



WATCHING IN 3D

Exploring with Multibeam Sonar

CASE STUDY 4: Exploring a Hotspot Volcano

(Vailulu'u)

What is a Hotspot Volcano?

In much the same way that plumes rise buoyantly in a lava lamp, plumes of mantle magma (molten rock) are theorized to rise buoyantly from a source within Earth's deep mantle. When such a plume rises into the shallow mantle, it partially melts and the melt may then rise to the surface where it can erupt

- ▶ as a hotspot volcano. Hotspot volcanism is distinct in that it does not
- ▶ originate from processes that produce the more common submarine
- ▶ volcanism that occurs at boundaries of Earth's tectonic plates.

Mantle plumes that form hotspots are thought to be relatively stationary. As a tectonic plate moves over the location of a plume eruption, it carries successively older volcanoes with it. As hotspot volcanoes are transported by plate motion away from the mantle plume, hotspot volcanism stops. Eventually the hotspot volcanoes become extinct, gradually subside, and are eroded by wave action. Over geologic time, these

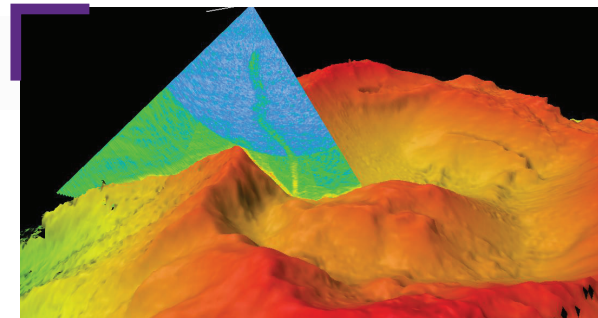
- ▶ processes produce lines of islands, atolls, and seamounts known as hotspot tracks, or chains. The youngest, active volcanoes are located within a region of the plate that overlies the mantle plume. Progressively older volcanoes form linear chains on the surface of the moving tectonic plate, downstream of the hotspot. Earth scientists use the directions of these volcanic chains, along with the age progression of the chain's volcanoes, to reconstruct histories of the relative motion between plates.

The Hawaiian Islands are an example of a hotspot track. The Island of Hawai'i is the youngest, and most active, volcano in the chain. Active volcanism on Loihi Seamount, located off the southeast end of the Island of Hawai'i, however, may signal the future

- ▶ location for creation of a new island in the chain. The Samoan Island chain is also an example of a plume-fed volcanic hotspot with Vailulu'u being the most recent active volcano at the southeastern end of the chain.

- ▶ This activity will guide you through exploration of the Vailulu'u Seamount, also a hotspot volcano, using 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, providing you first-hand experience using these tools to explore **multibeam sonar** capabilities in 3D. 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.

This activity will also introduce you to the NOAA Office of Ocean Exploration and Research website and the [2017 Okeanos Explorer CAPSTONE American Samoa Expedition: Suesuega o le Moana o Amerika Samoa](#) web pages where Vailulu'u was studied.



A plume of bubbles is shown rising from the seafloor at Vailulu'u Seamount in the mid-water multibeam sonar data. Image courtesy of the NOAA Office of Ocean Exploration and Research, 2017 American Samoa.

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



1 Listen
Multibeam sonar mapping system



2 Test
Conductivity, Temperature and Depth profilers (CTDs)



3 Photograph
Remotely Operated Vehicles (ROV)



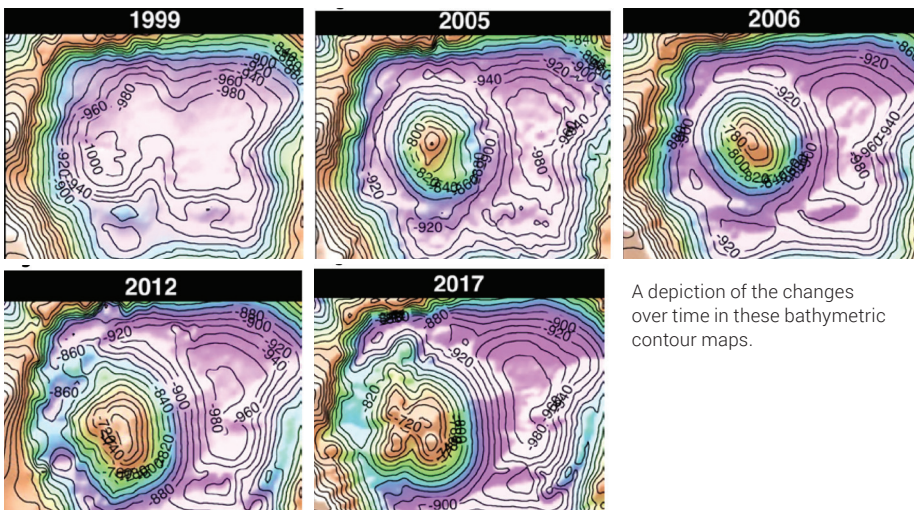
4 Share
Telepresence technologies



What Hotspot Volcano are We Exploring?

- Vailulu'u Seamount, located at the southeast end of the Samoan archipelago, has an incredibly dynamic history. Back in 2005, as a NOAA Office of Ocean Exploration and Research (OER) expedition team prepared to make their first dive on this underwater volcano, they made an unexpected discovery. A multibeam sonar image showed the volcano's "crater" that had not been present when Vailulu'u was visited five years earlier. More surprises were in store for the scientists as they investigated the new cone (which they named Nafanua for the Samoan goddess of war), including features that they named "Eel City" and "Moat of Death."

- Vailulu'u lies approximately 20 miles east of Ta'u Island in American Samoa. Like the Samoan Islands, Vailulu'u (and Nafanua) are believed to be the result of a hotspot; a sort of natural pipeline to reservoirs of magma in the Earth's mantle. The geologic history of the Samoan Islands and the recent emergence of Nafanua make it very likely that Vailulu'u will continue to erupt at intervals and eventually emerge from the sea surface as a new member of the Samoan Island chain.



- More recently, during the 2017 NOAA OER American Samoa Expedition, a team of scientists and technicians both at-sea and on shore conducted exploratory investigations to collect critical baseline information of unknown and poorly known deepwater areas in American Samoa and Samoa, with an emphasis on Rose Atoll Marine National Monument, National Marine Sanctuary of American Samoa, and National Park of American Samoa. This expedition was part of a major multi-year effort focused on deepwater areas of U.S. marine protected areas in the central and western Pacific called the Campaign to Address Pacific monument Science, Technology, and Ocean NEeds (CAPSTONE).



Learn more about seamounts on the NOAA OER Theme pages.

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



CAPSTONE

The central and western Pacific marine national monuments and national marine sanctuaries encompass over 742,000 square miles of emergent land, coral reef, ocean, and maritime heritage resources. They contain some of the last relatively pristine marine ecosystems on the planet and harbor numerous protected species, as well as undiscovered shipwrecks and cultural landscapes sacred to the indigenous peoples of the Pacific. Their designation is unprecedented in terms of geographic scope, ecological value, and national symbolism for ocean conservation. However, their remoteness creates substantial challenges. Most deep-water areas remain poorly known and are of high interest to federal and state agencies with research and management responsibilities.

Now that you know more about hotspot volcanoes, let's use the **OCEAN EXPLORATION DIGITAL ATLAS**, to explore Vailulu'u Seamount in the Pacific.

Exploring a Hotspot Volcano with Multibeam Sonar Tools

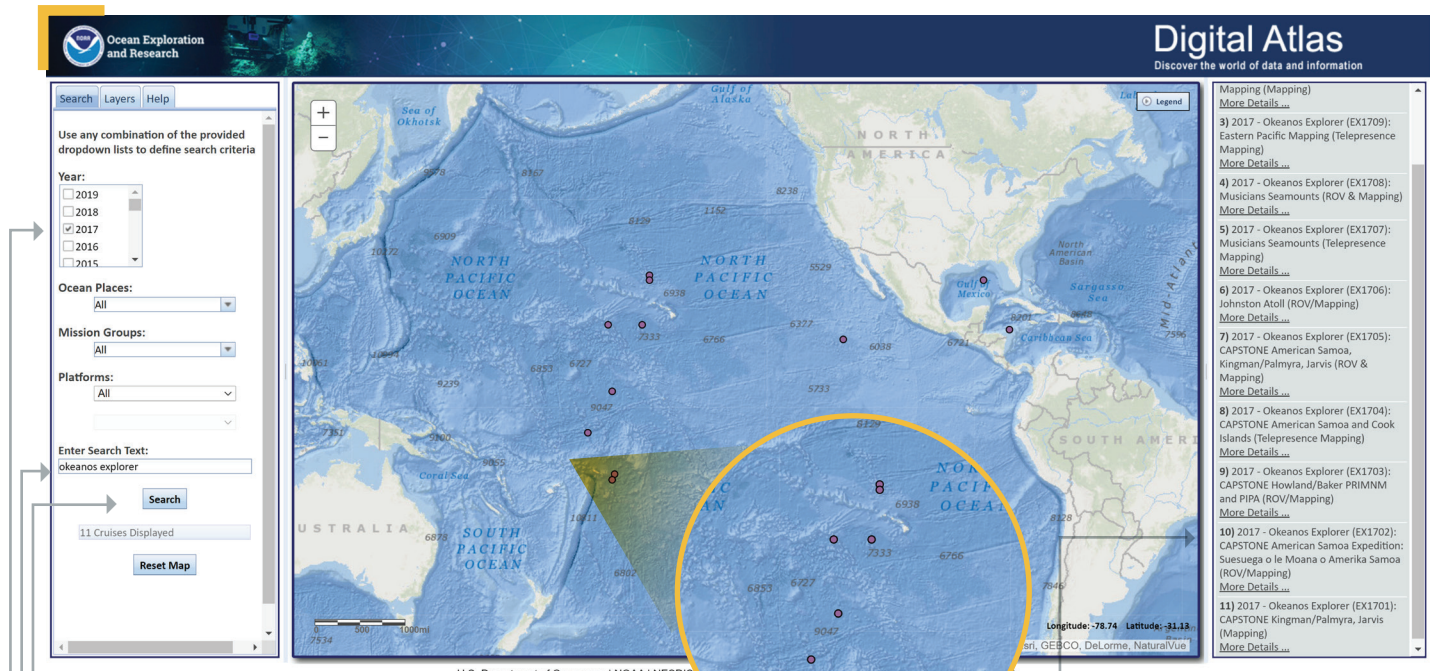
TOOL 1: Exploring an Underwater Volcano with the Ocean Exploration Digital Atlas

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.

Note: For a more detailed step-by-step tool guide of how to use the Ocean Exploration Digital Atlas, see the *Watching in 3D: Exploring with Multibeam Sonar activity package introduction*.

1. OPEN THE OCEAN EXPLORATION DIGITAL ATLAS:

- ▶ <https://www.ncei.noaa.gov/maps/oer-digital-atlas/mapsOE.htm>



2. CHOOSE YEAR AND VESSEL:

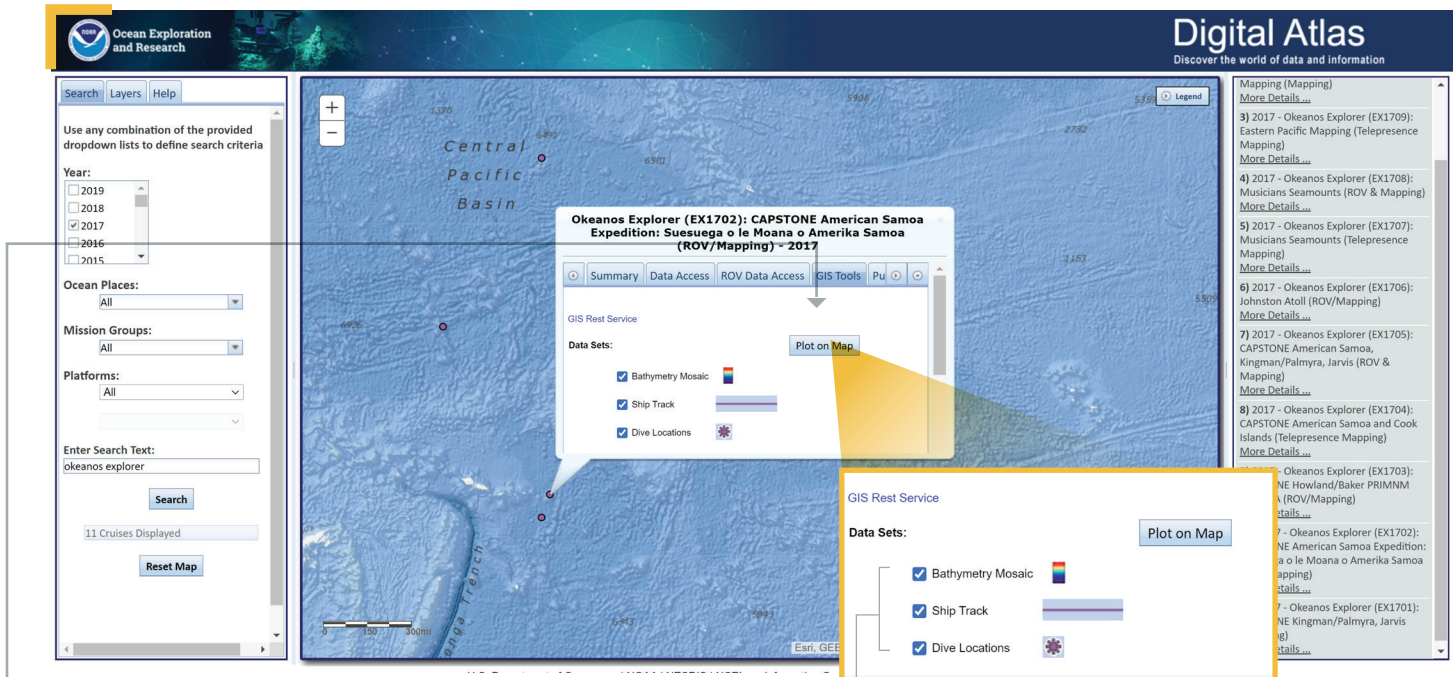
2017; *Okeanos Explorer*;
Search. The dots that appear are all the 2017 *Okeanos Explorer* expeditions.

3. CHOOSE EXPEDITION:

2017 *Okeanos Explorer* CAPSTONE American Samoa Expedition: Suesuega o le Moana o Amerika Samoa (EX1702).

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

Exploring a Hotspot Volcano with Multibeam Sonar Tools *cont.*



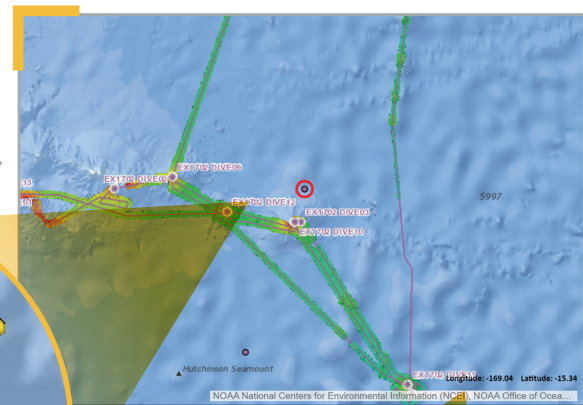
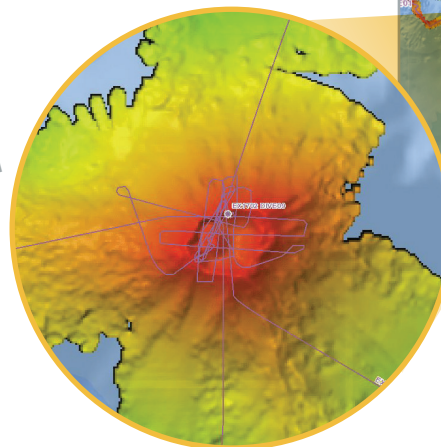
4. **PLOT ON MAP:** Click on the GIS Tools tab in the pop-up window, select the appropriate boxes (all three for this mission) and click Plot on Map.

✓ GIS stands for Geographic Information Systems.

5. **LOOK CLOSER:** Click on the map and holding the left mouse button down, move the view slightly to the right and use the center mouse button to zoom in until the names of the dives appear.

6. **DIVE IN:** Look for the dive that explored Vailulu'u, EX1702 Dive 9. What do you think the ship was doing here to make those purple lines on the map? Can you think of anything in your life that makes similar patterns?

The purple lines are the ship's track, or where it "mowed the lawn." Zoom in to get a closer look at Vailulu'u.



Check longitude and latitude to make sure you are in the right place!

Longitude: -169.04 Latitude: -14.21

(provided in decimal format)

Now that you have found your dive and Vailulu'u, try the second tool, **FLEDERMAUS**, to explore this Pacific seamount even further.

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



Exploring a Hotspot Volcano with Multibeam Sonar Tools *cont.*

TOOL 2: Exploring a Hotspot Volcano with Fledermaus

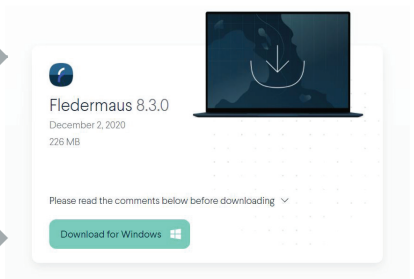
An important technique for studying multibeam images uses a three-dimensional data visualization system called Fledermaus. Fledermaus software allows the user to view and manipulate 3D models of seafloor features, providing insight into the geological structure of an area and helping to pinpoint ideal locations for further exploration.

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

Note: For a more detailed step-by-step tool guide of how to use Fledermaus software, see the [Watching in 3D: Exploring with Multibeam Sonar activity package introduction](#).

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

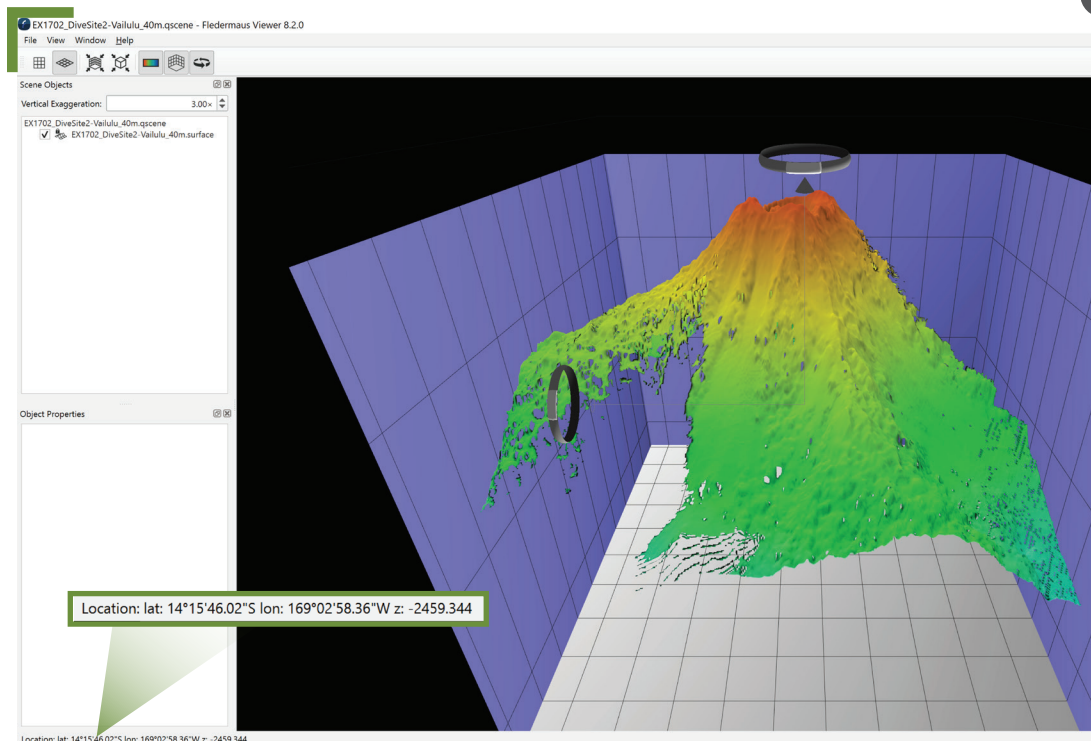
Download the Fledermaus Viewer software (8.2.2 or newer) from the dropdown menu at <https://www.qps.nl/downloads/fledermaus/>. Fill in the contact form, selecting the version appropriate to your operating system. You will receive a link via email to download the program.



2. CHOOSE SCENE: Download this interactive, 3D scene file of Vailulu'u and save it onto your hard drive:

▶ 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 Vailulu'u scene file created from the multibeam sonar data collected as the ship traveled over and mapped the seafloor in this region.



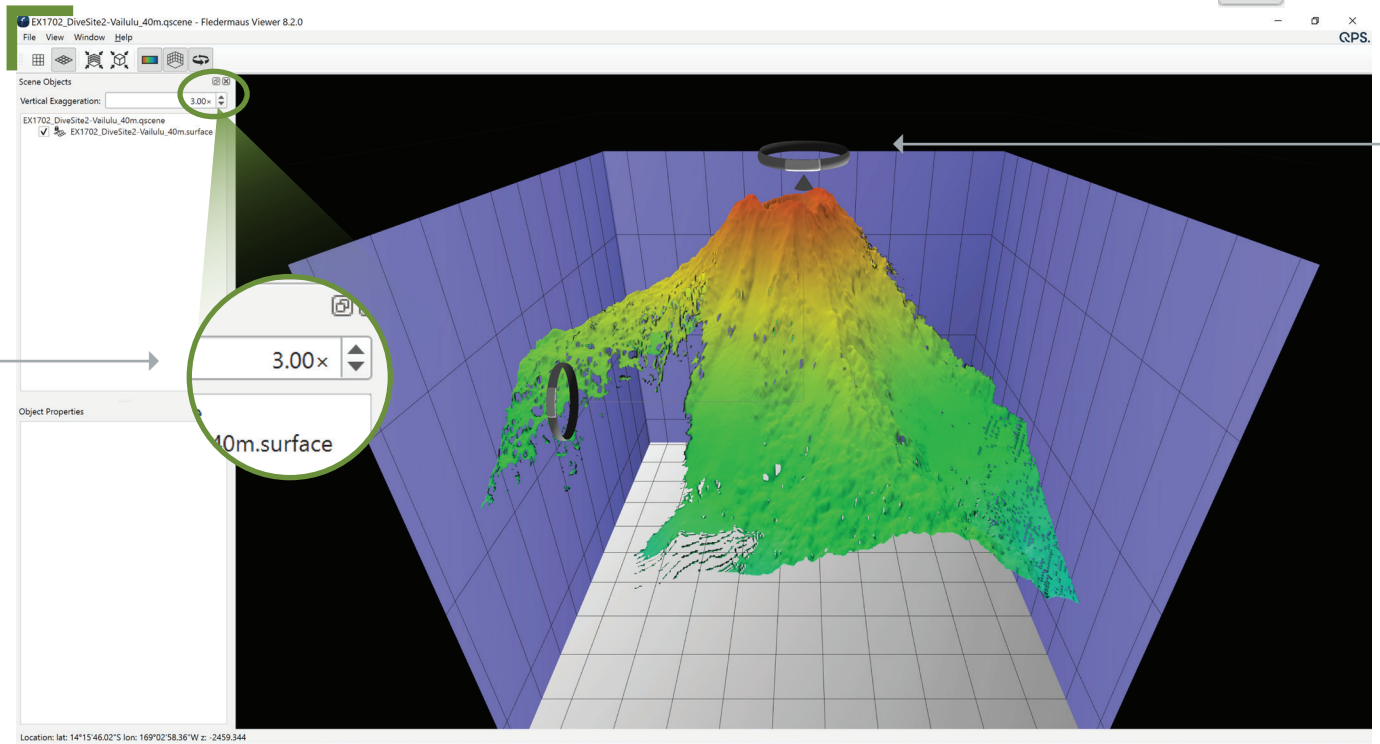
✓ In the Fledermaus scenes, the ocean floor is shown as a three-dimensional image. Latitude and longitude are indicated in degrees, minutes and seconds. The x-axis represents longitude, the y-axis represents latitude, and the z-axis represents depth. When you move the cursor over the image, the window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



Exploring a Hotspot Volcano with Multibeam Sonar Tools *cont.*

3. INTERACT: While the actual size is 1.00x, you'll notice the vertical exaggeration is set at 3.00x, which exaggerates the image in order to view the structure in more detail. Change the exaggeration to 6.00x and see what happens. The rings on the left and at the top of the image can be used to manipulate the view, too.

4. INTERACT FURTHER: In the Scene Objects box, different views of the region being explored can be selected. 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 case study of Vailulu'u Seamount only has one view option; other case studies have more, including options for viewing, including slope, ROV tracks and more. Try zooming in to get a closer look! To return to the original scene file if needed, use the second icon in the top toolbar.



5. EXPLORE: Looking at the image, what are you curious about?

- What is the length of the seamount from east to west?
- What is the length of the seamount from north to south?
- What is the deepest point of this seamount? What is the shallowest point?
- What depth variations do you notice in the center of the volcano?
- How tall is the cone in the center of the volcano?

Based on your observations and where you know this seamount is located:

- What might be the reason this seamount is an active volcano?
- What organisms might live here? Why?
- What is succession and what might that mean in this environment?
- Do you think different organisms live at different depths on this seamount? Why or why not?
- Why did the scientists select this seamount/volcano for exploration? If you were the scientist leading this expedition and exploring this seamount for the first time, where would you choose to send the ROV? What considerations do you think need to be made when deciding what regions to select for further exploration?

Now that you have explored Vailulu'u Seamount, check out the **EXPEDITION WEB PAGES** on the NOAA Office of Ocean Exploration and Research website for more information and resources.





Exploring a Hotspot Volcano with Multibeam Sonar Tools *cont.*


TOOL 3: Expedition Web Pages

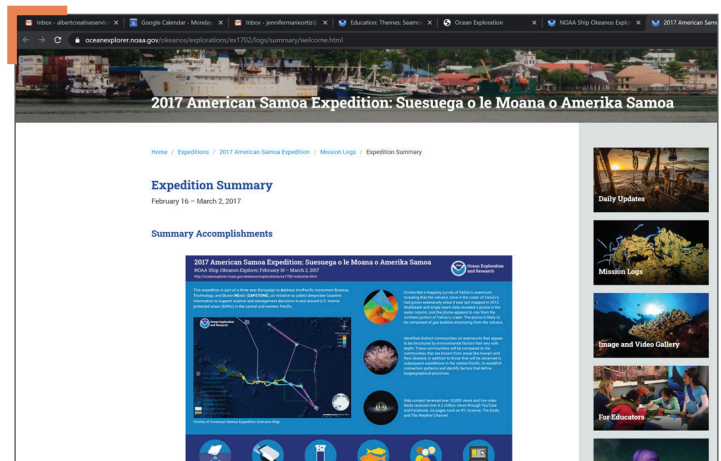
Each expedition has specific web pages on the [NOAA Office of Ocean Exploration and Research website](https://oceanexplorer.noaa.gov). The 2017 Okeanos Explorer CAPSTONE American Samoa Expedition: Suesuega o le Moana o Amerika Samoa Expedition web pages contain more information about the Vailulu'u Seamount that was explored, as well as other expedition discoveries.

- ▶ <https://oceanexplorer.noaa.gov/okeanos/explorations/ex1702/logs/summary/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!

This web page can also be accessed by repeating steps 1-3 of the [Ocean Exploration Digital Atlas](#) and selecting the Summary tab (see page 3). 



1. BE THE EXPLORER

What was discovered?

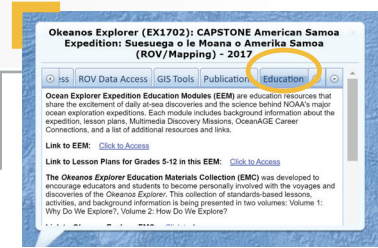
- ▶ On the [2017 Okeanos Explorer CAPSTONE American Samoa Expedition: Suesuega o le Moana o Amerika Samoa Expedition web page](#), click [Daily Updates](#).
 - READ the exploration team's log from Dive 9, February 24, 2017.
 - WATCH the highlight videos to hear the team describe their findings.
 - Now ask yourself:
 - *What is an archipelago? Can you explain why the islands of Samoa illustrate an example of a "hotspot"?*
 - *Looking at the contour maps of Vailulu'u on page 2, what is the difference in cone height in the center of the volcano between 1999 and 2017? What does this tell you?*
 - *What is succession and how is it illustrated on Vailulu'u?*
 - *Why might scientists be interested in continuing to explore this area over time?*
 - *If you were to take what you learned from this exploration, and go back to investigate further, what would be your area of interest? What would you want to know?*



For Educators: Additional Resources and Extension

1. EDUCATION TAB

- ▶ In the [Ocean Exploration Digital Atlas](#) instructions on page 3 of this lesson, repeat steps 1-3, select the **Education** tab for a variety of supplemental educational resources.



2. SEAMOUNTS THEME PAGE

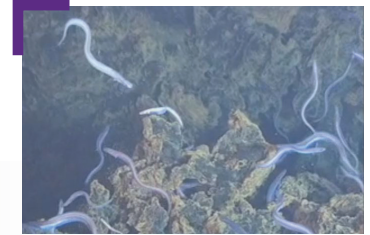
- ▶ The [Seamounts Theme page](#) and [Vents and Volcanoes Themes page](#) provide additional essays, lessons, images, videos and more.

3. FURTHER MULTIMEDIA

- ▶ [Seamounts](#), Les Watling Ph.D., University of Hawai'i at Manoa; In this 45 minute video, Dr. Les Watling, marine scientist the University of Hawai'i at Manoa, provides an excellent description of the formation of seamounts, their geology and their associated ecological and biological diversity.

4. EXTENSION: Student Activity

- ▶ Watch the video [Eel City](#) to see what the scientists found in 2005. These eels, small synphobranchids (*Dysommima rugosa*), had never before been studied in their natural habitat.



Hotspot Volcano Lesson URLs/Links

- Page 1:**
- ▶ Plume of bubbles: <https://oceanexplorer.noaa.gov/okeanos/explorations/ex1702/logs/feb22/media/vailulu2.html>
 - ▶ Volcanic hotspots: <https://oceanexplorer.noaa.gov/facts/volcanic-hotspot.html>
 - ▶ Submarine volcanism: <https://oceanexplorer.noaa.gov/facts/volcanoes.html>
 - ▶ Tectonic plates: <https://oceanexplorer.noaa.gov/facts/plate-boundaries.html>
 - ▶ Hotspot tracks/chains: <https://oceanexplorer.noaa.gov/okeanos/explorations/ex1705/background/geology/welcome.html>
 - ▶ Samoan Islands: <https://oceanexplorer.noaa.gov/okeanos/explorations/ex1702/background/geology/welcome.html>
 - ▶ Fly-through video: <https://oceanexplorer.noaa.gov/explorations/12fire/background/laubasin/laubasin.html>
 - ▶ 2017 *Okeanos Explorer* CAPSTONE American Samoa Expedition: Suesuega o le Moana o Amerika Samoa Expedition Web Page: <https://oceanexplorer.noaa.gov/okeanos/explorations/ex1702/welcome.html>
 - ▶ Listen (photo): <https://oceanexplorer.noaa.gov/okeanos/edu/collection/media/hdwe-MMBkqnd.pdf>
 - ▶ Test (photo): <https://oceanexplorer.noaa.gov/okeanos/edu/collection/media/hdwe-WCIntro.pdf>
 - ▶ Photograph (photo): <https://oceanexplorer.noaa.gov/okeanos/edu/collection/media/hdwe-URintro.pdf>
 - ▶ Share (photo): <https://oceanexplorer.noaa.gov/okeanos/edu/collection/media/hdwe-TPbkqnd.pdf>
- Page 2:**
- ▶ Archipelago: <https://oceanexplorer.noaa.gov/okeanos/explorations/ex1702/background/geology/media/fig3-800.jpg>
 - ▶ Themes page: <https://oceanexplorer.noaa.gov/edu/themes>
 - ▶ Eel City and the Moat of Death (video): <https://oceanexplorer.noaa.gov/explorations/05vailulu/welcome.html>
 - ▶ Hotspot chains: <https://oceanexplorer.noaa.gov/okeanos/explorations/ex1705/background/geology/welcome.html>
 - ▶ CAPSTONE: <https://oceanexplorer.noaa.gov/okeanos/explorations/capstone/welcome.html>
 - ▶ Rose Atoll Marine National Monument/National Marine Sanctuary of American Samoa: <https://www.nps.gov/npsa/index.htm>
 - ▶ National Park of American Samoa: <https://www.nps.gov/npsa/index.htm>
- Page 3:**
- ▶ Watching in 3D: Exploring with Multibeam Sonar activity package intro: <https://oceanexplorer.noaa.gov/okeanos/edu/collection/media/hdwe-Watching3DInstructions.pdf>
 - ▶ Ocean Exploration Digital Atlas: <https://www.ncei.noaa.gov/maps/oe-digital-atlas/mapsOE.htm>
- Page 5:**
- ▶ Watching in 3D: Exploring with Multibeam Sonar activity package intro: <https://oceanexplorer.noaa.gov/okeanos/edu/collection/media/hdwe-Watching3DInstructions.pdf>
 - ▶ Fledermaus Viewer software: <https://www.qps.nl/downloads/fledermaus/>
 - ▶ Vailulu'u 3D scene file: https://www.ncei.noaa.gov/waf/OER-Media/ex1702/EX1702_DiveSite2-Vailulu_40m.qsz
- Page 7:**
- ▶ NOAA Office of Ocean Exploration and Research website: <https://oceanexplorer.noaa.gov/>
 - ▶ 2017 *Okeanos Explorer* CAPSTONE American Samoa Expedition: Suesuega o le Moana o Amerika Samoa Expedition Web Page: <https://oceanexplorer.noaa.gov/okeanos/explorations/ex1702/welcome.html>
 - ▶ Daily Updates: <https://oceanexplorer.noaa.gov/okeanos/explorations/ex1702/dailyupdates/dailyupdates.html>
- Page 8:**
- ▶ Ocean Exploration Digital Atlas: <https://www.ncei.noaa.gov/maps/oe-digital-atlas/mapsOE.htm>
 - ▶ Seamounts Theme page: <https://oceanexplorer.noaa.gov/edu/themes/seamounts/welcome.html>
 - ▶ Vents and Volcanoes Theme page: <https://oceanexplorer.noaa.gov/edu/themes/vents-and-volcanoes/welcome.html>
 - ▶ Seamounts (video): <https://vimeo.com/88841596>
 - ▶ Eel City (video): https://oceanexplorer.noaa.gov/explorations/05vailulu/media/movies/eel_city_podcast_qt320.m4v

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: oceaneducation@noaa.gov. If reproducing this lesson, please cite NOAA as the source, and provide the following URL: <https://oceanexplorer.noaa.gov>.