NAUTILUS EXPLORATION PROGRAM

2013 Season Overview

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Overview of Purpose

This document is a collection of information gathered from various sources about the upcoming Nautilus Exploration Program's 2013 expedition season. It is intended as a source of vetted and edited material for disseminating publicly.

It is a *living* document and will be updated regularly when significant changes and updates are required. If you are unsure about it's currency, please contact the author for the latest version.

Please be aware that all the information contained in this document is fluid leading up to, and during, the 2013 expedition season.

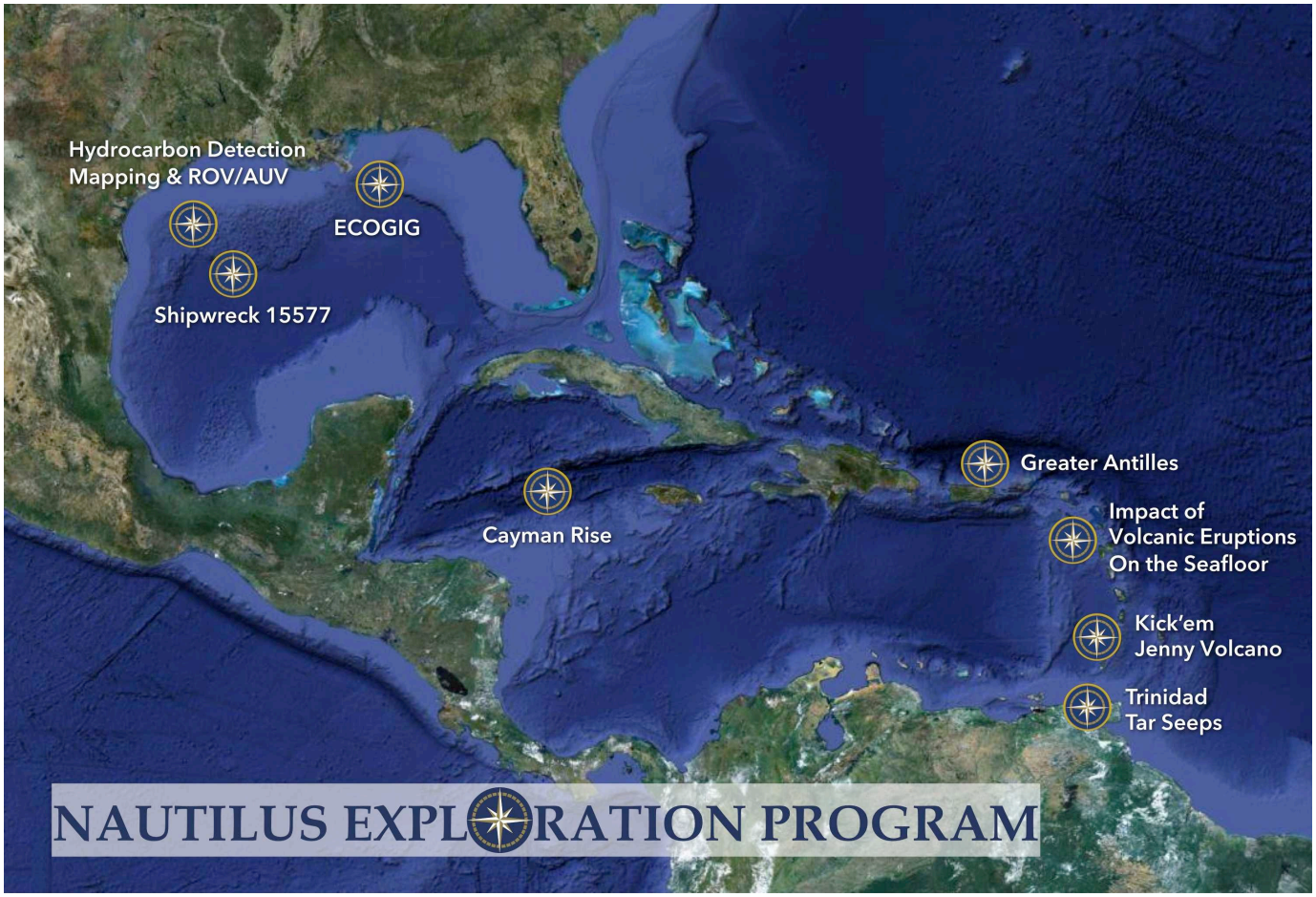
NAUTILUS EXPLORATION PROGRAM

Contents

NAUTILUS EXPLORATION PROGRAM

1. 2013 Nautilus Exploration Program Overview

Cruise Dates	21 June – 31 August 2012 (subject to change) 4 October – 16 November 2013 (subject to change)
Areas of Exploration	Gulf of Mexico, Caribbean Sea and Mediterranean Sea
Countries of Operation	United States, Puerto Rico, Cayman Islands, Montserrat, Dominica, Grenada & Turkey
Total Days	125+ days of exploration
Number of Participants	150+ explorers



NAUTILUS EXPLORATION PROGRAM

2013 Nautilus Exploration Program Itinerary

Dates*	Activity	Location
Jun 3 - Jun 17	Mobilization	Galveston, Texas
Jun 21 – Jul 4	ECOGIG	Gulf of Mexico
Jul 8 – Jul 17	Natural Hydrocarbon Detection Mapping	Gulf of Mexico
Jul 17 – Jul 25	Shipwreck 15577	Gulf of Mexico
Jul 28 – Aug 12	Natural Hydrocarbon Detection ROV/AUV	Gulf of Mexico
Aug 19 – Aug 30	Cayman Rise	Cayman Islands
Oct 4 – Oct 18	Greater Antilles	Puerto Rico
Oct 21 – Oct 28	Impact of Volcanic Eruptions on the Seafloor	Montserrat & Dominica
Nov 1 – Nov 17	Kick'em Jenny Volcano & Trinidad Tar Seeps	Grenada

*All dates subject to change

NAUTILUS EXPLORATION PROGRAM

2013 Nautilus Exploration Program Expedition Summary

From June through November of 2013, Exploration Vessel *Nautilus* will explore the Gulf of Mexico and the Caribbean Sea. Our rotating Corps of Exploration aboard EV *Nautilus* will be mapping the geological, biological, archaeological and chemical aspects of these regions to depths of approximately 4000 meters (13,123 feet). During the expedition, we will be sharing our discoveries live on the web via telepresence technology, putting the unexplored ocean directly in your hands via our interactive websites - Nautilus Live and Exploration Now.

The 2013 expedition season consists of multiple cruise legs and will begin off the U.S. coast in the Gulf of Mexico. Subsequent cruise legs will bring the ship and the Nautilus Corps of Exploration to the Cayman Islands, Puerto Rico, Montserrat, Dominica, and Grenada in the Caribbean Sea. Our Corps of Exploration will also join researchers in the Mediterranean Sea off the coast of Turkey aboard the STS *Bodrum*.

E/V Nautilus is a 64-meter (211-foot) exploration vessel equipped with state-of-the-art exploration and telepresence technology. Our primary remotely operated vehicles (ROVs) on board, named *Hercules* and *Argus*, will be used to view the seafloor with high definition video, take environmental measurements and collect geological and biological samples. We will be utilizing our brand new hull-mounted multibeam system, side-scan sonar and subbottom sonar technology to explore the seafloor and seek out compelling targets for closer investigation.

Dr. Robert Ballard and Dr. Katherine Croff Bell of the Ocean Exploration Trust lead the Nautilus Corps of Exploration, which includes a rotating team of more than 150 scientists, engineers, educators and students as they explore these poorly understood regions of the world's oceans. All of the video and data that we collect will be transmitted via satellite to the Inner Space Center, located at the University of Rhode Island Graduate School of Oceanography, where Dr. Ballard is a professor of oceanography. From this "mission control," our video feeds from the ship and under the sea will be broadcast live on the internet so that anyone in the world can join our Corps of Exploration from home and be a part of the exploration as it happens.

You can follow the expedition live at *www.explorationnow.org* starting on **June 21, 2013.**

The 2013 Nautilus Exploration Program is made possible through partnerships with the National Oceanic and Atmospheric Administration (NOAA), Ocean Exploration Trust (OET) Bechtel, Sea Research Foundation, National Geographic Society, Office of Naval Research, and the University of Rhode Island.

NAUTILUS EXPLORATION PROGRAM

2013 Nautilus Exploration Program Season Quick Facts

Cruise Dates	21 June – 31 August & 4 October – 16 November, 2013
Total Days	125+ days of exploration
Number of Participants	150+ explorers
Areas of Exploration	Gulf of Mexico, Caribbean Sea and Mediterranean Sea
Countries of Operation	United States, Puerto Rico, Cayman Islands, Montserrat, Dominica, Grenada, Turkey
Science Subject Areas	Archaeology, Biology, Chemistry, Engineering, Geology, Geography, Maritime History, Technology
Lead Scientists	Dr. Tom Weber, University of New Hampshire Dr. Erik Cordes, Temple University Dr. Jack Irion, BOEM Frank Cantelas, NOAA Frederick Hanselmann, Texas State University Dr. Richard Camilli, WHOI Dr. David Valentine, UC Santa Barbara Dr. Cindy Lee Van Dover, Duke University Dr. Uri ten Brink, US Geological Survey Dr. Steven Carey, University of Rhode Island
Expedition Leaders	Dr. Katherine Croff Bell, Ocean Exploration Trust Dr. Michael Brennan, University of Rhode Island Dr. Nicole Raineault, University of Rhode Island Dr. Chris Roman, University of Rhode Island Dr. Dwight Coleman, University of Rhode Island
Expedition Partners	National Oceanic and Atmospheric Administration (NOAA), Ocean Exploration Trust, Bechtel, Sea Research Foundation, National Geographic Society, Office of Naval Research, and University of Rhode Island

NAUTILUS EXPLORATION PROGRAM

Nautilus Exploration Program Overview

Nautilus Exploration Program Mission

We are an international Corps of Exploration consisting of marine scientists, engineers, communicators, educators and students. Our primary objective is to explore the ocean seeking out new discoveries in the fields of geology, biology, maritime history, archaeology, and chemistry while pushing the boundaries of engineering, technology, education and communications. We aim to share our story and our science with explorers around the world via live telepresence from aboard Exploration Vessel *Nautilus* and additional research vessels. Our Corps of Exploration aspires to serve as role models for the next generation of explorers, scientists, engineers and educators. We promise to bring our audience only cutting edge exploration, live from the bottom of the ocean as we explore landscapes that have never been explored before.

Our Objectives

- *To explore areas of the ocean that have never been explored before, seeking out new discoveries in the fields of geology, biology, maritime history, archaeology, and chemistry*
- *To conduct all scientific research to the highest international academic standard*
- *To push the boundaries of ocean engineering, technology, education and communications*
- *To share our expeditions with explorers around the world via live telepresence*
- *To serve as role models for the next generation of explorers*
- *To spread the excitement of ocean exploration and turn everyday viewers into explorers*

About the Nautilus Exploration Program

The Nautilus Exploration Program was founded in 2008 by Dr. Robert Ballard. Our international exploration program centers on scientific exploration of the seafloor launched from aboard the Exploration Vessel *Nautilus*, a 64-meter (211-foot) exploration vessel currently based in the Caribbean Sea and additional research vessels. In addition to conducting pure scientific research, the Nautilus Exploration Program offers telepresence to explorers on shore via live video, audio and data feeds from our ships. The Program also includes an education component that brings educators and students on ocean expeditions.

2. Expedition: Ecosystem Impacts of Oil and Gas Inputs to the Gulf (ECOGIG)

Cruise dates	21 Jun – 4 July 2013
Lead Scientist	Dr. Erik Cordes, Temple University
Expedition Leader	Dr. Michael Brennan, University of Rhode Island
Operations Leader	Reuben Mills, Ocean Exploration Trust
Area of Exploration	Gulf of Mexico
Country of Operation	United States
Expedition Length	14 days
Main Operations	ROV *Hercules*, ROV *Argus*

Project Description (Author: Dr. Erik Cordes)

This expedition is part of a larger research program focused on examining the ecosystem-level response to oil and gas in the Gulf of Mexico. This research group is called the ECOGIG Consortium, which is made up of scientists from a wide variety of disciplines studying current flow, ocean chemistry, microbial activity, deep-sea coral communities, and everything in between. This group is looking primarily at natural oil and gas seepage into the Gulf, but using these natural processes to learn more about what happened after the Deepwater Horizon oil spill of 2010. On this cruise, we will mostly focus on the deep-sea corals and their response to the oil spill, but this work will include information from all of the other groups of scientists to fully understand what is happening.

Our plan is to return to a number of sites where we have documented impacts of the oil spill to deep-sea corals and continue our monitoring of these sites. We will take a large number of pictures of the same corals that we have been following since the impacts were first discovered. When we compare these images to the previous pictures, they will tell us how the corals are changing over time and whether they are recovering or getting worse. We will start at some of the large Lophelia coral reefs where we have not yet seen any impact, and then move deeper to the Paramuricea sea-fan sites that include both impacted and undisturbed sites.

We will also collect corals from some of these sites and conduct experiments on them to see what their response is to low levels of oil and dispersant exposure. We will monitor their health over time, and also take a series of samples to examine their genetic response. Usually, when an organism is exposed to a toxin, it begins to make proteins that will help them deal with the effects. We will be able to see the genes that make those proteins get turned on in response to the oil exposure. It will help us learn whether some corals are more resistant to the oil exposure, perhaps because they live close to natural seeps. This will also give us a tool to use in the future to determine if a coral has been exposed to a toxin in its environment, even after the toxin is long gone.

The other main objective of the cruise is to collect sediment samples and look at the communities that live in the mud near healthy coral communities and at natural oil seeps. Push cores will be taken by the ROV and brought to the surface where they are processed. All of the tiny animals are picked out of them and identified. The bacteria and other microbes living in the sediments will also be examined to see what they are and what they might be eating, including oil.

This cruise is a little different from most of the others we have all been on, since these projects and the scientists working on them will not only be on *Nautilus,* but also our partner ship on this cruise, *RV Endeavor. Endeavor*, from the University of Rhode Island, will be collecting water samples above our sites and will be taking large core samples of mud around the edges of the sites. We will have the eyes on the seafloor, but they will be able to take a lot of samples that we cannot get ourselves in order to completely characterize the habitats and the natural oil and gas inputs into the ecosystem. It will take a lot of coordination, but we will get a much more complete picture of the system than we ever would have alone.

Paramuricea: A healthy colony of the sea fan Paramuricea from a site further to the southwest of the spill. This site was discovered during our surveys following the spill in 2011.

3. Expedition: Natural Hydrocarbon Detection Mapping

Cruise dates	8 July – 17 July 2013
Lead Scientist	Dr. Tom Weber, University of New Hampshire
Expedition Leader	Dr. Nicole Raineault, University of Rhode Island
Operations Leader	Reuben Mills, Ocean Exploration Trust
Area of Exploration	Gulf of Mexico
Country of Operation	United States
Expedition Length	10 days
Main Operations	Multibeam Mapping

Project Description

Many of the world's offshore marine environments experience prolific natural seepage of hydrocarbons to the seafloor. In the waters off North America alone, natural hydrocarbon seepage is estimated to contribute more than 50 million gallons of oil to marine waters in a year (Oil in the Sea III: Inputs, Fates, and Effects, National Research Council of the National Academies, The National Academies Press, Washington D.C., 2003). Hydrocarbon gas is also emitted from seafloor seeps. It rises through the water as bubble plumes, and is likely a significant source of methane to the atmosphere (e.g. Solomon et al., Nature Geoscience, 2009). Despite the large volume of crude oil and gas released from these seeps, the seepage rates are slow enough that local seep environments support large, specialized communities of underwater organisms. Multiple studies have shown that these communities and their associated chemical and geologic processes are very heterogeneous, and can change significantly from one region of hydrocarbon seepage to another.

The U. S. Gulf of Mexico contains hundreds of these natural seafloor seeps that can be studied very effectively using both automated and remotely operated vehicles (AUVs and ROVs). This project will study the seep environment in the western Gulf of Mexico. Shallow sediment cores from this region suggest that seepage in the western Gulf may be less prolific than the better-studied portions of the eastern Gulf. We seek to characterize this seep environment, and understand the biologic and geologic processes that are associated with it. The results of the

study will provide a baseline to compare variability of natural seep environments within a single geographic region.

Key Concepts

- This is a 2-part expedition (mapping, then ROV/AUV operations) and it's how the Nautilus hopes to operate in the future. The mapping team will be the advance team to go into an area for exploration to produce quality maps that can be used to plan ROV dives for exploration of the most interesting areas.
- During this first expedition, we will be mapping the surface and shallow subsurface geology of 3400 km (2112 miles) of seafloor in water depths from 1000-3000 meters (3280-9842 feet). With the ship speed of 10 knots, the planned work will take 7-8 days.
- The two mapping systems, a multibeam echosounder and sub-bottom profiler will help us understand the surface, water column (backscatter), and subsurface geology associated with seeps.
- The mapping we do in July will help the lead scientists of the ROV/AUV expedition in early August. The maps we create on the first expedition will allow the ROV/AUV team target their dives to the most geologically interesting areas, such as areas where we think we've found natural seeps.
- In addition to being excellent planning tools, these maps also provide spatial awareness to our ROV pilots, who must navigate some very difficult terrain like volcanic calderas and steep escarpments.
- Determining the distribution, abundance, and activity of natural gas seeps is important because it is a missing piece of our understanding of the Earth's carbon budget. Natural gas seeps from the sea floor, which are commonly, but not exclusively methane, are now thought to be more common and need to be accounted for when trying to understand global sources of greenhouse gases, which affect the Earth's climate.
- The natural gas seeps are also energy sources for chemosynthetic organisms and provide habitat to unique communities of organisms. Locating the seeps with a multibeam can help us target these seeps for ROV exploration of the benthic communities, which can lead to the conservation of critical habitat.

4. Expedition: Shipwreck 15577

Cruise dates	17 July – 25 July 2013
Lead Scientists	Dr. Jack Irion, Bureau of Ocean Energy Management Frank Cantelas, NOAA
Expedition Leader	Dr. Michael Brennan, University of Rhode Island
Operations Leader	Reuben Mills, Ocean Exploration Trust
Principal Investigator	Frederick Hanselmann, Texas State University Meadows Center for Water and the Environment
Area of Exploration	Gulf of Mexico
Country of Operation	United States
Expedition Length	8 days
Main Operations	ROV *Hercules*, ROV *Argus*

Project Description (Authors: Dr. James Delgado, Frederick Hanselmann, Dr. Jack Irion, Chris Horrell, and Frank Cantelas)

The Discovery

In April 2012, the National Oceanic and Atmospheric Administration (NOAA) ship *Okeanos Explorer* conducted the first reconnaissance of shipwreck site 15577 as part of an interdisciplinary exploration mission focusing on deep water hard-bottom habitat, naturally occurring gas seeps, and potential shipwrecks in the Gulf of Mexico. First identified as a side scan sonar target in 2011, the brief remotely operated vehicle (ROV) dive made a truly exciting discovery that will contribute significantly to our understanding of a turbulent period of American history. The shipwreck appears to be an undisturbed, early 19th century, wooden-hulled, copper-clad sailing vessel containing artillery, firearms, navigation instruments, cooking and food storage items, medicines, and personal artifacts.

The sonar target first came to light when Shell Oil notified the Bureau of Offshore Energy Management (BOEM) and the Bureau of Safety and Environmental Enforcement (BSEE),

agencies of the U.S. Department of Interior tasked with overseeing oil and gas exploration and development on the Gulf of Mexico Outer Continental Shelf, that a side scan sonar target resembling a shipwreck had been found in their lease area 90 miles from Flower Garden Banks National Marine Sanctuary some 274 km (170 miles) southeast of Galveston, Texas.

The site lies in 1,330 meters (4,363 feet) of water. The depth and lack of nearby oil and gas industry infrastructure suggested that the vessel might be well preserved. The target imaged in the sonar data collected by Fugro Geosciences revealed a tightly contained site with a sharp hull-formed outline measuring approximately 25 meters (84 feet) long by 7.9 meters (26 feet) wide with indications off one beam of what were thought to be the remains of two masts.

This tantalizing discovery is one of the more significant shipwreck sites discovered in the Gulf of Mexico to date because of its amazing degree of preservation from a critical period in history in which new nations were forming at the end of Colonial era and the Gulf was opening to global trade. As it has not yet been identified, the wreck is referred to as the "Monterrey Shipwreck" after Shell's name for their proposed development.

Further Investigation

In a partnership between the Meadows Center for Water and the Environment at Texas State University and the Ocean Exploration Trust, a team of top-notch archaeologists and other scientists from NOAA's Office of Ocean Exploration and Research and Office of National Marine Sanctuaries, BOEM, BSEE, the Texas Historical Commission (THC) will return to the site. They will conduct detailed documentation and recover a small number of artifacts in order to determine the historical and socio-cultural context within which it operated and, hopefully, also identify the shipwreck. Discoveries and findings will be shared with the general public through a variety of media including telepresence, video streams, and future exhibition, all of which will inform people in the Gulf Coast and the international community about early trade, commerce, and maritime activity in the Gulf of Mexico.

The goal of the project is to systematically study the shipwreck through in-depth documentation, including mapping the site using ROV technology. In addition, the expedition plans to recover artifacts for conservation, analysis, exhibition, future study, and public outreach. As the archaeological assemblage is out of the physical reach of traditional underwater collection and excavation techniques through the use of SCUBA, remotely operated technology will be the tool by which data are collected during field work. The documentation and sampled artifacts will be used to address research questions including, but not limited to, the age, function and cultural affiliation of this vessel. To accomplish this incredibly complex operation, archaeologists will work on board the research vessel *E/V Nautilus* stationed at the surface of the water, 1300 meters (4,300 feet) over the site.

The Monterrey Shipwreck is a mystery. Exactly how old is it? Whose ship was it? How did it sink? What stories can it tell? Can some of those stories link us to specific individuals in the past? Answers come from scientific investigation and, with this shipwreck, the remains of the vessel and the things inside it will hopefully tell their tales. These artifacts – clothing, cooking equipment, weapons, and the ship's own equipment not only provide clues to the identity of the shipwreck, but also tell stories of the crew, the activity that was occurring during that time period, and can allow for further examination of the "big picture" of maritime activity in the Gulf of Mexico by examining this well-preserved "time capsule" of a shipwreck.

Research Objectives

1. Create a detailed, geo-referenced photo-mosaic and micro-bathymetric acoustic map of the site to produce a site plan in order to determine the extent of the site (including any associated debris field), to determine which diagnostic artifacts will aid in interpreting the shipwreck, to accurately place the visible contents of the ship within their relative context, and to map the physical remains of the ship's hull.

2. Obtain a sample of diagnostic artifacts in order to assign a date to the shipwreck. These artifacts will provide clear historical time markers that will aid in determining the age range of the use-life of the vessel, the functional purpose of the vessel (e.g., merchant, privateer, naval, etc.), as well as provide clues to the nationality and cultural affiliation of the vessel.

3. Understand the site preservation processes that have occurred during the wrecking and settling of the wreck, as well as the on-going processes currently active at the site.

4. Conduct related interdisciplinary scientific experiments that will provide additional information regarding the condition of the site as well as its potential as a habitat for benthic biological organisms. Video data collected during the 2012 archaeological reconnaissance showed the presence of a living tube worm within the confines of the hull; a phenomenon never before witnessed in the Gulf of Mexico. The site also does not appear to be near the presence of a hydrothermal seep where these animals are typically found living in symbiosis with chemosynthetic bacteria. Water, sediment and wood samples samples may help archaeologists and biologists determine how this site has become a benthic habitat.

Conclusion

The goals of this project are to bring the best available technology and a highly competent team to solve the mystery of the Monterrey Wreck. What is it? Whose ship was it? Why was it out on these waters? How was it lost? We believe the remains on the sea bed and the work being done offer the best chance to answer these questions.

This will be the deepest shipwreck to be systematically investigated in the Gulf of Mexico. This project is a bold step into a new and emerging frontier for science and in particular for archaeology. It may rewrite history or add clarity to forgotten events in the early history of the Gulf. It will also provide hard data on the deep ocean environment, and how that environment helped preserve this amazing time capsule from some two hundred years ago.

Additionally, the systematic mapping, the video and photographs, as well as other data will be available for study by other archaeologists and ocean scientists. Many reports, scientific papers and publications will result from this project, which is at the forefront of creating standardized methodology for doing deepwater excavation/collection of historic sites with ROV technology.

This project will not only benefit science, archaeology, and history. The images and data, and the detailed maps, as well as the recovered artifacts, will provide an excellent means by which exhibits, popular publications, and educational and public programs will be developed. They will focus on this cutting edge application of technology to underwater research and archaeology, but also on Texas history and the interconnectedness and role of the former Republic, the United States as it expanded in those times, and other states and countries at the cusp of globalization when the world we now live in was coming into being.

5. Expedition: Natural Hydrocarbon Detection ROV/AUV

Cruise dates	28 July – 12 Aug 2013
Lead Scientists	Dr. David Valentine, UC Santa Barbara Dr. Richard Camilli, Woods Hole Oceanographic Institution
Expedition Leader	Dr. Chris Roman, University of Rhode Island
Operations Leaders	Reuben Mills, Ocean Exploration Trust Carl Kaiser, Woods Hole Oceanographic Institution
Area of Exploration	Gulf of Mexico
Country of Operation	United States
Expedition Length	15 days
Main Operations	ROV *Hercules*, ROV *Argus*, *Sentry AUV*

Project Description

Many of the world's offshore marine environments experience prolific natural seepage of hydrocarbons to the seafloor. In the waters off North America alone, natural hydrocarbon seepage is estimated to contribute more than 50 million gallons of oil to marine waters in a year (Oil in the Sea III: Inputs, Fates, and Effects, National Research Council of the National Academies, The National Academies Press, Washington D.C., 2003). Hydrocarbon gas is also emitted from seafloor seeps. It rises through the water as bubble plumes, and is likely a significant source of methane to the atmosphere (e.g. Solomon et al., Nature Geoscience, 2009). Despite the large volume of crude oil and gas released from these seeps, the seepage rates are slow enough that local seep environments support large, specialized communities of underwater organisms. Multiple studies have shown that these communities and their associated chemical and geologic processes are very heterogeneous, and can change significantly from one region of hydrocarbon seepage to another.

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6. Expedition: Cayman Rise

Cruise dates	19 August – 30 August 2013
Lead Scientist	Dr. Cindy Lee Van Dover, Duke University
Expedition Leader	Dr. Katherine Croff Bell, Ocean Exploration Trust
Operations Leader	Reuben Mills, Ocean Exploration Trust
Principal Investigators	Dr. Robert Ballard, Ocean Exploration Trust Dr. Katherine Croff Bell, Ocean Exploration Trust
Area of Exploration	Mid-Cayman Rise Spreading Center
Country of Operation	Cayman Islands, British Overseas Territory
Expedition Length	12 days
Main Operations	ROV *Hercules*, ROV *Argus*

Project Description (Author: Dr. Cindy Lee Van Dover)

The Cayman Rise is a short 100-km-long (62 mile) segment of mid-ocean ridge about 4000 km (2485 miles) removed from the Mid-Atlantic Ridge system that bisects the Atlantic Ocean Basin and is isolated from the East Pacific Rise by the Isthmus of Panama.

This expedition will be one in a series of British, Japanese, and US programs on the Cayman Rise in 2013 and will take advantage of the opportunity to collect samples for analysis of temporal dynamics of biological processes. We will dive on the Von Damm vent field on Mount Dent, on the slopes of Mount Dent, and on other areas of interest with *Hercules* and *Argus* to observe and sample biological and geological systems.

The Von Damm vent field and the Mount Dent Oceanic Core Complex are sites of intense research activity. Their proximity to the US and their location within British territorial waters make them geographically convenient for US- and UK-based field campaigns. We are keen to understand how the vent invertebrates are allied to taxa found at vents on the Mid-Atlantic Ridge and the East Pacific Rise and to invertebrates that colonize seep environments in the Caribbean and Gulf of Mexico.

Expedition Objectives

- Collection of shrimp and gastropods for time-series study of reproductive dynamics and for genetic studies of population structure
- Collection of macrozooplankton and mid-water invertebrates (salps, jellies, etc) above hydrothermal vents to study vertical nutrient flux and pelagic productivity
- Video surveys of time-series stations at vents for study of community dynamics
- Collection of microbes and organisms for carbon-flow studies
- Geological transects across the OCC and miscellaneous samples of rocks
- Vertical transects (4000 meter/13,100 foot relief) to survey/sample corals & invertebrates
- Exploration and sampling of targets identified during the June 2013 R/V Falkor expedition to the Cayman vents
- Artist's sessions, to work with Hercules to collect video for documentary art studies

Background

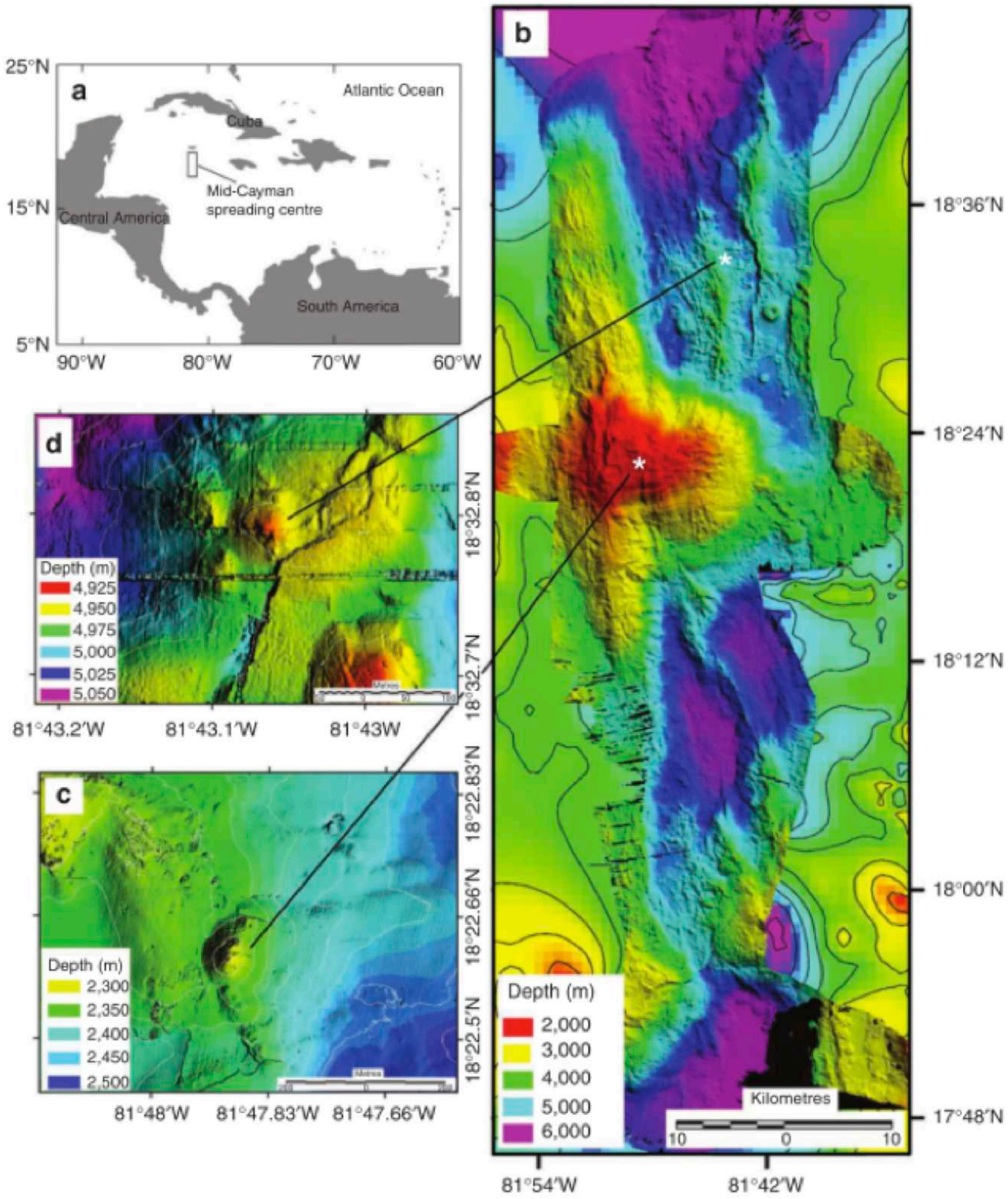
Initial exploration of the Cayman Rise was motivated by the potential for discovery of an extremely deep (5000m/16,404feet) hydrothermal vent expected to have unusual physical and chemical properties important to understanding natural abiotic organic chemistry and by the potential for discovery of new vent species with unusual adaptations on this isolated ridge segment. First evidence for hydrothermal activity on the Cayman Rise was obtained from plume prospecting of the water column along the 100-km (62 mile) length of the spreading center October 2009. Two sites of seabed venting and shrimp-dominated communities — the relatively shallow Von Damm field at 2300m (7545 feet) and the deep Beebee vent field at 5000 m (16,404 feet) — were discovered in March-April 2010. Since these initial discoveries, multiple field programs have been undertaken or are planned for 2013 to build on our understanding of the biological and geological attributes of these vent ecosystems.

The Von Damm vent field situated on the summit (2300m/7545 feet) of the Mount Dent oceanic core complex (OCC) is the primary target for this expedition. An OCC, also called a megamullion, is a dome-like feature (~2500m/8202 foot relief) of lower crust and mantle rock exposed at the seabed by seafloor spreading. The vent field supports an invertebrate fauna comprising taxa allied to those found on Mid-Atlantic Ridge vents and those found at seep sites along continental margins. The slopes of the OCC are ideal for study of the vertical distribution of benthic invertebrate species in the region.

We also plan to use video and other documentary tools to explore and interpret the aesthetics and/or science of deep seascapes. The deep sea is the largest biome on Earth, yet it is rarely visited and interpreted by artists. The arts and humanities deliver a sense of place and perspective; they can express emotion that is absent in technical prose of scientists.

Expected Outcomes

- Histological analysis of reproductive condition and molecular analysis of genetic diversity of samples from different cohorts of shrimp and gastropods at the Von Damm vent field in August 2013 within the context of similar data from samples collected in January 2012 and in January and June 2013
- Quantification of macrozooplankton and mid-water invertebrate distribution in relation to hydrothermal vents and assessment of the contribution of chemosynthetic primary production at the vents to pelagic secondary production
- Quantitative measures of temporal dynamics of invertebrate populations at vents
- Stable isotope analysis of microbes and organisms to race flow of organic carbon in the system
- Increased understanding of the geological context of the OCC through observation of geomorphology and rock types
- Taxonomic classification and vertical distribution maps of large marine invertebrates along 4000-m vertical transects.
- Short clips of edited work in progress suitable for airing and discussing live; a 'field' video art product with narrative; a final video product with narrative suitable for dissemination on the internet and elsewhere.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18°24′N
18°12′N
18°00′N
17°48′N
81°54′W
81°42′W
c
Depth (m)
2,300
2,350
2,400
2,450
2,500
18°22.5′N
18°22.66′N
18°22.83′N
81°48′W
81°47.83′W
81°47.66′W
d
Depth (m)
4,925
4,950
4,975
5,000
5,025
5,050
18°32.7′N
18°32.8′N
81°43.2′W
81°43.1′W
81°43W

7. Expedition: Greater Antilles

Cruise dates	4 October – 18 October
Lead Scientist	Dr. Uri ten Brink, US Geological Survey
Expedition Leader	Dr. Dwight Coleman, University of Rhode Island
Operations Leader	Reuben Mills, Ocean Exploration Trust
Principal Investigators	Dr. Robert Ballard, Ocean Exploration Trust Dr. Katherine Croff Bell, Ocean Exploration Trust
Area of Exploration	Puerto Rico
Country of Operation	Puerto Rico
Expedition Length	14 days
Main Operations	ROV *Hercules*, ROV *Argus*

Project Description (Author: Dr. Dwight Coleman)

We intend to work off the north coast of Puerto Rico, proximal to where a large M7.2 1918 earthquake produced a tsunami that struck northwestern corner of the island. Multibeam bathymetry and additional seismic profiles have identified a large landslide in that area and hydrodynamic models suggest that it could have been the source of the tsunami. This target will be investigated with the *Hercules* and *Argus* ROVs. We will also dive along several transects up the vertical walls of the Mona Rift, which are 4000m (13,123 feet) to 1500m (4921 feet) depth.

The Septentrional fault is the major strike-slip fault taking the oblique motion between the Caribbean and North American plate. Its offshore extension at depths of 1000-2000 m (3280-6560 feet) is clearly observed on multibeam bathymetry. The fault ends in an unusual circular depression, not seen in any major strike-slip fault system around the world. We intend to investigate this feature and other nearby faults north of the island. Fluid flow is highly likely along these faults and the nature of biological communities in the region will be explored. There also may be mud volcanoes along the faults that will be investigated.

Transects across the tilted carbonate platform north of Puerto Rico will provide evidence for slope failure and fissure development within the platform, which are probably induced by fresh water seepage. The platform was horizontal near sea level until 3 million years ago, but its northern edge is now at depths of 2500-4000 m (8202-13,123 feet). The transect can be extended farther north down the 1-1.5 km (.6-.9 miles) thick cliff-like edge of the carbonate platform, which will provide a geological cross-section as well as likely fresh water seepages.

We will also investigate Mona Passage to the west of the island, which is between the Dominican Republic and Puerto Rico. This passage is one of the entry points for surface Atlantic waters that circulate into the Caribbean. The water becomes warmer and saltier in the Caribbean and returns back to the Atlantic via the Gulf of Mexico as the Gulf Stream. Multibeam bathymetry clearly shows flow marks on the seafloor across the shallowest parts of the passage that will be investigated with the ROV to explore the nature of the seafloor and the diversity of biological communities. The passage is crossed by many normal faults that are probably active, but because of current erosion, the surface is cleared of recent sediments. Targeted dives to find pockets of sediments offset by the faults will be sampled and dated.

The 1867 Virgin Islands earthquake and tsunami devastated both St. Thomas and St. Croix. The source of the earthquake is unknown, but using multibeam bathymetry and tsunami modeling the likely fault has been located along a scarp crossing the northern wall of the Virgin Islands Basin. We intend to verify the location and orientation of this fault with direct seafloor observations, because the wall is almost devoid of sediment. This region will also be investigated with a vertical transect across the northern wall of the Virgin Islands basin from depths between 4000 m (13,123 feet) and 50 m (164 feet).

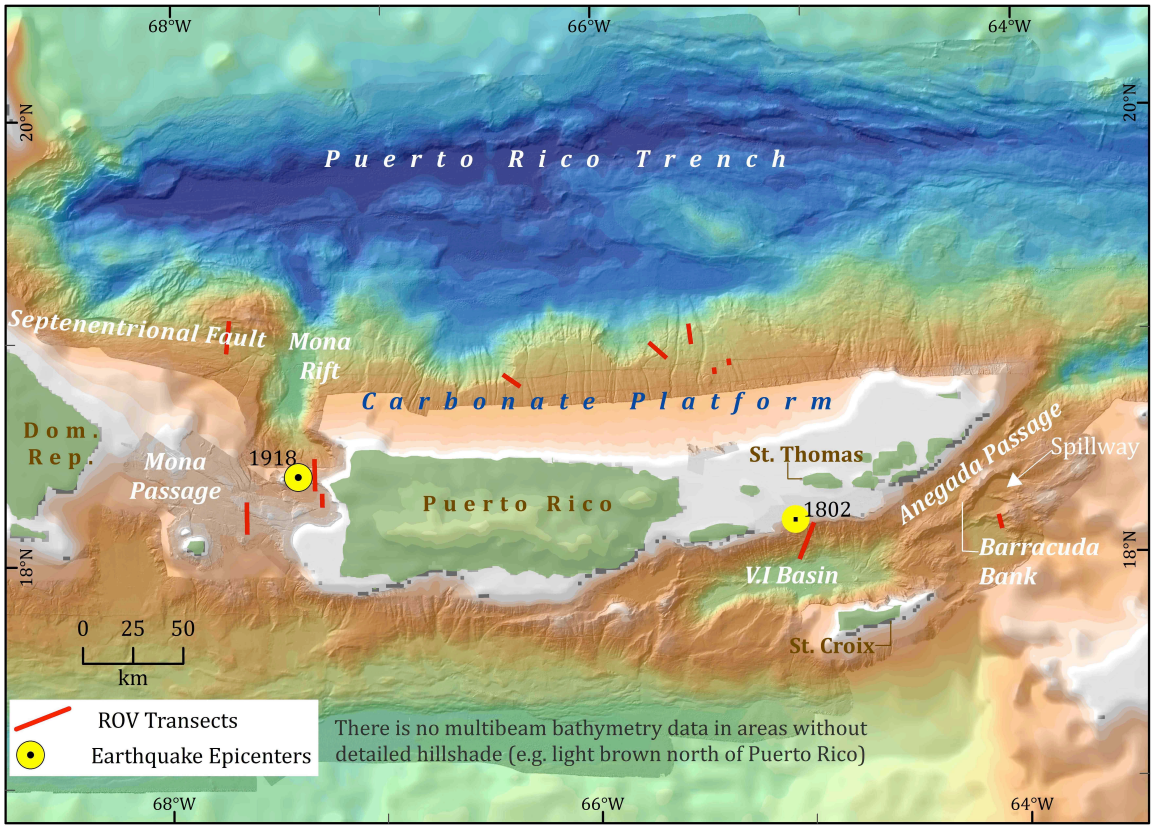
Additionally, there are some faults and mounds on the floor of the Virgin Islands Basin that could focus fluid flow and the biology of these regions will be investigated, sampled and imaged. Anegada Passage, which is mostly in British Virgin Islands EEZ, is the only conduit for Atlantic intermediate water into the Caribbean Sea. All other waters entering the Caribbean Sea from the central Atlantic are surface waters because the other sills are only a few hundreds of meters deep. Most of the intermediate waters were thought to run along the northern wall of the passage but bathymetry and seismic stratigraphy suggest another route and a spillway for the waters farther south. This spillway is bounded by Barracuda bank, a narrow bank, which rises from a depth of 2000 m (6562 feet) to 40 m (131 feet) over 3 km (1.86 miles). The top of the bank is only 1 km (.62 miles) wide and is flat. Nothing is known about the formation of the bank and the possible biological activity on its crest. This region will be explored with the ROV system.

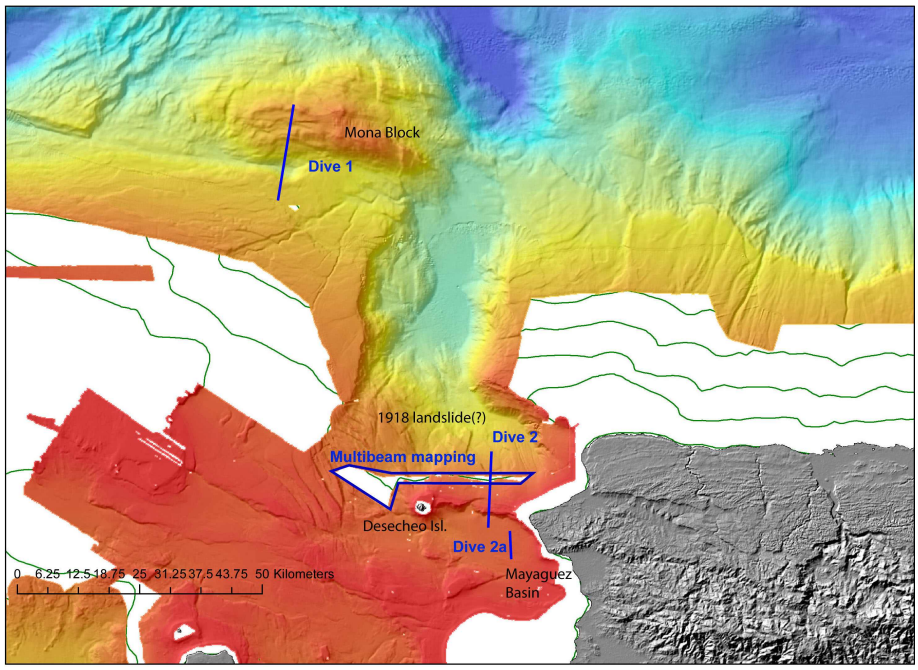
Relevant Background

The USGS has been engaged in Caribbean exploration and research during the past decade. The foundation for this work was established with funding by Ocean Exploration to map the Puerto Rico trench using the multibeam sonar system aboard the NOAA ship Ronald H. Brown. The work received additional boost from Congress following the 2004 Sumatra earthquake and tsunami and has since expanded to include diverse exploration methods such as multichannel seismic reflection, sediment coring, deployment of ocean bottom seismometers to record earthquakes, paleo-tsunami studies, installation of GPS stations, as well as additional multibeam bathymetry mapping.

Mapping of more than 200,000 km^2 (77,220 square miles) of the ocean floor around Puerto Rico and the Virgin Islands was completed with resolution varying from 150 m (492 feet) to 5 m (16 feet) depending on water depth. Analysis and modeling of various data sets, the assembly of historical earthquake catalog, and geophysical modeling followed. The work led to a detailed view of the Caribbean in scales ranging from several hundred kilometer deep upper mantle to a few centimeter thick storm and tsunami deposits. It led to the understanding of many (but not all!) of the geological processes that shaped this part of the world and their associated natural hazards. The work was accomplished in cooperation with other government and academic institutions both within and outside the U.S., including the University of New Hampshire, the NOAA Office of Ocean Exploration and Research, the NOAA Pacific Marine Environmental Laboratory, and the NOAA Biogeography program.

NAUTILUS EXPLORATION PROGRAM





The first two dive sites for the Greater Antilles expedition

Version 2.5 September 23, 2013

8. Expedition: Impact of Volcanic Eruptions on the Seafloor

Cruise dates	21 October – 28 October 2013
Lead Scientist	Dr. Steven Carey, University of Rhode Island
Expedition Leader	Dr. Katherine Croff Bell, Ocean Exploration Trust
Operations Leader	Reuben Mills, Ocean Exploration Trust
Principal Investigators	Dr. Robert Ballard, Ocean Exploration Trust Dr. Katherine Croff Bell, Ocean Exploration Trust
Area of Exploration	Montserrat, Dominica
Country of Operation	Montserrat, Dominica
Expedition Length	8 days
Main Operations	ROV *Hercules*, ROV *Argus*

Project Description (Author: Dr. Steven Carey)

Explosive volcanic activity in the Lesser Antilles island arc (West Indies) produces large quantities of volcanic ash and pumice that is being delivered to the shallow and deep marine environments of the eastern Atlantic Ocean and western Caribbean Sea. In particular, the islands of Montserrat and Dominica have been the source of massive discharges of volcanic material into the sea. Relatively little is known about the direct impacts of this process on the formation of submarine geological deposits and on the fragile marine biological communities that surround the islands.

On Montserrat the Soufriere Hills volcano has been erupting since 1995 leading to evacuation of most of the southern part of the island and leading to a devastating impact to the island's economy. About 1 km^3 of andesite magma has been erupted and much of this material has ended up in the ocean in the form of volcanic ash and debris, mostly through the mechanism of large collapses of the lava dome, often accompanied by great explosions. The material is transported down the slopes of the volcano as hot mixtures of gas and particles that travel at speed in excess of 100 mph, known as pyroclastic flows.

The recent volcanic episode also included a devastating volcanic blast on 26th December 1997 that affected the west flanks of the volcano and razed two villages to the ground, sweeping the houses, their contents, and other objects such as trucks and tractors, into the sea. These events provide a remarkable opportunity for the application of state-of-the-art ocean exploration techniques to understand the dynamics of pyroclastic flows that are discharged into the ocean and their effects on the marine environment.

On this cruise, *Nautilus* will use side-scan sonar surveys and remotely operated vehicles (ROVs) to investigate the area to the southwest, south and east of Montserrat where large quantities of volcanic material has entered the sea. At several locations the discharges of volcanic material have expanded the coastline of Montserrat seaward and added new land.

The main objectives of the work are to define the areas of the seafloor that have been impacted by the volcanic flows and examine the response of the local biological communities. Samples will be collected with the ROV for geochemical analysis in order to fingerprint the source of the volcanic material on the island. Downslope transects with the ROV will be carried out to characterized changes in the nature of the seafloor and associated biological communities as a function of water depth.

In addition, the nature of several unexplored submarine volcanoes southeast and southwest of the Montserrat will be investigated by ROV exploration. These small submarine volcanoes are relatively close to Montserrat and given the recent activity of the Soufriere Hills center it is important to identify other possible locations of future volcanic eruptions in the area. If they have been recently active, these small volcanoes could potentially be the sites of active hydrothermal venting and mineralization.

To the south of Montserrat is the larger volcanic island of Dominica. This island has been the site of some of the largest explosive eruptions in the Lesser Antilles region and has recently been the focus of intense earthquake activity that caused significant alarm on the part of the island's residents. The volcanoes on Dominica have been subject to catastrophic collapse during the evolution of the island resulting in enormous debris avalanches. In general the collapses have been preferentially directed into the Caribbean Sea because of the local tectonics of the Lesser Antilles and the steeper western flanks of the volcanic slopes. These collapse have led to the creation of a highly irregular seafloor dominated by megablocks up to several hundred meters in diameter.

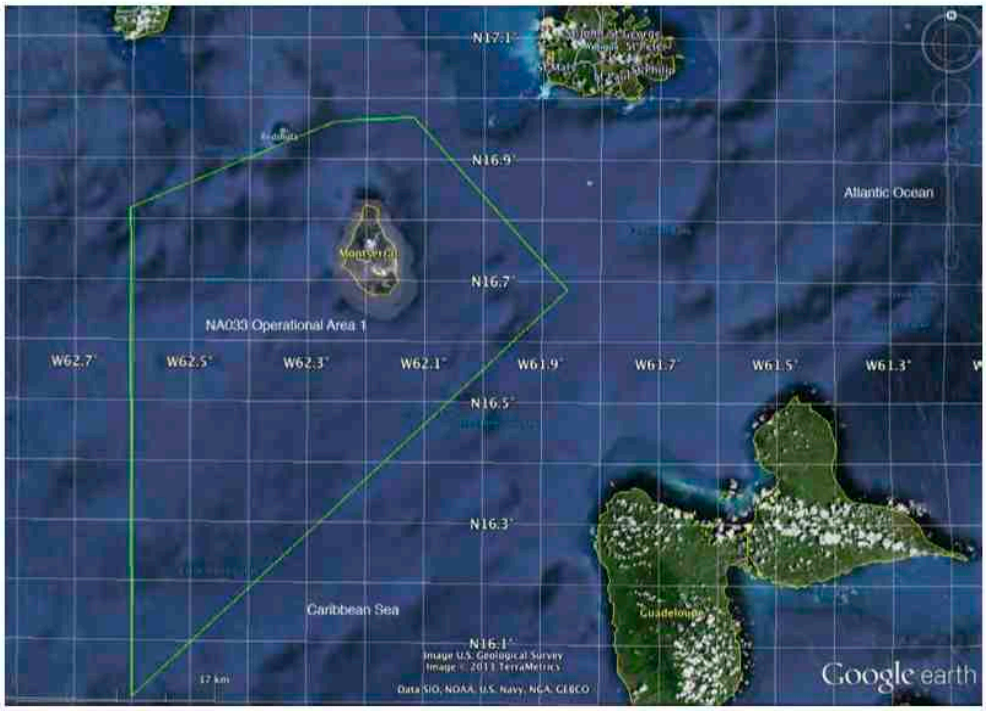
Offshore of Dominica, multibeam mapping and seismic profiling identified at least three major debris avalanches resulting from collapse of the island's western flanks (DePlus et al., 2001). The debris avalanches were recognized based on their distinctive hummocky topography and hyperbolic reflections from 3.5 kHz echosounder data. In the Grenada basin the extent of deposits associated with collapses from Dominica is estimated at 3500 km^2.

No ROV explorations of this area have previously been carried out. *Nautilus* will explore and sample the blocks using ROVs in order to obtain information about the timing of the collapse events and their specific source areas on Dominica. It is anticipated that these megablocks in the deep sea will be site of active biological colonization due to their rugged topography. In addition, ROV exploration will focus on the shallow offshore area of southern Dominica where submarine hydrothermal degassing has been observed and is part of a highly active seismic zone that may represent an area of future volcanic activity.

Previously published research data relating to the project:

1. Hart, K., Carey, S., Sigurdsson, H., Sparks, RSJ, and Robertson, R. (2004) Discharge of pyroclastic flows into the sea during the 1996-1998 eruptions of the Soufriere Hills volcano, Montserrat. *Bulletin of Volcanology* v. 66, 599-614.
2. Trofimovs, J. et al., 2006. Submarine pyroclastic deposits formed at the Soufriere Hills volcano, Montserrat (1995-2003): What happens when pyroclastic flows enter the ocean? Geology, .v 34 (7), p. 549-552.
3. Deplus, C., LeFriant, A., Boudon, G., Komorowski,J.C., Villemant, B., Harfod, C., Segoufin, J. and J.L. Cheminee, (2001). Submarine evidence for large-scale debris avalanches in the Lesser Antilles arc. *Earth Planet. Sci. Lett.*, vol., 192, 145-157.
4. Lindsay, J., Stasiuk, M. and Shepherd, J. (2003). Geological history and potential hazards of the late-Pleistocene to Recent Plat Pays volcanic complex, Dominica, Lesser Antilles. *Bull. Volc.*, v. 65, p. 201-220.
5. Le Friant, A., Harford, C.L., Deplus, C., Boudon, G., Sparks, R.S.J., Herd, R.A., and Komorowski, J.C., (2004) Geomorphological evolution of Montserrat (West Indies): Importance of flank collapse and erosional processes: *Geological Society [London] Journal*, v. 161, p. 147–160.

A.



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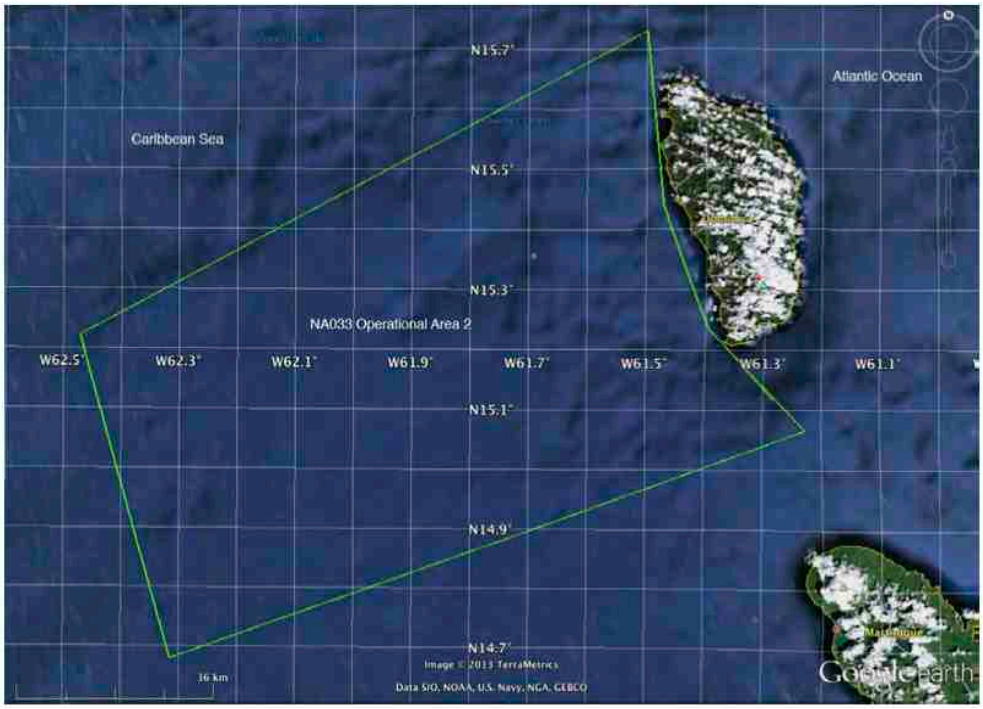


Maps showing the locations of the operational areas in the waters of a) Montserrat and Antigua and b) Dominica

9. Expedition: Kick'em Jenny & Trinidad Tar Seeps

Cruise dates	1 November – 16 November 2013
Lead Scientist	Dr. Steven Carey, University of Rhode Island
Expedition Leader	Dr. Katherine Croff Bell, Ocean Exploration Trust
Operations Leader	Reuben Mills, Ocean Exploration Trust
Principal Investigators	Dr. Robert Ballard, Ocean Exploration Trust Dr. Katherine Croff Bell, Ocean Exploration Trust
Area of Exploration	Kick'em Jenny Volcano & Trinidad Tar Seeps
Countries of Operation	Grenada
Expedition Length	16 days
Main Operations	ROV *Hercules*, ROV *Argus*

Project Description (Author: Dr. Steven Carey)

Kick'em Jenny is the most active and dangerous submarine volcano in the Caribbean Sea (Devine and Sigurdsson, 1995). During the past century it has shown a history of progressive growth with explosive eruptions that pose hazards to the local island populations of the Lesser Antilles (e.g. Dondin et al., 2012). Specific hazards include explosive eruptions that can breach the sea surface and the potential for tsunamis generation from shallow water explosions or edifice collapse (Lindsay et al., 2005).

Kick'em Jenny is located on the western flank of the Lesser Antilles arc, just offshore of the island of Grenada. The volcano was discovered in 1939, when numerous earthquakes were felt, and tsunamis affected Grenada, the Grenadines, and reached as far as Barbados. An explosive eruption broke the surface and produced ash-laden columns that reached up to 300 m (984 feet) above the sea surface (Devas, 1974). There have been at least eleven eruptions since that event, and some of them have caused disturbances at the surface and minor tsunamis.

A reconnaissance survey in 1962 showed that the depth to the crater rim was 223 to 232 m (731-761 feet). The depth decreased as a result of each successive eruption, reaching a minimum of 160 m (525 feet) by 1978. The first detailed survey of the volcano in 1972 revealed a 1300 m (4265 foot) high conical structure, constructed on the western flank of the arc. The summit crater was found to be at a depth of 190 m (623 feet) and approximately 180 m (590 feet) in diameter. Two prominent 70 to 150 m (230-492 foot) high west-facing scarps east of the volcano were identified as north-trending normal faults, defining the shelf break of the west flank of the arc. The 1977 eruption resulted in significant shoaling of the volcano's summit to 160 m (524 feet) and this area was more dome-shaped rather than a distinct crater.

The first multi-beam survey of the volcano in 1985 confirmed the earlier findings, but showed that the region between the volcanic cone and the Grenada Basin to the west is one of rather irregular topography. Submersible dives in 1989, a few months after the 1988 eruption, revealed that the volcanic cone consisted of both pyroclastic deposits and pillow-like lava flow units. Abundant and thick layers of bacteria surrounded the crater rim and draped the crater walls. They consisted dominantly of proteobacteria, such as the filamentous sulfur-oxidizing bacterium *Thiotrix* as well as *Beggiatoa* bacteria, that probably have a chemosynthetic dependency on sulfur species emanating from the crater and the sulfur present in the young volcanic deposits after the recent eruption.

The first investigation of the volcano following the December 2001 eruption was a 2003 multi-beam survey by the NOAA research vessel *Ronald H. Brown*. The survey yielded a high-resolution image of the volcano and surrounding region, revealing new details regarding its structure. The most striking feature is an arcuate west-facing scarp that surrounds much of the volcanic cone to the south, west, and north. The new data shows that the Kick'em Jenny volcanic cone is located inside a major 5 km wide horse-shoe shaped and west-facing depression that most likely was formed by slope failure and associated debris avalanche.

ROV explorations of the crater floor found high temperature (>250° C) venting of fluids and gases, along with the discovery of new species of vent specific worms (Wishner et al., 2005). Venting of fluids is occurring within a small depression nested within the main crater of the volcano. The inner crater is covered with fine-grained sediment and vigorous gas plumes were found by ROV surveys in 2003. The nature of the gas being discharged is unknown but likely contain high contents of carbon dioxide, like most other degassing arc volcanoes, and if so, there is the possibility that local acidification of bottom waters could be occurring in the inner crater, making this an interesting area for interdisciplinary chemical and biological studies.

This expedition will conduct ROV exploration and mapping of Kick'em Jenny volcano. Samples of volcanic rocks and gases will be collected for geochemical analysis and high resolution mapping of the crater floor will be carried out to define the nature of the active hydrothermal system. ROV explorations will be extended into the Grenada basin in order to examine a large

debris avalanche deposit that is likely associated with an ancestral Kick'em Jenny volcano. SEABEAM mapping during the 2003 cruise of the *R/V Brown* also revealed the existence of five small volcanoes that were previously unknown in the area. Three are conical in shape with well-defined craters, whereas two have a dome-like morphology. One of the cones, provisionally named Kick'em Jack, is similar in size to Kick'em Jenny and exhibits a horse-shoe shaped crater with an interior dome. The discovery of these new craters raises many questions about the magmatic system feeding this area. Are there multiple magma chambers and sources for these different centers or are they related to a central feeding system? From a hazards perspective it is important to know whether these centers have been recently active or are they mostly dormant. New ROV explorations during this expedition will examine and sample these largely unexplored volcanic centers.

To the south of Grenada lie the islands of Trinidad and Tobago, home to some of the largest marine gas and oil production fields in the Caribbean Sea. In the Gulf of Paria and to the east of Trinidad, areas of the seafloor are suspected to contain natural petroleum and methane seeps. Within hydrocarbon-rich environments such as seeps, numerous oil degrading bacteria have been identified which may utilize the hydrocarbons as a source of energy, and serves as a supplementary food source for meio- and macro-benthic organisms in shallow water.

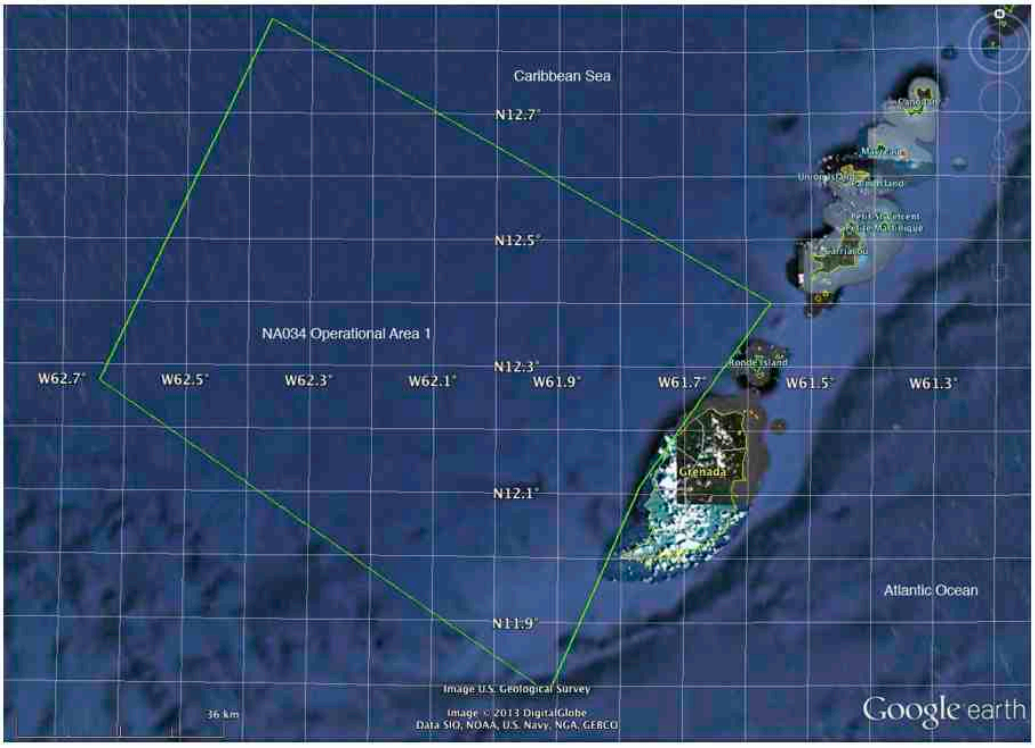
Part of this expedition will conduct mapping and ROV exploration of areas with potential methane/petroleum seeps and mud volcanoes in search of diverse micro and macro biological communities. The ultimate goal of this exploration would be to provide critical data such as: marine geological observations on the seabed character and distribution of sediments, and biodiversity (fauna and flora) and distribution assessments. Such data can be integrated to map biotopes using seabed faunal assemblages overlaid with seabed habitats (sediments and/or geological structures). This type of seabed characterization that documents unique interactions between the marine ecosystems and geological environment will be useful in order to guide future coastal and marine management decisions for Trinidad and Tobago.

Previously published research data relating to project:

1. Devas, R.P., 1974. A history of the island of Grenada, 1498-1796. Carenage Press, Grenada.
2. Devine, J, and Sigurdsson H (1995) Petrology and eruption styles of Kick'em Jenny submarine volcano, Lesser Antilles island arc. *J Volcanol Geotherm Res* 69:35–58.
3. Dondin F., et al. (2012). Sector collapse at Kick'em Jenny submarine volcano (Lesser Antilles): numerical simulation and landslide behavior. Bull Volc., v. 74, p. 595-607.
4. Lindsay JM, Shepherd JB, Wilson D (2005) Volcanic and scientific activity at Kick 'em Jenny submarine volcano 2001–2002: implications for volcanic hazards in the Southern Grenadines, Lesser Antilles. *Nat Hazards* 34:1–24.
5. Wishner, K., Graff, J., Martin, J., Carey, S., Sigurdsson, H. and B. Seibel (2005). Are midwater shrimp trapped in the craters of submarine volcanoes by hydrothermal venting? *Deep-Sea Research*, v. 52, 1528-1535.

NAUTILUS EXPLORATION PROGRAM

A.



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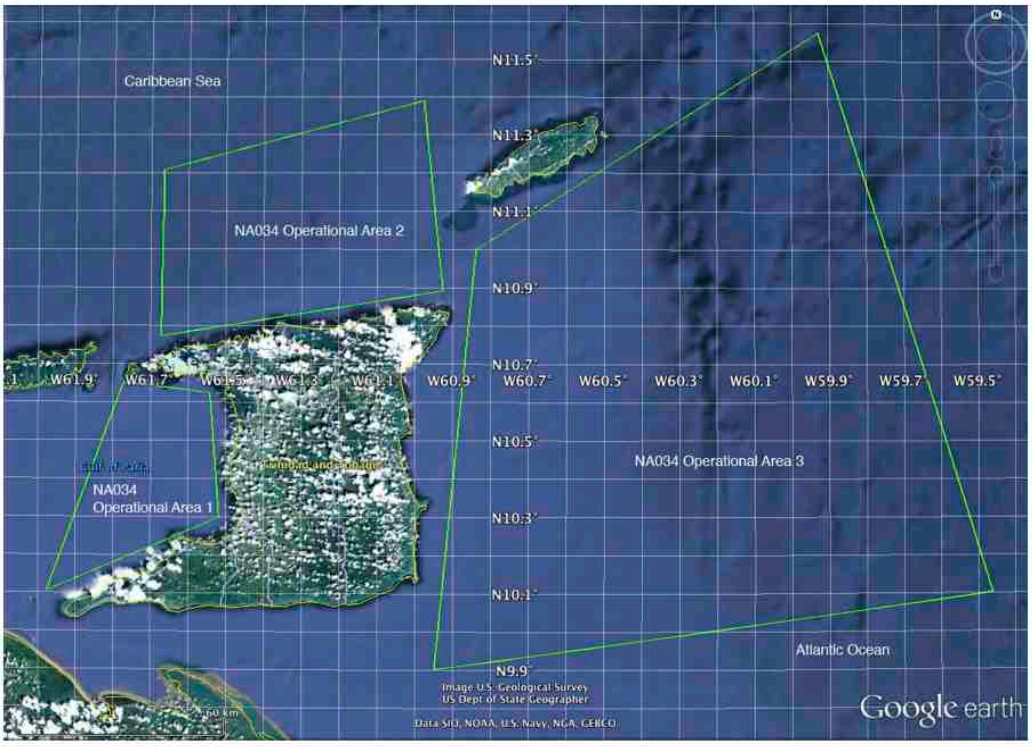
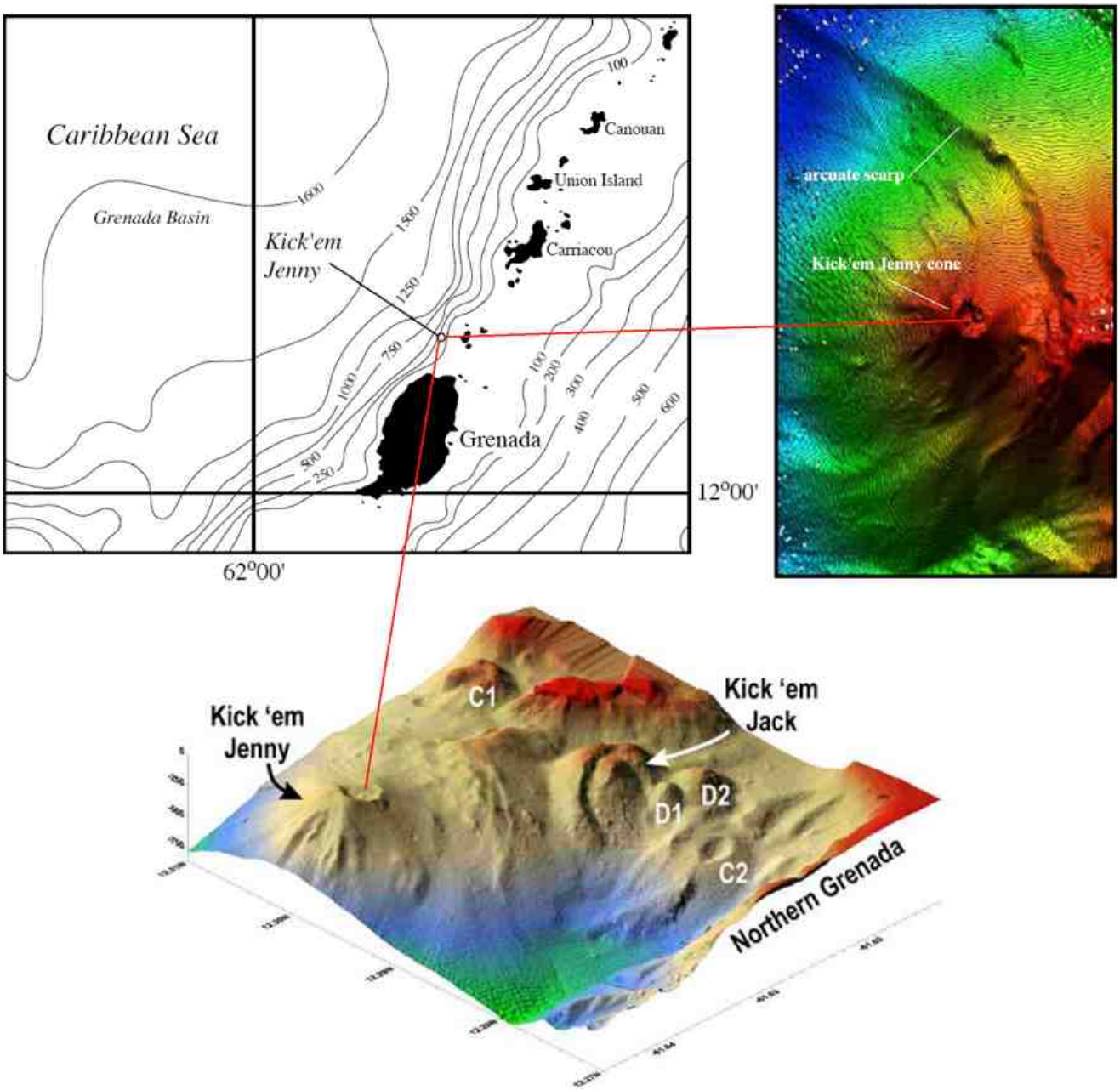


Maps showing the locations of the operational areas in the waters of a) Grenada and b) Trinidad & Tobago

Version 2.5 September 23, 2013

NAUTILUS EXPLORATION PROGRAM



10. Equipment & Technology

Exploration Vessel Nautilus is equipped with some of the latest technological systems, helping to advance the frontiers of ocean exploration. Primary capabilities include science class remotely operated vehicles (ROVs), high-resolution seafloor mapping, and real-time satellite transmission of data.

Systematic exploration consists of a tiered approach of information gathering in geographic regions about which we know little or nothing, but where there is high potential for discovery. The first step involves studying large areas of unknown or poorly known ocean regions using sonar mapping systems. *Nautilus* currently uses side scan sonar systems on two towfish, *Diana* and *Echo*, for seafloor mapping, and we recently installed a new hull-mounted multibeam sonar this past winter. Water column properties may also be surveyed using CTDs and other towed sensor packages to record salinity and temperature at depth.

In the second tier of exploration, resulting data are used to identify areas of further interest to be explored using our ROVs, *Hercules* and *Argus*. The objective is to explore, locate and describe new habitats, geological processes, cultural sites, and unknown phenomena, establishing a rich foundation of information to catalyze further scientific efforts.

As the Corps of Exploration aboard *Nautilus* conduct operations at sea, satellite technology is used to transmit video, sensor and audio data to shore in real time. These high-definition data streams are transmitted via high bandwidth Internet-2 to the expedition's "mission control" at the Inner Space Center (ISC), located at the University of Rhode Island's Graduate School of Oceanography. The feed is also transmitted to other shore-based Exploration Command Centers (ECCs) developed in strategic locations around the U.S. and in other parts of the world.

A standard definition version of the live video from the ISC is then transmitted via standard Internet so that scientists, students and the general public can participate in the investigation of the unexplored deep ocean simultaneously with *Nautilus*-based teams via www.nautiluslive.org. These new high-speed, real-time links to shore provide a unique opportunity for the inclusion of participants from diverse communities who may not otherwise be involved in oceanographic exploration, including scientists, engineers and learners of all ages from around the world.

NAUTILUS EXPLORATION PROGRAM

Exploration Vessel (E/V) *Nautilus*

Length	64.23 meters (211 feet)
Beam	10.5 meters (34.5 feet)
Draft	4.9 meters (14.75 feet)
Tonnage	1249 gross, 374 net
Main Propulsion	Single 1286 kw (1700 HP), controllable pitch
Speed	10 knots service, 12 knots maximum
Endurance	40 days
Range	24,000 kilometers (13,000 nautical miles)
Dynamic Positioning	300kW azimuthing jet-pump (stern), 250kW tunnel (bow)
Classification	Germanischer Lloyd (GL) 100 A5 E1 (Ice Strengthened)
Built	1967, Rostock, E. Germany
Formerly	Alexander von Humboldt (East German research vessel)
Berthing	48 persons (17 crew; 31 science/operations)
Flag	St Vincent and the Grenadines
Communication Broadcast	C-band satellite communications, 18 mbps (HD video)
Call sign	J8B3605

Shipboard Exploration Technology

Remotely Operated Vehicles (ROVs)

E/V Nautilus has two shipboard remotely operated vehicles (ROVs) named *Hercules* and *Argus* that work in tandem. This *Hercules* and *Argus* system is a state-of-the-art deep-sea robotic laboratory capable of exploring depths up to 4,000 meters (13,123 feet). Each of the ROVs has its own suite of cameras and sensors that receive electrical power from the surface through a fiber-optic cable, which also transmits data and video. Engineers and scientists control the vehicles from a control room aboard *Nautilus*, with some dives lasting more than three days. The system is a versatile tool capable of supporting a wide range of oceanographic instrumentation and sampling equipment. They have surveyed ancient shipwrecks, discovered hydrothermal vents, and explored habitats in oceans and seas around the world.

| ROV *Hercules*

ROV *Hercules*

Since it was first launched in 2003, *Hercules* has been working in tandem with *Argus* to explore the geology, biology, archaeology, and chemistry of the deep sea. *Hercules* is equipped with a high-definition video camera, four HMI lights, two manipulator arms, and a variety of oceanographic sensors and samplers, including a suite of high-resolution mapping tools. *Hercules* weighs about 5,200 lbs in air and can deliver approx. 150 lbs of samples or tools to and from the seafloor.

For more information about our vehicle systems, you may contact our Director of Operations, Reuben Mills, at reuben@oceanexplorationtrust.org.

ROV *Argus*

Argus was first launched in 2000 as a deep-tow system capable of diving as deep as 6000 meters (19,685 feet). *Argus* is now typically used in tandem with *Hercules*, where it hovers several meters above in order to provide a bird's-eye view of *Hercules* on the seafloor. It is also capable of working as a stand-alone system as a towed-body instrument for large-scale deepwater survey missions.

Towfish *Diana*

Diana is an Edgetech 4200 HF side-scan sonar towfish that uses dual frequencies with a range of approximately 200 meters (650 feet) on either side. The *Diana* system is capable of being towed to a depth of 2000 meters (6562 feet), but is currently limited by cable length to a working depth of 600 meters (1970 feet). *Diana's* transducers can also be installed on the Argus towsled, which increases the towing depth to a maximum of 4000 meters (13,123 feet).

Towfish *Echo*

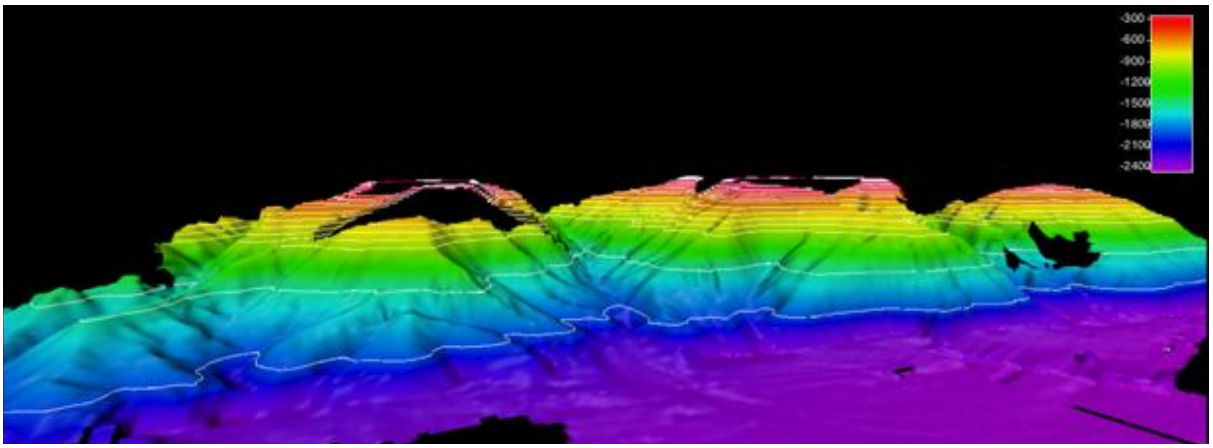
Echo is a five-channel Benthos deep-tow side-scan sonar system rated to 3,000 meters (9,842 feet) water depth. Echo's operating frequencies are 100 and 400 kHz, which cover a total swath width up to 1,000 meters (3280 feet). Echo is also equipped with a Chirp 2-7 kHz subbottom profiler that permits identification of subseafloor features.

Kongsberg EM 302 Multibeam Echosounder

E/V Nautilus recently installed a new hull-mounted Multibeam echosounder for efficiently mapping the seafloor. The EM 302 is a 30 kHz multibeam echosounder composed of two long transducer arrays mounted in a T-shape on the hull of *EV Nautilus.* The ship is now capable of mapping the seafloor from 10 to 7000 meters (33 – 22,965 feet) water depth as the ship cruises at 8-10 knots.

The multibeam echosounder collects bathymetric, surface sediment characteristic, and water column data. The information it collects is useful for identifying areas or features of interest; creating bathymetric charts for ROV dive planning and situational awareness; and locating hydrothermal vents and gas or oil seeps.

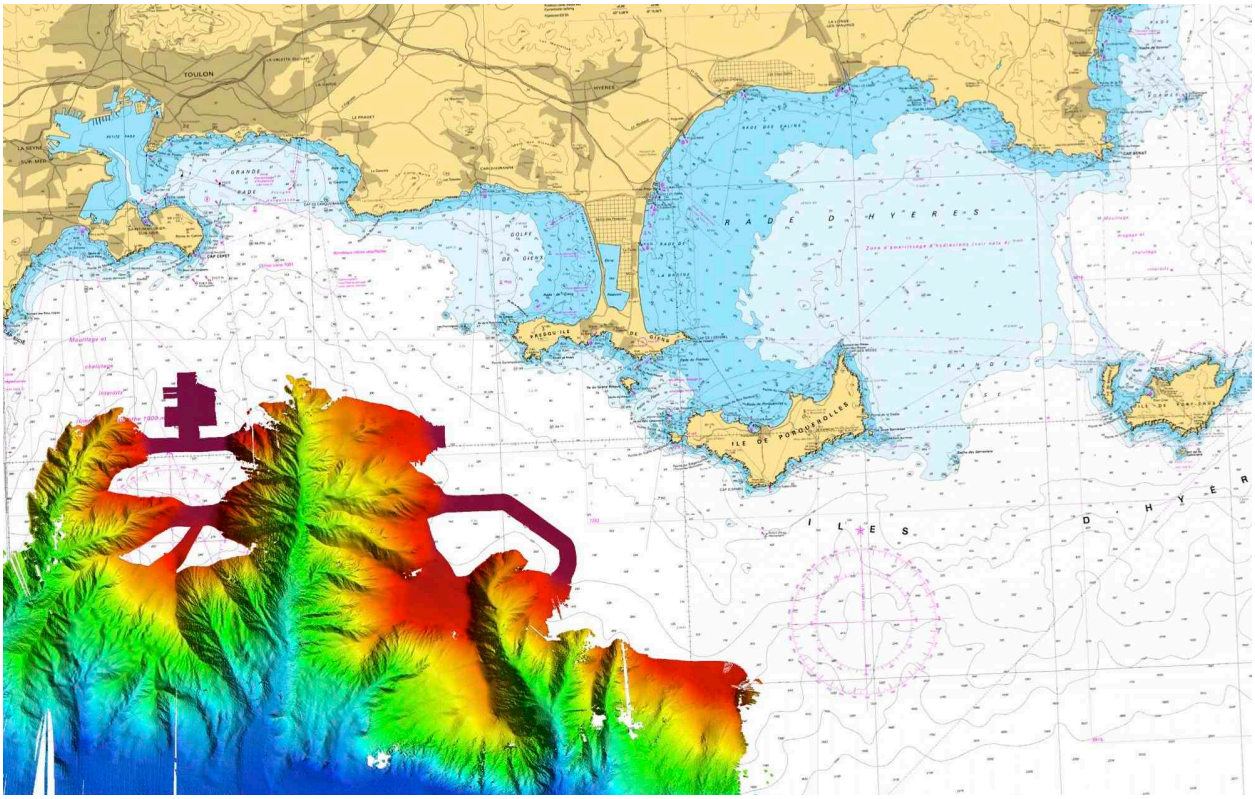
Below is bathymetric data from the EM 302 during its trial run in Toulon Canyon, France.



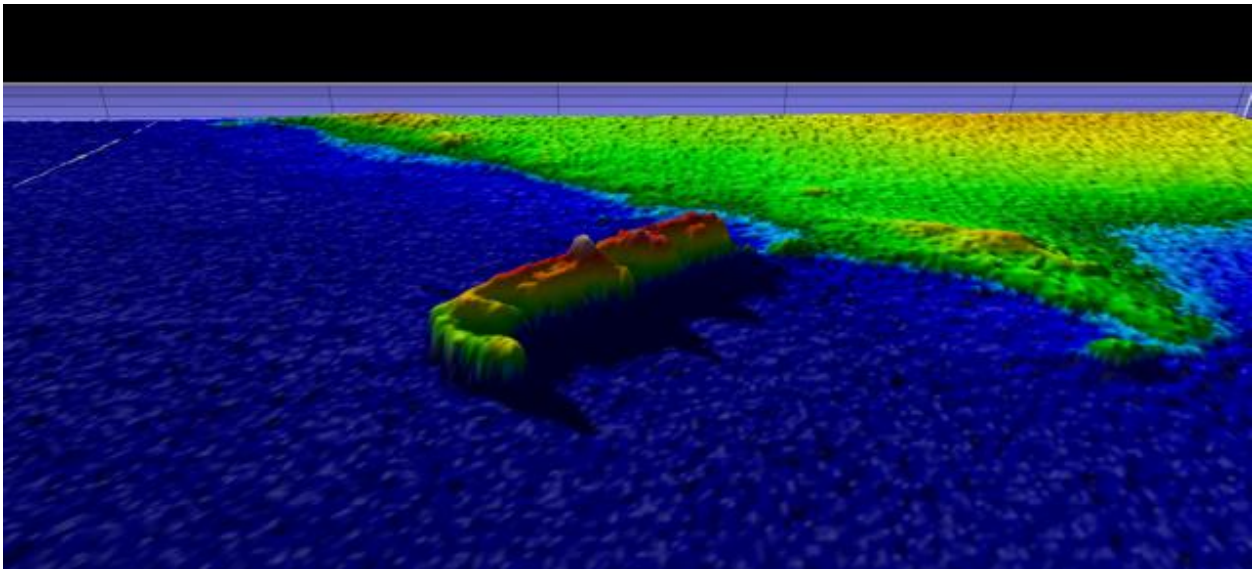
Knudsen K3260 Sub-bottom Profiler

The K3260 is a sub-bottom echosounder mounted inside the hull of *EV Nautilus*. The echosounder operates at low frequencies (3.5-210 kHz) allowing sound to penetrate the layers of sediment. This creates a cross-section of the seafloor, revealing the structure of the sub-surface geology. Scientists can use the data to identify ancient features including channels, faults, and levees. The K3260 can operate in full ocean depths.

NAUTILUS EXPLORATION PROGRAM



EM 302 Sea Acceptance Trial in Toulon Canyon, France in Spring 2013



Shipwreck imaged with the EM 302 near France

11. Communications & Telepresence

Telepresence Systems

Telepresence technology enables real-time participation in ocean exploration expeditions from shore. EV *Nautilus* is equipped with a satellite dish that allows us to send data and video back to our "mission control" at the Inner Space Center in real-time while our Corps of Exploration is investigating the seafloor. The application of telepresence technology for ship-based work is extremely efficient as it permits unlimited access to personnel on shore, transcending schedules, expertise, skills, and abilities of traditional shipboard teams.

Telepresence also enables the development of partnerships between geographically dispersed groups who otherwise might not have the opportunity to collaborate due to cost or logistics, and ultimately allows for the most efficient use of all resources, as access to data and information between ship and shore is immediate and sustained for the duration of an expedition. It also allows our Corps of Exploration aboard *Nautilus* to confer with our "Doctors on Call" – Ph.D. scientists on shore who specialize in the areas our team at sea is exploring.

Telepresence Reach 2010 – 2012

Since the Nautilus Exploration Program started streaming our undersea exploration live to shore in 2010, we have reached millions of participants all over the world.

- We have spent a total of **10 months** at sea
- Nearly **55,000 people** have participated in Live Events through our partner aquariums, museums, schools, and afterschool programs
- Nearly **200,000 viewers** from **173 countries** have watched Nautilus Live and have asked our Corps of Exploration at sea more than **40,000 questions** through the website
- **1.5 million** schoolchildren participate annually in JASON Learning, our partner in providing education through exploration
- More than **5 million** people have been reached through press coverage of *Nautilus*
- **15,000,000 viewers** watched our episode of *60 Minutes* in 2010
- An estimated **20,000,000+ viewers** watched our 5-part ocean exploration series, *Alien Deep with Bob Ballard*, on National Geographic Channel that aired in 2012

Exploration Now

Exploration Now is a 24-hour exploration newsroom providing live coverage of ocean exploration from around the world accessible to the general public at www.explorationnow.org (site in progress). Exploration Now allows our audience to experience once in a lifetime discoveries as they happen in real time. It brings the general public one step closer to joining our Corps of Exploration and other explorers on board EV *Nautilus* and other research vessels as they explore all over the world. This interactive initiative is a collaboration of non-profits, educational institutions, research centers, aquariums, and science centers across the United States and around the world. Our live interactive feed, Nautilus Live, is brought to you by Exploration Now and brings live video from the depths of the ocean and interactive shows from the field to a global audience of armchair explorers at home and children and families at aquariums, science centers, schools, and Boys & Girls Clubs.

The main homepage of Exploration Now will serve as an operational dashboard, showing the locations of all of our exploration projects around at the globe, as well as live streaming video feeds from active expeditions, recent highlight videos, and news briefs from the Exploration Now Production Studio.

Although its initial coverage is focusing on ships at sea around the world using underwater vehicles in real-time, in future years Exploration Now will expand its coverage to include ocean explorers using a variety of other tools including mid-water gliders, divers exploring corals reefs and underwater cave systems; and ocean bottom monitoring networks. Exploration Now will also expand to include terrestrial explorers in remote parts of the world from mountaintops to tropical rain forests.

Exploration Now is physically based at the Center for Ocean Exploration in the Inner Space Center at the University of Rhode Island's Graduate School of Oceanography. Live broadcasts and interactive programming will be distributed by the dedicated Exploration Now and Nautilus Live websites and a network of Ocean Exploration Centers, including aquariums, science centers, and schools. Audiences at our Ocean Exploration Centers will have the opportunity to interact live with our Corps of Exploration and other explorers while they are in the field making new discoveries via Nautilus Live.

Exploration Now and Nautilus Live activities include:

- Hourly updates on the Exploration Now website
- Daily live Q&A interactions with audiences at partner educational institutions, such as the Mystic Aquarium, Titanic Belfast Museum, Houston Museum of Natural Science, Texas State Aquarium and Aquarium of the Pacific
- Daily chat sessions with experts at sea aboard active vessels or ashore at Mission Control

Shore-Based Centers

Exploration Centers

Our suite of Exploration Centers includes Exploration Command Centers (ECCs), Exploration Learning Centers (ELCs), and Ocean Exploration Centers (OECs). These Exploration Centers are installations at educational, scientific and academic institutions that stream high-bandwidth video, audio, and data. This Exploration Now network allows scientists, engineers, and students to participate in expeditions in the field in real time.

Exploration Centers are modeled after the ship's Command Center and the Inner Space Center and can accommodate any audience size, location, and educational or research focus.

- **Ocean Exploration Centers (OECs)** are geared toward large, high-traffic audiences at museums, aquariums, and science centers, such as at the Ocean Exploration Center in Mystic Aquarium's Nautilus Live Theater.
- **Exploration Learning Centers (ELCs)** are smaller, more intimate installations for schools and after-school programs, such as the Boys & Girls Clubs.
- **Exploration Command Centers (ECCs)** are located at universities and research institutions world-wide, and allow for shore-based scientific participation in oceanographic expeditions, as well as undergraduate and graduate education, such as the ECC at the NOAA Pacific Marine Environmental Laboratory.

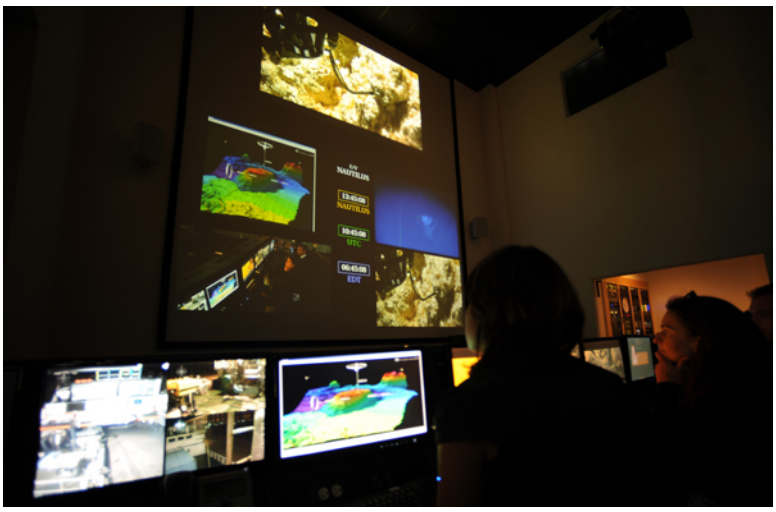
OEC Highlight: Nautilus Live Theater

The Nautilus Live Theater is our premier Ocean Exploration Center (OEC) venue. This state-of-the-art theater space is located at the Mystic Aquarium in Mystic, Connecticut. Aquarium visitors can learn about EV *Nautilus* and other live expeditions by virtually joining Dr. Robert Ballard's Corps of Exploration aboard *Nautilus* through live video feeds and interactions. The Nautilus Live Theater is located in the Ocean Exploration Center at Mystic Aquarium, home of the *Titanic - 12,450 Feet Below* exhibit.

During our 2013 Nautilus Exploration Program expedition season, the Nautilus Live Theater hosts multiple daily theater shows that include an expedition presenter guiding audiences through recent dive highlights, expedition maps, current live video feeds and live interactions with the Corps of Exploration aboard *Nautilus* and other vessels.

Mission Control: The Inner Space Center

The Inner Space Center (ISC) at the University of Rhode Island Graduate School of Oceanography serves as the shore-based telepresence hub or "mission control" for multiple ships of exploration, including E/V *Nautilus*. The ISC facility is connected to Internet2, which permits high bandwidth streams of video, audio, and data to flow from the ship to shore where it is captured, displayed and disseminated in real time. The Inner Space Center also hosts teams of scientists and engineers at the facility during operations, so they can communicate with their counterparts at sea and monitor the expedition in real time.



| Inner Space Center

Exploration Now Production Studio

The Exploration Now production studio at the Center for Ocean Exploration at the University of Rhode Island serves as the brick-and-mortar home of Exploration Now. The Exploration Now studio is the interactive hub of our live broadcasts and ensures that our explorers in the field connect every day with audiences around the world at science centers, aquariums and museums. Our Exploration Now production team also produces daily news updates, provides the latest information on new discoveries and events, and creates highlight videos of recent exciting dives. When our explorers are not actively in the field, the Exploration Now broadcast studio hosts explorers on shore for live interactions, including scientists, engineers and educators who have sailed aboard *Nautilus* and other research vessels.

For more information about Exploration Now, you may contact our Exploration Now Executive Producer, Scott Munro, at scott@oceanexplorationtrust.org.

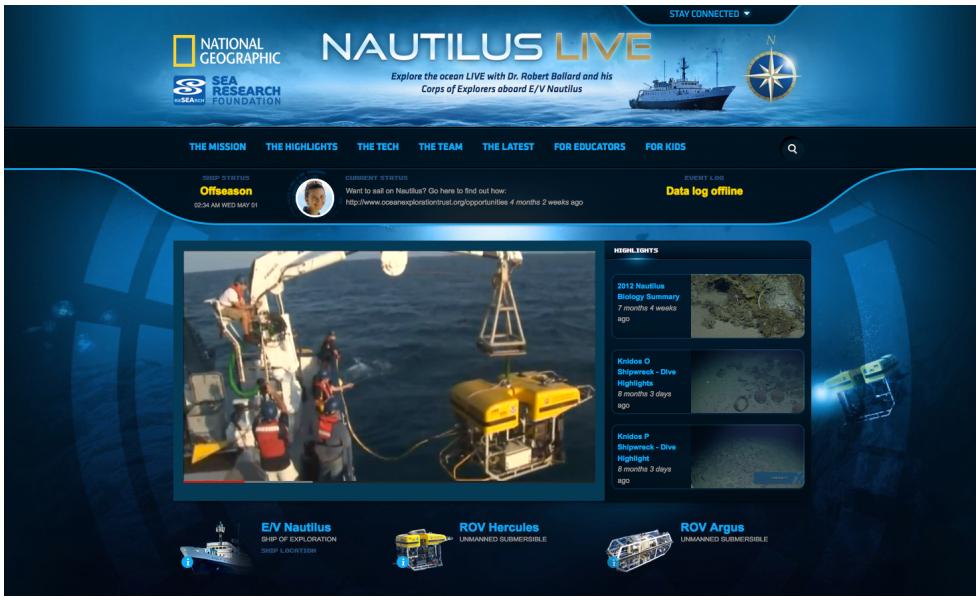
Web-Based Communications

Exploration Now Website

The Exploration Now website (http://www.explorationnow.org) provides web access to live video feeds coming from multiple ships and expeditions 24/7 365 days a year.

Nautilus Live Website

The Nautilus Live website (http://www.nautiluslive.org) provides web access to live video feeds coming from the ROVs and shipboard cameras on *Nautilus* to the Inner Space Center. The website provides a fuller picture of *Nautilus* exploration by surrounding the live feeds with supplemental information about the expedition, including live news updates and audio commentary from the Corps of Exploration. The site also displays the status of operations, including a location map, and a constantly updating display of the notes that are being recorded by the science team. Photos and highlight videos are updated on the site daily during operations.



| Nautilus Live Website

Nautilus Live Social Media

The Corps of Exploration aboard *Nautilus* and at the Inner Space Center keep in touch with Nautilus Live viewers through a dedicated Facebook page, Twitter feed and YouTube channel.

12. Education Programs

The Nautilus Exploration Program field season offers students and educators many opportunities to get involved, both directly and indirectly, in ocean exploration. Live-access exposure to actual shipboard research activities where exciting discoveries are made can be a key contributor to engaging educators, students and families in learning about science, technology, engineering and mathematics (STEM) subjects. In addition to its role as a platform for innovation in technology and ocean exploration, the Nautilus Exploration Program's field season provides a unique opportunity for developing an array of education and outreach programs to engage and inspire people of all ages.

The Nautilus Exploration Program provides multiple opportunities for hands-on experience aboard E/V *Nautilus*, other vessels, and at the University of Rhode Island. Our Honors Research Program is available to junior and senior high school students for an authentic research experience both at sea and ashore. Various at-sea internships in science and engineering are available for undergraduate and graduate students. Our Educator at Sea Science Communications Fellowship Program is available for formal and informal educators interested science communications. Selected applicants become members of our Corps of Exploration for 2013 and most will have the opportunity to work aboard *Nautilus* or another vessel for a 2-4 week period. All participants engage in education and outreach activities.

The Ocean Exploration Trust's educational programs are developed and executed in partnership with several organizations, including Bechtel, the Office of Naval Research, Sea Research Foundation (SRF), National Geographic Society (NGS), and the University of Rhode Island Graduate School of Oceanography.

For more information about the Ocean Exploration Trust's Education Programs, you may contact our Director of Education, Allison Fundis, at allison@oceanexplorationtrust.org.

Shipboard Education Programs

Science and Engineering Internship Program

The Ocean Exploration Trust's Science and Engineering Internship Program aims to train undergraduate and graduate students studying ocean science, engineering and video/film in the at-sea environment. Intern positions entail 2-5 week periods working aboard E/V *Nautilus* and other vessels as Data Loggers, ROV Pilots, or Video Engineers. All of our interns spend their time at sea working with a wide array of scientists, engineers, students, and educators. Science interns learn how to make scientific observations and process digital data and physical samples. ROV interns learn how to maintain and operate our exploration vehicles and systems. Video engineering and film interns learn how to operate video for our ROVs and work with our communications team to share our Corps of Exploration story. All interns gain experience in communications and leadership, including participating in outreach activities, such as live interviews with shore. The Internship Program is funded in part by the Office of Naval Research.

The Science and Engineering Internship Program will be bring 15 students to sea during the 2013 expedition season:

<u>2013 Ocean Science Interns</u>
Jamie Wagner
Hometown/High School: Pittsboro, NC
Current/Recent School: Duke University, Durham, NC

Steve Auscavitch
Hometown/High School: Milford, CT
Current/Recent School: University of Maine, Orono ME

Mathieu Mercier-Gingras
Current/Recent School: University de Montreal, Quebec

Katherine Rodrigue
Hometown/High School: East Greenwich, RI
Current/Recent School: University of Rhode Island, Kingston, RI

Nam Siu
Hometown/High School: Palm Harbor, FL
Current/Recent School: Western Washington University, Bellingham, WA

2013 Seafloor Mapping Interns
Aaron Chesler
Hometown/High School: Waitsfield, VT
Current/Recent School: St. Lawrence University, Canton, NY

Renato (Renny) Kane
Hometown/High School: Wayne, PA
Current/Recent School: University of Delaware, Newark, DE

2013 ROV Engineering Interns
Stephen Estrin
Hometown/High School: Long Beach, CA
Current/Recent School: Long Beach College

Michael Smith
Hometown/High School: Lanoka Harbor, NJ
Current/Recent School: University of Rhode Island

2013 Video Engineering and Filmmaking Interns
Cyril Alex Martin
Hometown/High School: Benton, PA
Current/Recent School: Rochester Institute of Technology, Rochester, NY

Alan Franks
Hometown/High School: Adamsville, AL
Current/Recent School: Montana State University, Bozeman, MT

Hilary Hudson
Hometown/High School: Tacoma, Washington
Current/Recent School: Montana State University, Bozeman, MT

Catherine McCaughey
Hometown/High School: Coventry, RI
Current/Recent School: University of Rhode Island, Kingston, RI

Adele Bennett
Hometown/High School: Australia
Current/Recent School: University of Otago, Dunedin, New Zealand

Educator at Sea Science Communication Fellowship

The Ocean Exploration Trust's Educator At Sea Science Communication Fellowship Program aims to train formal and informal educators in basic Science Communication. Educator at Sea positions entail 2-4 week periods working aboard E/V *Nautilus* and other vessels as communicators of the expedition. From aboard the ship, Educators at Sea use our Exploration Now website to share our expedition with global audiences on shore. They further participate in interactive presentations with student groups and public audiences to engage people of all ages in scientific exploration. An equally important aspect of the program is bringing the expedition back home to local student populations and communities after our Educators have joined us at sea.

Sailing with us also offers Educators at Sea opportunities to deepen their understanding of how science, technology, mathematics, and engineering (STEM) apply to real-world situations, especially as they relate to ocean exploration. Educators are invited to witness every aspect of the expedition to make it come alive for Exploration Now viewers by interacting with and interviewing various members of the expedition team and observing operations on deck, in the control van and in onboard labs. As a result, Educators at Sea bring real-world applications of STEM back into their classrooms, organizations and local communities.

Educators at Sea also network with their peers and expedition team members from prominent ocean research institutions and universities to create STEM-focused lesson plans for use with their students. They can then leverage these relationships and experiences to create plans linked to national and local teaching standards and advance *Ocean Literacy Essential Principles and Fundamental Concepts*.

The Educator at Sea Science Communication Fellowship Program will bring 21 educators to sea during the 2013 expedition season. Prior to their expeditions, our selected educators participated in an intensive multi-day training workshop with experienced members of the Corps of Exploration at the University of Rhode Island from May 6-9, 2013. During this Science Communication Workshop, our Educators at Sea prepared for shipboard responsibilities by attending sessions hosted by scientists, engineers and communicators to learn about their expedition's mission, science and technologies. The Educator at Sea Science Communication Fellowship Program is sponsored in major part by the Bechtel and the Office of Naval Research.

NAUTILUS EXPLORATION PROGRAM

Our 2013 Educators at Sea

Lead Educators

Sam Garson, Science Department Chair
Mount Rainier High School, Des Moines, WA

Steven Hosking, Director of Technology
The Williams School, New London, CT

Noelle Turner, Science Teacher
Bearden High School, Knoxville, TN

Tiffany Risch, Science Teacher
Coventry High School, Coventry, RI

New Educators

Gillian Ashenfelter, Science Teacher
Lick-Wilmerding High School, San Francisco, CA

Stella Barth, Science Teacher
The Williams School, New London, CT

Lauren Bello, Science Teacher
Liberty Middle School, Clifton, VA

Megan Cook, Young Explorer/Writer
Mission Blue, San Francisco, CA

Cindy Duguay, Gifted and Talented Program Teacher
RSU #52, Turner, ME

Brian Facemire, History Teacher
Cape Henry Collegiate School, Virginia Beach, VA

Stacy Gale, Science Teacher
Paul Cuffee School, Providence, RI

Burnham Hall, Assistant Director of Guest Services
Mystic Aquarium, Mystic, CT

Susan Heaney, Ocean Exploration Centre Manager
Titanic Belfast, Belfast, Northern Ireland

Toni Ivey, Assistant Professor of Science Education
Oklahoma State University, Stillwater, OK

Alejandra Martinez, Science Teacher
Eagle Pass Independent School, Eagle Pass, TX

Patricia Miloslavich, Professor
Universidad Simon Bolivar, Caracas, Venezuela

Hannah Prior, Program Director
Sir Peter Blake Trust, Auckland, New Zealand

Mike Romano, Science Teacher
Acton-Boxborough Regional High School, Sommerville, MA

Aundrea Rue, Science Educator
Carolina Forest High School, Conway, SC

Bethany Smith, Teacher
Chesapeake Governor's School, Urbanna, VA

Lisa Wu, Lab Director & Teacher
Thomas Jefferson High School for Science and Technology, Arlington, VA

Honors Research Program

The Ocean Exploration Trust's Honors Research Program (HRP) invites junior and senior high school students to participate in a seven-week summer research and exploration program. Students work with scientists at the University of Rhode Island (URI) Graduate School of Oceanography (GSO) and are also invited to join our Corps of Exploration aboard Exploration Vessel (E/V) *Nautilus* and other vessels. Selected students conduct research and develop an individual project on an oceanographic topic throughout the summer and will learn to process and interpret data using computer science and engineering. The program itinerary includes five weeks living at the URI dormitories and participation in exciting research at GSO. Students then spend one week at sea, where they will work as part of the Corps of Exploration team, building a geographical information system (GIS) project in real-time. Upon return, all students must complete a report for the Ocean Exploration Trust, as well as present findings to their school classes. The HRP Program is funded in part by Bechtel and the Office of Naval Research.

The Honors Research Program will be bring 12 high school students to sea during the 2013 expedition season from the following high schools:

Kinkaid – Houston, TX

Lick-Wilmerding High School – San Francisco, CA

La Salle Academy – Providence, RI

North Kingstown High School – North Kingstown, RI

Kamehameha High School Kapālama – Haleiwa, HI

Deerfield Academy – Greenfield, MA

Mount Rainier High School – Des Moines, WA

L&N STEM Academy – Knoxville, TN

The Williams School – New London, CT

Cape Henry Collegiate Academy – Virginia Beach, VA

Thomas Jefferson High School for Science and Technology – Alexandria, VA

Mercer Island High School – Mercer Island, WA

13. Key Expedition Links and Contacts

Expedition Communications

Exploration Now
http://www.explorationnow.org

Nautilus Live
http://www.nautiluslive.org

Nautilus Live on Facebook
http://www.facebook.com/nautiluslive

Nautilus Live on Twitter
http://twitter.com/EVNautilus

Nautilus Live on YouTube
http://www.youtube.com/EVNautilus

Additional Publications and Materials

"New Frontiers in Ocean Exploration: The E/V *Nautilus* 2012 Field Season and Summary of Mediterranean Exploration"
http://www.tos.org/oceanography/archive/26-1_supp.html

"New Frontiers in Ocean Exploration: The E/V *Nautilus* 2011 and NOAA Ship *Okeanos Explorer* Field Season"
http://www.tos.org/oceanography/archive/25-1_supplement.html

"New Frontiers in Ocean Exploration: The E/V *Nautilus* 2010 Field Season"
http://www.tos.org/oceanography/archive/24-1_supp.html

Partner Organizations

Ocean Exploration Trust
http://oceanexplorationtrust.org

Sea Research Foundation (Mystic Aquarium, JASON Learning and Immersion Learning)
http://www.searesearch.org

Inner Space Center – University of Rhode Island
http://isc.gso.uri.edu

Graduate School of Oceanography – University of Rhode Island
http://www.gso.uri.edu

NOAA Office of Ocean Exploration and Research
http://explore.noaa.gov

National Geographic Society
http://www.nationalgeographic.com

NAUTILUS EXPLORATION PROGRAM

Expedition Communications Contacts

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Primary Science & Operations Contact

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