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Cruise Report: EX-12-05 Leg 1: Blake Plateau Exploration Using *Sentry* AUV

Davisville, RI, to Morehead City, NC
July 5, 2012 – July 24, 2012

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Abstract

The *Blake Plateau Exploration Using* Sentry *AUV* expedition (EX-12-05 Leg 1) was a combined NOAA Office of Ocean Exploration and Research (OER), National Science Foundation (NSF), and the National Deep Submergence Facility (NDSF) at the Woods Hole Oceanographic Institution (WHOI) cruise from July 5 to 24, 2012, with multiple objectives that included mapping, autonomous underwater vehicle (AUV) engineering, and telepresence-enabled AUV exploration. The 20-day expedition conducted was composed of two parts: (1) three days of engineering dives with the *Sentry* AUV and (2) using a suite of technologies to conduct exploratory interdisciplinary investigations off the east coast of the United States at the deep-sea areas of the Blake Ridge Diapir (BRD), Cape Fear Diapir (CFD), and Hatteras Transverse Canyon (HTC). Mapping operations targeted areas containing no or poor-quality modern mapping data, resulting in nearly 4,500 square kilometers mapped in high resolution. During the expedition, 14 *Sentry* AUV dives were attempted, but one was cancelled due to weather. Additionally, three CTD casts were successfully completed. This report contains summaries of the operations for this expedition, including several student projects. All data associated with this expedition have been archived and are publicly available through the NOAA Archives.

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1. Introduction

By leading national efforts to explore the ocean and make ocean exploration more accessible, the NOAA Office of Ocean Exploration and Research (OER) is filling gaps in basic understanding of deep waters and the seafloor, providing deep-ocean data, information, and awareness. Exploration within the U.S. Exclusive Economic Zone (EEZ) and international waters, as part of Seabed 2030 efforts to produce a bathymetric map of the world ocean floor by 2030, supports key NOAA, national, and international goals to better understand and manage the ocean and its resources.

Using the latest tools and technology, OER explores unknown areas of the deep ocean. NOAA Ship *Okeanos Explorer* is one such tool. Working in close collaboration with government agencies, academic institutions, and other partners, OER conducts deep-sea exploration expeditions using advanced technologies on *Okeanos Explorer*, mapping and characterizing areas of the ocean that have not yet been explored. Collected data about deep waters and the seafloor—and the resources they hold—establishes a foundation of information and fills gaps in the unknown.

All data collected during *Okeanos Explorer* expeditions adhere to federal open-access data standards and are publicly available shortly after an expedition ends. This ensures the delivery of reliable scientific data needed to identify, understand, and manage key elements of the ocean environment.

Exploring, mapping, and characterizing the U.S. EEZ are necessary for a systematic and efficient approach to advancing the development of ocean resources, promoting the protection of the marine environment, and accelerating the economy, health, and security of our nation. As the only federal program solely dedicated to ocean exploration, OER is uniquely situated to lead partners in delivering critical deep-ocean information to managers, decision makers, scientists, and the public—leveraging federal investments to meet national priorities.

2. Expedition Overview

From July 5 to 24, 2012, OER and partners—including a team of scientists, engineers, and technicians both at sea and on shore—conducted a two-part, interdisciplinary ocean exploration expedition on *Okeanos Explorer* to test technology and to collect critical baseline information and improve knowledge about unexplored and poorly understood deepwater areas of the Hatteras Transverse Canyon (HTC), the Blake Ridge Diapir (BRD) and Cape Fear Diapir

(CFD) areas off the east coast of the United States. EX-12-05 Leg 1 was part of a series of expeditions contributing to the NOAA Atlantic Canyons Undersea Mapping Expeditions (ACUMEN) campaign. As such, EX-12-05 Leg 1 was designed to provide timely, actionable information to support decision-making based on reliable and authoritative science. Like other NOAA ACUMEN expeditions, it also served as an opportunity for the nation to highlight the uniqueness and importance of deepwater environments.

2.1 Expedition Purpose

The EX-12-05 Leg 1, *Blake Plateau Exploration Using* Sentry *AUV* cruise represented a partnership between OER, the National Science Foundation (NSF), and the National Deep Submergence Facility (NDSF) at Woods Hole Oceanographic Institution (WHOI)—with each partner bringing different but complementary objectives to the table. OER's primary focus during EX-12-05 Leg 1 was to test the use of an autonomous underwater vehicle (AUV) operated from NOAA Ship *Okeanos Explorer* while the ship was outfitted for "full" exploration mode—with joint remotely operated vehicle (ROV) operations—to explore what it would take to integrate an AUV into telepresence-enabled exploration. The primary NSF objective for this cruise focused on survey data collection using the *Sentry* AUV and *Okeanos Explorer* systems at the BRD and CFD areas, to support a follow-on NSF-funded project at Blake Ridge in 2013 with Principal Investigator (PI), Cindy Lee Van Dover. The NSF and WHOI/NDSF objectives for this cruise included a series of engineering trials and experiments with the *Sentry* AUV capabilities.

The 20-day expedition was composed of two parts. The first part focused on three days of engineering dives with the *Sentry* AUV, from July 8 to 10, 2012. Engineering tests included using telepresence technology to have an engineer remotely start up and oversee the ship's launch of the AUV from shore, as well as the unplanned use of telepresence to conduct remote engineering and diagnostic tests. The engineering dives were planned with scientists from the U.S. Geological Survey (USGS) and the University of Maine to maximize the value of data acquired, and were conducted at the HTC.

The second part of the cruise focused on exploring the diversity of seep habitats on the BRD and CFD system and used the onboard suite of technologies to prospect for seep environments. Much of the data analysis and cruise direction came from the core team of scientists, including PI Cindy Lee Van Dover, who were located on shore for the duration of the cruise. This core team of scientists participated in real and near-real time from the Inner Space Center (ISC) in Rhode Island, collaborating with the onboard team to provide daily input and direction on the next steps of the cruise. The findings from this part of the cruise lay the groundwork for further scientific exploration and sampling planned with the *Jason* ROV as part of an NSF-funded study of population connectivity in seep invertebrates.

Both parts of the cruise included operating an AUV from NOAA Ship *Okeanos Explorer* for the first time—and explored how to integrate the *Sentry* AUV into telepresence-enabled systematic ocean exploration.

NOAA Ship *Okeanos Explorer* is one of the newest additions to the NOAA fleet and was commissioned in 2008. It provides accommodations for up to 46 crew and technicians. Unique to this ship is that most of the scientists remain ashore. Via telepresence, live images and other science data flow over satellite and high-speed Internet pathways to scientists standing watches in Exploration Command Centers (ECCs). During this expedition, core scientists worked from ECCs at the University of Rhode Island (URI). These scientists added their expertise in real time to operations at sea.

2.2 Objectives

The objectives of the cruise came from the main expedition partners: WHOI, NSF and OER. The WHOI/NDSF objective was to conduct a series of engineering trials and experiments with the *Sentry* AUV, including the use of telepresence to conduct remote operations. The NSF objective was to survey the BRD and CFD areas for cold seep communities in support of an NSF grant studying population connectivity in seep invertebrates in the Gulf of Mexico, Atlantic and Pacific. Both of these efforts supported OER's objective: to bring an AUV onboard NOAA Ship *Okeanos Explorer* for the first time and assess what it would take to integrate an AUV into telepresence-enabled operations. Specifically, this expedition sought to:

- Test the ability to operate the *Sentry* AUV from aboard *Okeanos Explorer* as if the ship were in full exploration mode (with joint ROV operations);
- Conduct three engineering dives with WHOI equipment in deep water (5,000-6,000 m);
- Test operational and engineering procedures to prepare the *Sentry* AUV for deployment remotely through telepresence;
- Test the functional capacity of the ISC at URI to host and support engineering objectives for an AUV cruise from *Okeanos Explorer*;
- Explore the use of telepresence during AUV operations by streaming AUV data (e.g., underwater vehicle data and/or navigation data) to shore;
- Map and explore the diversity of seep habitats of the BRD system;
- Collect a full photomosaic cover of and investigate the temporal stability of subsurface conduits at the BRD;
- Map two additional diapirs for evidence of seepage, with photo ground truth of map targets;
- Test efficacy of multiple approaches to localizing seeps (i.e., mapping, sensors, images, water column plumes, etc.);
- Acquire data to look for evidence of mass wasting and sediment transport;

- Add to pre-existing United Nations Convention for the Law of the Sea (UNCLOS) and *Okeanos Explorer* bathymetric data coverage in the region, if possible;
- Collect multibeam, single-beam, and sub-bottom data during transit;
- Collect multibeam and sub-bottom data at the primary project sites, including water-column data where appropriate;
- Re-establish standard CTD operating procedures on *Okeanos Explorer*;
- Support a shoreside artist's efforts to create a documentary film of the program;
- Train and develop new engineers, mapping interns, and watchstanders.

3. Participants

EX-12-05 Leg 1 included onboard mission personnel as well as shore-based science personnel who participated remotely via telepresence technology. Various personnel from different organizations participated in the expedition. See **Tables 1 and 2** for lists of onboard and shoreside personnel who supported EX-12-05 Leg 1.

Table 1. NOAA Ship *Okeanos Explorer* onboard mission personnel during EX-12-05 Leg 1.

ON-BOARD MISSION PERSONNEL	
Elliott, Kelley (OER)	Expedition Coordinator
Pinner, Webb (OER)	Telepresence lead
Lobecker, Meme (OER)	Co-Mapping Lead
Skarke, Adam (OER)	Co-Mapping Lead
Brothers, Laura (USGS)	Senior Scientist/Mapping Watchstander
Paxton, Dominique (UCAR)	Mapping Watchstander
Kaiser, Carl (WHOI)	AUV Team Lead
Billings, Andrew (WHOI)	AUV Team
Fujii, Justin (WHOI)	AUV Team
Duester, Al (WHOI)	AUV Team
Bingham, Brian (UCAR)	AUV Support
Carlson, Joshua (UCAR)	AUV Support
Van Uffelen, Lora (UCAR)	AUV Support
Brian, Roland (UCAR)	Video Engineer
Smithee, Tara (UCAR)	Video Intern
Sheehan, Jay (UCAR)	CTD Technician/Mapping Watchstander
Reser, Brendan (OER)	Data Manager

Table 2. List of personnel who participated in EX-12-05 Leg 1 from shore at URI.

PRIMARY SHORESIDE SCIENCE TEAM MEMBERS	
Martinez, Catalina (OER)	Regional Manager
Coleman, Dwight (URI/ISC)	Director, Inner Space Center
Kennedy, Brian LTJG (OER)	Expedition Operations
Knott, Bob (URI/ISC)	Senior Broadcast Engineer
Kinsey, James (WHOI)	AUV Team/Engineer
Catanach, Kathryn Scanlon (USGS)	Senior Scientist
Waller, Rhian (University of Maine)	Marine Biologist
Van Dover, Cindy (Duke University)	Science Lead/Principal Investigator (PI)
Yoerger, Dana (WHOI)	Senior AUV Engineer
German, Chris (WHOI)	Senior Scientist
Shimizu, Megumi (Duke University)	Scientist (PhD Student, Biology)
Wagner, Jamie (Duke University)	Scientist (PhD Student, Biology)
McKelvey, Zachary (Duke University)	Undergraduate Duke Bookout Scholar
McEntee, Molly (Duke University)	Undergraduate Duke Bookout Scholar
Sharuga, Stephanie (Louisiana State University [LSU])	Guest Masters Student
Jones, Meghan Rose (University of Miami)	Scientist (Marine Geology)
Chubet, Alena (Skidmore College)	Scientist (Marine Geology)
Brubaker, Philip (Duke University)	MFA Student, Documentary Film Maker
LePage, David (URI/ISC)	Broadcast Engineer
Deciccio, Alex (URI/ISC)	Video Editor
Sutcliffe, Derek (URI/ISC)	Systems Engineer
Williams, Angela (URI/ISC)	Graduate Student Watchstander/Assistant Video Editor
McCaughey, Catherine (URI/ISC)	ISC Student Watchstander
Sweet, Donald (URI/ISC)	ISC Student Watchstander
Wallin, Brenton (URI/ISC)	ISC Student Watchstander
Canton, Michael (URI/ISC)	ISC Student Watchstander
Trowbridge, Hunter (URI/ISC)	ISC Student Watchstander
Zimmer, Harrison (URI/ISC)	Graduate Student ISC Watchstander
Smart, Clara (URI/ISC)	Graduate Student/Mapping Specialist
LaFrance, Monique (URI/ISC)	Graduate Student/Mapping Specialist

3.1 Participating Institutions

- National Oceanic and Atmospheric Administration (NOAA) Office of Ocean Exploration and Research (OER)
- The National Science Foundation (NSF)
- Woods Hole Oceanographic Institution (WHOI)
- National Aeronautics and Space Agency (NASA) Maritime Aerosol Network (MAN)
- National Deep Submergence Facility (NDSF), Deep Submergence Lab, Woods Hole Oceanographic Institution (WHOI)
- Duke University Marine Lab
- University of Rhode Island (URI)
- University Corporation for Atmospheric Research (UCAR) Joint Office for Science Support (JOSS)
- University of New Hampshire (UNH) Center for Coastal and Ocean Mapping (CCOM), Jere A. Chase Ocean Engineering Lab
- Louisiana State University (LSU)

4. Methodology

To accomplish its objectives, EX-12-05 Leg 1 used:

- Dual-bodied ROV system (ROVs *Little Hercules* and *Seirios*) to conduct daytime seafloor and water column surveys.
- *Sentry* AUV to work standalone and in tandem with the ship's dual-bodied ROV system.
- Sonar systems (Kongsberg EM 302 multibeam sonar, Knudsen 3260 sub-bottom profiler, Simrad EK60 split-beam sonars to conduct mapping operations at night and when the AUV was on deck.
- A high-bandwidth satellite connection to provide real-time ship-to-shore communications (telepresence).

All environmental data collected by NOAA must be covered by a data management plan to ensure they are archived and publicly accessible. The Data Management Plan for EX-12-05 Leg 1 in Gottfried (2012).

4.1 Description of NOAA Ship *Okeanos Explorer* Sensors and Systems

NOAA Ship *Okeanos Explorer*, R 337 (Call letters: WTDH), is NOAA's only ship dedicated exclusively for ocean exploration (**Table 3**). *Okeanos Explorer* is one of the six former U.S. Navy T-AGOS class ships acquired and converted by NOAA for use as scientific research ships. Originally built for anti-submarine warfare, former USNS *Capable* was commissioned as NOAA Ship *Okeanos Explorer* on August 13, 2008. Prior to commissioning, the vessel underwent extensive refurbishment from 2005 – 2008 by Todd Pacific Shipyards Corporation, including adding mission space for the ROV hanger, bow and stern thrusters, fairings for mapping sensors, and bridge upgrades. The ship has been outfitted with a hull-mounted deepwater multibeam echo sounder (MBES), a single-beam echo sounder (SBES), and a sub-bottom profiler (SBP), along with host of ancillary equipment. In 2011 the ship was integrated with a dual-body ROV system (*Little Hercules* and *Seirios*) with a depth rating of 4,000 m.

Vessel Specifications

Table 3. NOAA Ship *Okeanos Explorer* vessel specifications.

Hull Number	337	**Cruising speed**	10 knots
Call letters	WTDH	**Mapping speed**	7-10 knots
Builder	VT Halter Marine, Inc., Moss Point, MS	**Berthing**	46
Launched	October 28, 1988	**Commissioned officers**	6
Delivered to NOAA	September 10, 2004	**Licensed engineers**	3
Commissioned	August 14, 2008	**Crew**	27
Length overall (LOA)	68.3 m (224 feet)	**Scientists**	19
Breadth	13.1 m (43 feet)	**Ambar Rigid Hull Inflatable Boat (RHIB)**	2
Draft	5.13 m (16.83 feet) Bow Thruster Retracted 6.12m (20.08 feet) Bow Thruster Lowered	**Full Load displacement** **Gross Tons (U.S.)** **Gross Tons (International)**	2,312 long tons 1,517 long tons 2,062 long tons
Range	9,600 nm	**Light ship displacement**	1,616 long tons
Endurance	40 days		

NOAA Ship *Okeanos Explorer* (EX) is equipped with a Kongsberg Dynamic Position (DP) System (K-Pos DP 11, IMO Class 1) that has been integrated with the ship's propulsion, rudder, and navigation systems to help her maintain position during operations, which require precise station keeping. The DP system uses the unique set of one 500 hp retractable bow thruster and two hydraulic 250 hp tunnel stern thrusters to maintain ship's position to within three meters during ROV dive operations.

The meteorological data comes from a suite of standard meteorological sensors including air temperature, pressure, wind speed and direction, and Radiometers—the Eppley Laboratory, Inc., Precision Spectral Pyranometer (PSP) measures shortwave irradiance, and the Precision Infrared Radiometer (PIR) measures longwave irradiance.

The Scientific Computer System (SCS)

SCS software is developed by NOAA, specifically for the NOAA fleet, and is a data acquisition system designed for oceanographic and fisheries applications. Onboard *Okeanos Explorer*, the SCS is used to send data displays to remote stations (SCS Client) throughout the labs as well as to shore. All of the oceanographic and meteorological sensors on board are routed through the SCS. The system makes the data available for real-time manipulation and processing. The software the SCS uses has been customized to work with the wide range of instruments aboard

NOAA vessels. Both raw data and processed information can be viewed in either text or graphical forms at numerous computer stations networked throughout the ship. The SCS is configured to automate some of the transfer process, getting the data ashore in near-real time.

Deck Equipment

Okeanos Explorer is equipped with a Dynacon Model 766 Traction Winch installed below deck holding 8,000 m of 17 mm Rochester 2351 electromechanical cable (three fiber optic conductors shrouded with triple armor). This cable is fitted with a Focal Technologies Corporation Model 176 electrical slip ring coupled to a Focal Technologies Corporation Fiber Optic Rotary Joint (Model 242). This rotary joint boasts four power passes (each capable of 5,000 VAC) and three single-mode passes. This cable serves as the primary umbilical for the ROV and camera sled systems. Main control of the Dynacon winch resides in the winch room, with remote controls located above the ROV hangar at an aft control station as well as in the ROV control room.

The winch employed aboard the *Okeanos Explorer* for hydrographic operations (CTD, Tow-yo, Water Sampling, etc.) is a Markey Desh-5 equipped with 8,000 m of 9.5 mm electromechanical cable. This winch is installed on a turntable, which allows its use through the stern A-Frame or the starboard J-Frame.

Dynacon, Inc., of Bryan, Texas, built the stern A-Frame that is installed on the *Okeanos Explorer*. This (dual-luff) A-Frame boasts a safe working load (SWL) overboard of 20,000 pounds and a safe luffing load of 8,000 pounds in Sea State 4.

The J-Frame on the starboard side of the *Okeanos Explorer* supports over-the-side operations such as CTDs, Tow-yos and Water Sample Collection. The J-Frame is rated for a 3,500-pound SWL for a vertical CTD cast using a 9.5mm (0.375 inch) electromechanical cable from the Markey hydrographic winch. The J-Frame also has a towing capability of 3,000 pounds at angles of up to 45 degrees from vertical for Tow-yo operations or a small net.

The ROV crane is a Hydrapro Model HP40/13KESO. It is mounted on the port aft corner of the aft deck and is used exclusively for launch and recovery of the ROV or an AUV system. The crane can be controlled by a wireless belt pack controller that allows the operator to move about on the aft deck to achieve the maximum vantage point during operations. A simple mechanical swing arrester is mounted to the end of the lifting boom, which stabilizes the ROV during launch and recovery. The ROV crane utilizes a high tensile strength synthetic line instead of wire rope.

The General Purpose Crane on the starboard side of the fantail is a Hydra Pro HP46/18KE-6600 knuckle and boom crane used for various purposes, such as loading stores and equipment from the pier. The crane has a variable reach from 10 feet out to a maximum of 46 feet. The load capacity varies depending on the cranes reach. At 10 feet, the crane is rated for 24,000 pounds and at the maximum extent of 46 feet, the crane has a SWL of 6,600 pounds.

The Small Boat Davits are both hydraulic Vestdavits (PLR-3600) with a single point launch and recovery system. The davits are both equipped with a manual launch and recovery system. The port side davit is equipped with a hydraulic charge accumulator, which allows to the boat to be deployed even in the event of a complete loss of ships power.

Mapping

During this expedition, the *Okeanos Explorer* was equipped with a 30 kHz Kongsberg EM 302 multibeam sonar, a 3.5 kHz Knudsen SBP 3260 sub-bottom profiler, and an 18 kHz Kongsberg EK60 single-beam sonar. Multibeam seafloor bathymetry and backscatter data—as well as multibeam and single-beam water column backscatter data—were collected continuously. Additionally, sub-bottom profile data were collected at specific locations of interest.

The ship used an onboard Applanix version 4 Position and Orientation System for Marine Vehicles (POS MV) sensor to record and correct multibeam data for any of the ship's motion prior to logging. The satellite service C-NAV Global Positioning System (GPS) system provided Differential Global Positioning System (DGPS) correctors to the POS MV with positional accuracy greater than 2.0 m.

All data corrections (motion, sound speed profile, sound speed at sonar head, vessel draft, and sensor offsets) were applied in real time during acquisition with Kongsberg's data acquisition software, Seafloor Information System (SIS) version 3.6.4, build 176. Sippican expendable bathythermograph (XBT) casts (Deep Blue, maximum depth 760 m) were taken every six hours, or more frequently, as required by physical oceanographic conditions. XBT cast data were converted to SIS-compliant format using the NOAA developed tool for XBT processing: Velocipy. Lobecker et al (2012) provides a detailed description of the parameters and settings used for EM 302 data acquisition.

Onboard processing of bathymetric data was performed using Teledyne Computer Aided Resource Information System (CARIS) Hydrographic Information Processing System (HIPS), version 6.1. Data were cleaned using the CARIS 'Swath Editor' and 'Subset Editor' tools. A grid cell size of 50 m was chosen for the bathymetric grids. Onboard processing of seafloor and water column backscatter data was conducted using Interactive Visualization Systems (IVS) Fledermaus Geocoder and Midwater, respectively, limited only to specific targets. Detailed processing of seabed and water column backscatter data for sites of interest was completed onboard using the IVS Fledermaus suite, version 7. Angular offsets are tabulated in **Table 4**.

Table 4. Angular offsets for Transmit (Tx) and Receive (Rx) transducer as determined during a patch test conducted in May 2010.

	Roll	Pitch	Heading
Tx Transducer	0.0	0.0	359.98
Rx Transducer	0.0	0.0	0.03
Attitude	0	-0.80	0.0

Sun Photometer

During EX-12-05 Leg 1, regular observations of aerosol optical depth at the ship's location were made with a sun photometer instrument. Observations were made up to four times a day during clear sky conditions. These data were collected as a survey of opportunity in collaboration with the NASA MAN component of the Aerosol Robotic Network (AERONET). AERONET is a network of sun photometers that measure atmospheric aerosol properties around the world. MAN complements AERONET by conducting sun photometer measurements on ships of opportunity to monitor aerosol properties over the global ocean. The MAN program provided the collection instrumentation and archived all resultant data. For information about the MAN program please refer to (last accessed December 2020): http://aeronet.gsfc.nasa.gov/new_web/maritime_aerosol_network.html

Aerosol optical depth data collected on EX-12-05 Leg 1 may be accessed at: http://aeronet.gsfc.nasa.gov/new_web/cruises_new/OkExplorer_12_0.html

CTD and XBT

Okeanos Explorer has two Sea-Bird Electronics, Inc. (SBE) 9/11 Plus CTD, each with dual 3plus temperature and 4C conductivity sensors (**Figure 1**). This unit is capable of collecting temperature, conductivity, and pressure in real time. Depth, salinity, and sound velocity are calculated in real time via SBE Seasave acquisition software. One complete package is used to collect data and the other is kept as a spare. The ship must hold station using DP mode to conduct a CTD cast. The CTD is lowered through the water column at 60 m/minute.

Figure 1. (Left) Deck Unit (SBE 11) for acquisition of real-time sound speed profile from SBE 9plus CTD. (Right) Horizontal mounted CTD with dual Temperature and Conductivity sensors and SBE 32 Carousel for 24-bottle water sampling.

The Sippican XBT casts are conducted on the aft deck with a portable launcher. Expendable Sound Velocity (Sippican XSV) probes are also used to measure sound velocity directly. The data are collected in real time with the WinMK21 acquisition software (**Figure 2**).

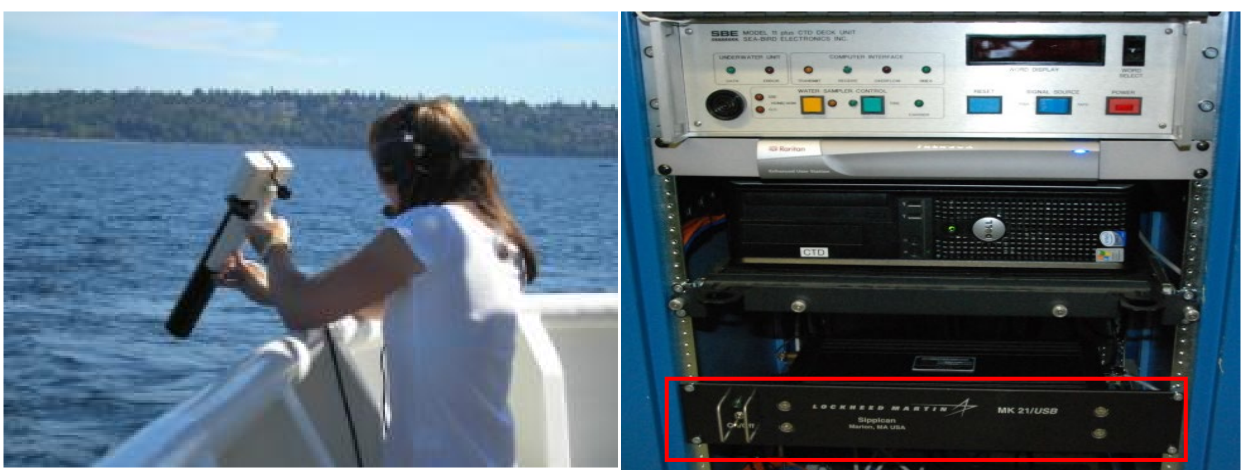

Figure 2. Sippican XBT launch from the aft deck (left). Deck unit for Sippican XBT (right).

Sound speed profiles obtained from CTD/XBT casts can be converted to SIS-compliant data format using Velociwin, version 8.92 Plus. The SBE 911plus CTD is connected to the SBE 32 Carousel. The SBE 32 is rigged with 24 Niskin 2.5 L water-sampling bottles. The bottles can be triggered to close at any depth during a cast through the Seasave acquisition software on the CTD computer in the dry lab. During this expedition, the CTD rosette was also equipped with sensors including Oxygen Reduction Potential (ORP), Dissolved Oxygen (DO), light scattering spectroscopy (LSS), and an altimeter. The CTD was also equipped with a *Sentry* AUV transponder for precise CTD location with respect to the *Sentry* AUV if in the water, and on the bottom. Vertical CTD casts were conducted off the J-Frame during the cruise.

VSAT System (Very Small Aperture Terminal)

An onboard VSAT antenna allows for high-speed connectivity to Internet2. A 3.7m C-Band SeaTel Tracking Satellite Dish sits atop the main mast in the ship's radome for real-time communications with shore. The ship is capable of uploading up to 20 Mbps (megabits per second), or downloading 5 Mbps. In general, cruises not conducting ROV operations will use 5 Mbps upload/ T1 download. The 20 Mbps rate is primarily used for live ROV operations when sending high-definition video, audio, and data streams to shore. This bandwidth allows for the use of real-time voice intercom communications between the ship and shore shore-based ECCs.

Exploration Command Centers (ECCs)

At the time of this expedition, there were seven ECCs located around the country that provided scientists and explorers the ability to participate in missions directly from shore. The ECCs were located at:

- NOAA Pacific Marine Environmental Laboratory (PMEL), Sand Point, Seattle, WA
- NOAA PMEL, Newport, OR
- NOAA Headquarters, Silver Spring, MD
- University of New Hampshire, New Durham, NH
- University of Rhode Island, Kingstown, RI
- Institute for Exploration, Mystic Aquarium, Mystic, CT
- Stennis Space Center, MS

The ECCs were equipped with three large flat-screen high-definition (HD) monitors for viewing live imagery from the ship, computer workstations for receiving and viewing data feeds from the ship; and an Internet Protocol (IP) telephone RTS system for real-time, two-way audio communications with the ship's control room.

The primary role of the ECCs is to provide a broader base of intellectual capital to exploration, and to allow explorers to join in the ongoing exploration from shore. ECCs are also education and outreach venues. During EX-12-05 Leg 1, the science team and PI joined the exploration from shore, operating from the URI's ISC. A description of the shore-based facilities used to host the mission team can be found in Section 4.2.

4.2 Description of URI Shore-Based Facilities Used to Host the Mission Team

URI Inner Space Center (ISC)

The ISC is equipped with telepresence technologies and personnel to support interactive exploration operations onboard multiple ships simultaneously while they're at sea and connected to shore via a high-bandwidth, satellite-enabled Internet2 network. Within the ISC facility, there is a mission control room to host scientists, engineers, students, and other personnel participating in expeditions live (**Figure 3**), and a video production facility to support the creation and delivery of live educational broadcasts and post-production of products as requested. Both the mission control and production facilities can be utilized to establish a shore-based operations center for real-time interactivity with the ships enabled by telepresence technology. The live streaming video and data feeds are managed using the ISC's recording, archiving, and distribution systems to facilitate real-time operations. The ISC's telecommunications capability, supported primarily by a sophisticated broadcast quality intercom system, enables voice interactivity between the ISC and the ship. In addition to supporting the live streams and communication with the ship, the ISC supports interactivity with a widely-distributed network of ECCs, strategically located around the country and even in other parts of the world, that are connected via Internet2.

The ISC also supports a small data center with online data servers and archival systems. The operational team on watch can record, manage, archive, and distribute the information streamed by the ships through these systems.

Figure 3. Mission Control at the URI Inner Space Center: A large projection screen can display multiple live feeds of video, data, and supporting information. ISC and mission personnel work at science stations, where they have access to multiple computers, video recording and playback devices, and intercom systems for communicating with telepresence-enabled ships at sea, and other participating ECCs. Currently, the ISC can host up to 15 on-site participants. *Photo courtesy of Alex DeCiccio, Inner Space Center.*

Coupled to both the ocean exploration operations and scientific data center operations at the ISC, the mission control space is used as an education and hands-on training facility for staff, including undergraduate and graduate students. Lastly, the mission control space is a visually appealing and exciting environment where tours and events for the general public are coordinated.

4.3 Description of *Sentry* AUV and Ultra-Short Baseline (USBL) Tracking

The *Sentry* AUV is a member of the WHOI NDSF and was commissioned during the summer of 2010. Initially designed for operations down to 4,500 m (14,764 feet) depth, *Sentry's* capability has been extended to 6,500 m (21,450 feet) (**Table 5**). *Sentry* can be mobilized readily for use as a standalone vehicle on a wide range of research vessels, but can also be used very effectively in tandem with *Alvin* or an ROV such as the NDSF's *Jason* to improve the efficiency of deep submergence investigations.

Sentry carries an extensive scientific sensor suite as standard, but can also accommodate additional user-provided science payloads—enabling it to be used for a variety of oceanographic (midwater) as well as near-seabed (imaging, geophysical survey) investigations. *Sentry* produces bathymetric and magnetic maps of the seafloor and is capable of taking high-quality digital color photographs in a variety of deep-sea terrains, including along mid-ocean ridges, at ocean margins, and in complex settings such as hydrothermal vent and cold seep ecosystems.

Sentry's navigation system uses a Doppler velocity log and inertial navigation system, aided by acoustic navigation systems (USBL was used during EX-12-05 Leg 1). The USBL system also provides acoustic communications, which can be used to obtain the vehicle state and sensor status as well as to re-task the vehicle.

As well as traditional uses established by previous AUVs (seafloor mapping, bottom photography, hydrothermal plume detection and investigation), *Sentry* is increasingly being utilized for a much wider range of oceanographic applications. In 2010, for example, it was used on an NSF Rapid Response Research (RAPID) cruise working almost exclusively in midwater to detect and trace hydrocarbon plumes dispersing through the Gulf of Mexico (Camilli et al., 2010).

Specifications

Table 5. Summary table of *Sentry* AUV operating specifications.

Depth Capability:	6,500 m
Dimensions:	Length: 2.9 m (9.7 feet)
	Width* 2.2 m (7.2 feet)
	Height 1.8 m (5.8 feet)
Weight:	1,250 kg (2,750 pounds) without extra science gear
Operating Range:	70-100 km, (38-54 miles) depending on speed, terrain, and payload
Operating Speed:	0-1.2 m/s (0-2.3 knots)
Propulsion:	4 brushless DC electric thrusters on pivoting wings
Energy:	Lithium Ion batteries, 13 kWh
Bus power:	48-52 Volts DC
Endurance:	20-40 hours, depending on mission type
Recharge time:	10 hours
Descent/Ascent speed:	40 m/minute for both descent and ascent, 2,400 m/hour
Navigation:	USBL Navigation with real-time acoustic communications and/or Long baseline (LBL) using acoustic transponders, Doppler Velocity Log (DVL), and Inertial Navigation System (INS)

**Width of body with fins extended (without fins: 0.8 m/2.7 feet)*

Science and Engineering Sensors

Sentry is equipped with a standard suite of scientific and engineering sensors. In addition, *Sentry* is a sufficiently flexible platform that additional sensors can be interfaced by PIs, according to their specific interests and scientific needs. All sensors are rated to 6,000 m (19,685 feet), except as noted.

Vehicle Sensors

- Pressure: Paroscientific 8B7000-I, Digiquartz depth sensor, rated to 7,000 m (23,000 feet).
- DVL: RD Instruments, 300 kHz.
- Attitude sensors (internal—pitch, roll, heading).
- Phins INS (internal).
- Forward-looking sonar: Dual, Imagenex 852, 675 kHz, 45° beam width each, overlapped.

Geophysical Sensors

- Multibeam mapping sonar: Reson 7125, 400 kHz, 512 beams, 50-200 m track spacing.
- Edgetech 4 kHz to 20 kHz 4-24 kHz chirp sub-bottom profiler.
- Three high-precision, digital, three-axis fluxgate magnetometers were installed in 2011; two mounted mid-ships (port, starboard) in a horizontal gradient mode, and a third mounted centrally within the vehicle above the other two in a vertical gradient mode.

Oceanographic sensors

- Current Transformer (CT) sensor: Glider Payload CTD (GPCTD), Neil Brown Ocean Sensors, Inc. (conductivity and temperature).
- Optical Backscatter (OBS): Seapoint Turbidity Meter.
- Seafloor photography: lKxlIK, 12-bit color still camera with strobe, rated to 4,500 m (14,764 feet). Camera repetition rate was initially set for 7 seconds, but revised to 3.3 seconds later in the cruise.
- Eh electrode (redox sensor).

See Section 3, Vehicle Configuration, on page 4 of the *Sentry* Operations Report (Kaiser et al., 2014) for information about the vehicle configuration for EX-12-05 Leg 1

4.4 Operations Overview

4.4.1 Area of Operations

EX-12-05 Leg 1 was conducted offshore of the east coast of the United States, from Davisville, RI, south to the Blake Ridge off the coast of South Carolina, and then west to Morehead City, NC (**Figure 4**). There were two areas of focused exploration during this cruise. Three days of AUV engineering dives and mapping operations were conducted in deep water at the HTC, about 350 km east-southeast of Morehead City, NC. Following the completion of these engineering dives, *Okeanos Explorer* transited to the primary project operations area on the Blake Ridge, approximately 300 km off the coast of South Carolina. For the rest of the cruise, 24-hour exploration operations were conducted on the BRD and CFD complex as well as the 800-1,000 m isobath from July 11 to 23. Mapping operations were conducted during all transits.

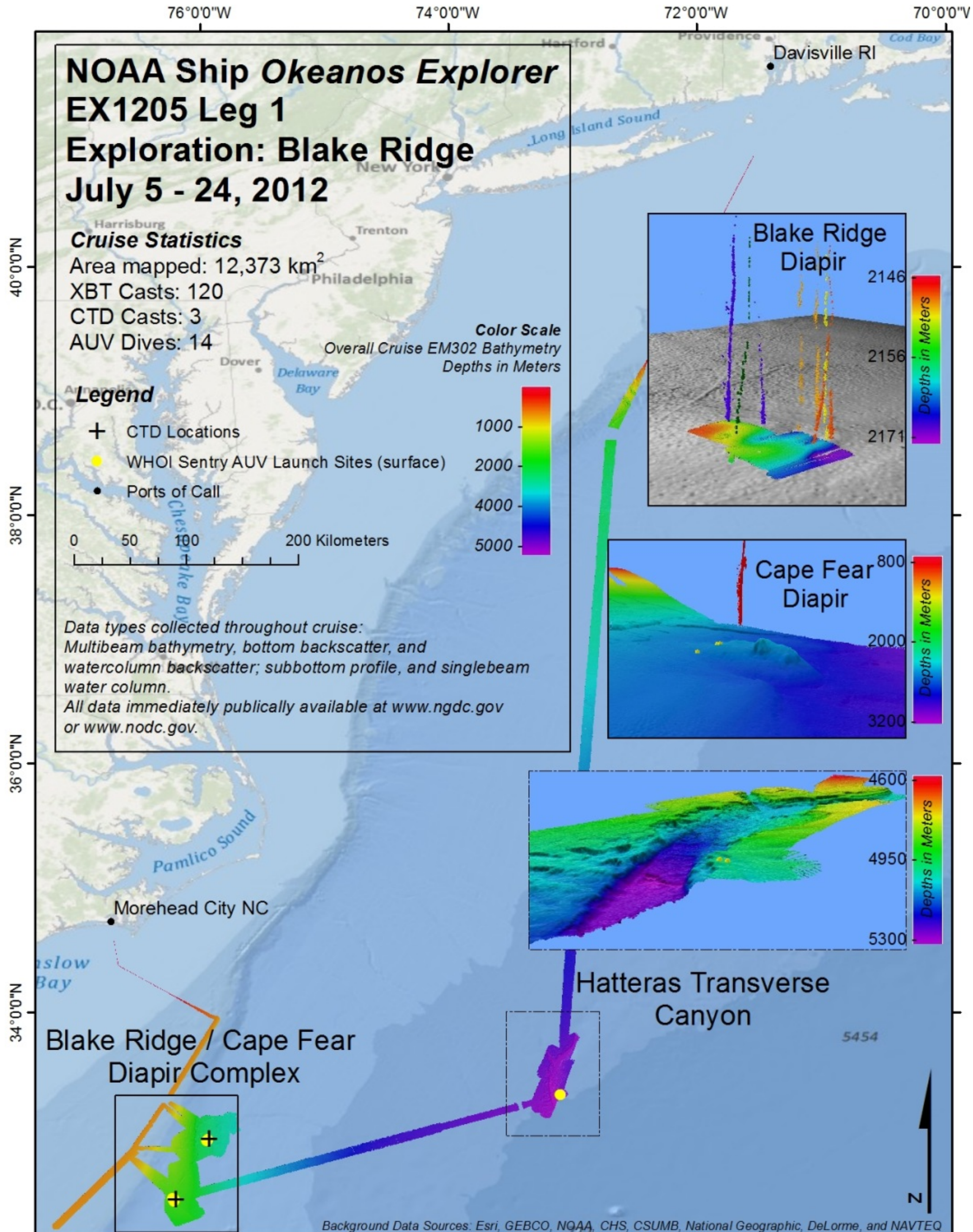

Figure 4. Map summarizing operations conducted by *Okeanos Explorer* during EX-12-05 Leg 1.

4.4.2 Summary of Operations

Operations started on July 5, 2012 from Davisville, RI and ended on July 24, 2012 in Morehead City, NC. **Table 6** has a summary of daily operations and activities.

Table 6. Summary of daily at-sea operations and activities during EX-12-05 Leg 1. *All times listed are local ship time. Local ship time was -4 hours from Universal Time Coordinated (UTC).*

Date	Operations	Activity Summary
5-Jul-12	1345 - Departed Davisville, RI. Transit to USBL Calibration site.	• Mapping: Acquired underway data, including EM 302 and EK60 data en route to USBL calibration site. • Three XBTs conducted.
6-Jul-12	Transit mapping operations. 0740 - Commence USBL Calibration. 1930 - USBL Calibration completed. Transit to HTC.	• Mapping: Acquired EM 302 and EK60 underway data while transiting to USBL calibration site. • Conducted USBL calibration. • Mapping: Acquired underway data while transiting to HTC, including EM 302 and EK60. • Shipboard safety drills. • Four XBTs conducted.
7-Jul-12	Transit to HTC. 1000-1800 - SBP operations.	• Mapping: Acquired underway data while transiting to HTC, including EM 302, EK60, and Knudsen 3260. • Seven XBTs conducted.
8-Jul-12	0740 - Mapping systems secured. 0820 - Transducer Pole Lowered. 0954 - Deploy EX1205L1_AUV01_SENTRY139. 1800 - Recover EX1205L1_AUV01_SENTRY139. 1813 - Transducer Pole Raised. 1815 - EM 302 and EK60 Survey operations commence.	• AUV 139 Engineering Dive in HTC. Remotely conducted software pre-dive and testing. Conducted remote watch-standing. • Mapping operations to redefine the edges of HTC, cover AUV 139-141 dive sites. • Five XBTs conducted.
9-Jul-12	0822 - Transducer Pole Lowered. 0921 - Deploy EX1205L1_AUV02_SENTRY140. 1929 - Recover EX1205L1_AUV02_SENTRY140. 1940 - Transducer Pole Raised. 2000 - EM 302 and EK60 mapping operations commence.	• AUV 140 Engineering Dive in HTC. Remotely conduct the final AUV start up from shore, with only passive at-sea oversight. • Mapping operations to define the edges of the confluence of HTC. • EM 302 ping test conducted with *Sentry* and USBL in water. Interference observed. • Two XBTs conducted.
10-Jul-12	0825 - Transducer Pole Lowered. 1029 - Deploy EX1205L1_AUV03_SENTRY141. 1629 - Recover EX1205L1_AUV03_SENTRY141. 1638 - Transducer Pole Raised. EM 302, EK60, and Knudsen 3260 mapping operations.	• AUV 141 Engineering Dive in HTC. • EM 302 ping test again conducted with *Sentry* and USBL in water. Interference reduced but still present. • Mapping operations: SBP line conducted over HTC as transit commenced. Transit operations to BRD. • Three XBTs conducted.

11-Jul-12	EM 302, EK60, and Knudsen 3260 mapping operations. 1342 - Transducer Pole Lowered. 1436 - Deploy EX1205L1_AUV04_SENTRY142. 1803-1949 - CTD01 cast conducted (aborted). 2102-2333 - CTD02 cast conducted.	• Mapping transit operations to BRD. SBP re-occupation survey at BRD. EM 302 and EK60 detected BRD seep in water column backscatter data. • CTD01 and CTD02 Operations at BRD—due to high current, it is not possible to do a vertical CTD cast. Cast paused three times due to lightning in the area. • Three XBTs conducted.
12-Jul-12	0643 - Recover EX1205L1_AUV04_SENTRY142. 0651 - Transducer Pole Raised. EM 302, EK60 mapping operations. 1000 - EM 302, EK60, and SBP operations. 1801 - Transducer Pole Lowered. 1832 - Deploy EX1205L1_AUV05_SENTRY143.	• AUV 142 Operations at BRD. Sidescan sonar (SSS) low-resolution strip; high-resolution multibeam strip (partial, aborted due to high speed error). • Mapping operations: EK60 survey in morning extending water column coverage N and S of existing survey area (new seep detected). High-resolution SBP survey at BRD commenced at 1000. • Three XBTs conducted.
13-Jul-12	0732 - Recover EX1205L1_AUV05_SENTRY143. 0740 - Transducer Pole Raised. EM 302 and EK60 mapping operations. 0900 - SBP mapping operations commence. 1799 - SBP mapping operations secured. 1814 - Transducer Pole Lowered. 1839 - Deploy EX1205L1_AUV06_SENTRY144.	• AUV 143 Operations at BRD. High-resolution SSS/photos (partial, dive aborted due to entanglement). • AUV 143 fouled by polypropylene line, and aborted early. • Mapping: EM 302 and EK60 transit mapping north of BRD. High-resolution SBP survey at BRD. • Conducted fire and emergency drills and abandon ship drill. • Two XBTs conducted.
14-Jul-12	0905 - Recover EX1205L1_AUV06_SENTRY144. 0916 - Transducer Pole Raised. 0900 - EM 302, EK60, and SBP mapping operations. 1908 - Transducer Pole Lowered. 1934 - Deploy EX1205L1_AUV07_SENTRY145.	• AUV 144 Operations at BRD. BRD N—Middle, main high-resolution SSS/photos. BRD N high-resolution multibeam. AUV recovered one hour later to make up for early abort yesterday. • Mapping: High-resolution SBP survey at BRD. Mapping survey N and E of BRD in high backscatter variability area. • Two XBTs conducted.
15-Jul-12	0935 - Recover EX1205L1_AUV07_SENTRY145. 0942 - Transducer Pole Raised. 0945 - EM 302, EK60, and SBP mapping operations commence. 1813 - Transducer Pole Lowered. 1850 - Deploy EX1205L1_AUV08_SENTRY146.	• AUV 145 operations at BRD S and N. BRD S—high-resolution multibeam. BRD N—high-resolution photomosaic (partial camera failure, after 1,000 photos; Eh hits are within the same timeframe; connected on the end cap). • *Sentry* AUV CTD changed out after S145. • Mapping operations North S unbreached diapir, N to CFD (seep seen in EM 302 and EK60 CFD water column data). • Two XBTs conducted.
16-Jul-12	0834 - Recover EX1205L1_AUV08_SENTRY146. 0840 - Transducer Pole Raised. 0845 - EM 302, EK60, and SBP mapping operations commence. 1814 - Transducer Pole Lowered. 1835 - Deploy EX1205L1_AUV09_SENTRY147.	• AUV 146 operations at CFD. High-resolution SSS survey (operations shifted to CFD while troubleshooting camera). • Mapping operations N of CFD to second unbreached diapir. South over fault (included SBP data). • Two XBTs conducted.

17-Jul-12	0830 - Recover EX1205L1_AUV09_SENTRY147. 0841 - Transducer Pole Raised. 0845 - EM 302, EK60, and SBP mapping operations commence. 1822 - Transducer Pole Lowered. 1848 - Deploy EX1205L1_AUV10_SENTRY148.	• AUV 147 operations at BRD N. BRD S—high-resolution multibeam (3-4 lines) to fill-in gaps. BRD N—high-resolution multibeam (3-4 lines) to fill in gaps. BRD main seep—photomosaic, 200 m x 200 m box. • Hazard to navigation located in photos at BRD main. • Mapping: continue S along the backscatter at BRD (below main BRD) • Two XBTs conducted.
18-Jul-12	0928 - Recover EX1205L1_AUV10_SENTRY148. 0935 - Transducer Pole Raised. 0945 - EM 302, EK60, and SBP mapping operations. 2000 - mapping operations secured. 2016 - Transducer Pole Lowered. 2037 - Deploy EX1205L1_AUV11_SENTRY149.	• AUV 148 operations at BRD S. BRD S—photomosaic and multibeam. No photo overlap. • Mapping operations west to 800-900 m isobath. Followed isobath contour to NE until 1600m (no seep plumes detected), then east to CFD. • Three XBTs conducted.
19-Jul-12	1238 - Recover EX1205L1_AUV11_SENTRY149. 1249 - Transducer Pole Raised. 1300 - EM 302, EK60, and SBP mapping operations.	• AUV 149 operations at CFD. CFD photomosaic over animal and plume seep signals (bacterial mat and clams documented). • Mapping operations: Mapping to S and W of CFD. Transit mapping to BRD changed to 800 m isobath due to inclement weather. Fill in lines around BRD. • No AUV launch due to incoming inclement weather. • Ceiling leak damaged data storage. • Two XBTs conducted.
20-Jul-12	1330 - EM 302, EK60, and SBP mapping operations secured. 1623 - Transducer Pole Lowered. 1652 - Deploy EX1205L1_AUV12_SENTRY150.	• Overnight Mapping operations: 270 km extent between 800 m and 1,000 m isobath contour. Isobath mapping suspended at 0800 to commence transit mapping to BRD. Multiple mapping lines run over known BRD plumes to assess multibeam sonar's ability to detect plumes in high sea state. • Initial launch of AUV aborted due to hydraulic leak in port side crane. Hose fixed in one hour—AUV launched with no problem. • Conducted fire and emergency drill and abandon ship drill. • Four XBTs conducted.
21-Jul-12	1145 - Recover EX1205L1_AUV12_SENTRY150. 1153 - Transducer Pole Raised. 1200 - EM 302, EK60, and SBP mapping operations. 2000 - Mapping operations secured. 2010 - Transducer Pole Lowered. 2032 - Deploy EX1205L1_AUV13_SENTRY151.	• AUV 150 Operations at BRD N, Middle, and S. BRD—single and multibeam gaps filled. BRD Middle—photo survey. BRD N – photo survey. Photo strip over W plume. • Mapping operations at the Cape Fear Slide. Transit mapping from BRD to CFD. Coverage built to E and W of existing coverage. • 2 XBTs conducted

22-Jul-12	0844 - Recover EX1205L1_AUV13_SENTRY151. 0852 - Transducer Pole Raised. 0910 - CTD03 cast conducted. 1130 - EM 302, EK60, and SBP mapping operations. 1230 - SCUBA dive on hull. 1530 - Mapping operations resume. 2041 - Transducer Pole Lowered. 2100 - Deploy EX1205L1_AUV14_SENTRY152.	• AUV 151 Operations at CFD. CFD photo survey east of S149 block; multibeam to E and SW. • CTD03 Cast at CFD. • Mapping operations at CFD, including perpendicular crossing line. Afternoon mapping operations to the east of CFD. • Deck greased cable for the in-port, conducted SCUBA dive on the hull to clear debris from sea chests. • Two XBTs conducted.
23-Jul-12	1430 - Recover EX1205L1_AUV14_SENTRY152. 1446 - Transducer Pole Raised. 1500 - EM 302, EK60, and SBP mapping operations, including transit mapping.	• AUV 152 Operations at CFD. Multi-height Eh survey (7 mab, 5 mab, 3.5 mab; nested, decreasing in area with depth, biased to NW current). Multibeam survey for water column profile. Gap fill, multibeam CFD E photo survey (Eh spike and geological features; 30-m spacing. CFD SW photo survey; 30-m spacing. CFD S SSS to SE edge, continuing N along slope. CFD E SSS. • Mapping operations: Fill in the Cape Fear Slide map; expand 800 m isobath contour mapping; transit across continental shelf to Beaufort Inlet sea buoy. • Two XBTs conducted.
24-Jul-12	~0700 - Mapping operations secured. 0900 - Alongside Berth 7, Morehead City, NC.	• Transit Mapping operations to Morehead City. • Two XBTs conducted.

4.4.3 Table of CTD Locations

Table 7. Table summarizing CTD casts conducted during EX-12-05 Leg 1. Additional information about each cast can be found on the CTD Rosette Summary Forms in **Appendix A**.

	CTD Cast Summary Table										
CTD Cast Name	**Site**	**Max Depth (m)**	**Target Position**		**Deployment Location**		**Time & Location at Depth**		**Recovery Location**		**Notes**
CTD001_20120712	Blake Ridge Diapir	1409	32° 29.453'N	76° 11.618'W	32° 29.453'N	76° 11.618'W	32° 29.453'N	76° 11.618'W	32° 29.453'N	76° 11.618'W	- Vertical cast. -Sensor data acquired included CTD, OPR, LSS, DO and Altimeter data. - No water samples collected.
	Notes: - Aborted cast at 1400m to reposition ship and attempt cast closer to target site due to extremely strong current. - DO sensor not in line with other sensors – very jagged profile.										
CTD002_20120713	Blake Ridge Diapir	2142	32° 28.9'N	76° 12.078'W	32° 28.9'N	76° 12.079'W	32° 29.014'N	76° 12.005'W	32° 29.032'N	76° 11.994'W	- Vertical cast. -Sensor data acquired included CTD, OPR, LSS, DO and Altimeter data. - No water samples collected.
	Notes: - Extremely strong current: with 2400m wire out CTD was >500m from the ship with a 45° Wire angle during most of the cast. - DO sensor not in line with other sensors – very jagged profile.										
CTD003_20120722	Cape Fear Diapir	2584	32° 58.621'N	75° 55.434'W	32° 58.489'N	76° 55.560'W	32° 58.503'N	76° 55.577'W	32° 58.501'N	76° 55.577'W	- Vertical cast. -Sensor data acquired included CTD, OPR, LSS, DO and Altimeter data. - No water samples collected.
	Notes: - Minimal current compared to previous. CTD distance was <200m from the ship at 2500m wire out. Current direction was 045. - Replaced dissolved oxygen sensor with spare and plumbed sensor in line with temperature conductivity and pump: Data was smooth for 200m, after 200m, possible short in instrument.										

4.4.4 Operational Use of URI Shore-Based Facilities (ISC and OSEC 115)

ISC Mission Control

ISC mission control was revamped just prior to this cruise to accommodate up to 15 simultaneous participants in preparation for hosting this mission team on shore. A second row of science stations was added with computers and intercoms, along with a taller bench at the back of the room to allow for up to three participants with laptops or a chart. A speaker phone was provided at the back table to accommodate science planning calls with the ship, and live streaming video of the ISC mission control space was added to the template on the OER website (oceanexplorer.noaa.gov) for mission purposes, for convenience of the team on shore, and to demonstrate additional outreach/education potential of the facility.

ISC mission control was the primary center of activity by the science and engineering participants, and was used in a multitude of ways including the following:

- Mission operations and planning
- Remote AUV engineering tests and operations
- Data access, processing, and analysis
- Scientific planning and discussions
- Daily science meetings and other communications between ship and shore
- Training of students and interns
- Tours for VIPs, students, and the general public

ISC mission control is normally an extension of the ship's control room for expedition scientists. During EX-12-05 Leg 1, mission control became an extension of the AUV workshop as well. With the addition of a virtual private network (VPN) one of the core AUV team engineers was able to conduct their duties from the ISC. This VPN could be extended to the OSEC 115 classroom, if required. The flexibility of the ISC's network allowed the *Sentry* computer network to be extended even further to included WHOI through a Secure Shell (SSH) tunnel. This allowed for subject matter experts be called in to troubleshoot software problems.

4.4.5 Ship-to-Shore Communications and Workflow

Ship-to-shore communications and workflow are critical components of telepresence-enabled expeditions. During EX-12-05 Leg 1, telepresence enabled shore-based participation for two different projects that occurred during the same cruise.

Hatteras Transverse Canyon (HTC)

The *Sentry* AUV engineering dives were conducted July 8 to 10 at the HTC. The dives conducted on July 8 and 9 included the use of telepresence to accomplish key objectives focused on remote start-up and testing of the AUV from shore, as well as remote watch-standing. Ship-to-shore communications for the engineering dives were primarily conducted using the RTS intercom units and instant messaging. The shipboard cameras were modified so onshore personnel could watch the *Sentry* team at work in the wet lab, and two intercom party lines were added to the RTS units to enable direct communication with the *Sentry* team in the wet lab, and with the *Okeanos Explorer* deck team during launch/recovery operations. Combined with a ship-to-shore *Sentry* VPN network, James Kinsey, from the WHOI AUV team, was able to effectively conduct AUV software pre-dive and testing, as well as remote watch-standing, during the July 8 dive and the final AUV start-up from shore for the July 9 dive.

A ship-to-shore science meeting was held on July 6 with scientists from USGS and the University of Maine to choose dive site locations for the AUV engineering dives and to discuss mapping data opportunities of interest to the science community. Post-dive briefings were held following the first two AUV dives to refine plans as needed, and included participation of ship and shore-based scientists, Laura Brothers (onboard) and Kathy Scanlon Catanach (from URI), both with USGS.

Blake Ridge Diapir (BRD) and Cape Fear Diapir (CFD) Exploration

During the Blake Ridge exploration portion of the cruise, daily science planning meetings were held with the science team onshore to go over the latest data and findings from previous dives, and to plan upcoming operations. The time of these meetings varied at different points during the cruise. Typically, the following topics were covered: an update from shipboard science on new data products and preliminary interpretations, an update from the *Sentry* team, and an update from the shoreside team on ongoing activities and insights. Then new data would be discussed, the dive plan for the coming night's dive reviewed and refined if needed, and the concept for the following day's operations and dive developed. Meetings were either held in the morning or early afternoon, with additional ship-to-shore interaction as needed to refine/finalize the mission plan through the afternoon.

AUV dive missions were jointly developed by AUV team members based both at-sea and ashore. Mission blocks would be defined by the Senior AUV Engineer onshore working with the science team. The mission would then be sent to the ship where the onboard AUV Team Lead would develop the detailed mission plan.

Aside from the daily science planning meetings conducted via teleconference while streaming desired visual aids over the live video feeds, internet-based tools facilitated communication. RTS intercom units located on the *Okeanos Explorer* and at the ISC enabled the at-sea or shore-based team to reach each other as needed (though connectivity losses were frequently experienced during this cruise). Instant messaging and e-mail among individuals was particularly effective for ship-to-shore communications. Context and updates about ongoing at-sea operations were provided to the shoreside team, primarily by streaming the relevant video feed to shore, and by posting regular updates about operations in the Eventlog. Questions, updates, and issues from the shoreside team were also posted to the Eventlog.

4.4.6 Expedition Operational Products/Data Processing

A suite of *Sentry* AUV cruise data products were developed during the cruise (**Table 8**). During the course of the cruise, a set of products needed for day-to-day operations and decision-making became apparent; these were prioritized to be sent to shore using the *Okeanos Explorer* file transfer protocol (FTP) Server, or made available via the *Sentry* ship-to-shore network. Data and product development and transfer workflow were established. Some *Sentry* data and products were further developed by team members based both at-sea and ashore. Below is a list of these *Sentry* AUV products developed and shared with the shoreside team in near-real time for day-to-day operations and decision-making. During the cruise, a daily inventory listing available AUV dive data and products on the *Okeanos Explorer* FTP Server was developed by the onboard data manager, and sent to the expedition team nightly.

Table 8. Table summarizing "standard" *Sentry* AUV data and products developed and shared with the shoreside team in near-real time for day-to-day operations and decision-making.

Sentry AUV Data & Products					
Data/Product	**Description**	**Format**	**Developer**	**Developer Location**	**Access Location**
AUV Pre-Dive Form		PDF	*Sentry* AUV Team	Shore	FTP Site; e-mail
AUV Navigation Track	Flat ASCII summary file (date, time, latitude, longitude, depth, height, conductivity, temperature, magnetometer)	.scc	*Sentry* AUV Team	Ship/Shore	Hard drive; FTP Site
AUV Dive Tracks	Summary file parsed from .scc file with date, time, and location the AUV went in the water, arrived on bottom, came off bottom, and out of the water	.txt	Data Manager	Ship	FTP Site; *Okeanos* Atlas
AUV Mission Plan	Georeferenced, planned AUV dive track	.kml	AUV Team Lead; EX Team	Ship	*Okeanos Explorer* Electronic Chart Display and Information System (ECDIS) and DP display
AUV Dive Tracklines	Planned and executed AUV dive tracks. End points of the dive. The dive path. Dive path,	.kml	Data Manager	Ship	FTP Site; *Okeanos* Atlas

	smoothed to 30 seconds.				
Gridded multibeam bathymetry	Gridded bathymetry	(.sd, .kmz, .xyz, and .tiff)	*Sentry* AUV Team	Ship/Shore	FTP Site; Carl Keiser's computer
AUV multibeam water column data	Mosaics of *Sentry* multibeam water column data, with basic navigation plots	.jpg	EX Team, working with *Sentry* AUV Team	Ship	FTP Site; e-mail. Only created for dives 145 and 148 as a test
CHIRP sub-bottom profiler data	Navigated raw data; annotated, gain corrected strip plot images of data tracks	.jsf, .jpg strip plots	*Sentry* AUV Team	Ship/Shore	Hard drive
CHIRP	Annotated gain corrected pictures of tracks	.jpg	*Sentry* AUV Team	Ship/Shore	Carl Keiser's computer; hard drive
Sidescan	GeoTIFF – Geolocated strips of gain corrected, bottom tracked sidescan data	.tiff, Chesapeake project files	*Sentry* AUV Team	Ship	FTP Site; Carl Keiser's computer
Processed thumbnail JPG images	Processed, color-balanced and equalized images	.jpg	*Sentry* AUV Team	Ship	FTP Site
Full resolution .tiff images	Processed, color-balanced and equalized images	.tiff	*Sentry* AUV Team	Ship	Priority subsets were posted to the FTP Site
Photomosaics	Photomosaic compilations of georeferenced, high-resolution images	.tiff	Science Team	Shore	FTP Site
Sensor data	CTD, Eh, Flourometer, DO	.scc; .sd	*Sentry* AUV Team and Science Team	Ship/Shore	FTP Site; Carl Keiser's computer
Navigation integrated sensor data	Navigation integrated sensor data (Eh and OBS)	.sd	Mapping Team	Ship	FTP Site
Multibeam water column mosaics	Mosaic images showing multibeam water column data	.jpg	EX Team	Ship	FTP Site; e-mail
AUV Dive Summary Form		PDF	*Sentry* AUV Team	Ship	E-Mail; *Sentry* Operations Report
Sentry Operations Report		PDF	*Sentry* AUV Team	Ship/Shore	E-Mail; Hard drive

A suite of *Okeanos Explorer* Program data and products were also developed using data acquired by *Okeanos Explorer* sensors and systems (**Table 9**). In addition to the production of standard *Okeanos Explorer* mapping data products, value-added products, including water column objects (.sd) and draped seafloor backscatter (.sd), were regularly produced by the onboard mapping team to meet the operational needs of this cruise.

Table 9. Table summarizing standard *Okeanos Explorer* sensor and systems data and products developed and shared with the shoreside team in near-real time during EX-12-05 Leg 1 for day-to-day operations and decision making.

Okeanos Explorer Data & Products					
Product	**Description**	**Format**	**Developer**	**Developer Location**	**Access Location**
Plan of the Day	Plan of the day detailing ship operations.	.docx, PDF	Operations Officer	Ship	EX Portal; FTP site
Regular Updates	Regular updates detailing ongoing ship operations.	.txt, verbal communication	EX Watch Leader	Ship (Watch Stander, Science, etc.)	Eventlog; RTS intercom; embedded audio
Eventlog	Scientists' online journal—where observations and updates about operations are logged.	.txt	Expedition participants; automated server	Geographically distributed	iChat server; FTP site
SITREPs	Daily status report detailing EX operations.	.docx, PDF	Expedition Coordinator	Ship	EX Portal; FTP site
Datasets	Raw oceanographic data, SCS, CTD, etc.	various	Webb's automated process; SSTs	Ship	FTP Site
Metadata	Metadata records.	XML	NESDIS	Shore	FTP Site
EK60 Single-Beam Data	Raw water column data. Where appropriate, a processed level two image.	.raw, Fledermaus .sd, image (.jpeg, .tiff)	Mapping team	Ship/Shore	FTP Site
Sub-Bottom Profiler Data	Raw data. Where appropriate, a processed geo-referenced vertical curtain.	.seg-y, .keb GeoTIFF.	Mapping team	Ship/Shore	FTP Site
Daily mapping progress bathymetry/ backscatter	Site-specific or cumulative daily bathymetry and backscatter.	GeoTIFF; Fledermaus .sd; Google Earth .kmz; ASCII text file; .jpg with polygon of daily progress	Mapping team	Ship	FTP Site

CTD Summary Forms	Summary of CTD cast results; detail sample collection.	.docx, PDF	Science Team	Ship and Shore	FTP Site
Raw Video Clips–Low-Resolution	Video clips from onboard and hand-held cameras.	.mov (H.264 at 1.5 MB at 640 x 320)	Video team	Ship	FTP Site

5. Clearances and Permits

Pursuant to the National Environmental Policy Act (NEPA), OER is required to include in its planning and decision-making processes appropriate and careful consideration of the potential environmental consequences of actions it proposes to fund, authorize, and/or conduct. The Companion Manual for NOAA Administrative Order 216-6A (https://www.nepa.noaa.gov/docs/NOAA-NAO-216-6A-Companion-Manual-03012018.pdf) describes the agency's specific procedures for NEPA compliance.

An environmental review memorandum was completed for all *Okeanos Explorer* expeditions in 2012 in accordance with Section 4 of the companion manual in the form of a categorical exclusion worksheet (Kennedy, 2014). Based on this review, a categorical exclusion was determined to be the appropriate level of NEPA analysis necessary, as no extraordinary circumstances existed that required the preparation of an environmental assessment or environmental impact statement.

The expedition did not involve any other Monuments or Sanctuaries in the vicinity. No samples were collected during the *Blake Plateau Exploration Using* Sentry *AUV* expedition (EX-12-05 Leg 1). The categorical exclusion letter can be found in **Appendix B**.

6. Schedule and Map

6.1 Expedition Schedule

From July 5 to 24, 2012, a team of scientists, engineers, and technicians—both at-sea and on shore—conducted exploratory interdisciplinary investigations of the HTC, BRD, and CFD areas off the east coast of the United States. The 20-day expedition was composed of two parts. The first part focused on three days of engineering dives with the *Sentry* AUV from July 8 to 10, 2012. The second part of the cruise focused on exploring the diversity of seep habitats on the BRD and CFD system, and used the onboard suite of technologies to prospect for seep environments. Both parts of the cruise included operating an AUV from NOAA Ship *Okeanos*

Explorer for the first time—and explored how to integrate the *Sentry* AUV into telepresence-enabled systematic exploration. A total of 14 AUV dives were conducted during the expedition, although one AUV dive was cancelled due to weather.

- July 5 – Departed Davisville, RI and began transit to the HTC; acquired underway data.
- July 6 – Conducted USBL Calibration; transit mapping operations.
- July 7 – Transit mapping operations.
- July 8 to 10 – Conducted *Sentry* AUV engineering dives at the HTC; conducted shipboard mapping operations.
- July 11 to 14 – Shipboard mapping, AUV and CTD rosette operations at the BRD.
- July 15 – Shipboard mapping and AUV operations at the CFD, unbreached diapir.
- July 16 to 17 – AUV operations at the BRD; shipboard mapping north of CFD to the second unbreached diapir.
- July 18 – AUV operations at the CFD; shipboard mapping operations along the 800-900 m isobaths and CFD.
- July 19 – AUV dive cancelled due to weather; shipboard mapping operations around the BRD.
- July 20 – AUV operations at the BRD; shipboard mapping along the 800-1,000 m isobaths.
- July 21 to 22 – Shipboard mapping, AUV and CTD rosette operations at the CFD; SCUBA dive on hull.
- July 23 – Shipboard mapping at the Cape Fear Slide and 800-1,000 m isobaths; departed the primary operating area, and commence transit to Morehead City, NC.
- July 24 – Ship arrived in Morehead City, NC. Expedition concludes.

6.2 Summary Maps

The maps below show the EM 302 multibeam collected with AUV *Sentry* deployment locations and CTD cast locations overlaid. The maps represent the major operational areas of EX-12-05 Leg 1, which were the HTC (**Figure 5**), the BRD, and the CFD (**Figure 6**).

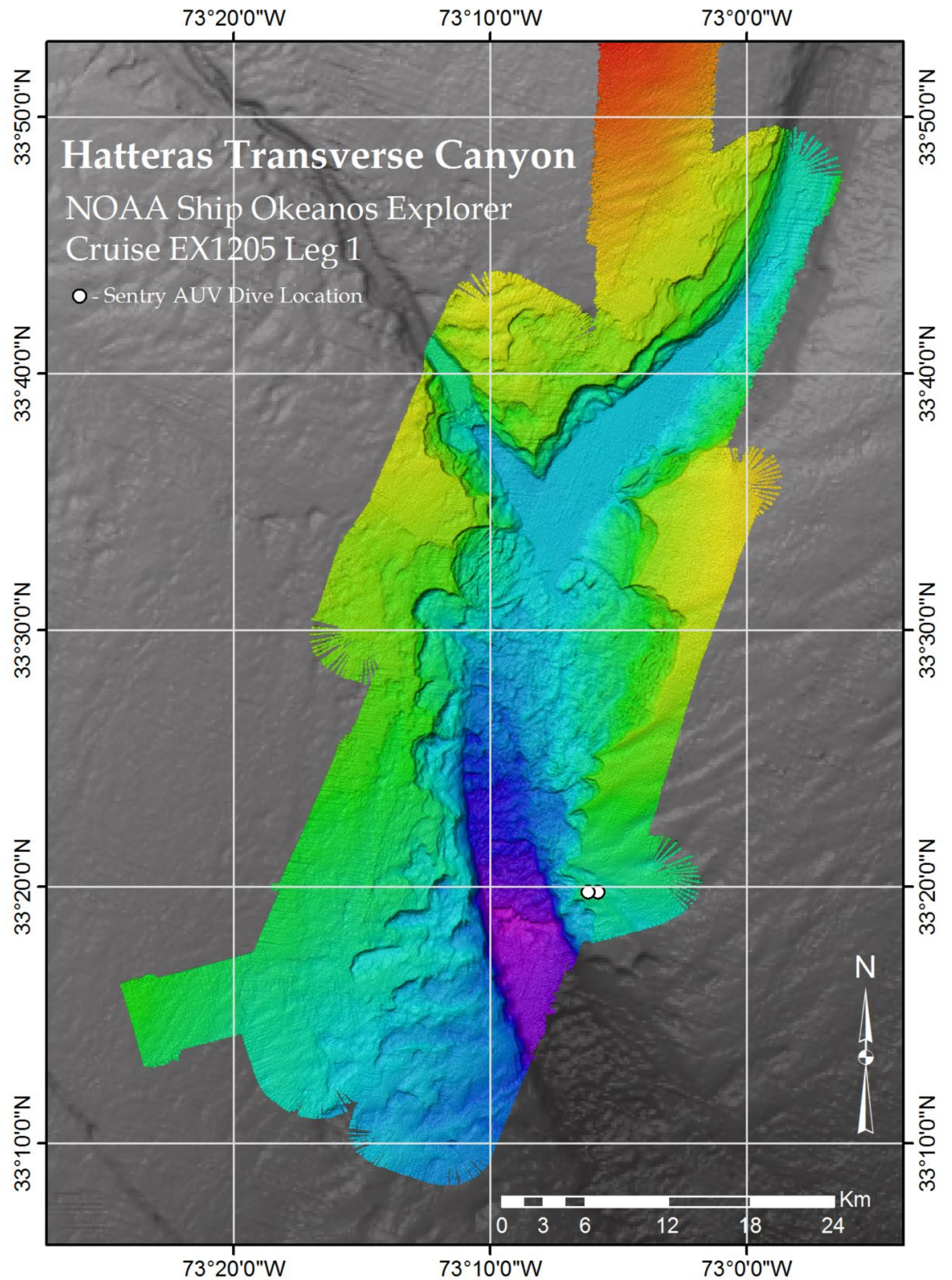

Figure 5. Map of the Hatteras Transverse Canyon (HTC) showing EM 302 bathymetry data and launch locations of three *Sentry* AUV engineering dives conducted during EX-12-05 Leg 1. Colors indicate depth, warm colors (red) indicate shallower depths and cool colors (blue) indicate deeper depths.

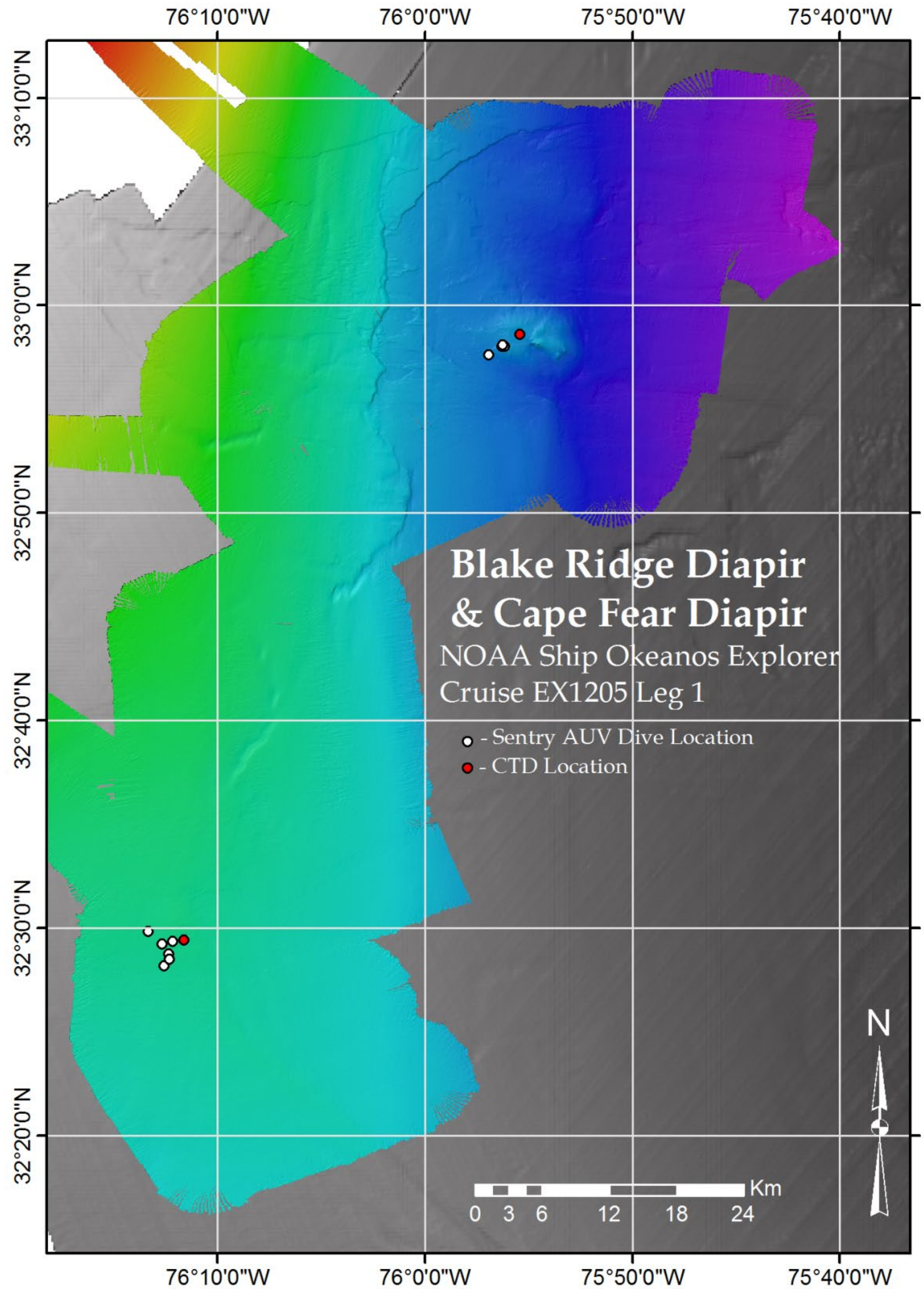

Figure 6. Map of the BRD and CFD areas showing EM 302 bathymetric data and launch location of the eleven *Sentry* AUV dives and three CTD casts conducted here during EX-12-05 Leg 1. Colors indicate depth, warm colors (red) indicate shallower depths and cool colors (blue) indicate deeper depths.

7. Results

7.1 Scientific Results

7.1.1 AUV Surveys

A total of 14 AUV surveys were accomplished during EX-12-05 Leg 1. Details are in **Table 10**.

Table 10: Table summarizing *Sentry* AUV dive launch locations, and locations where the AUV arrived and left the seafloor.

AUV Dive Summary Table								
AUV Dive Name	**AUV Launch Location**		**On Bottom**		**Off Bottom**		**Depth**	**Time**
Cruise_Dive#_Date(UTC)_SentryDive#	**Latitude (N)**	**Longitude (W)**	**Latitude (N)**	**Longitude (W)**	**Latitude (N)**	**Longitude (W)**	**Survey Mean (m)**	**Survey (hours)**
EX1205L1_AUV01_20120708_SENTRY139	33° 19.798'	73° 05.800'	33° 19.820'	73° 5.676'	33° 18.631'	73° 8.076'	5094	3.2
EX1205L1_AUV02_20120709_SENTRY140	33° 19.798'	73° 05.800'	33° 19.917'	73° 5.571'	33° 19.727'	73° 6.549'	5045	5.4
EX1205L1_AUV03_20120710_SENTRY141	33° 19.813'	73° 06.199'	33° 19.921'	73°, 5.861'	33° 19.907'	73° 6.399'	4971	1.3
EX1205L1_AUV04_20120711_SENTRY142	32° 29.869'	76° 13.334'	32° 30.630'	76° 12.726'	32° 29.585'	76° 13.334'	2164	13.6
EX1205L1_AUV05_20120712_SENTRY143	32° 28.197'	76° 12.577'	32° 28.547'	76° 12.438'	32° 29.857'	76° 11.832'	2141	8.8
EX1205L1_AUV06_20120713_SENTRY144	32° 29.383'	76° 12.147'	32° 29.434'	76° 11.934'	32° 30.049'	76° 11.964'	2141	11.6
EX1205L1_AUV07_20120714_SENTRY145	32° 28.767'	76° 12.347'	32° 29.232'	76° 12.008'	32° 30.358'	76° 11.863'	2143	11.5
EX1205L1_AUV08_20120715_SENTRY146	32° 57.606'	75° 56.936'	32° 58.365	75° 56.395'	32° 59.329'	75° 56.323'	2588	11.1
EX1205L1_AUV09_20120716_SENTRY147	32° 29.256'	76° 12.652'	32° 29.768'	76° 12.211'	32° 29.743'	76° 11.620'	2155	11.6
EX1205L1_AUV10_20120717_SENTRY148	32° 28.509'	76° 12.305'	32° 29.001'	76° 11.604'	32° 29.430'	76° 11.654'	2162	12.3
EX1205L1_AUV11_20120719_SENTRY149	32° 58.029'	75° 56.284'	32° 58.741'	75° 55.902'	32° 58.431'	75° 56.242'	2574	13.3
EX1205L1_AUV12_20120720_SENTRY150	32° 58.024'	75° 56.165'	32° 29.698'	76° 11.863'	32° 29.156'	76° 11.163'	2153	16.4
EX1205L1_AUV13_20120722_SENTRY151	32° 58.024'	75° 56.165'	32° 58.290'	75° 55.939'	32° 58.321'	75° 55.560'	2565	9.6
EX1205L1_AUV14_20120723_SENTRY152	32° 58.094'	75° 56.261'	32° 58.435'	75° 56.184'	32° 58.433'	75° 56.185'	2577	14.8

7.1.2 Accomplishments and Preliminary Results

Hatteras Transverse Canyon (HTC)

Before EX-12-05 Leg 1, only two research efforts had characterized the canyon: the national sidescan sonar effort GLORIA (1984), and the multibeam survey conducted as part of the UNCLOS (2006). From July 7 to 9 three *Sentry* engineering dives were conducted at the HTC. These dives were interspersed with shipboard mapping efforts. Engineering objectives of the *Sentry* included: proving out Sentry's capabilities to operate at > 5,000 m water depth, and improving instrumentation capabilities (a full list of engineering objectives can be found in the *Sentry* Operations Report- Kaiser et al. (2014)) Combining science with engineering objectives, *Sentry* collected high-resolution data along the canyon walls and edges. Analysis of the *Sentry*-collected, high-frequency sidescan sonar revealed the presence of extensional cracks in the seafloor and other indications of slope processes never before resolved in the canyon. *Okeanos Explorer* shipboard mapping efforts resulted in the highest resolution multibeam map to date of the central thalweg (deepest continuous inline within a valley or watercourse system) and the first sub-seabed data collected in the canyon in nearly thirty years. Multibeam data were collected with the same trackline orientation as the 2006 data to facilitate future quantitative comparisons and difference analyses of the two datasets.

Blake Ridge Diapir (BRD) and Cape Fear Diapir (CFD) Complex

The abundance and global distribution of cold seeps are unknown. Similarly, the diversity, frequency, and distribution of associated chemosynthetic ecosystems have yet to be determined (Wagner et al., 2013; Brothers et al., 2014). EX-12-05 Leg 1 combined the complementary data collection capabilities of the *Okeanos Explorer* and the *Sentry* AUV to identify and characterize cold seeps at the BRD and CFD. The *Okeanos Explorer* also conducted reconnaissance at the 800-900 m isobaths to test the hypothesis that the seafloor in those zones is currently degassing as a result of hydrate dissociation (Brothers et al., 2013; Skarke et al., 2014). Data types collected by the ship included multibeam bathymetry (including water column), 3.5 kHz sub-bottom, EK60 echosounder, and CTD data. *Sentry* collected multibeam bathymetry (including water column), sidescan sonar, chirp sub-bottom, reduction potential, optical backscatter, and photographic images.

Seep Identification

The combination of the *Okeanos Explorer's* shipboard systems and *Sentry*'s data collection capabilities resulted in the successful reanalysis of the known BRD seep (BRD Main) and the identification of three additional seep communities dominated by bathymodiolin mussels and vesicomyid clams on the BRD, each separated by 5 km or more from its nearest neighbor (BRD North, BRD Middle, BRD South). A seep community (bacterial mat, bubbles, and possible clams) was also discovered at the CFD, roughly 59 km north-northeast of the BRD.

New sites for seep investigation were initially identified based on water column anomalies (interpreted as bubble plumes) in the ship's multibeam and echosounder data. Subsequent dives by *Sentry* resolved coincident zones of high backscatter, micro-topographic relief, and acoustic and geochemical water column anomalies. These observations were "ground-truthed" as seabed seeps with *Sentry*-collected photos of extensive chemosynthetic communities (**Figure 7, 8** [BRD], and **Figure 9** [CFD]).

Photo surveys with overlapping images allow mosaic strips (e.g., **Figure 10**) to be constructed that allow researchers to piece together faunal relationships and the relationship of the fauna and seafloor features and bathymetry.

Co-located sub-bottom data indicated subsurface conduits associated with the seeps. With this methodology, cruise EX-12-05 Leg 1 resolved gas migration from 40 m below the seabed up to 1000 m above the seabed, mapped in high resolution the spatial distribution of chemosynthetic communities along the BRD and CFD, and more than tripled the number of known seep communities along the U.S. Atlantic margin. These findings lay the groundwork for further scientific exploration and sampling planned with ROV *Jason* as part of an NSF-funded study of population connectivity in seep invertebrates.

In addition, EX-12-05 Leg 1 collected sub-bottom data with the same instrumentation and acquisition parameters as a 2003 survey described in Hornbach et al. (2007). The co-located surveys are the first 4-dimensional, high-resolution sub-bottom dataset collected at a major gas hydrate province and will give insight into the temporal evolution of subsurface migration pathways.

Other scientific benefits of EX-12-05 Leg 1 included the collection of multibeam data in previously unmapped areas of the continental shelf, an examination of the effects of sea state on the resolution of water column anomalies, and further geophysical characterization of the Cape Fear fault and slide complex.

Eight biology and geology students, ranging from undergraduates to doctoral candidates, participated in the expedition from shore. Their projects include field testing an AUV mounted Eh sensor, high resolution imaging of the sub-seafloor, ArcGIS data analysis, Fledermaus data analysis, and an artistic video documentary included in **Appendix C**; a deep-sea field guide is included in **Appendix D**.

Figure 7. Mussel bed at BRD Main

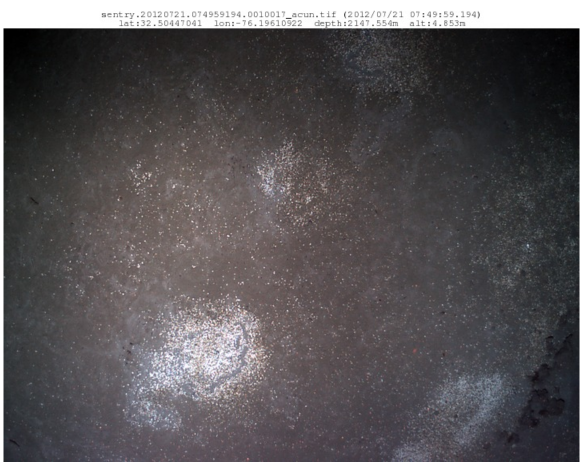

Figure 8. ‘Puddles’ of vesicomyid clams at BRD North.

Figure 9. Bacterial Mat, CFD

Figure 10. Partial photomosaic of a mussel bed, BRD Main.

7.1.3 Table of Gas Plume Locations

Table 11. Table showing the location of gas seep plumes detected and documented during the cruise. *Note that another table listing the location and depth of gas seeps detected by the* Okeanos Explorer *mapping systems can be found in Lobecker et al (2012).*

Location	Seep #	Latitude (N)	D	M	S	Longitude	D	M	S	Latitude (DD)	Longitude (DD)
Cape Fear Diapir	1	32d 58' 42.04"	32	58	42.04	75d55'30.85"W	75	55	30.85	32.97834444	75.92523611
Blake Ridge Diapir - South	2	32 d 29' 21.9"	32	29	21.9	76d11'34.8"W	76	11	34.8	32.48941667	76.19300000
Blake Ridge Diapir - proper	3	32 d 29' 43.5"	32	29	43.5	76d11'30.7"W	76	11	30.7	32.49541667	76.19186111
Blake Ridge Diapir - proper	4	32 d 29' 37.4"	32	29	37.4	76d11'27.3"W	76	11	27.3	32.49372222	76.19091667
Blake Ridge Diapir - proper	5	32 d 29' 44.9"	32	29	44.9	76d11'23.9"W	76	11	23.9	32.49580556	76.18997222
Blake Ridge Diapir - North	6	32 d 30' 19.8"	32	30	19.8	76d11'50.0"W	76	11	50	32.50550000	76.19722222
Blake Ridge Diapir - West (weak)	7	32 d 29' 39.17"	32	29	39.17	76d11'53.26"W	76	11	53.26	32.49421389	76.19812778

7.1.4 Exploration for Cold Seeps Using the Sentry AUV

This cruise represented the first occasion in which *Sentry* was used with great efficiency to prospect for cold seep activity in previously unexplored terrain, and to precisely locate new benthic communities on the seabed.

Because of the experimental nature of the approach, multiple techniques were applied drawing upon extensive first-hand experience in prior related work including:

- The nature of cold seep ecosystems, in general, and the known BRD main site, in particular;
- The use of previous AUVs in hydrothermal exploration, prospecting for and locating focused and diffuse hydrothermal flow at mid-ocean ridges;
- The use of sidescan sonar to prospect for and locate indurated hard grounds arising from methane oxidation and carbonate precipitation along other ocean margins.

The Importance of the Shipboard Mapping Team

In all of the uses of *Sentry*, described below, it would be impossible to overstate the fundamental importance of the shipboard mapping operations conducted by the *Okeanos Explorer* shipboard team in first surveying much broader areas of the seafloor to identify areas of active gas flow from the seabed and to provide the broad geological context (from both bathymetry and shipboard acoustic backscatter) as a framework from which to plan the *Sentry* dives. Just as is the case for hydrothermal exploration, where the use of CTD Tow-yos is an essential precursor data set, the team would not have enjoyed so many successes with *Sentry* throughout each AUV dive on this cruise if the *Okeanos Explorer* shipboard mapping team had not already provided optimize site selection or targets on the localized areas where the team should—and the even larger areas where the team should not—begin to work.

Techniques at the Team's Disposal

In preparing for the expedition, the multiple techniques the team had arranged to have at its disposal included:

- Detailed mapping capabilities using *Sentry's* Reson multibeam sonar.
- High- (100 kHz) and low- (400 kHz) frequency sidescan sonar.
- In situ water column sensing (including CTD, optical clarity, DO, and Eh).
- Seafloor photography using a digital still camera.

a) Use of gas plume identification from EM 302 multibeam surveys.

The identification of gas plumes was 100% successful (n=2) at helping to localize sites of active fluid flow from the seafloor to the level of being able to photograph (and, hence, localize precisely) at least one site of active fluid flow at both the BRD and at the CFD.

At the BRD, there were four sets of distinct gas plume sources resolved from the shipboard mapping team; and three of these, which were located along stroke from each other, were associated with benthic communities (of four sets of benthic communities found) while a fourth gas plume, located by the shipboard team to have a source to the West of the main BRD complex, was not detected in any of the AUV-based approaches, despite repeat attempts to prospect for its source using the various techniques available from *Sentry*—sidescan, multibeam, water column sensing, and bottom photography. By the end of the cruise, the source of that fourth gas plume remained enigmatic and, overall, the success of using gas plume detection to locate specific sites on the seafloor can be assigned a success rate of 75% from either one of two perspectives:

- Only three of the four gas plumes identified from the *Okeanos Explorer* coincided with benthic communities found on the seafloor by *Sentry* within the cruise duration.
- Only three of the four benthic communities found by *Sentry* at the seafloor (BRD South, BRD Main, BRD North) had gas plumes associated with them.

b) Use of high-frequency sidescan sonar surveys at 5 m altitude

This was one of the most efficient and rewarding modes of exploration employed by *Sentry* throughout the cruise. Both the low-frequency (~100 kHz) and high-frequency (~400 kHz) sidescan techniques provided a much wider swath of seafloor insonification, at any given altitude, than the Reson multibeam system; therefore, it was decided at an early stage of the cruise to use this approach first, to cover the maximum area of seafloor for detailed investigation per hour of *Sentry* survey time. While both low-frequency (LF) and high-frequency (HF) surveys were conducted on the first dive, with the LF surveys flown at higher altitude providing a much larger footprint of seafloor surveyed per unit time, a compelling advantage of the HF sonar surveys was that when flown close above the seafloor (5 m altitude) *Sentry* could not only obtain wide swaths of backscatter imagery (line spacing was routinely 150 m to ensure good overlap between adjacent survey lines), but could simultaneously obtain co-registered ground-truthing photographs along the center line of the area insonified.

This has long been the aspiration of all deep-towed sidescan sonar surveys conducted by vehicles such as *TOBI* in the UK and the *DSL-120* and *IMI-30* systems operated by Hawaii Mapping Research Group (HMRG) in the U.S. In the same vein, 100 kHz surveys flown by *Sentry* on one previous cruise would also be conducted at altitudes too high above the seafloor to collect co-registered photographs. But because of the unique capabilities of *Sentry*—compared to other AUVs as well as to deep-tow systems—the team was able to conduct these innovative and highly successful co-registered sidescan and photographic surveys. Using this approach at BRD, the team was able to locate four separate sets of hard ground, lying along strike, including the known BRD mound and confirm that each of these four sites all hosted their own communities of large chemosynthetic fauna over the course of two *Sentry* dives (S143 and S144). Likewise, the first HF survey at CFD was sufficient not only to localize multiple hard grounds, but also to find the only area located to date of active fluid flow.

7.2 Adding an AUV to Telepresence Operations

EX-12-05 Leg 1 was the first time an AUV was operated onboard NOAA Ship *Okeanos Explorer*, and the primary cruise objective for OER was to look at what it would take to integrate an AUV into telepresence-enabled exploration, and whether an AUV and ROV could be jointly operated during the same cruise. Initial findings and recommendations on conducting future joint AUV/ROV operations onboard *Okeanos Explorer* on the same cruise are captured in Section 7.4. A cruise operations overview can be found in Section 4.4 of this report, including a description of how the shore-based facilities at URI were used to host the mission team during the expedition (Section 4.4.4) and a description of how ship-to-shore communications occurred and kept the shoreside team engaged (Section 4.4.5).

A key component of engaging a team in an ongoing cruise through telepresence is ensuring enough appropriate context and information is provided to the shoreside team during a cruise. During EX-12-05 Leg 1, a 10 Mbps pipe allowed the real-time streaming of two video feeds; these video feeds varied from presentations of the real-time navigation display of the AUV on the seafloor, real-time data acquisition screens from shipboard sonars or the CTD rosette, and equipment launch and recovery video showing personnel onboard the ship working in key workspaces. Furthermore, the acquisition, development, and ship-to-shore transfer of a standardized suite of data and products are critical to successful shore-based participation. EX-

12-05 Leg 1 made steps forward in the identification, development, and transfer of standardized AUV data products. While the products developed for this cruise were specific to meeting the needs of this particular project and PI, a suite of priority products for this cruise were identified and sent to shore as quickly as possible. During the process, some AUV data and products that could be considered for a standardized suite during more traditional *Okeanos Explorer* telepresence-enabled cruises were identified, as well as pre-cruise preparations needed for incorporating fly-away systems, helping to pave the way forward. A description of the data and products developed, and made available ship-to-shore during the cruise, can be found in Section 4.4.5 of this report.

Beyond adapting telepresence operations to accommodate the *Sentry* AUV, the application of telepresence to AUV operations proved valuable. Having an expanded shore-based team provided greater daily man-hours, additional multidisciplinary skill sets, and greater intellectual capital than are typically available onboard during a 'traditional' research cruise. This enabled a higher level of data processing and analysis between the ship and shore, and led to more efficient use of AUV bottom time.

7.2.1 Remote Start-up and Launch of an AUV

Three engineering dives were conducted at the HTC under a joint funding model between NSF (*Sentry* time) and NOAA (ship time). The objectives of these engineering tests included remote start-up and launch of an AUV. The results of the engineering dive objectives, including the use of telepresence, are on pages 6-8 of the *Sentry* Operations Report, Kaiser et al. (2014). The most relevant section is below:

Telepresence Operations and Engineering

Nearly all parts of the software pre-dive and testing were conducted from shore with the assistance (as normal) of a mechanic on deck. This worked acceptably, but is not a good long term fit for *Sentry* operations. However, shore-based personnel were able to stand a watch and interact with the vehicle via acoustic communications without shipboard involvement, which can be useful in some circumstances. The power of telepresence engineering was discovered to have significant long-term potential. In this model, experts on shore can be brought in to help diagnose and solve vehicle problems almost as though they were on the ship. This was used to significant advantage several times.

7.3 Joint AUV/ROV Operations

7.3.1 Overview/Background

OER's primary focus during EX-12-05 Leg 1 was not only to test the use of an AUV operated from *Okeanos Explorer* during telepresence-enabled operations, but furthermore to operate as if the ship was outfitted for "full" exploration mode with joint ROV operations. When the cruise was initially discussed, the desire was to have the AUV deployed from the starboard crane, as the ROV is operated from the aft deck during ROV operations. This, however, required installation of spectra line on the crane prior to the cruise. Following later discussions with the ship, it was determined both that there was insufficient time to make this happen prior to the cruise, and that such changes weren't high enough priority to merit permanent modifications for a cruise that served as a test. Since the ROV crane onboard already met the requirements, the decision was made to proceed and operate the AUV from the aft deck with the knowledge that the starboard crane could be modified, if needed, for future joint operations.

7.4 Telepresence and Oceanographic Training

Limited space onboard oceanographic research vessels has long placed a carrying capacity on engagement with and training of young scientists in research methods, processes, and practices. The shipboard experience includes a socialization element that is arguably selective for individuals who thrive in team situations, and that is facilitated by shared life and objectives onboard a small floating island with little outside distractions. These value-added social conditions might seem difficult to achieve in a shore-based mission, but EX-12-05 Leg 1 was successful in developing a shipboard-like experience—including the sensibility of being linked to (if not on) a ship and consequent reluctance to leave the ISC for extended periods during mission-active hours. Special to EX-12-05 Leg 1 was the use of an AUV with no real-time feed of images or data, yet with AUV mission planning and data analysis predominantly based shoreside and with superb support staff, the immediacy and relevance of the shore-based team was patent.

EX-12-05 Leg 1 linked three shoreside and two shipboard scientists and engineers with eight shoreside and one shipboard students, from July 12 to 23. Shoreside students arrived on site with very little understanding of the telepresence experience or of the types, quality, and quantity of data products that would be delivered to shore and available for analysis from AUV operations. Students immediately began to explore data sets and were assisted in this by the shore-based professional OER staff and students from URI as well as through access to software supplied by the ISC (**Figure 11**). Project scientists also assisted in this by presenting high-level objectives, thereby encouraging entrepreneurship and ownership of subprojects. Project scientists were also able to formally and informally mentor students in approaches to their research.

Figure 11. The student team engaged with *Okeanos Explorer* scientists, with Megumi Shimizu (second from left) briefing the ship and shore teams on the upcoming *Sentry* mission (S151). The large screen projects a computer screen on the ship with planning data.

Some Key Elements to Successful Training by Telepresence

- Identification of compelling exploration goals addressed with the right tools.
- Maintenance throughout the mission of shore-based leads in AUV mission planning.
- Engagement of trainees in all ship-to-shore planning sessions from the beginning.
- Enabling trainees by engaging them in team projects, empowering teams to contribute to planning missions, and learning to respond to and take advantage of new information, ideas, and developments.
- Critical mass: group dynamics across disciplines, skill sets, and experience enable problem solving, creativity, and productivity. The size of the student team should be well matched to the number of mentors; a three-to-eight ratio seemed to work well.
- Delivery of shipboard data in as near-real time as possible; OER data folks did a superb job of pushing data as fast as possible.
- Coaching trainees on how to plan science missions, and then giving them responsibility for planning missions based on their building understanding of the science through their analyses.
- Sharing of information (imperfectly done, but the team tried to share ship-to-shore communications among scientists and engineers with students by forwarding e-mail messages—even the weather report).
- Shore-based support for analytical tools (expertise, software).
- Daily meetings with trainees to share updates and news, as well as to obtain status reports and understandings of challenges, needs, and bottlenecks.
- Rich social interactions between scientists, engineers, and students (especially meals for the shoreside team) and shared experiences with the ship (e.g., sharing via telepresence as *Sentry* took on a personality, introductions to team members, teleconference interactions, visiting marine centers, etc.).
- Provision of readings for scientific context.

Future enhancements

- More ship, science, and student engagement:
    - Introductory sessions (introductions and context) with science team prior to the cruise.
    - Enable the ship to view the science team on shore as part of telepresence.

- Enable the ship to view the shoreside science products in the same way that shipboard science products can be viewed.
- Find a way for shore-based students to participate in the discussion and interpretation of shipboard data analyses, and ship-based students to participate in the discussion and interpretation of shore-based data analyses (e.g., more formal and informal engagement between students and scientists in both directions across the ship-to-shore interface).
- Enable student-to-student interactions and student-to-scientist interactions from ship-to-shore.

7.5 Outreach/Media Events

A live ship-to-shore telepresence event was held with the PMEL ECC on July 17, 2012, to introduce the *Okeanos Explorer* Program to NOAA's Deputy Undersecretary of Operations (DUSO), in Seattle, WA, (**Figure 12**). The DUSO was given an overview of OER and the *Okeanos Explorer* Program, with a discussion point focused on strategic partnerships, before going live with NOAA Ship *Okeanos Explorer*. An onboard welcome greeting and explanation of current operations and live video feeds was given by the *Okeanos Explorer* Commanding Officer, and a brief overview of the ongoing expedition was given by the Expedition Coordinator. A few minutes of questions and answers were exchanged before the event was brought to a close.

Figure 12. NOAA DUSO Dr. David Titley, RADM Devaney, and *Okeanos Explorer* Program Manager, Craig Russell, watched the live video feeds and interacted with the ship during a live telepresence event.

8. Data

The *Okeanos Explorer* Program's innovative "end-to-end" data management model ensures that exploration data are rapidly made publicly available, and that information is easy to find and readily usable by a broad range of user communities. *Okeanos Explorer* team members champion standards and develop streamlined methods that support these objectives.

During the 2012 expeditions, a synchronization procedure was implemented, and worked well, to optimize the ship's bandwidth to transmit data from ship-to-shore. This procedure, called Rsync, utilizes a tiered structure of prioritized data to be transmitted continuously. At the top of each hour, the Rsync process starts over with the first tier and continues on until completely finished, or until the top of the next hour. The OER data management team can access data that has been transmitted to shore as soon as they are available. In this way, data handling and documentation can be done in minimal turnaround time.

The Data Management Plan for EX-12-05 Leg 1 is detailed in Gottfried (2012).

8.1 Acoustic Operations Data Access

All data links were confirmed in December 2020.

Mapping data acquisition and processing report

The mapping data acquisition and processing for EX-12-05 Leg 1 is detailed in Lobecker et al. (2012).

Multibeam Sonar (Kongsberg EM 302)

All data links were last confirmed to be valid December 2020.

The multibeam dataset for the expedition is archived at the National Centers for Environmental Information (NCEI) and accessible through their Bathymetric Data Viewer (https://maps.ngdc.noaa.gov/viewers/bathymetry/). To access these data, click on the Search Bathymetric Surveys button, select "NOAA Ship *Okeanos Explorer*" from the Platform Name dropdown menu, and select "EX1205L1" from the Survey ID dropdown menu. Click OK, and the ship track for the cruise will appear on the map. Click the ship track for options to download the data.

Sub-Bottom Profiler (Knudsen Chirp 3260)

The sub-bottom profiler was not run during any of EX-12-05 Leg 1 AUV dive operations, but generally was operated during multibeam mapping operations. These data are archived at NCEI and accessible through their Trackline Geophysical Data Viewer (https://maps.ngdc.noaa.gov /viewers/geophysics/). To access these data, select "Subbottom Profile" under Marine Surveys and click on Search Marine Surveys. In the pop-up window, select "EX1205L1" in the Filter by Survey IDs dropdown menu. Click OK, and the ship track for the cruise will appear on the map. Click the ship track for options to download data.

Split-beam Sonars (Simrad EK60)

EK60 water column data for EX-12-05 Leg 1 are archived at NCEI and available through their Water Column Sonar Data Viewer (https://www.ngdc.noaa.gov/maps/water_column_sonar/index.html). To access these data, click on the Additional Filters button, deselect "All" next to Survey ID, and select "EX1205L1" from the Survey ID list. Click OK, and the ship track for the cruise will appear on the map. Click on the ship track for options to download data.

8.2 CTD Data Access

CTD profile data from EX-12-05 Leg 1 are archived at NCEI and available through OER's Digital Atlas (https://www.ncei.noaa.gov/maps/oer-digital-atlas/mapsOE.htm). To access these data, click on the Search tab, enter "EX1205L1" in the Enter Search Text field, and click Search. Click on the point that represents EX-12-05 Leg 1 to access data options. In the pop-up window, select the Data Access tab for a link to download the CTD profile data.

8.3 *Sentry* AUV Data

All data collected by *Sentry* during the EX-12-05 Leg 1 cruise are available through Woods Hole Oceanographic Institute's website (https://sentrymeta.whoi.edu/sentry/?cruise=EX1205_VanDover12). This includes a cruise report, a data summary, and dive specific maps, multibeam, and photos.

9. References

All reference links were confirmed in December 2020.

Brothers, D. S., Ruppel, C., Kluesner, J. W., Brink, U. S., Chaytor, J. D., Hill, J. C., Andrews, B. D. and Flores, C. (2014). Seabed fluid expulsion along the upper slope and outer shelf of the U. S. Atlantic continental margin. Geophysical Research Letters, 41(1), 96-101. doi:10.1002/2013gl058048

Brothers, L. L., Van Dover, C. L., German, C. R., Kaiser, C. L., Yoerger, D. R., Ruppel, C. D., Lobecker, E., Skarke, A. D. and Wagner, J. K. S. (2013). Evidence for extensive methane venting on the southeastern U.S. Atlantic margin. Geology, 41(7), 807-810. doi:10.1130/g34217.1

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Hornbach, M.J., Ruppel, C., and Van Dover, C.L. (2007). Three-dimensional structure of fluid conduits sustaining an active deep marine cold seep. Geophysical Research Letters, 34(5). doi: 10.1029/2006GL028859

Kaiser, C., Yoerger, D., Kinsey, J., Billings, A., Duester, A., and Fujii, J. (2014). Sentry Operations Report for the EX1205 Cruise. WHOI ABE/Sentry Operations Group Report. https://sentrymeta.whoi.edu/wp-content/uploads/2017/04/2012-vandover-cruise-report.pdf

Kennedy, B.R.C. (2014) Project Instructions for NOAA Ship Okeanos Explorer EX-14-04 Leg II and III: Our Deepwater Backyard: Exploring the Atlantic Canyons and Seamounts, Leg II (ROV and VIPs) September 4-10, 2014, Leg III (ROV, mapping, CTD) September 16-October 7, 2014. NOAA Office of Ocean Exploration and Research, Silver Spring, MD 20910. Retrieved from: https://repository.library.noaa.gov/view/noaa/859

Lobecker, E., Skarke, A.D., Nadeau, M., Brothers, L.L., Bingham, B.L., Stuart, L., Sheehan, J., Paxton, D. (2012). Mapping data acquisition and processing report: EX-12-05 Leg 1, Exploration Blake Plateau, July 5 - 24, 2012. NOAA Expedition Report. NOAA Institutional Repository. Office of Ocean Exploration and Research, Office of Oceanic and Atmospheric Research, NOAA, Silver Spring, MD 20910, doi:10.7289/V5J38QJ0

Skarke, A., Ruppel, C., Kodis, M., Brothers, D. and Lobecker, E. (2014). Widespread methane leakage from the sea floor on the northern US Atlantic margin. Nature Geoscience, 7(9), 657-661. doi:10.1038/ngeo2232

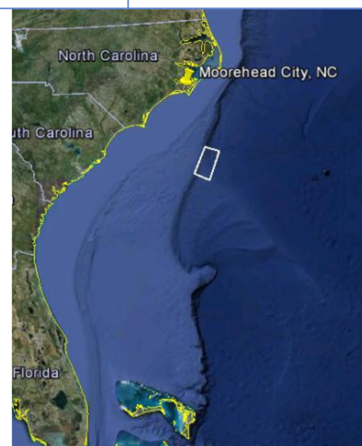
Wagner, J. K. S., McEntee, M. H., Brothers, L. L., German, C. R., Kaiser, C. L., Yoerger, D. R. and Van Dover, C. L. (2013). Cold-seep habitat mapping: High-resolution spatial characterization of the Blake Ridge Diapir seep field. Deep-Sea Research Part II-Topical Studies in Oceanography, 92, 183-188. doi:10.1016/j.dsr2.2013.02.008

10. Appendices

Appendix A. CTD Rosette Summary Forms

EXPLORE

CTD Cast Name	Cruise: EX1205L1	CTD Number: CTD001	Date: 7/12/2012			
Expedition Coordinator/ Science Team Lead	Kelley Elliott/Cindy Van Dover					
General Area Descriptor	Blake Ridge					
Site Name	Blake Ridge Diapir					
Type of CTD Operation	☒ Vertical Cast ☐ Po-Go					
	☐ Tow-Yo ☐ Combination					
Target Position	32° 29.453'N					
	76° 11.618'W					
Deployment Time & Location	UTC Time	22:08				
	Latitude	32	º	29.629	'	N
	Longitude	76	º	11.892	'	W
Time & Location At Depth	UTC Time	2246	Target Depth/Range	20 mab (2200m)		
	Latitude	32	º	29.639	'	N
	Longitude	76	º	11.453	'	W
Recovery Time & Location	UTC Time	0006	Maximum Depth (m)	1409		
	Latitude	32	º	29.603	'	N
	Longitude	76	º	11.495	'	W
CTD Sensor Data Acquired	☒ CTD P 0906 T1 5023 T2 5026 C1 3455 C2 3456					
	☒ ORP 07 Votage Channel 05					
	☒ LSS 12790 Voltage Channel 02 ☒ LSS 12791 Voltage Channel OFF					
	☒ Dissolved Oxygen Voltage Channel 04 ☒ Altimeter Voltage Channel 00					
	☐ Other (*specify*) ____________ Voltage Channel __ ____________ Voltage Channel __					
Water Samples Collected?	☐ Yes ☒ No If Yes, Number of Bottles Tripped: ______________					
Sample Processing	Sample Type(s): ___ ________________________________					
	☐ Processed on board ☐ Preserved ☐ Chemicals ________________________					
	☒ None ☐ Room Temp Storage ☐ -80 Freezer ☐ -20 Freezer ☐ Refrigerator					



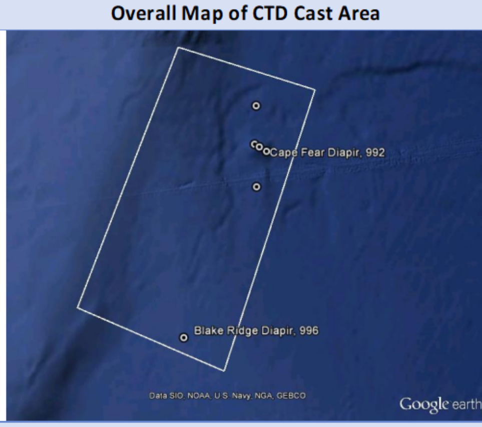
NOAA SHIP OKEANOS EXPLORER

Data Archival	Tethys FTP site
Equipment Malfunctions	Dissolved oxygen sensor not in line with other sensors – very jagged profile.
Special Notes	Extremely strong current – aborted cast at 1400m to reposition ship and attempt cast closet to target site.
Scientists Involved *(name / location / affiliation / email)*	Chris German (WHOI), cgerman@whoi.edu Cindy Van Dover (Duke), clv3@duke.edu Laura Brothers (USGS), lbrothers@usgs.gov

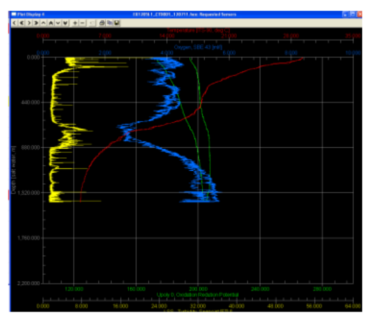
Purpose of the CTD operation: Acquire data over the Cape Fear Diapir

Description of the Data/Results:

Overall Map of CTD Cast Area	Screen Grab of Data



Overview of Cast site



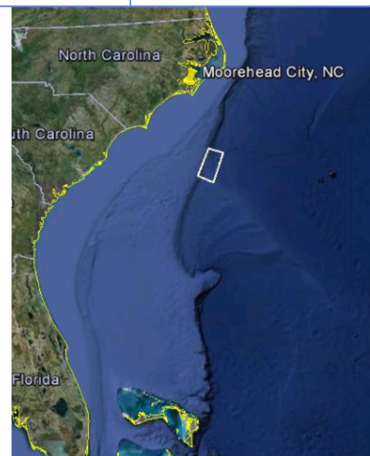
SeaSave Data Acquisition Screen

Please direct inquiries to:	**NOAA Office of Ocean Exploration & Research** **1315 East-West Highway (SSMC3 10th Floor)** **Silver Spring, MD 20910** **(301) 734-1014**

EXPLORE

CTD Cast Name	Cruise	CTD Number	Date
	EX1205L1	CTD002	7/13/2012

Expedition Coordinator/ Science Team Lead	Kelley Elliott/Cindy Van Dover	
General Area Descriptor	Blake Ridge	
Site Name	Blake Ridge Diapir	
Type of CTD Operation	☒ Vertical Cast ☐ Po-Go	
	☐ Tow-Yo ☐ Combination	
Target Position	32° 28.900'N	
	76° 12.078'W	



Deployment Time & Location	UTC Time	01:07				
	Latitude	32	º	28.900	'	N
	Longitude	76	º	12.079	'	W
Time & Location At Depth	UTC Time	02:48	Target Depth/Range	20mab		
	Latitude	32	º	29.014	'	N
	Longitude	76	º	12.005	'	W
Recovery Time & Location	UTC Time	03:29	Maximum Depth (m)	2142		
	Latitude	32	º	29.032	'	N
	Longitude	76	º	11.994	'	W

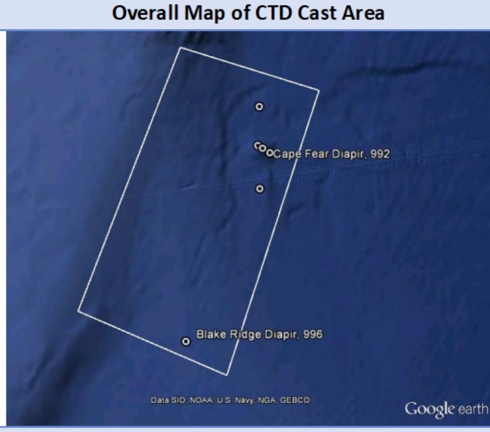
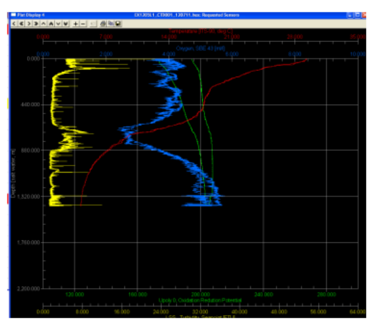
CTD Sensor Data Acquired	☒ CTD **P** 0906 **T1** 5023 **T2** 5026 **C1** 3455 **C2** 3456
	☒ ORP 07 Votage Channel 05
	☒ LSS 12790 Voltage Channel 02 ☒ LSS 12791 Voltage Channel OFF
	☒ Dissolved Oxygen Voltage Channel 04 ☒ Altimeter Voltage Channel 00
	☐ Other (*specify*) ___________ Voltage Channel __ ___________ Voltage Channel __
Water Samples Collected?	☐ Yes ☒ No If Yes, Number of Bottles Tripped: _____________
Sample Processing	Sample Type(s): ___ ________________________________
	☐ Processed on board ☐ Preserved ☐ Chemicals _______________________
	☒ None ☐ Room Temp Storage ☐ -80 Freezer ☐ -20 Freezer ☐ Refrigerator

NOAA SHIP OKEANOS EXPLORER

Data Archival	Tethys FTP site
Equipment Malfunctions	Dissolved oxygen sensor not in line with other sensors – very jagged profile.
Special Notes	Extremely strong current - With 2400m wire out CTD was >500m from the ship with a 45° Wire angle during most of the cast.
Scientists Involved *(name / location / affiliation / email)*	Chris German (WHOI), cgerman@whoi.edu Cindy Van Dover (Duke), clv3@duke.edu Laura Brothers (USGS), lbrothers@usgs.gov

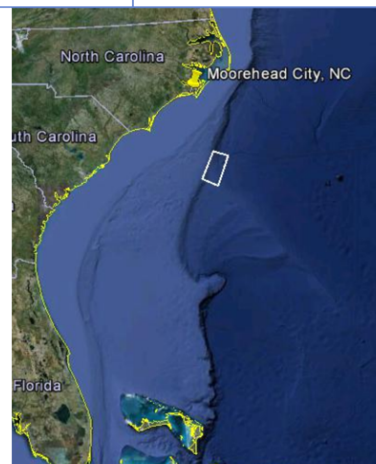
Purpose of the CTD operation: Acquire data over the Cape Fear Diapir

Description of the Data/Results:

Overall Map of CTD Cast Area	Screen Grab of Data
	
Overview of Cast site	*SeaSave Data Acquisition Screen*
Please direct inquiries to:	**NOAA Office of Ocean Exploration & Research** **1315 East-West Highway (SSMC3 10th Floor)** **Silver Spring, MD 20910** **(301) 734-1014**

EXPLORE

CTD Cast Name	Cruise: EX1205L1	CTD Number: CTD003	Date: 7/22/2012
Expedition Coordinator/ Science Team Lead	Kelley Elliott/Cindy Van Dover		
General Area Descriptor	Blake Ridge		
Site Name	Cape Fear Diapir		
Type of CTD Operation	☒ Vertical Cast ☐ Po-Go	☐ Tow-Yo ☐ Combination	
Target Position	32° 58.621'N	75° 55.434'W	



Deployment Time & Location	UTC Time	13:15				
	Latitude	32	º	58.489	'	N
	Longitude	76	º	5.560	'	W
Time & Location At Depth	UTC Time	14:03	Target Depth/Range	20mab		
	Latitude	32	º	58.503	'	N
	Longitude	76	º	55.577	'	W
Recovery Time & Location	UTC Time	15:10	Maximum Depth (m)	2584		
	Latitude	32	º	58.501	'	N
	Longitude	76	º	55.577	'	W

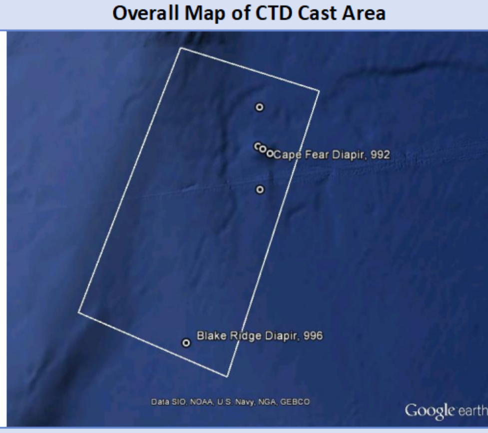
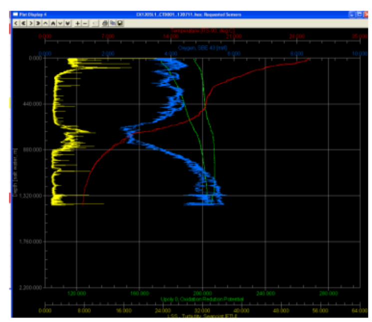
CTD Sensor Data Acquired	☒ CTD **P** 0906 **T1** 5023 **T2** 5026 **C1** 3455 **C2** 3456
	☒ ORP 07 Votage Channel 05
	☒ LSS 12790 Voltage Channel 02 ☒ LSS 12791 Voltage Channel OFF
	☒ Dissolved Oxygen Voltage Channel 04 ☒ Altimeter Voltage Channel 00
	☐ Other (*specify*) ___________ Voltage Channel __ ___________ Voltage Channel __
Water Samples Collected?	☐ Yes ☒ No **If Yes, Number of Bottles Tripped:** _____________
Sample Processing	Sample Type(s): ___ ________________________________
	☐ Processed on board ☐ Preserved ☐ Chemicals ______________________
	☒ None ☐ Room Temp Storage ☐ -80 Freezer ☐ -20 Freezer ☐ Refrigerator

NOAA SHIP OKEANOS EXPLORER

Data Archival	Tethys FTP site
Equipment Malfunctions	Replaced dissolved oxygen sensor with spare and plumbed sensor in line with temperature conductivity and pump. Data was smooth for 200m, after 200m, possible short in instrument.
Special Notes	**Minimal current compared to CTD001 and CTD002. CTD distance was <200m from the ship at 2500m wire out. Current direction was 045.**
Scientists Involved *(name / location / affiliation / email)*	Chris German (WHOI), cgerman@whoi.edu Cindy Van Dover (Duke), clv3@duke.edu Laura Brothers (USGS), lbrothers@usgs.gov

Purpose of the CTD operation: Acquire data over the Cape Fear Diapir

Description of the Data/Results:

Overall Map of CTD Cast Area	Screen Grab of Data
	
Overview of Cast site	*SeaSave Data Acquisition Screen*
Please direct inquiries to:	**NOAA Office of Ocean Exploration & Research** **1315 East-West Highway (SSMC3 10th Floor)** **Silver Spring, MD 20910** **(301) 734-1014**

NOAA SHIP OKEANOS EXPLORER

Appendix B. Categorical Exclusion Letter

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
OCEANIC AND ATMOSPHERIC RESEARCH
Office of Ocean Exploration and Research
Silver Spring, MD 20910

June 21, 2012

MEMORANDUM FOR: The Record

FROM: John McDonough
Deputy Director NOAA Office of Ocean Exploration and Research (OER)

SUBJECT: Categorical Exclusion for NOAA Ship *Okeanos Explorer* cruise EX1205 Leg 1

NAO 216-6, Environmental Review Procedures, requires all proposed projects to be reviewed with respect to environmental consequences on the human environment. This memorandum addresses the NOAA Ship *Okeanos Explorer's* scientific sensors possible affect on the human environment.

Description of Projects

This project is part of the Office of Ocean Exploration and Research's "Science Program". It will conduct autonomous underwater vehicle (AUV) operations and ocean mapping activities designed to increase knowledge of the marine environment. This project is entitled "EX1205 Sentry AUV Cruise" and will be led by Kelley Elliott, an Expedition Manager for NOAA OER. The work will be conducted in July at several locations in the North Atlantic. A 6,000 meter AUV will be deployed and CTD rosette casts will be conducted during the expedition. The Kongsberg EM 302 multibeam (30 kHz) and the Kongsberg EK 60 singlebeam (18 kHz) will be operated during the project. A Knudsen 3260 Sub-Bottom Profiler may also be operated. Additionally, expendable bathythermographs (XBTs) will be conducted in conjunction with multibeam data collection. Multibeam mapping operations will be conducted at all times during the transit.

Effect of Projects

As expected with ocean research with limited time or presence in the marine environment, this project will not have the potential for significant impacts. Knowledgeable experts who are aware of the sensitivities of the marine environment will conduct the at-sea portions of this project.

Categorical Exclusion

This project would not result in any changes to the human environment. As defined in Sections 5.05 and 6.03.c.3 (a) of NAO 216-6, this is a research project of limited size or magnitude or with only short-term effects on the environment and for which any cumulative effects are negligible. As such, this project is categorically excluded from the need to prepare an environmental assessment.

Appendix C. Student Projects

Eight biology and geology students, ranging from undergraduates to doctoral candidates, participated in the expedition from shore, working side-by-side with three shoreside senior scientists. The students arrived on site with little understanding of telepresence and the types of data that would be made available to shore and available for analysis from AUV operations. With software and assistance from professional and student staff at the ISC, and guidance from the senior scientists engaged in the expedition, the students processed and analyzed data from the *Sentry* AUV. This section summarizes the projects and products generated by the shoreside students during the cruise.

Preliminary Report: Eh Team (Z. McKelvey, M. Shimizu)

Problems/Questions to be Answered

The primary objective of this project was to determine if Eh sensor data could be used as a viable tool on AUV missions related to cold seep biology. An Eh sensor is an electrochemical device on the AUV that is used to measure reduced particles, or particles that are oxygen-poor. As the sensor comes into contact with these particles, the sensor's output reading lowers (**Figure 13**). This drop in Eh is referred to as an Eh anomaly.

Eh data from .scc files were imported into excel together with date, time, and latitude/longitude data. First derivatives of Eh values (dEh/dt) were imported from the Aux 2 column of the .scc files.

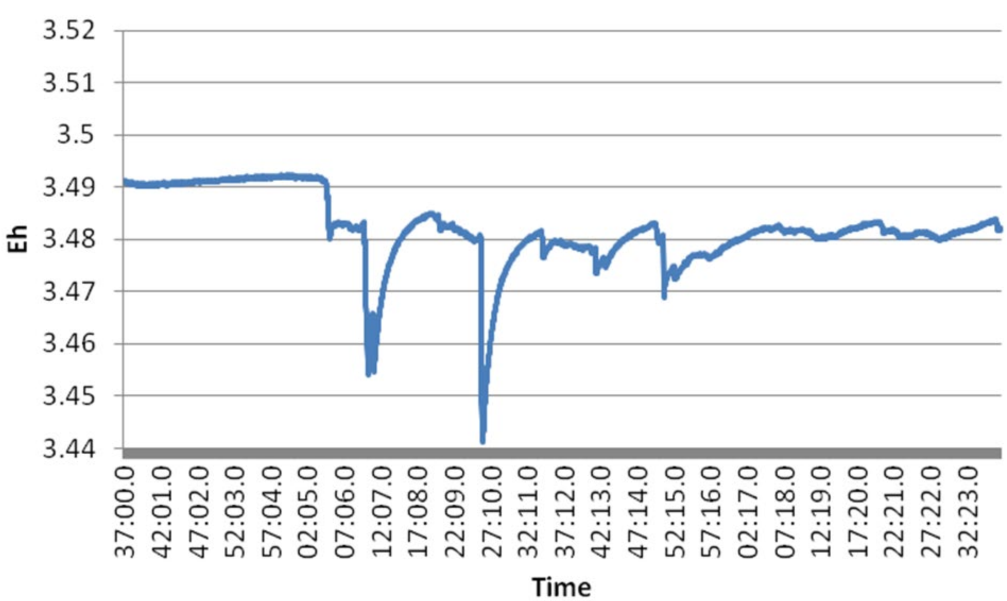


Figure 13. Eh sensor data against time taken from *Sentry* 147 at the main site of the BRD. The sharp drops in Eh are times when the Eh sensor measured reduced particles in the water column, also known as Eh anomalies.

Moving closer to the source of the reduced particles, the Eh anomaly is expected to increase in magnitude. Related to this change in magnitude, as an area is rastered over multiple times, the same Eh anomaly is expected to appear at differing magnitudes relating to how close to the source the line is run (**Figure 14**). To begin moving toward completion of the objective, a few basic questions were chosen to explore. The first of these questions was the usefulness of Eh sensor data as an indicator of the location of cold seeps or cold seep-related animals. To explore this question further, an inquiry for any correlation between anomalies in the Eh data and the location of seep-related animals was conducted.

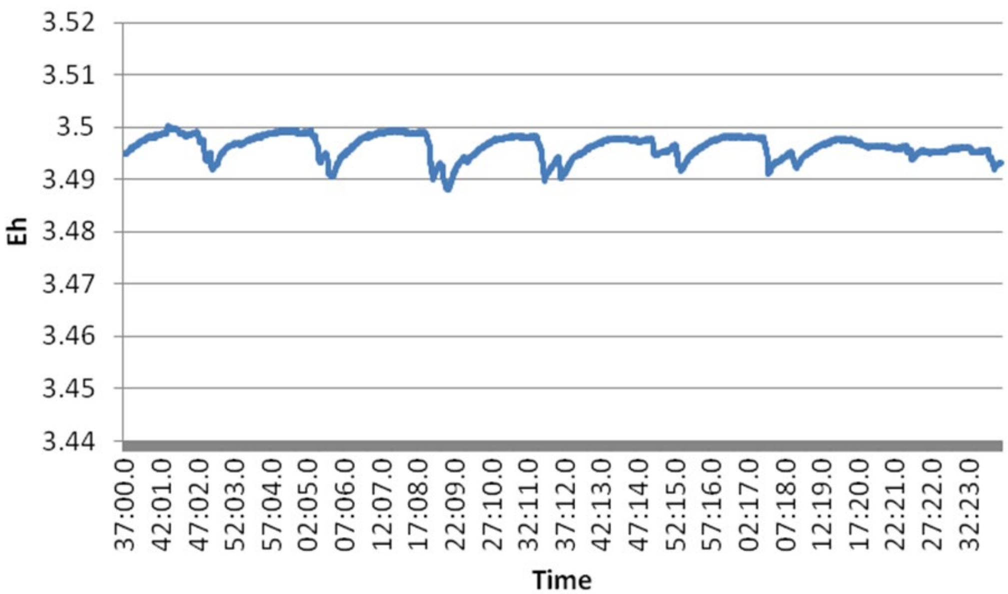


Figure 14. Eh sensor data against time taken from *Sentry* 147 at the main site of the BRD. Similar shape in all Eh anomalies suggests that the anomalies all relate to the same area of interest on the seafloor. Changes in magnitude of similar anomalies relate to the distance from the area of interest on the seafloor where the data were collected.

Approach

Exploration of the objective began using two approaches. The first approach was to plot Eh sensor data from *Sentry* 147 against time on a linear chart (**Figures 13 and 14**). Once plotted, the start and end times corresponding to all of the anomalies in the Eh sensor data were then pulled out. After the acquisition of a time frame for each Eh anomaly the photographs corresponding with the same ranges in time were then pulled. These two data points were used to examine if Eh anomalies directly related to photographs containing seep-related animals. There were no seep-related animals found in the photographs corresponding with Eh anomalies. The second approach was then to pull all of the photographs from *Sentry* 147 that contained seep-related animals (only photographs containing mussels, both living and dead, were examined) in order to determine where in space these animals occurred in relation to Eh anomalies (**Figure 15**).

Figure 15. Photograph from *Sentry* 147 at the main site of the BRD. This photo contains both living mussels (the dark colored organisms) and dead mussels (shells covered in sediment). The photographs also contain essential information such as time stamps, latitude, longitude, depth, and altitude.

Geographic Information System (GIS) was used to plot geo-referenced track lines from *Sentry's* mission. Using the track line plot, two separate overlays were made to examine the correlation between seep-related animals and Eh sensor data. The first overlay plotted geo-referenced raw Eh sensor data and geo-referenced seep-related animal locations, while the second overlay plotted the derivative of the geo-referenced Eh data and geo-referenced seep-related animal locations (**Figure 16**). The purpose of this was to see if there was a spatial correlation between Eh sensor data anomalies and seep-related animals (see Preliminary Results section below). Analysis of similar data and overlays from other *Sentry* missions was also being conducted. Finally, a multilayer Eh survey was run at 3.5 m, 5 m (normal), and 7 m altitude to examine how altitude could play a role in the Eh sensor's ability to locate seep-related animals.

Preliminary Results

As mentioned in the Approach section above, no apparent correlation was found with Eh anomalies and seep-related animals using the first approach to analyze the data. However, when the plot of the derivative of the Eh sensor data was overlaid in GIS with seep-related animal locations for *Sentry* 147, there was a correlation between the two. The GIS plot of the derivative of the Eh sensor data showed that the animals were found to be northwest of the Eh anomalies in two separate locations at a distance of approximately 70 m (**Figure 16**). This relationship was attributed in direction and distance to the effect that currents are able to have on Eh sensor data. Because *Sentry*'s Eh sensor collected data from this dive at an altitude of 5 m, the particles the sensor measures were able to drift some distance as they rose in the water column.

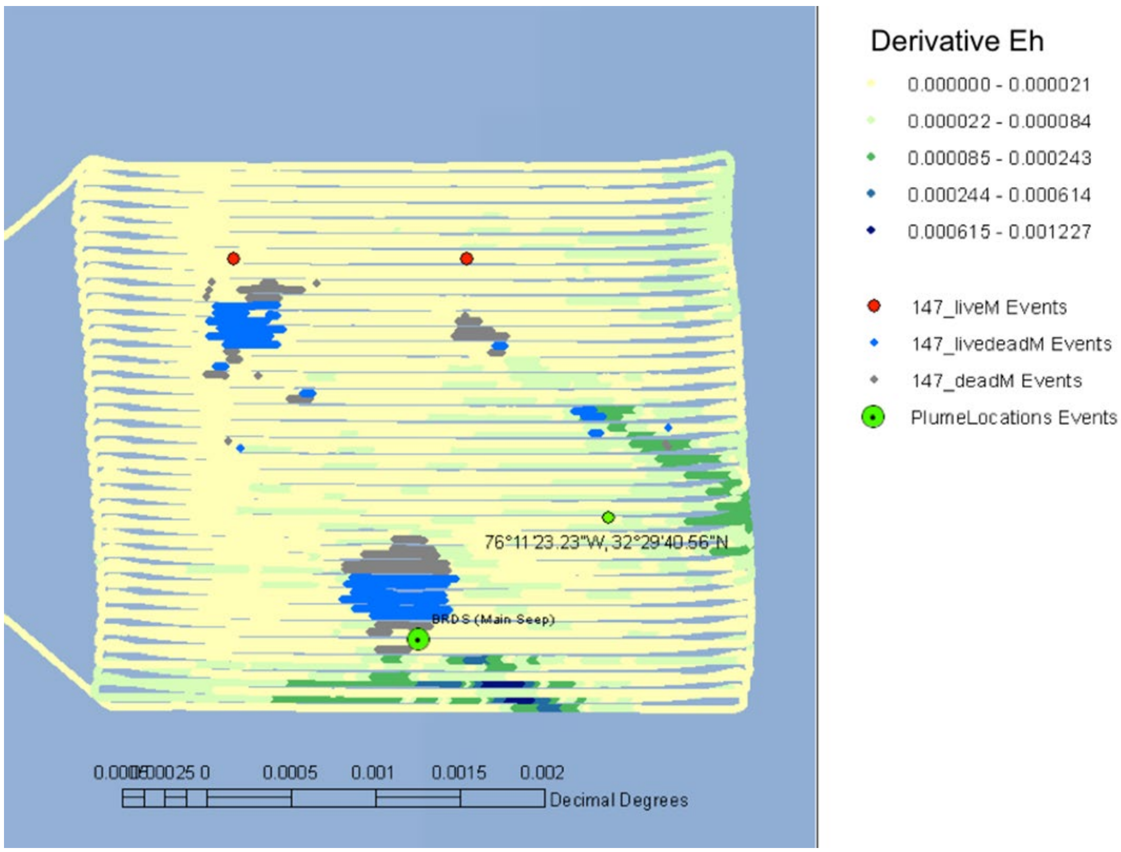


Figure 16. GIS overlay of the derivative of Eh and seep-related animals from *Sentry* 147 at the main site of the BRD. Clusters of living and dead mussels (grey and light blue) are shown to be to the northwest of largest Eh hits (dark blue and green).

To further analyze the effect this drift is able to have on the Eh sensor data's ability to locate seep-related animals, a multilayer Eh survey was used over the same area at different altitudes. The overlay of the raw Eh sensor data turned out to be too difficult to examine and determine any correlation.

Moving Toward a Final Product

As more data were acquired and analyzed, the goal was to add to the preliminary results and acquire a completed final product. This final product should include more dives and more locations (*Sentry* 147 and 148 at BRD and *Sentry* 151 and 152 at CFD) as well as an analysis of the multilayer Eh survey. This final product should provide sufficient data to determine if Eh sensor data is a viable way to locate seep-related animals, and also how altitude affects reliability of Eh sensor data.

Blake Ridge Diapir (BRD) Depressions (M. McEntee)

In 2003, high-resolution 3D imaging of the main Blake Ridge seep identified four sub-seafloor conduits that indicate movement of methane-rich seepage upwards through several sedimentary layers to four visible depressions on the seafloor (Hornbach et al., 2007). The conduits converged with depth and appeared to stem from a single fluid conduit. No data on the associated biological communities was collected at the time, and the team was interested to see if the 3D mapping could accurately predict the location of biological communities. AUV *Sentry* conducted multibeam mapping over the main Blake Ridge seep and surrounding area that resulted in higher resolution maps of the four depressions (**Figure 17**). On Dive 147, a comprehensive photo survey was conducted over the area to examine the biological communities associated with the pockmarks. Preliminary results indicated that live and dead mussel beds were present at all four of the depressions and not on higher ground in the surrounding area (**Figure 18**). Information from the photo survey will be used to further map the distribution of fauna.

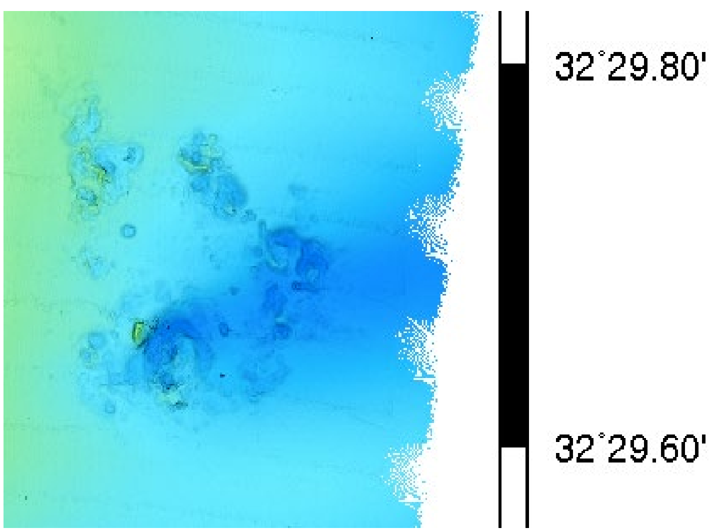


Figure 17. Bathymetry of the four depressions based on AUV sentry multibeam data.

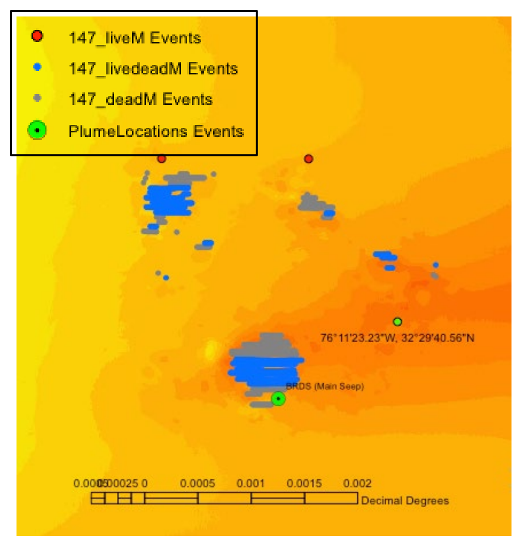


Figure 18. Location of dead and live mussel beds in relation to the four seafloor depressions.

Data Analysis Using ArcGIS (M. Jones and A. Chubet)

This project was successful in spatially representing the data received from the ship by using ArcGIS software. As soon as various members of the shoreside team analyzed biological, chemical, or geological data, it was added to the map. To begin the process, ArcCatalog was opened and a folder was created which could be accessed in GIS. When opening GIS, the projection was changed to WGS-84, a Geographic Coordinate System with a datum corresponding to actual center of the Earth. Students were asked to organize their datasets, sent via e-mail, into an excel spreadsheet. Minor adjustments were made to the data, making sure that each column had a heading and that there were either no spaces between words, or that the spaces were replaced by underscores. Unless the data are properly managed, GIS cannot read the data, and thus cannot be added to the map. Each dataset was converted into a .csv file, added to the map, and exported into the folder that was previously created in ArcCatalog. The x and y values were displayed, and a color scheme was chosen that best fit the data. Under properties, the values of each dataset to plot, the color scheme, and classification were all dictated in order to fine-tune the presentation. A series of .tiff files—specifically photos, photo mosaics, and bathymetric maps—were georeferenced using latitude and longitude to link where the photo was seen or the data were collected to a certain point on the map. For accuracy, two to four points were used to georeference the images.

A plethora of GIS utilities were explored to find methods that were best suited for representing the *Okeanos Explorer*'s and *Sentry*'s data. The most difficult data to input into GIS were individual photos from *Sentry* and the bathymetric mapping data. Transferring the bathymetric maps that were originally produced in MatLab resulted in a partial reduction in quality. Additionally, extra effort was required in order to insure that individual photos from *Sentry* were georeferenced properly. Some possible ways to resolve these issues would be to develop a script, which would automatically georeference *Sentry's* photos using its navigation information, and to process the multibeam data directly into GIS. The issues were temporarily resolved, however, by manipulating GIS's presentation of the multibeam maps, produced by Dana Yoerger of WHOI, and input each photo into GIS individually.

The most effective portion of this GIS work was plotting the Eh in comparison to the locations of biological and geological interest. The mapping software allowed for utilization of this information to determine the most important sites to explore with the *Sentry* AUV. The visualization of these variables also added clarity to how currents affect the movement of Eh hits in the water column, and how depressions and mounds may influence organism's locations.

Data Analysis Using Fledermaus (J. Wagner)

On the shore, the science team needed a way to effectively visualize the maps being created on the ship. ArcGIS became the primary method for creating multi-layer maps with multibeam bathymetry, survey lines, Eh derivative plots, location of geological features (outcrops), and seep animal locations. However, to view bathymetry in 3D, Fledermaus was an excellent tool.

Fledermaus is a 3D geo-spatial mapping and analysis tool that allows interactive zooming, rotation, and visualization. A further asset of the program is that the shipboard team was working with the program, and could send .sd and .scene files to shore (these files may also be viewed in iView. This allowed the shoreside team to explore and investigate new data, in depth and on their own timeframe, without needing to infringe on the ship scientists' time. Fledermaus, though a complex program with a wide array of tools, has the benefit of being simple to learn to navigate just for visualization purposes.

Fledermaus allowed the addition of multibeam data (both from *Okeanos Explorer* and *Sentry*), tracklines, backscatter pictures, points of interest, and plumes collected from the ship's water column data. Visualization of the plumes is not possible in ArcGIS, so having both of these mapping programs was useful for interpretation and visualization of the deep-sea sites that were being explored. Fledermaus allowed for the viewing of the plumes in 3D, which is necessary to spatially separate the plumes in three dimensions and to determine the number of plumes (a single plume versus multiple plumes). Further, seeing the placement of the plumes in relation to the multibeam bathymetry was helpful when planning missions for upcoming dives, given that plumes are strong indicators of a nearby seep. Fledermaus also can easily create topographical profiles, which is another useful way to view the topography. Fledermaus was used to generate pictures for publication that show the multiple plumes of the BRD (**Figure 19**) and the single plume at the CFD (**Figure 20**)(Wagner et al. 2013).

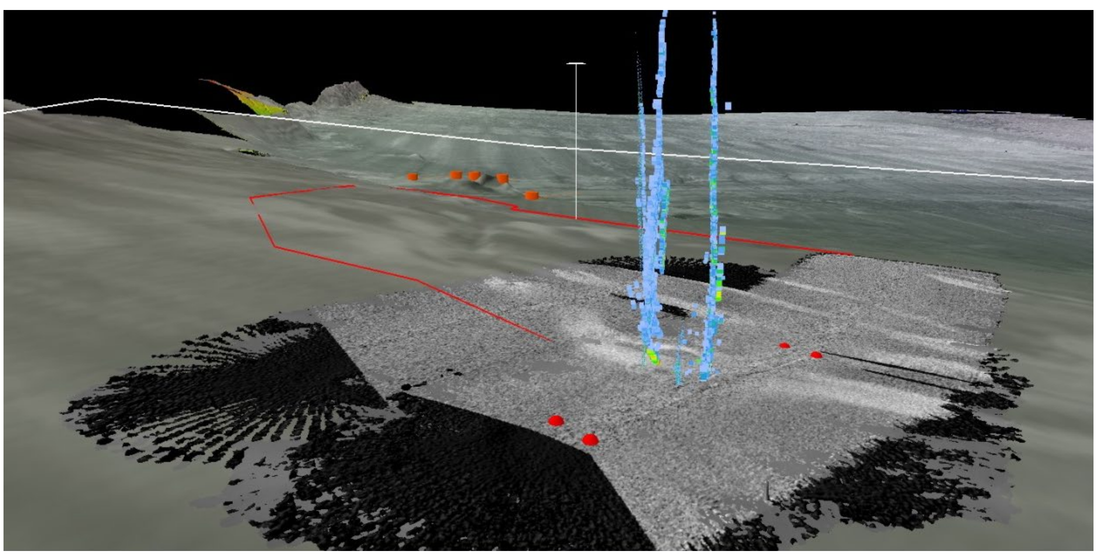


Figure 19. Bubble plumes at the BRD Main and BRD North seep sites.

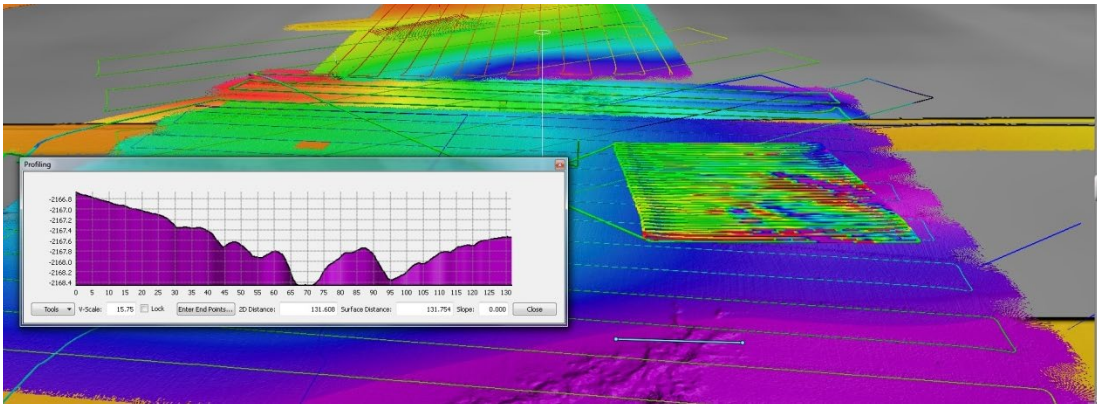


Figure 20. BRD—underlay: shipboard multibeam bathymetry; box: *Sentry* multibeam bathymetry of BRD Main; inset: depth profile corresponding to blue line (BRD South).

Artistic Video Documentary (P. Brubaker)

My objective going into this expedition was to make an artistic documentary that remained faithful to scientific content as well as featuring stylish visuals. In the course of making the film, I found myself in the role of traditional documentarian, capturing life as it happened. Going into this project, I knew very little about how data would be gathered and what my fellow students would be doing. Now that the cruise is over, I have a better idea of how the research is conducted and the significance of the information. In the process of editing the film, I will interface with Principal Investigator (Dr. Cindy Van Dover) for any questions I may have about the background of the scientists featured in the project. I have participated in the trip more than I thought I would, but I have found that to be necessary to keep up with the flow of information, allowing me to make a film that is true to the nature of the expedition. It was not enough to simply be an observer with a camera. My goal is not to make a film strictly for scientists, but for an audience of cinema lovers, while also portraying the scientific aspect in an accurate way. I would love to see my film screened in public. I have a history of showing my documentaries in film festival settings, and this film will surely find interest in science-themed film festivals and perhaps documentary film festivals in general.

While I have only been gathering footage during this expedition, ideas are forming in my head as to how I want to shape the project. The theme of telepresence is an overarching factor as to how this expedition was run and how the very nature of observing someone whom you see on the ISC screen mirrors the experience of watching a film. In the case of telepresence, the remoteness of the shoreside team from the ship creates a poignant distance, but also serves a definite purpose as how best to communicate crucial data. Being on the boat may have been more exciting, but high-tech telepresence provided more potential for exploring the artistic/experimental aspects of the cruise.

During the course of the filming, I collected several interviews with key members of the team, and this footage will also find its way into the finished product. Overall, I look forward to being able to start sculpting my copious amount of footage into a real film. I am grateful for this opportunity to be an artist full-time. The final video is linked under Brubaker (2014).

Biology: Catalogue of Animals (M. McEntee)

A "Deep-Sea Field Guide" was developed by shoreside scientists, cataloguing the biology imaged during *Sentry* AUV dives. This Field Guide is included as **Appendix D.**

Deep-Sea Field Guide

Mollusca

Mussel (live)
Bathymodiolus heckerae
Depth: 2,153.271 m
Dive 144, Photo 4603
Date: 2012/07/14
Comments: Closely related to *Bathymodiolus boomerang.* Includes adult and juvenile mussels. Live mussels indicate the center of the seep.

Mussel (dead)
Bathymodiolus heckerae
Depth: 2,171.654 m
Dive 143, Photo 2028
Date: 2012/07/13
Comments: Dead mussels are generally found at the periphery of live mussel beds and indicate proximity to an active or old seep.

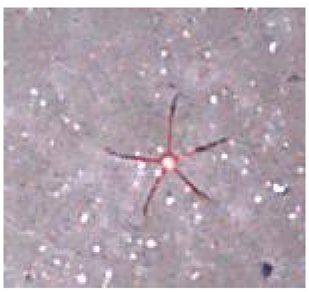
Clam
Vesicomya cf. *venusta*
Depth: 2,161.158 m
Dive 144, Photo 1614
Date: 2012/07/14
Comments: Found either scattered or in dense patches. Dense clams indicate proximity to a seep site.

Octopus
Unidentified species
Depth: 2,153 m
Dive 144, Photo 4666
Date: 2012/07/14

Octopus
Unidentified species
Depth: 2,596.978 m
Dive 152, Photo 485
Date: 2012/07/23

Brisingid sea star
Freyella sp.
Depth: 2,148.754 m
Dive 144, Photo 5394 Date:
2012/07/14
Comments: Usually found on rocky outcrops.

Brisingid sea star
Freyella sp.
Depth: 2,165.658 m
Dive 147, Photo 900 Date:
2012/07/17
Comments: Usually found on soft sediments.



Brittle star Unidentified species
Depth: 2,144.538 m
Dive 144, Photo 5393 Date:
2012/07/14

Sea star
Unidentified species
Depth: 2,152.95 m
Dive 145, Photo 558 Date:
2012/07/15

Sea star
Unidentified species
Depth: 2,152.594 m
Dive 145, Photo 1148 Date:
2012/07/15

Sea star

Unidentified species
Depth: 2,170.717 m
Dive 143, Photo 1007 Date: 2012/07/13

Sea star
Unidentified species
Depth: 2,166.956 m
Dive 147, Photo 1607 Date: 2012/07/17

Sea star
Unidentified species
Depth: 2,151.66 m
Dive 150, Photo 9012 Date: 2012/07/21

Sea star
Unidentified species
Depth: 2,151.532 m
Dive 150, Photo 8664 Date: 2012/07/21

Sea star
Unidentified species
Depth: 2,160.525 m
Dive 150, Photo 640 Date: 2012/07/20

Sea star
Unidentified species
Depth: 2,151.513 m
Dive 150, Photo 8653 Date:
2012/07/21

Sea star
Unidentified species
Depth: 2,597.911 m
Dive 152, Photo 1729 Date:
2012/07/23

Sea star
Unidentified species
Depth: 2,593.509 m
Dive 152, Photo 3595 Date:
2012/07/23

Sea star
Unidentified species
Depth: 2,171.346 m
Dive 148, Photo 2833 Date:
2012/07/18

Sea star
Unidentified species
Depth: 2,162.467 m
Dive 150, Photo 1822 Date:
2012/07/21

Sea star (circle) Unidentified species
Depth: 2,597.023 m
Dive 146, Photo 2238 Date: 2012/07/16
Comments: Circular indentations indicate a sea star buried beneath the soft sediment.

Sea cucumber Unidentified species
Depth: 2,173.911 m
Dive 143, Photo 246 Date: 2012/07/12

Sea cucumber Unidentified species
Depth: 2,164.461 m
Dive 147, Photo 3146 Date: 2012/07/17

Sea cucumber Unidentified species
Depth: 2,620.831 m
Dive 152, Photo 6480 Date: 2012/07/23

Sea cucumber Unidentified species
Depth: 2,160.162 m
Dive 150, Photo 1758 Date: 2012/07/21

Sea cucumber Unidentified species
Depth: 2,160.384 m
Dive 150, Photo 294 Date: 2012/07/20

Sea cucumber Unidentified species
Depth: 2,159.704 m
Dive 150, Photo 261 Date: 2012/07/20

Sea cucumber Unidentified species
Depth: 2,163.136 m
Dive 150, Photo 3590 Date: 2012/07/21

Sea cucumber Unidentified species Depth: 2,173.519 m
Dive 143, Photo 1189 Date: 2012/07/13

Sea urchin Unidentified species
Depth: 2,165.642 m
Dive 147, Photo 3198 Date: 2012/07/17

Sea urchin Unidentified species
Depth: 2,597.406 m
Dive 152, Photo 5579 Date:
2012/07/23

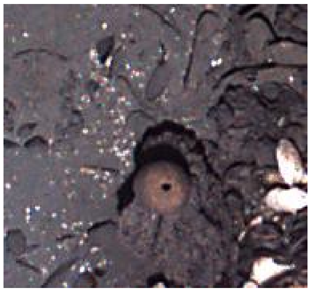
Cake urchin
Sarsiaster griegi
Depth: 2,166.147 m
Dive 147, Photo 1038 Date:
2012/07/17

Shrimp
Nematocarcinus sp.
Depth: 2,564.147 m
Dive 146, Photo 3471 Date:
2012/07/16

Shrimp
Nematocarcinus sp.
Depth: 2,583.704 m
Dive 149, Photo 977 Date:
2012/07/19

Squat lobster Unidentified species
Depth: 2,162.63 m
Dive 144, Photo 365 Date:
2012/07/13

Squat lobster Unidentified species
Depth: 2,148.754 m
Dive 144, Photo 5394 Date:
2012/07/14



Sponge
Unidentified species
Depth: 2,161.466 m
Dive 144, Photo 1619
Date: 2012/07/14

Sponge
Unidentified species
Depth: 2,594.872 m
Dive 146, Photo 150
Date: 2012/07/16

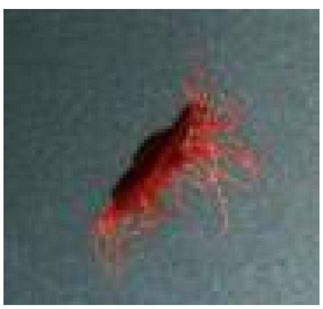
Glass sponge Unidentified species Depth: 2,172.248 m
Dive 143, Photo 1169 Date: 2012/07/13

Glass sponge Unidentified species
Depth: 2,595.775 m
Dive 152, Photo 4743 Date: 2012/07/23

Jellyfish
Unidentified species Depth:
2,159.253 m
Dive 143, Photo 5215
Date: 2012/07/13

Jellyfish
Unidentified species
Depth: 2,163.791 m
Dive 147, Photo 581 Date:
2012/07/17

Jellyfish
Unidentified species
Depth 2,610.151 m
Dive 146, Photo 1360 Date:
2012/07/16

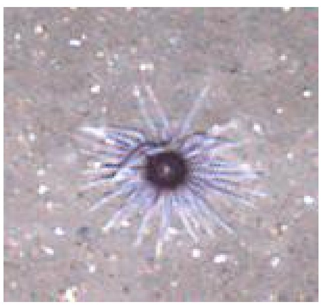


Jellyfish
Unidentified species
Depth: 2,586.687 m
Dive 149, Photo 176 Date:
2012/07/19

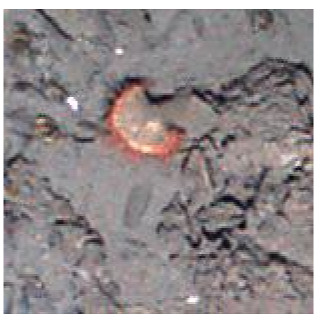
Jellyfish
Unidentified species
Depth: 2,607.178 m
Dive 152, Photo 10791 Date:
2012/07/23

Jellyfish
Unidentified species
Depth: 2,595.282 m
Dive 151, Photo 1736 Date: 2012/07/22

Stalked jellyfish
Stauromedusae
Depth:2,592.512 m
Dive 149, Photo 290 Date: 2012/07/19



Anemone
Unidentified species
Depth: 2,154.083 m
Dive 144, Photo 4611 Date 2012/07/14



Flytrap anemone
Actinoscyphia sp.
Depth: 2,162.567 m
Dive 147, Photo 3257 Date: 2012/07/17

Coral
Gorgonia sp.
Depth: 2,148.754 m
Dive 144, Photo 5394 Date: 2012/07/14

Coral
Gorgonia sp.
Depth: 2,161.843 m
Dive 150, Photo 6173 Date: 2012/07/21

Coral
Unidentified species
Depth: 2,161.448 m
Dive 144, Photo 1618
Date: 2012/07/14

Coral
Unidentified species
Depth: 2,151.589 m
Dive 150, Photo 12257 Date: 2012/07/21

Coral
Unidentified species
Depth: 2,591.995 m
Dive 152, Photo 806 Date: 2012/07/23

Coral
Unidentified species
Depth: 2,571.23 m
Dive 152, Photo 8242 Date: 2012/07/23

Sea whip
Unidentified species
Depth: 2,582.65 m
Dive 146, Photo 4399 Date: 2012/07/16

Sea pen
Unidentified species
Depth: 2,597.778 m
Dive 152, Photo 1481 Date: 2012/07/23

Coral
Unidentified species
Depth 2,596.94 m
Dive 146, Photo 2145 Date: 2012/07/16

Unidentified species
Depth: 2,591.892 m
Dive 151, Photo 2481 Date: 2012/07/22

Unidentified species
Depth: 2,610.109 m
Dive 152, Photo 10824 Date: 2012/07/23

Unidentified species
Depth: 2,593.761 m
Dive 152, Photo 720 Date: 2012/07/23

Siboglinidae Unknown species
Depth: 2,162.001 m
Dive 150, Photo 1727 Date: 2012/07/21

Sea skate
Unidentified species
Depth: 2,584.81 m
Dive 149, Photo 747 Date: 2012/07/19

Sea skate
Unidentified species
Depth: 2,164.767 m
Dive 149, Photo 657 Date: 2012/07/17

Chimaera
Unidentified species
Depth: 2,587.839 m
Dive 149, Photo 1054 Date: 2012/07/19

Unidentified species
Depth: 2,168.395 m
Dive 142, Photo 2593 Date: 2012/07/12

Unidentified species
Depth: 2,164.094 m
Dive 143, Photo 2215 Date: 2012/07/13

Unidentified species
Depth: 2,163.89 m
Dive 143, Photo 2844 Date: 2012/07/13

Unidentified species
Depth: 2,155.875 m
Dive 144, Photo 2451 Date: 2012/07/14

Hagfish
Unidentified species
Depth: 2,163.261 m
Dive 149, Photo 4734 Date: 2012/07/17

Unidentified species
Depth: 2,162.109 m
Dive 150, Photo 1507 Date: 2012/07/20

Unidentified species
Depth: 2,173.41 m
Dive 148, Photo 4000 Date: 2012/07/18

Unidentified species
Depth: 2,171.288 m
Dive 148, Photo 1015 Date: 2012/07/18

Unidentified species
Depth: 2,155.159 m
Dive 150, Photo 7027 Date: 2012/07/21

Unidentified species
Depth: 2,161.4 m
Dive 150, Photo 3653 Date: 2012/07/21

Unidentified species
Depth: 2,152.492
Dive 150, Photo 7318 Date: 2012/07/21

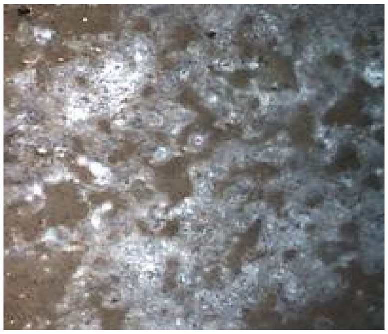
Unidentified species
Depth: 2,594.845 m
Dive 152, Photo 4185 Date: 2012/07/23

Unidentified species
Depth: 2,592.296 m
Dive 151, Photo 303 Date: 2012/07/22

Unidentified species
Depth: 2,587.081 m
Dive 152, Photo 966 Date: 2012/07/23

Unidentified species
Depth: 2,164.044 m
Dive 142, Photo 1865 Date: 2012/07/12

Unidentified species
Depth: 2,590.445 m
Dive 151, Photo 2769 Date: 2012/07/22



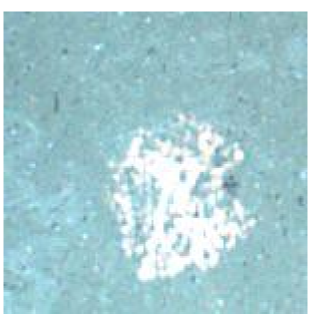
Microbial mat
Depth: 2,591.897 m
Dive 146, Photo 2664
Date: 2012/07/16
Comments: Indicates close proximity to an active seep site.

Unidentified species
Depth: 2,595.116 m
Dive 152, Photo 4576 Date: 2012/07/23

Unidentified species
Depth: 2,523.836 m
Dive 152, Photo 10194 Date: 2012/07/23

Unidentified species
Depth: 2,160.111 m
Dive 150, Photo 1291 Date: 2012/07/20

Unidentified species
Depth: 2,163.301 m
Dive 150, Photo 5892 Date: 2012/07/21



Unidentified species
Depth: 2,152.439 m
Dive 150, Photo 7362 Date: 2012/07/21

Unidentified species
Depth: 2,159.433 m
Dive 150, Photo 250 Date:
2012/07/20

Unidentified species
Depth: 2,591.859 m
Dive 152, Photo 801 Date:
2012/07/23

Unidentified species
Depth: 2,620.473 m
Dive 152, Photo 6499 Date:
2012/07/23

Mat
Depth: 2,154.526 m
Dive 145, Photo 291 Date:
2012/07/15

Appendix E. AUV Operations Lessons Learned

1 A/E—1st Assistant Engineer
2 A/E—2nd Assistant Engineer
2C—2nd Cook
3D—Three-dimensional
AB—Able Seaman
ABGL—Acting Boatswain Group Leader
ACB—Active Chief Boatswain
ACUMEN—Atlantic Canyons Undersea Mapping Expeditions
AERONET—NASA Aerosol Robotic Network
ASCII—American Standard Code for Information Interchange
AUV—Autonomous underwater vehicle
BOEM—Bureau of Ocean Energy Management
BRD—Blake Ridge Diapir
CARIS—Teledyne Computer Aided Resource Information System
CC—Chief Cook
CDR—Commander
CCOM—UNH Center for Coastal and Ocean Mapping
CET—Chief Electronic Technician
CFD—Cape Fear Diapir
CME—Chief Mechanical Engineer
CO—Commanding Officer
CS—Chief Steward
CT—Current Transformer
CTD—Conductivity, temperature, and depth
DGPS—Differential Global Positioning System
DO—Dissolved oxygen
DP—Dynamic positioning
DUSO—Deputy Undersecretary of Operations
DVL—Doppler Velocity Log
ECC—Exploration Command Center
ECDIS—Electronic Chart Display and Information System
EEZ—Exclusive Economic Zone
ENS—Ensign
EX—NOAA Ship Okeanos Explorer
EU—Engine Utilityman
FTP—File transfer protocol

GIS—Geographic Information System
GPCTD—Glider Payload CTD
GPS—Global Positioning System
GVA—General Vessel Assistant
HD—High-definition
HF—High-frequency
HIPS—Hydrographic Information Processing System
HMRG—Hawaii Mapping Research Group
hp—Horsepower
HTC—Hatteras Transverse Canyon
INS—Inertial Navigation System
IP—Internet Protocol
ISC—Inner Space Center
IVS—Interactive Visualization Systems
JO—Junior Officer
JOSS—UCAR Joint Office for Science Support
JUE—Junior Unlicensed Engineer
kHz—Kilohertz
kWh—Kilowatt hour
LBL—Long baseline
LCDR—Lieutenant Commander
LF—Low-frequency
LOA—Length overall
LSS—Light scattering spectroscopy
LSU—Louisiana State University
LT—Lieutenant
LTJG—Lieutenant Junior Grade
MAN—NASA Maritime Aerosol Network
MBES—Multibeam echo sounder
Mbps—megabits per second
NASA—National Aeronautics and Space Administration
Nav—Navigation Officer
NCDDC—NOAA National Coastal Data Development Center
NCEI—NOAA National Centers for Environmental Information
NDSF—WHOI National Deep Submergence Facility
NEPA—National Environmental Policy Act
NOAA—National Oceanic and Atmospheric Administration
NSF—National Science Foundation

OBS—Optical Backscatter
OER—NOAA Office of Ocean Exploration and Research
OMAO—NOAA Office of Marine and Aviation Operations
Ops—Operations Officer
ORP—Oxygen reduction potential
OSEC—Ocean Science and Exploration Center
PI—Principal Investigator
PIR—Precision Infrared Radiometer
PMEL—NOAA Pacific Marine Environmental Laboratory
POS MV—Position and Orientation System for Marine Vehicles
PSP—Precision Spectral Pyranometer
RADM—Rear Admiral
RAPID—NSF's Rapid Response Research
RHIB—Rigid hull inflatable boat
ROV—Remotely operated vehicle
RTS—A brand of intercom systems
Rx—Receive transducer
SAB—Science Advisory Board
SAFMC—South Atlantic Fishery Management Council
SBE—Sea-Bird Electronics
SCS—Scientific Computer System
SBES—Single-beam echo sounder
SBP—Sub-bottom profiler
SIS—Seafloor Information System
SSH—Secure Shell
SSS—Sidescan sonar
SST—Senior Survey Technician
SWL—Safe working load
Tx—Transmit transducer
UCAR—University Corporation for Atmospheric Research
UNCLOS—United Nations Convention for the Law of the Sea
UNH—University of New Hampshire
URI—University of Rhode Island
USBL—Ultra-short baseline
USGS—U.S. Geological Survey
USPHS—U.S. Public Health Service
UTC—Universal Time Coordinated
VoIP—Voice over Internet Protocol

VPN—Virtual private network
VSAT—Very Small Aperture Terminal
WHOI—Woods Hole Oceanographic Institution
XBT—Expendable bathythermograph
XO—Executive Officer
XSV—Expendable Sound Velocity