



## WATCHING IN 3D

Exploring with Multibeam Sonar

# CASE STUDY 4: Exploring a Hotspot Volcano

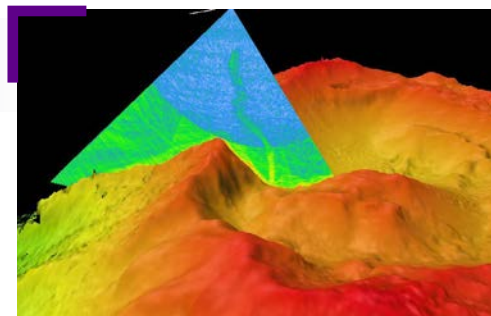
(Vailulu'u)

## 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 Kama'ehuakanaloa Seamount (formerly known as 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.



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

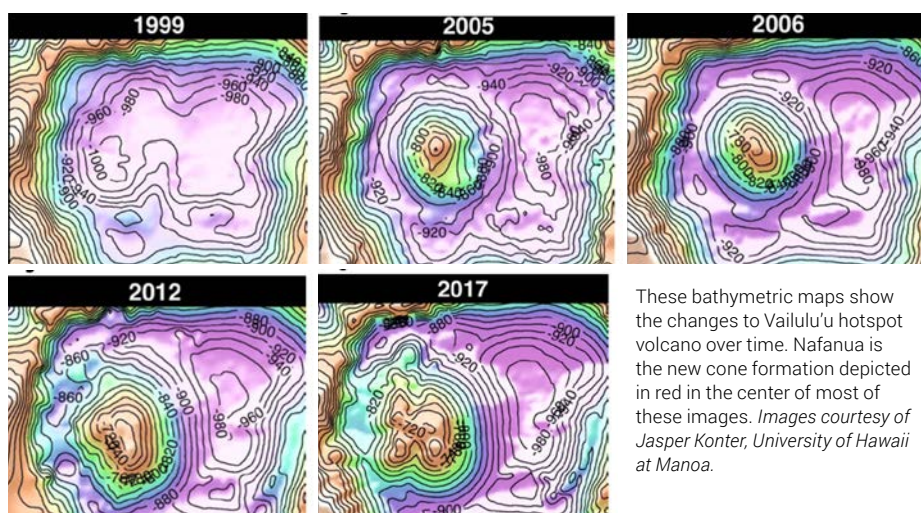
-  [NOAA Ocean Exploration Data Atlas](#) (a searchable, interactive expedition data map) and a demonstration video of [Fledermaus](#), a mapping data visualization software used by ocean explorers to view multibeam sonar data and imagery in 3D. [Multibeam sonar](#) is one of the most powerful tools available for modern deep-sea exploration, and can create high-resolution maps and three dimensional models.
-  You will also be introduced to the NOAA Ocean Exploration website and the [2017 Okeanos Explorer CAPSTONE American Samoa Expedition: Suesuega o le Moana o Amerika Samoa](#) web pages where Vailulu'u was studied.



## 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 Ocean Exploration 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.



These bathymetric maps show the changes to Vailulu'u hotspot volcano over time. Nafanua is the new cone formation depicted in red in the center of most of these images. Images courtesy of Jasper Konter, University of Hawaii at Manoa.

More recently, during the 2017 NOAA Ocean Exploration 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).

### 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.



## Student Investigation: Exploring a Hotspot Volcano with Multibeam Sonar Tools

### TOOL 1: Exploring a Hotspot Volcano with the NOAA Ocean Exploration Data Atlas

Now that you know more about hotspot volcanoes, let's use the NOAA Ocean Exploration Data Atlas to explore this feature.

#### OPEN THE ATLAS LINK:

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

#### INPUT THE EXPEDITION DETAILS:

Minimum Y(ear): 2017

Maximum Y(ear): 2017

Expedition Name: EX1702

(select code in the left hand drop down menu), CAPSTONE American Samoa: Suesuega o le Moana o Amerika Samoa  
(expedition name will appear in the right hand sidebar)

Platform Name (vessel): NOAA Ship *Okeanos Explorer*

**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).

#### CLICK ZOOM TO RESULTS

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

**LOOK CLOSER:** Holding the left mouse button down, shift the map and zoom in to find Remotely Operated Vehicle (ROV) Dive 9 (EX1702\_DIVE 09). This is atop Vailulu'u Seamount. Discuss the following questions with your group.

1. What do you think the ship was doing here to make those lines on the map? Can you think of anything in your life that makes similar patterns? \_\_\_\_\_  
\_\_\_\_\_

**DIVE IN:** Zoom in to see get a closer look at Vailulu'u.

2. What else do you notice? \_\_\_\_\_

**ZOOM OUT:** Zoom out farther to see where this hotspot volcano sits on the globe.

3. Describe its location. \_\_\_\_\_  
\_\_\_\_\_

4. Zooming in and out around the seamount/volcano, what other seafloor features do you notice/recognize on the map? \_\_\_\_\_



## Student Investigation: Exploring a Hotspot Volcano with Multibeam Sonar Tools *cont.*

### TOOL 2: Exploring a Hotspot Volcano with Fledermaus

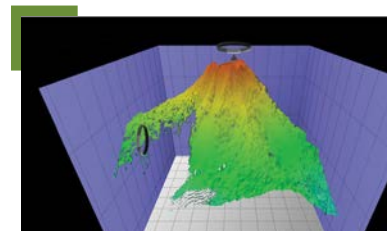
Now that you have found the ROV dive, you will view a video exploration of Vailulu'u Seamount within a platform called Fledermaus. This is a three-dimensional data visualization system used to view and manipulate 3D models of seafloor features, provide insight into the geological structure of an area and help to pinpoint ideal locations for further exploration. Use the video to help you discuss and answer the questions below.



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

#### **WATCH:** CASE STUDY 4 FLEDERMAUS VIDEO

**EXPLORE:** Based on your observations, answer the questions below.



1. What is the deepest point of this seamount/hotspot volcano? \_\_\_\_\_  
What is the shallowest point? \_\_\_\_\_
2. What is the general width of the seamount/hotspot volcano? \_\_\_\_\_
3. What is the width of the crater in the center of this seamount/hotspot volcano? \_\_\_\_\_
4. Looking at the profile view, what depth variations do you notice in the crater of the seamount/hotspot volcano?  
\_\_\_\_\_
5. What is the approximate steepest slope of this seamount/hotspot volcano in degrees? \_\_\_\_\_

#### **THINK ABOUT IT**

6. What organisms do you think might live here? Why? \_\_\_\_\_
7. What is succession and what might that mean in this environment? \_\_\_\_\_  
\_\_\_\_\_
8. If you were the scientist leading this expedition and exploring this seamount/volcano for the first time, where would you choose to send the ROV? \_\_\_\_\_  
\_\_\_\_\_
9. What considerations do you think need to be made when deciding what regions to select for further exploration?  
\_\_\_\_\_



## Student Investigation: Exploring a Hotspot Volcano with Multibeam Sonar Tools *cont.*

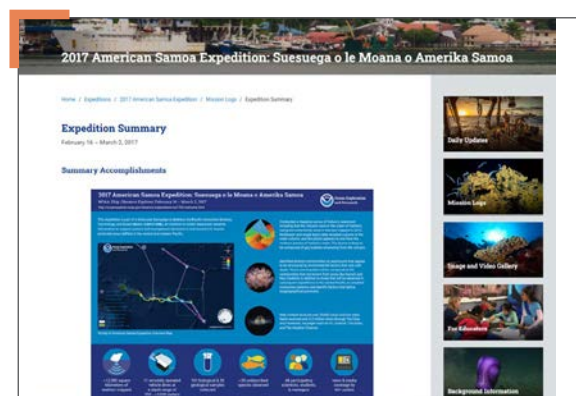
### TOOL 3: Expedition Web Pages

Now that you've explored the 3D map of Vailulu'u Seamount/Hotspot Volcano, check out the 2017 CAPSTONE American Samoa Expedition: Suesuega o le Moana o Amerika Samoa **EXPEDITION WEB PAGE** on the NOAA Ocean Exploration Website to learn more about what was studied here and some of the discoveries that were made.

- <https://archive.oceanexplorer.noaa.gov/oceanos/explorations/ex1702/logs/summary/welcome.html>

### HERE YOU CAN...

- read the Mission Summary
- read the Mission Logs and Daily Updates
- view beautiful imagery, videos and more!



### BE THE EXPLORER

#### What was discovered?

On the 2017 CAPSTONE American Samoa Expedition: Suesuega o le Moana o Amerika Samoa Expedition web page, click Daily Updates.

SELECT the Daily Update from Dive 9, February 24, 2017.

WATCH the highlight video called Vailulu'u Volcano to hear the team describe their findings.

1. Can you explain why the islands of Samoa illustrate an example of a "hotspot"? \_\_\_\_\_  
\_\_\_\_\_
2. 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? \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

### THINK ABOUT IT

3. How is succession illustrated on Vailulu'u? \_\_\_\_\_
4. Why might scientists be interested in continuing to explore this area over time? \_\_\_\_\_  
\_\_\_\_\_
5. Based on what you've learned, can you define an archipelago? \_\_\_\_\_  
\_\_\_\_\_



## Hotspot Volcano Lesson URLs/Links

- Page 1:**
- ▶ Plume of bubbles (image): <https://archive.oceanexplorer.noaa.gov/oceanos/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://archive.oceanexplorer.noaa.gov/oceanos/explorations/ex1705/background/geology/welcome.html>
  - ▶ Samoan Islands: <https://archive.oceanexplorer.noaa.gov/oceanos/explorations/ex1702/background/geology/welcome.html>
  - ▶ 2017 *Okeanos Explorer* CAPSTONE American Samoa Expedition: Suesuega o le Moana o Amerika Samoa Expedition Web Page: <https://archive.oceanexplorer.noaa.gov/oceanos/explorations/ex1702/welcome.html>
  - ▶ Listen: <https://oceanexplorer.noaa.gov/edu/materials/multibeam-sonar-fact-sheet.pdf>
  - ▶ Test: <https://oceanexplorer.noaa.gov/technology/ctd/ctd.html>
  - ▶ Photograph: <https://oceanexplorer.noaa.gov/edu/materials/rov-fact-sheet.pdf>
  - ▶ Share: <https://oceanexplorer.noaa.gov/technology/telepresence/telepresence.html>
  - ▶ Multibeam Sonar Fact Sheet (PDF): <https://oceanexplorer.noaa.gov/edu/materials/multibeam-sonar-fact-sheet.pdf>
- Page 2:**
- ▶ Samoan archipelago: <https://archive.oceanexplorer.noaa.gov/oceanos/explorations/ex1702/background/geology/media/ig3-800.jpg>
  - ▶ Eel City and the Moat of Death (essay with video): <https://archive.oceanexplorer.noaa.gov/explorations/05vailuluu/welcome.html>
  - ▶ Rose Atoll Marine National Monument: <https://www.fisheries.noaa.gov/pacific-islands/habitat-conservation/rose-atoll-marine-national-monument>
  - ▶ National Marine Sanctuary of American Samoa: <https://americansamoa.noaa.gov/>
  - ▶ National Park of American Samoa: <https://www.nps.gov/npsa/index.htm>
  - ▶ CAPSTONE: <https://archive.oceanexplorer.noaa.gov/oceanos/explorations/capstone/welcome.html>
- Page 3:**
- ▶ NOAA Ocean Exploration Data Atlas: <https://www.ncei.noaa.gov/maps/ocean-exploration-data-atlas/>
- Page 4:**
- ▶ Fledermaus video Hotspot Volcano: [https://oceanexplorer.noaa.gov/edu/materials/CaseStudy4\\_Vailuluu\\_HotSpot.mp4](https://oceanexplorer.noaa.gov/edu/materials/CaseStudy4_Vailuluu_HotSpot.mp4)
- Page 5:**
- ▶ 2017 *Okeanos Explorer* CAPSTONE American Samoa Expedition: Suesuega o le Moana o Amerika Samoa Expedition Web Page: <https://oceanexplorer.noaa.gov/oceanos/explorations/ex1702/welcome.html>
  - ▶ Daily Updates: <https://oceanexplorer.noaa.gov/oceanos/explorations/ex1702/dailyupdates/dailyupdates.html>
  - ▶ Daily Update, February 24, 2017: <https://oceanexplorer.noaa.gov/oceanos/explorations/ex1702/dailyupdates/dailyupdates.html#cbpi=feb24.html>
  - ▶ Vailulu'u Volcano (video): <https://www.youtube.com/watch?v=AZ4wRW5Wbns>

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