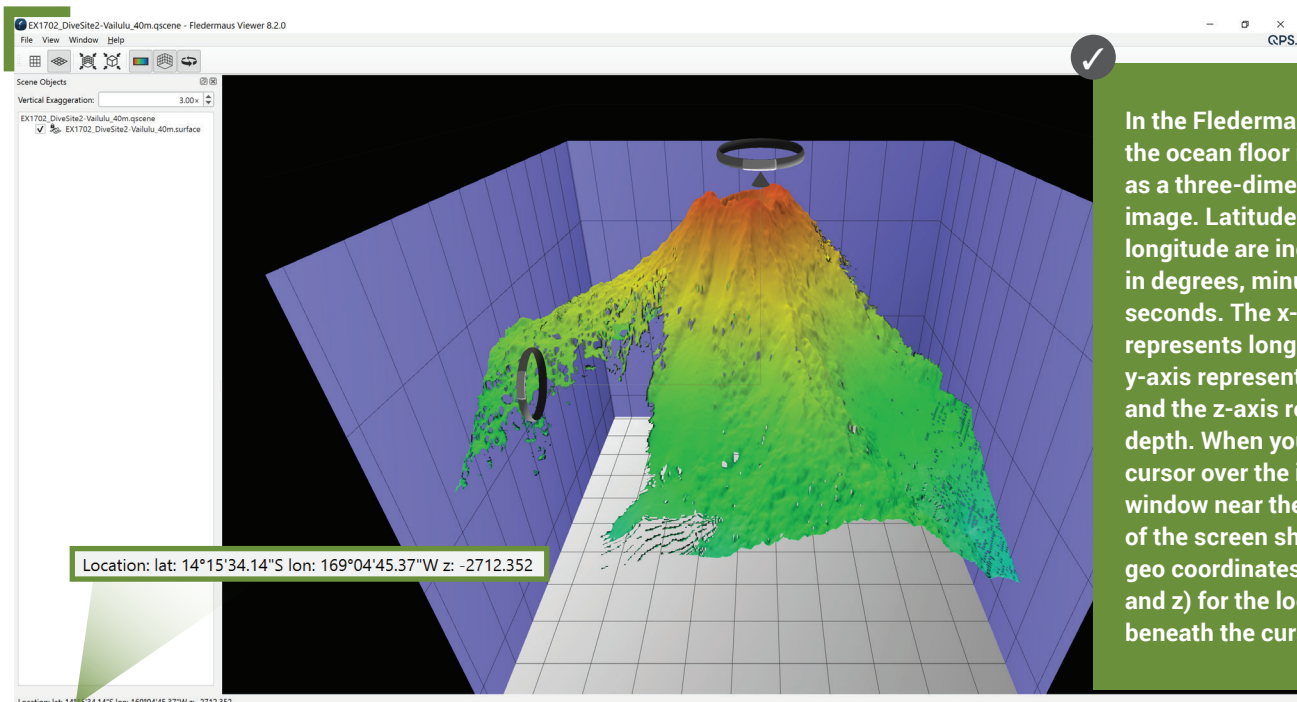
Download the Fledermaus Viewer software (8.2.2 or newer) from the

▶ dropdown menu at <https://www.qps.nl/downloads/fledermaus/>.

Fill in the contact form, selecting the version appropriate to your operating system. You will receive a link via email to download the program.

**2. CHOOSE SCENE:** Download this interactive, 3D scene file of the structure (Vailulu'u Hotspot Volcano) and save it onto your hard drive: [https://www.ncei.noaa.gov/waf/OER-Media/ex1702/EX1702\\_DiveSite2-Vailulu\\_40m.qsz](https://www.ncei.noaa.gov/waf/OER-Media/ex1702/EX1702_DiveSite2-Vailulu_40m.qsz).

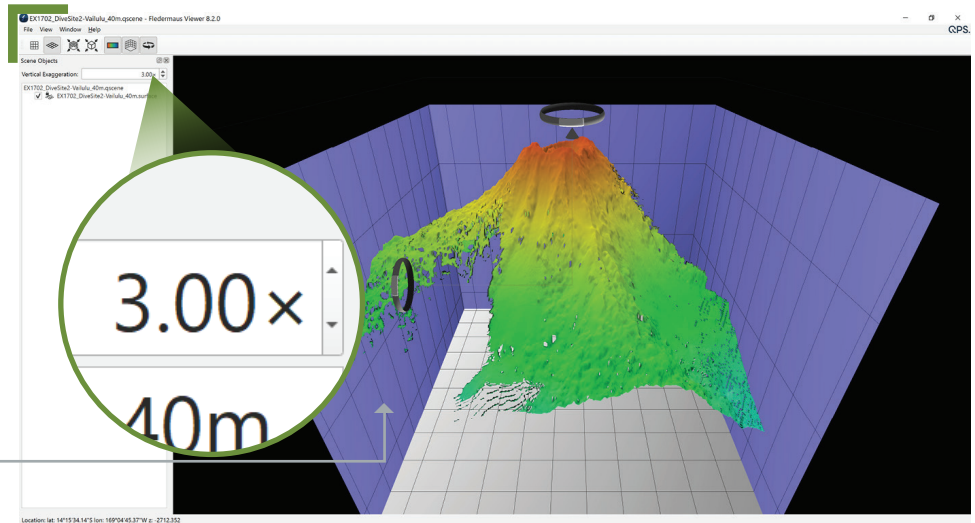
Then open the Viewer, and in the top left, select File and then Open Scene. Choose the scene you downloaded and this will open the 3D scene file of Vailulu'u Hotspot Volcano using Fledermaus, created from the multibeam sonar data collected as the ship traveled over and mapped the seafloor in this region.



In the Fledermaus scenes, the ocean floor is shown as a three-dimensional image. Latitude and longitude are indicated in degrees, minutes and seconds. The x-axis represents longitude, the y-axis represents latitude, and the z-axis represents depth. When you move the cursor over the image, the window near the bottom of the screen shows the geo coordinates (x, y, and z) for the location beneath the cursor.


## Tool Guides cont.

3. **INTERACT:** While the actual size is 1.00x, on the top left box you can increase the exaggeration to see the structure in more detail. Change the exaggeration to 3.00x and see what happens. The rings on the left and at the top of the image can be used to manipulate the view, too. To return to the original scene file if needed, use the second icon in the top toolbar.




4. **INTERACT FURTHER:** In the Scene Objects box, users can select different views of the region being explored. Checking the first box will provide a false color map of the region with purple being the deepest points and red being the shallowest points. This sample of Vailulu'u only has one view option; other case studies may have more, including options for viewing, including slope, ROV tracks and more.

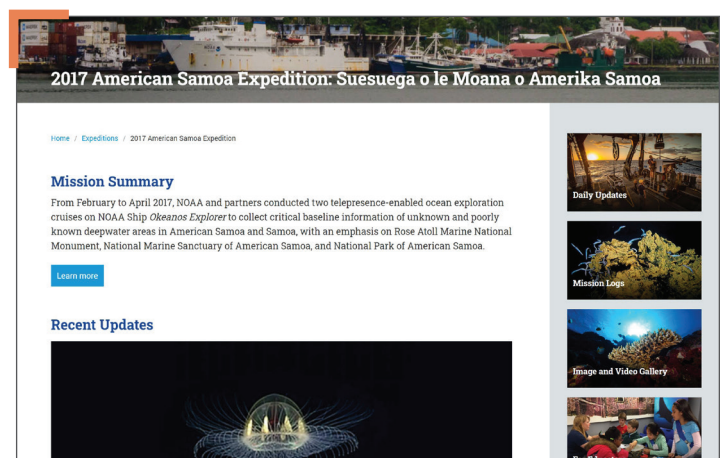
## TOOL 3: Expedition Web Pages

- ▶ Each expedition has specific web pages on the [NOAA Office of Ocean Exploration and Research website](https://oceanexplorer.noaa.gov). This example features the web page for *2017 Exploration of Vailulu'u Seamount in American Samoa (Case Study 4: Exploring a Pacific Hotspot Volcano)*. 
- ▶ <https://oceanexplorer.noaa.gov/oceanos/explorations/ex1702/welcome.html>

Here you can...

- meet the explorers
- watch a mission summary video
- read daily updates
- read mission logs
- read the mission plan
- view beautiful imagery, videos and more!

Each mission's expedition website can also be found by repeating steps 1-3 of the [Ocean Exploration Digital Atlas](#) and selecting the Summary tab (see page 5). 







## Activity Package URLs/Links

- Page 1:** ▶ Bathymetry: <https://oceanservice.noaa.gov/facts/bathymetry.html>
- Page 2:** ▶ Introduction to Ships of Exploration and Their Strategy for Ocean Exploration: <https://oceanexplorer.noaa.gov/oceanos/edu/collection/media/hdwe-StrategyBkgnd.pdf>  
▶ Introduction to Sonar and Multibeam Mapping: <https://oceanexplorer.noaa.gov/oceanos/edu/collection/media/hdwe-MMBkgnd.pdf>  
▶ Introduction to Water Column Investigations: <https://oceanexplorer.noaa.gov/oceanos/edu/collection/media/hdwe-WCIntro.pdf>  
▶ Introduction to Remotely Operated Vehicles and Autonomous Underwater Vehicles: <https://oceanexplorer.noaa.gov/oceanos/edu/collection/media/hdwe-URintro.pdf>  
▶ Introduction to Telepresence: <https://oceanexplorer.noaa.gov/oceanos/edu/collection/media/hdwe-TPbkgnd.pdf>  
▶ Listen (photo): <https://oceanexplorer.noaa.gov/oceanos/edu/collection/media/hdwe-MMBkgnd.pdf>  
▶ Test (photo): <https://oceanexplorer.noaa.gov/oceanos/edu/collection/media/hdwe-WCIntro.pdf>  
▶ Photograph (photo): <https://oceanexplorer.noaa.gov/oceanos/edu/collection/media/hdwe-URintro.pdf>  
▶ Share (photo): <https://oceanexplorer.noaa.gov/oceanos/edu/collection/media/hdwe-TPbkgnd.pdf>
- Page 3:** ▶ Theme pages: <https://oceanexplorer.noaa.gov/edu/themes>  
▶ CS 1: Exploring an Underwater Volcano (Kawio Barat): [https://oceanexplorer.noaa.gov/oceanos/edu/collection/media/CaseStudy\\_KawioBarat\\_Volcano.pdf](https://oceanexplorer.noaa.gov/oceanos/edu/collection/media/CaseStudy_KawioBarat_Volcano.pdf)  
▶ CS 2: Exploring Cold Seeps: [https://oceanexplorer.noaa.gov/oceanos/edu/collection/media/CaseStudy\\_ColdSeeps.pdf](https://oceanexplorer.noaa.gov/oceanos/edu/collection/media/CaseStudy_ColdSeeps.pdf)  
▶ CS 3: Exploring a Northeast U.S. Seamount (Mytilus): [https://oceanexplorer.noaa.gov/oceanos/edu/collection/media/CaseStudy\\_Mytilus\\_Seamount.pdf](https://oceanexplorer.noaa.gov/oceanos/edu/collection/media/CaseStudy_Mytilus_Seamount.pdf)  
▶ CS 4: Exploring a Hotspot Volcano (Vailulu'u): [https://oceanexplorer.noaa.gov/oceanos/edu/collection/media/CaseStudy\\_Vailuluu\\_HotSpot.pdf](https://oceanexplorer.noaa.gov/oceanos/edu/collection/media/CaseStudy_Vailuluu_HotSpot.pdf)  
▶ Underwater Volcanoes: <https://oceanexplorer.noaa.gov/edu/themes/vents-and-volcanoes/welcome.html>  
▶ Cold Seeps: <https://oceanexplorer.noaa.gov/edu/themes/cold-seeps/welcome.html>  
▶ Seamounts: <https://oceanexplorer.noaa.gov/edu/themes/seamounts/welcome.html>
- Page 4:** ▶ Fly-through videos: <https://oceanexplorer.noaa.gov/explorations/12fire/background/laubasin/laubasin.html>  
▶ *Ocean Explorer* Multibeam Animation: [https://oceanexplorer.noaa.gov/video\\_playlist/start/technology\\_multibeam.html](https://oceanexplorer.noaa.gov/video_playlist/start/technology_multibeam.html)  
▶ Ocean Mapping: An Essential Part of Ocean Exploration: <https://oceanexplorer.noaa.gov/oceanos/explorations/ex1703/logs/mar11/welcome.html>  
▶ Image 1 (before/after): <https://oceanexplorer.noaa.gov/oceanos/explorations/10index/background/plan/plan.html>  
▶ Image 2 (Pacific seamount): <https://oceanexplorer.noaa.gov/oceanos/explorations/ex1705/logs/photolog/welcome.html#cbpi=oceanos/explorations/ex1705/dailyupdates/media/may17-1.html>
- Page 5:** ▶ Ocean Exploration Digital Atlas: <https://www.ncei.noaa.gov/maps/oer-digital-atlas/mapsOE.htm>
- Page 7:** ▶ Fledermaus Viewer software: <https://www.qps.nl/downloads/fledermaus/>  
▶ Vailulu'u Hotspot Volcano 3D scene file: [https://www.ncei.noaa.gov/waf/OER-Media/ex1702/EX1702\\_DiveSite2-Vailuluu\\_40m.qsz](https://www.ncei.noaa.gov/waf/OER-Media/ex1702/EX1702_DiveSite2-Vailuluu_40m.qsz)
- Page 8:** ▶ NOAA Office of Ocean Exploration and Research website: <https://oceanexplorer.noaa.gov/>  
▶ American Samoa Expedition Web Page: <https://oceanexplorer.noaa.gov/oceanos/explorations/ex1702/welcome.html>

## Next Generation Science Standards (NGSS)

Activities presented here may be used to support specific elements of the NGSS and Ocean Literacy Essential Principles and Fundamental Concepts as described below.

### HS-PS4 Waves and Their Applications in Technologies for Information Transfer

*Performance Expectation*

**HS-PS4-5** Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.

**Science and Engineering Practice:** Obtaining, Evaluating, and Communicating Information.

**Disciplinary Core Ideas:** PS4.C Information Technologies and Instrumentation

**Crosscutting Concept:** System and System Models

**Connections to Engineering, Technology and Applications of Science:** Influence of Engineering, Technology and Science on Society and the Natural World

### HS-LS2 Ecosystems: Interactions, Energy, and Dynamics

*Performance Expectation*

**HS LS 2-6.** Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.

**Science and Engineering Practice:** Engaging in Argument from Evidence

**Disciplinary Core Idea:** LS2.C Ecosystem Dynamics, Functioning and Resilience

**Cross Cutting Concept:** Stability and Change

### Ocean Literacy Essential Principles and Fundamental Concepts

**Essential Principle 1.** Earth has one big ocean with many features. *Fundamental Concept e.*

**Essential Principle 5.** The ocean supports a great diversity of life and ecosystems. *Fundamental Concepts e, f, g.*

**Essential Principle 7.** The ocean is largely unexplored. *Fundamental Concepts a, b, d, e, f.*

## Information and Feedback



Ocean Exploration  
and Research

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