Section 1: Introduction

Introduction to Volume 2: How Do We Explore?

On August 13, 2008, the NOAA Ship *Okeanos Explorer* was commissioned as "America's Ship for Ocean Exploration;" the only U.S. ship whose sole assignment is to systematically explore Earth's largely unknown ocean. A key part of the vision underlying this assignment is that the *Okeanos Explorer* is a ship of discovery. Her mission is to find anomalies; things that are unusual and unexpected. When anomalies are found, explorers aboard the ship collect basic information that can guide future expeditions to investigate hypotheses based on this information. This process underscores an important distinction between exploration and research:

Exploration is about making new discoveries to expand our fundamental scientific knowledge and understanding and to lay the foundation for more detailed scientific investigations;

Research is about the attempt to understand things that have previously been discovered and leads to informed decision-making.

Exploring the unknown is a challenging assignment. Long voyages into remote areas and scientific studies both require careful planning to minimize risks, maximize the chances of obtaining useful information, and make the best use of financial resources. Explorers must do this kind of planning without knowing exactly what they will encounter and work within a scientifically informed "strategy" for exploring the relatively unknown ocean world. As such, the exploration strategy designed for the *Okeanos Explorer* has taken years to develop and has involved many scientists, engineers, ocean experts, and visionaries from across the globe.

Historically, many expeditions of discovery have preceded the voyages of the *Okeanos Explorer*. Two of the most famous are the Lewis and Clark Expedition (1804 – 1806) and the HMS *Challenger* Expedition (1872 – 1876). There are many differences between these expeditions, but several basic questions apply to all three:

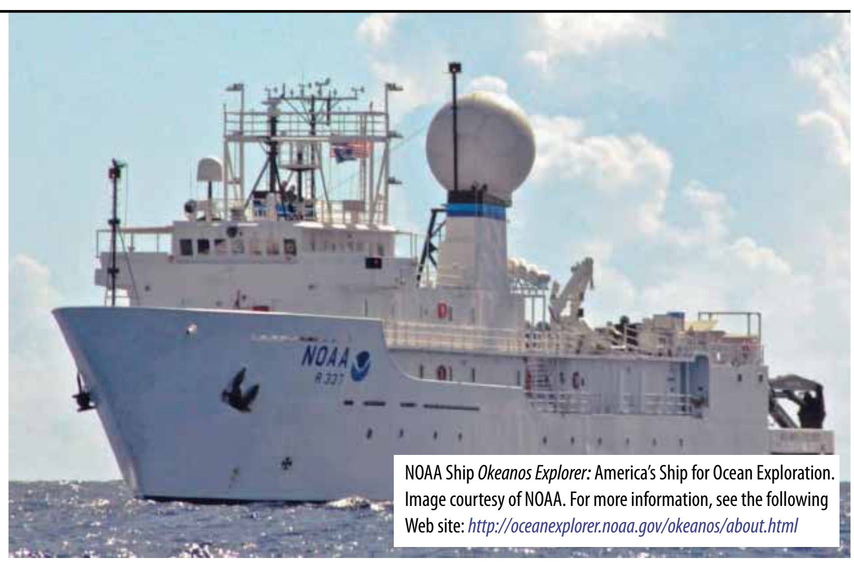
- Who looks for discoveries?
- Where do they look?
- How do they look?

Who's Looking?

This question is important because a discovery implies finding something that hasn't been found before. But if we see something that is new to us, how can we be reasonably sure that no one else has seen it before? The answer is that we need people who are knowledgeable about biology,

***Okeanos Explorer* Vital Statistics:**

Commissioned: August 13, 2008; Seattle, WA
Length: 224 feet
Breadth: 43 feet
Draft: 15 feet
Displacement: 2,298.3 metric tons
Berthing: 46, including crew and mission support
Operations: Ship crewed by NOAA Commissioned Officer Corps and civilians through NOAA's Office of Marine and Aviation Operations (OMAO); Mission equipment operated by NOAA's Office of Ocean Exploration and Research



NOAA Ship *Okeanos Explorer:* America's Ship for Ocean Exploration. Image courtesy of NOAA. For more information, see the following Web site: *http://oceanexplorer.noaa.gov/okeanos/about.html* geology, chemistry, physical science, and many other fields; in other words, we need to have experts that can participate in the process of looking.

The primary objective of the Lewis and Clark Expedition was to explore the Missouri River and its connection (if any) to the waters of the Pacific Ocean for purposes of commerce. But President Thomas Jefferson (who commissioned the expedition) was an avid citizen scientist, and wanted to find out everything possible about the natural history of the unexplored American West. Scientific observations depended primarily upon the expertise of one individual: expedition leader Meriwether Lewis, who was trained as a multidisciplinary "expert" through studies with members of the American Philosophical Society, including specialists in astronomy, mathematics, medicine, fossils, botany, and zoology. The other (approximately 45) members of the expedition were chosen for physical condition, marksmanship, or special skills (such as the ability to speak native American languages) needed by the expedition.

In contrast, the HMS *Challenger* Expedition's primary objective was to gather information about a wide range of ocean features, such as seawater temperatures, chemistry, currents, marine life, and geology of the seafloor. The expedition was led by naturalist Charles Wyville Thompson and included five other scientists and a crew of 216.

Like HMS *Challenger*, the specific objective of the *Okeanos Explorer* is scientific: to explore Earth's unknown ocean for the purpose of discovery and the advancement of knowledge. The ship is able to accommodate 46 people, most of whom (about 28) are ship's crew. But while scientific experts aboard the ship are in the minority, dozens of other scientists ashore can actively participate in exploration activities. This is a fundamental difference between *Okeanos Explorer* missions and previous voyages of discovery, and is possible because of a technological capability known as telepresence. This capability uses advanced broadband satellite communication to allow people in remote locations to observe and interact with events aboard the ship. Live images can be transmitted from the seafloor to scientists ashore, classrooms, and newsrooms, opening new educational opportunities that are a major part of the *Okeanos Explorer's* objective for advancement of knowledge. Telepresence also makes it possible for shipboard equipment to be controlled by scientists in shore-based Exploration Command Centers. Thanks to telepresence, many more scientists can be looking for discoveries during *Okeanos Explorer* missions than has been possible in previous voyages of discovery.

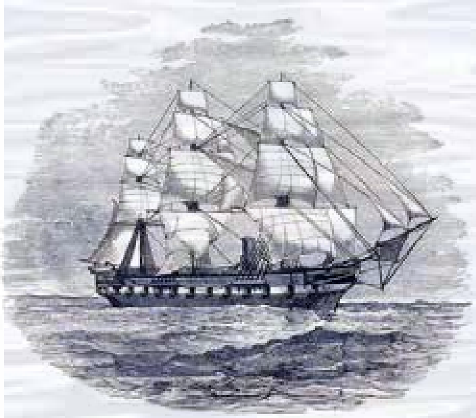
Where to Look?

The answer to this question usually depends upon the overall objectives of an expedition. The Lewis and Clark Expedition was focused primarily upon the Missouri River as a potential route for navigating to the Pacific Ocean, so the location of the River determined where they looked. . . until they reached the river's headwaters and still saw no sign of the Pacific. After that, they continued to head west, trying to find a way past the "terrible mountains" of the Rockies.

A primary objective of the HMS *Challenger* Expedition was to "investigate the physical conditions of the deep sea in the great ocean basins (as far as the neighborhood of the Great Southern Ice Barrier) in regard to depth, temperature, circulation, specific gravity and penetration of light." As a result of this requirement, the expedition covered 69,000 miles, entered all oceans except the Arctic, and collected data from 362 stations along its route. Because they wanted to investigate most of Earth's ocean, expedition leaders planned to take samples at intervals that were as evenly-spaced as possible. This worked out to taking samples at 200-mile intervals.

William Clark. Image courtesy Wikipedia.
http://upload.wikimedia.org/wikipedia/commons/6/66/William_Clark-Charles_Willson_Peale.jpg

Meriweather Lewis. Image courtesy Wikipedia.
http://media-2.web.britannica.com/eb-media/63/10263-050-BB45DC47.jpg



The HMS *Challenger*.
http://www.19thcenturyscience.org/HMSC/HMSC-INDEX/index-linked.htm

The science and ship crew of the HMS *Challenger* in 1874. The original crew of 216 had dwindled to 144 by the end of the long expedition. Image courtesy of NOAA.
http://www.19thcenturyscience.org/HMSC/HMSC-INDEX/group.jpg

Since Earth's ocean is 95% unexplored, the *Okeanos Explorer* mission also encompasses a very large geographic area. Between April 2006 and March 2008, the overall exploration strategy for the *Okeanos Explorer* was developed by a group of more than 50 scientists that represented a broad cross-section of the oceanographic community. Meetings among these scientists were facilitated by NOAA's Ocean Exploration Advisory Working Group (OEAWG). (For more information about the OEAWG, see *http://www.sab.noaa.gov/Working_Groups/Working_Groups.htm*).

Although the ocean is largely unexplored, we can obtain clues about where to begin looking by considering some of the exciting and scientifically-important deep-sea discoveries such as seamounts, hydrothermal vents, cold seeps, convergence zones, ocean trenches, and deep reefs. So, part of the *Okeanos Explorer* exploration strategy is to focus on areas where there is a high potential for new discoveries; but the OEAWG also emphasized the importance of including systematic exploration of unknown areas. These two strategic elements led to a concept of "boxes" and "sticks." "Boxes" are target areas of high interest where there is a reasonable likelihood that new discoveries will be made. "Sticks" are the routes that the ship will follow from one target area to the next. These routes will usually be through unknown, poorly studied regions that can be systematically investigated as the ship passes through. For more about the sticks and boxes exploration strategy, see *http://oceanexplorer.noaa.gov/okeanos/explorations/ex1006/welcome.html*.

How to Look?

This question focuses on exploration technologies. The most important single instrument for any voyage of discovery is the observer that is able to recognize unusual or unique features and events, and make an accurate record of these observations. To date, only humans are able to meet these requirements. In addition to the "official" record of observations, less formal individual records have been extremely valuable to providing a complete picture of events that took place during historic voyages of discovery. While Meriwether Lewis kept meticulous records of formal observations over three years,

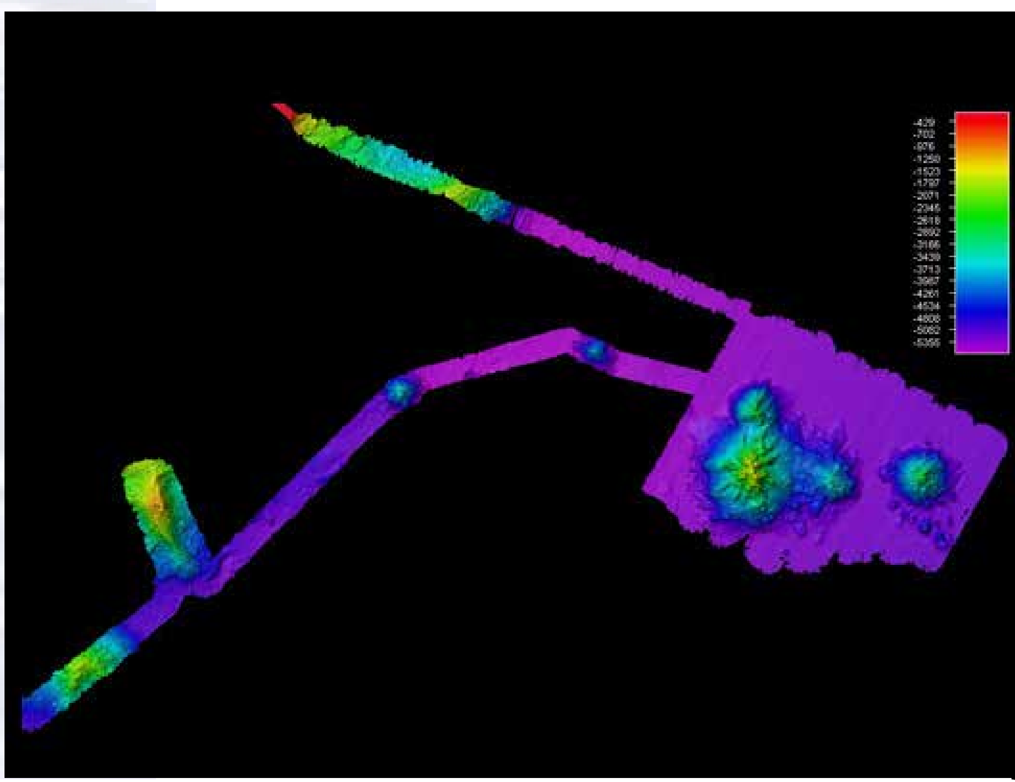


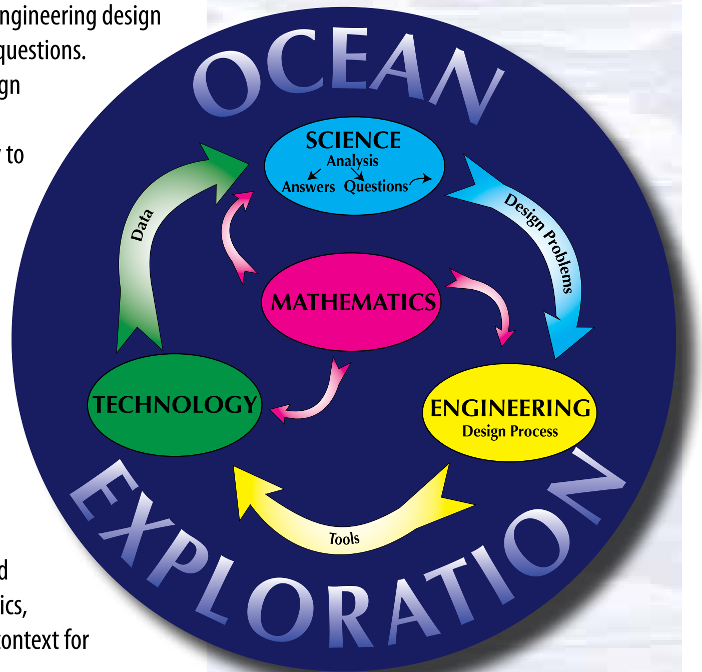
Image showing multibeam bathymetry collected off of Hawaii's Big Island during the NOAA Ship *Okeanos Explorer's* 2009 field season. The long skinny lines represent "sticks" in the ship's exploration model, whereas the larger areas represent "boxes." Image created using Fledermaus version 7 using cruise EX0909 data. Image courtesy of NOAA *Okeanos Explorer* Program.
http://oceanexplorer.noaa.gov/okeanos/explorations/ex1006/background/hires/sticks_boxes_hires.jpg

William Clark's journal often provides more details about the daily experiences of the members of the expedition. The official record of the HMS *Challenger* Expedition fills 50 volumes and includes more than 29,000 pages; but much of what we know about events during the expedition comes from letters written by Joseph Matkin, the ship's assistant steward.

During the Lewis and Clark, HMS *Challenger*, and *Okeanos Explorer* expeditions alike, a variety of technological instruments augment human observation abilities. For Lewis and Clark, these include a mariner's compass, surveying instruments, and a portable microscope. The list for HMS *Challenger* is much larger, including weighted ropes for measuring depth; dredges and nets; specially constructed thermometers and hydrometers; water sampling bottles, and photographic cameras.

The foundation of modern ocean exploration is the integration of science, technology, engineering, and mathematics (STEM). Scientific questions drive the engineering design process, which produces technology that provides data to answer the questions. Mathematics helps translate scientific questions into engineering design problems, provides tools that help create technological solutions, and assists with interpreting and analyzing data obtained with technology to answer scientific questions.

Each element provides internal feedback, as well as feedback to the other elements. Answers to one set of scientific questions often result in new questions. Engineering design is a cyclic process that progressively improves potential solutions to a given problem. Technological solutions in one field may stimulate new scientific questions, or new approaches to engineering design. Advances in mathematics can provide new ways of looking at data that result in better understanding, as well as new ways of solving problems and answering questions. NOAA's Ocean Exploration Education Program is not a STEM program; but because modern ocean exploration is based on the integration of science, technology, engineering, and mathematics, materials produced by this program can be used to create an exciting context for STEM instruction.



The foundation of modern ocean exploration is the integration of science, technology, engineering, and mathematics. Image courtesy of Mel and Sandy Goodwin.

The *Okeanos Explorer* Exploration Strategy

The overall *Okeanos Explorer* strategy is based on finding anomalies; conditions or features that are different from the surrounding environment. This is because anomalies may point the way to new discoveries, which are part of the ship's mission. Changes in chemical properties of seawater, for example, can indicate the presence of underwater volcanic activity, hydrothermal vents, and chemosynthetic communities. Once an anomaly is detected, the exploration strategy shifts to obtaining more detailed information about the anomaly and the surrounding area. An important concept underlying this strategy is a distinction between exploration and research. As a ship of discovery, the role of *Okeanos Explorer* is to locate new features in the deep ocean, and conduct preliminary characterizations of the site that provide enough data to justify potential follow-up by future expeditions.

This strategy involves three major activities:

- Underway reconnaissance;
- Water column exploration; and
- Site characterization.

The ROV Team Lead, Commanding Officer, and Science Team Lead talk about our operations at the Mid-Cayman Rise with participants located at both the Silver Spring ECC, and URI's Inner Space Center. Image courtesy of NOAA *Okeanos Explorer* Program, MCR Expedition 2011.
http://oceanexplorer.noaa.gov/okeanos/explorations/ex1104/logs/hires/daily_updates_aug9_1_hires.jpg

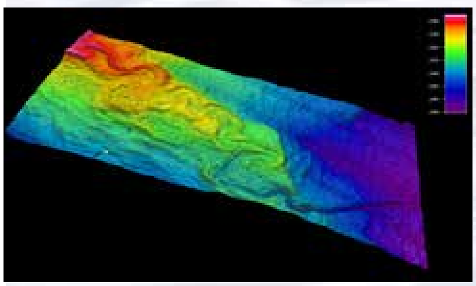


Image of an underwater river feature on the seafloor in the Northern Gulf of Mexico. Colors indicate depth. Image courtesy of the NOAA *Okeanos Explorer* Program.
http://oceanexplorer.noaa.gov/okeanos/explorations/ex1202/logs/hires/apr2-2-hires.jpg

A gas capture device, affectionately known as the "methane bucket," was added to the front of the *Little Hercules* remotely operated vehicle for several dives. Gas from natural seafloor seeps was captured in the device at depth, where it forms a mix of hydrate (methane ice) and gas, and was then brought to shallower, warmer waters, where the hydrate dissociated, in order to estimate the volume of gas collected. Image courtesy of the NOAA *Okeanos Explorer* Program.
http://oceanexplorer.noaa.gov/okeanos/explorations/ex1202/logs/hires/apr29-1-hires.jpg

Underway reconnaissance involves mapping the ocean floor and water column while the ship is underway, and using other sensors to measure chemical and physical properties of seawater. Water column exploration involves making measurements of chemical and physical properties "from top to bottom" while the ship is stopped. In some cases these measurements may be made routinely at pre-selected locations, while in other cases they may be made to decide whether an area with suspected anomalies should be more thoroughly investigated. Site characterization involves more detailed exploration of a specific region, including obtaining high quality imagery, making measurements of chemical and physical seawater properties, and obtaining other appropriate types of data.

In addition to state-of-the-art navigation and ship operation equipment, this strategy depends upon four key technologies:

- Telepresence (discussed in Lesson 2);
- Multibeam sonar mapping system (discussed in Lessons 3, 4, and 5);
- CTD (an instrument that measures conductivity, temperature, and depth) and other electronic sensors to measure chemical and physical seawater properties (discussed in Lessons 6, 7, and 8); and
- A Remotely Operated Vehicle (ROV) capable of obtaining high-quality imagery in depths as great as 4,000 meters (discussed in Lessons 9, 10, and 11).

The strategy for NOAA OER ocean exploration was the result of over five years of planning, field trials, and state-of-the-art technology that ultimately came together for the first time on one ship, the *Okeanos Explorer*, during her maiden voyage to explore the deep waters of Indonesia during the INDEX-SATAL 2010 Expedition (*http://oceanexplorer.noaa.gov/okeanos/explorations/10index/welcome.html*). This expedition was an international collaboration between scientists from the United States and Indonesia to explore the deep ocean in the Sangihe Talaud Region, located in the 'Coral Triangle', the global heart of shallow-water marine biodiversity. Questions such as "Who's Looking?", "Where To Look?" and "How To Look?" for this maiden voyage are described first hand, by Dr. Stephen H. Hammond, Acting Chief Scientist, NOAA Office of Ocean Exploration and Research, in the article starting on page 14 excerpted from *Current, The Journal of Marine Education*, Volume 28, Number 1, 2012, *http://oceanexplorer.noaa.gov/edu/oceanage/current.html*.

Ocean Exploration: Interdisciplinary Expeditions to Reveal an Unknown Ocean

This map, while extremely informative, could mislead one to assume that the global seafloor is fully mapped. In fact, the bathymetry shown is at very low-resolution, expecially in the southern latitudes. Image courtesy of Heezen and Tharp, World Ocean Floor Panorama, 1977.

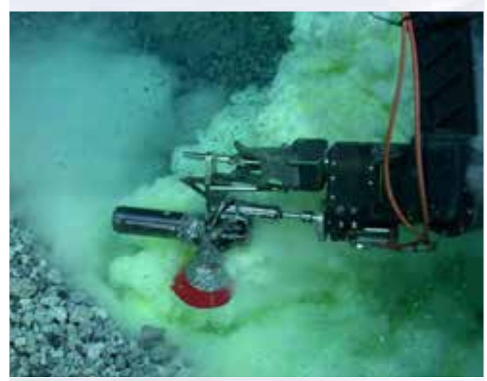
By Dr. Stephen H. Hammond

Although it is surprising to many, the disquieting fact is that the Earth's ocean remains virtually unexplored. Even though one can easily find bathymetric maps of all the world's seafloors, in fact, nearly all of them present relatively low-resolution representations of seafloor topography. It is also a fact that we have much higher resolution maps of the surfaces of planets and moons in our solar system than we do of Earth.

NOAA, as the Nation's civilian ocean agency with responsibility for ocean stewardship, has a goal of understanding the effects of planetary-scale submarine volcanism on the ocean. To accomplish this, the effort must be interdisciplinary. The expertise of a geological oceanographer is required to understand the volcanological processes. Physical and chemical oceanographers provide expertise into understanding how an eruption impacts the surrounding water. Biological oceanographers understand how an eruption's physical and chemical manifestations impact existing ecosystems in the area and, interestingly, also initiate new ecosystems especially adapted to eruption-produced hydrothermal venting. It was this kind of interdisciplinary synergy that led to the discovery of chemosynthetic animal communities associated with venting at several locations along the Galápagos Rift in 1977, forever changing our understanding of life on Earth.

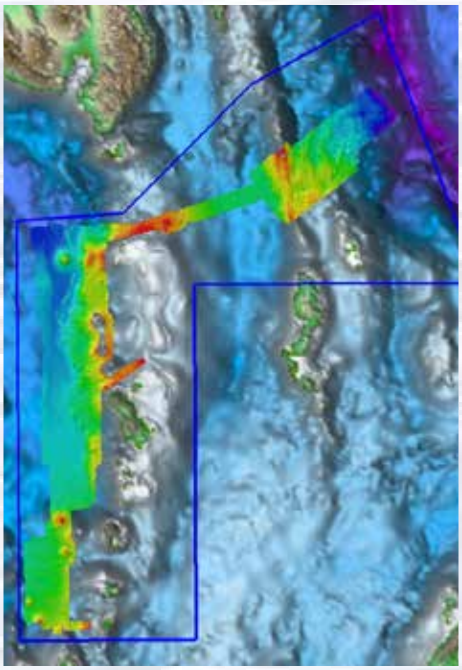
Image of a very active hydrothermal site on Kawio Barat submarine volcano taken by the ROV *Little Hercules*. Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010. *http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/hires/june30_update_hires.jpg*

Coincidentally, very recent exploration of submarine volcanoes in the Mariana Arc revealed, for the first time, spectacular examples of volcanoes spewing immense quantities of carbon dioxide and sulfur dioxide. Both styles of venting are resulting in intense acidification of the volcanoes' regional environments. Although from a human perspective the environments around these volcanoes are highly toxic, each volcano is host to a unique ecosystem of highly adapted organisms. Recognizing that the global ocean is becoming acidified as a consequence of absorbing increasing quantities of atmospheric carbon dioxide, these discoveries raise the possibility of utilizing these volcanoes as natural ocean acidification laboratories. Again, gaining an understanding of these and other submarine volcanism sites and their environmental impacts requires an interdisciplinary oceanographic approach.

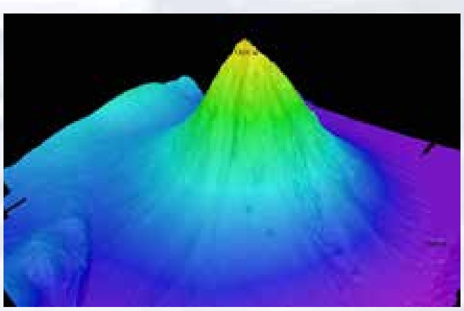


Sampling gas bubbles at a volcanically active vent on NW Rota-1 submarine volcano, Mariana Arc, in March 2010. The yellow and white material is particulate elemental sulfur produced by degassing of sulfur dioxide from erupting lava. The gases produced by volcanically or hydrothermally active submarine volcanoes often results in local to regional regions of high acidity. Image courtesy of James F. Holden, UMass Amherst. *http://oceanexplorer.noaa.gov/okeanos/explorations/10index/background/plumes/media/gas_bubbles_sampling.html*

Map showing the Coral Triangle region—the most diverse and biologically complex marine ecosystem on the planet. The Coral Triangle covers 5.7 million square km, and matches the species richness and diversity of the Amazon rainforest. Although much of the diversity within the Coral Triangle is known, most still remains unknown and undocumented. Image courtesy of www.reefbase.org.
http://oceanexplorer.noaa.gov/okeanos/explorations/10index/background/hires/coral_triangle_hires.jpg



The NOAA Ship *Okeanos Explorer* mapped an area larger than the state of Delaware during its maiden international voyage to explore Indonesia's deep seas. The new bathymetry is shown by the bright colors. Such high-resolution bathymetry is required in order to effectively explore seafloor features in more detail with ROVs. Image courtesy of NOAA *Okeanos Explorer* Program.



Okeanos Explorer's EM302 multibeam sonar mapping system produced this detailed image of the Kawio Barat seamount, which rises around 3800 meters from the seafloor, and was found to be hydrothermally active. Images courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010.
http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/hires/june26fig1_hires.jpg

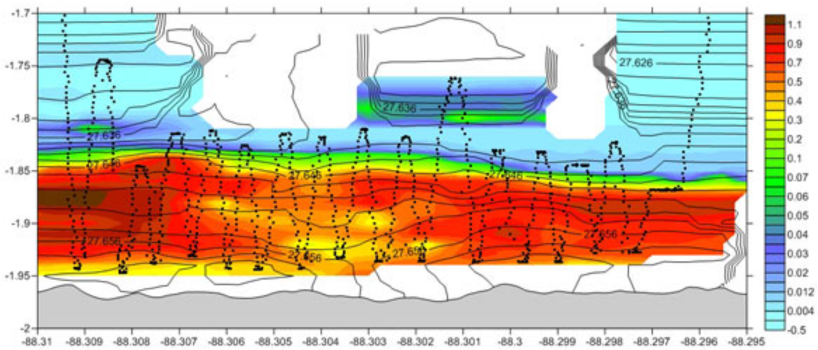
Discoveries in Indonesia's Deep Seas

In the summer of 2010, the NOAA Ship *Okeanos Explorer* embarked on its maiden voyage of exploration (*http://oceanexplorer.noaa.gov/okeanos/explorations/10index/welcome.html*). The expedition was the culmination of a long and complicated planning effort that involved high-level diplomatic, science, and technical leadership in the U.S. and Indonesia. Indonesia has long been recognized for the spectacular diversity of its land-based fauna. Indonesia's shallow seas likewise are rich with a diversity of marine life. What particularly intrigued the interests of both U.S. and Indonesian ocean scientists was to find out if Indonesia's deep seas, which are nearly unexplored, are just as biologically diverse.

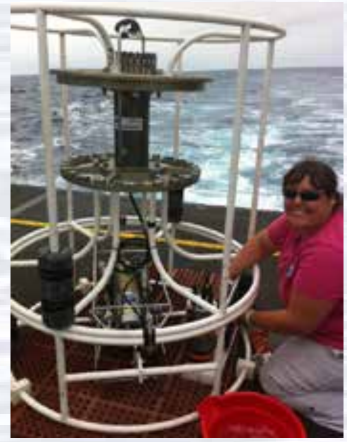
The geological setting of the Indonesian region is incredibly complicated. Indonesia itself consists of 17,000 inhabited islands all of which lie in an area of multiple spreading centers and collision, or subduction zones. There are vast areas of relatively shallow seas punctuated by trenches and deeps that reach depths of more than 9 km. The area is subject to incessant earthquakes and is the most volcanically active region on the planet. Knowing this—and combined with the knowledge that areas of volcanically and hydrothermally active submarine volcanoes elsewhere in the world are places where spectacular biological discoveries are common—an interdisciplinary team of U.S. and Indonesian oceanographers devised a cruise plan that they believed offered a high probability of finding never-before-seen ecosystems.

The expedition planning began with highly skilled mapping technicians working closely with the scientists to create a high-resolution map of the area of interest. Utilizing this map, the interdisciplinary science team could then pick targets where active submarine volcanoes were most likely to be encountered. Once the *Okeanos Explorer* reached the exploration area, her state-of-the-art multibeam sonar mapping system was used to create more refined bathymetric maps of the target exploration areas, with the first leg of the expedition primarily devoted to creating a map of the entire exploration area.

Once the map was completed, features that were clearly volcanic in origin were identified by the science team. The second phase of exploration consisted of steaming slowly over the areas of interest while repeatedly lowering and raising a conductivity-temperature-depth (CTD) sensor package to depth. Operated by a Senior Survey Technician onboard the ship, the CTD provided real-time data that revealed whether or not there were heat and chemical plumes in the water column. The CTD survey was augmented by the ability to take water samples by triggering Niskin bottles when plumes were encountered. With input from chemical oceanographers ashore who specialize in hydrothermal vent chemistry, the onboard science team was able to guide the CTD's path through the water column and home in on areas from which plumes were originating.

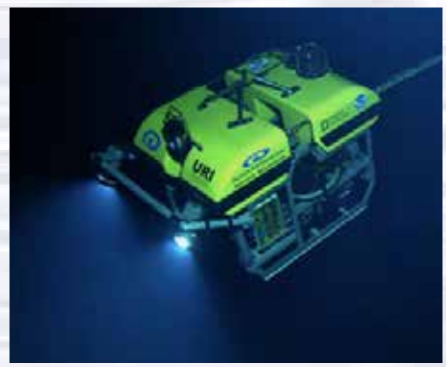


CTDs are slowly tow-yo'ed through the water column (the path of the CTD is shown by the sawtooth line in the data plot) in order to detect, and then home in on, heat and particulate plumes coming from active eruptions or hydrothermal vents. Image courtesy of NOAA *Okeanos Explorer* Program.
http://oceanexplorer.noaa.gov/okeanos/explorations/ex1103/logs/july17/media/ex1103l2_tow01.html



A conductivity/temperature/depth (CTD) sensor package. Image courtesy of NOAA *Okeanos Explorer* Program.
http://oceanexplorer.noaa.gov/okeanos/explorations/ex1103/logs/july16/media/ctd.html

The third and ultimate phase of the exploration was then to deploy a remotely operated vehicle (ROV) equipped with thrusters (for precise maneuvering), lights, and high-definition cameras. The ROV and its companion overhead vehicle were tethered to the ship by a fiber-optic tow cable. Both the ROV, and the overhead vehicle (whose chief utility was to eliminate any ship motion being transferred to the ROV) then embarked on a near-bottom, high-resolution visual search for active venting. The ROV, *Little Hercules*, which was made state-of-the-art for this expedition, produced stunning HD video imagery of both the geology and biology of the dive sites.



Little Hercules during one of its dives in Indonesia. Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010.
http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/hires/1june29_hires.jpg

When the Galápagos Rift discoveries were made, the principal near-bottom visual search tool was a human occupied submarine (or vehicle), an HOV. The deepest diving HOVs can carry a maximum of three persons and are limited to a few hours when at their maximum depths. By contrast, video and other sensor information from an ROV is transmitted by fiber optic cable to the overhead vessel thereby enabling the entire science team on the ship to participate in real-time in the dive. Moreover, an ROV can hypothetically stay submerged indefinitely.

The *Okeanos Explorer*, however, has another capability that makes even the methodology just described pale by comparison in terms of real-time accessibility to the seafloor. The *Okeanos Explorer* is one of only two civilian ocean exploration vessels in the world equipped with "telepresence." Telepresence is made possible by a broadband satellite-based communication system that enables three high-definition video streams to not only be accessible onboard the ship but also to be transmitted from the ship to shore-based "Exploration Command Centers" with Internet2 connectivity. In addition, the video and one-way audio can be provided in near real-time on the Ocean Exploration Program's website (*http://oceanexplorer.noaa.gov*). Combined, these means of communication enable a virtually unlimited number of interested scientists, educators, students, and the public to participate in real-time exploration and discovery.

Telepresence: real-time, broadband video and audio communications made possible by the *Okeanos Explorer's* powerful satellite antenna (red arrow). Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010.
http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/july09/media/okeanos_vsat.html

The telepresence-enabled U.S./Indonesian expedition was a spectacular success. The deep Indonesian seas are indeed biologically diverse and pristine. To illustrate a participating biologist noted that previously no one had ever seen the numbers and species diversity of deep corals encountered in the areas explored with the ROV. Further, a spectacular active vent site was discovered on the top of a large volcano (Kawio Barat; see page 15). The site

Scientists observe the video feed from *Little Hercules* and record their observations in the Eventlog. Image courtesy of NOAA *Okeanos Explorer* Program.
http://oceanexplorer.noaa.gov/okeanos/explorations/ex1103/logs/july13/media/seattle_ecc_scott_jim.html

is characterized by numerous active white smokers, massive sulfide chimneys densely colonized by what appear to be new species of animals, including dense populations of barnacles. All told, it was estimated that there were over 100 new species of vertebrates and invertebrates observed, including many new species of deep-sea corals. A high-resolution bathymetric map of an area approximately the size of Maryland was produced for an area of the seafloor never before explored.

Findings of the expedition are now being assessed and interpreted by the interdisciplinary science team. Results are being presented at professional meetings and will be published in scientific journals. Data from the U.S./ Indonesian expedition, as well as any other expedition of the *Okeanos Explorer*, are open and available to those requesting them virtually as soon as they are accessible, which is yet another important pioneering way of expediting ocean exploration. Ocean science educators are connecting classroom teachers and informal educators through lessons plans, professional development, and other offerings to the science of ocean exploration and the people who make it happen. The oceans are still almost entirely unexplored. NOAA's Ocean Exploration Program with its many partners is endeavoring to change that.

Dr. Stephen R. Hammond is the Acting Chief Scientist of the National Oceanic and Atmospheric Administration's (NOAA) Office of Ocean Exploration and Research as well as Director of the NOAA Pacific Marine Environmental Laboratory's Ocean Environment Research Division and Vents program. His is an adjunct professor in the College of Ocean and Atmospheric Studies at Oregon State University.

Arrays of monitors in the ship's control room (below) and on shore (above) in Exploration Command Centers include high-resolution video streaming from the ROV as it operates on the seafloor. Images courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010.
http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/july27/media/control_room.html

Notes: