Sonar Images Hydrothermal Vents in Seafloor Observatory

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Hydrothermal plumes venting from black smokers and diffuse flow discharging from the surrounding area of the seafloor are important as agents of transfer of heat, chemicals, and biological material from the crust into the ocean in quantitatively significant amounts [*Elderfield and Schultz,* 1996]. An unprecedented time series of three-dimensional (3-D) volume images of plumes rising tens of meters from black smoker vents and of concurrent 2-D maps of diffuse flow discharging from surrounding areas of the seafloor illuminates the turbulent behavior of hydrothermal fluid transfer into the ocean (see Figure 1).

Correlation of flow behavior with simultaneous in situ measurements of discharge temperature and composition will advance understanding of the role of such flow in dissipating heat and dispersing chemicals and organic matter into the ocean. To accomplish this, the new Cabled Observatory Vent Imaging Sonar (COVIS) was installed this past fall (September 2010), and operations were initiated with in situ sensors in the first cabled observatory on an ocean ridge, the North-East Pacific Time-series Undersea Networked Experiments (NEPTUNE) Canada Observatory located in the Main Endeavour Field (MEF) on the Juan de Fuca Ridge, nearly 200 nautical miles off British Columbia in the northeastern Pacific Ocean.

COVIS Installation

From the time seafloor hydrothermal flow was discovered, in the 1970s, observations have been taken generally at close range (meters) using light and have spanned only the short durations of oceanographic research cruises (weeks). To advance understanding of seafloor hydrothermal flows, the COVIS team has developed acoustic methods that extend underwater observational ranges beyond light to image buoyant plumes of black smokers in 3-D. These methods measure plume flow velocity, volume flux, and bending by ocean currents and map the surrounding areas of diffuse flow [*Rona et al.,* 2002]. Visualization techniques are used to reconstruct and measure these flows from the acoustic data. The COVIS experiment has evolved from snapshots obtained by mounting specially modified sonar instruments on human-occupied vehicles (U.S. Navy submersibles *Turtle* and *Sea Cliff* in the early 1990s) to a 23-hour time series imaging the bending of a major hydrothermal plume in response to tidal forcing at the MEF using the remotely operated vehicle (ROV) *Jason* in 2000 [*Rona et al.,* 2006]. The present connection to a seafloor observatory extends the potential time series to external forcing on seafloor hydrothermal flow and resultant fluxes by oceanic processes (tides on time scales of hours to months) and by geologic events (earthquakes and volcanic activity on time scales of months to years).

Working with the Remotely Operated Platform for Ocean Science group (ROPOS; http://www.ropos.com/) on a NEPTUNE Canada cruise of R/V *Thomas G. Thompson* (TN 254, 12 September to 9 October 2010), scientists from the University of Washington and Rutgers University successfully connected COVIS to the NEPTUNE Canada cabled observatory and initiated data acquisition on 29 September 2010. COVIS, which is equipped with a customized Reson 7125 multibeam sonar, 400/200 kilohertz projectors, and a rotator system to orient acoustic transducers, is positioned to acquire acoustic data from a fixed site on the floor of the ridge's axial valley at a range of tens of meters from the Grotto vent cluster in the MEF (see Figure 1).

There the sonar is programmed to make three types of acoustic measurements: (1) volume backscatter intensity from suspended particulate matter and temperature fluctuations in black smoker plumes, which are used to reconstruct the width and shape of the buoyant portion of a plume and to estimate dilution of the hydrothermal fluids by entrainment of ambient seawater; (2) Doppler phase shift, which is used to obtain the velocity of flow at various levels as it rises in a buoyant plume; and (3) scintillation, which is used to image in 2-D the area of diffuse flow seeping from the seafloor. Tidal currents and pressures are available from a NEPTUNE Canada current meter mooring situated in the axial valley 2.9 kilometers to the north as well as from a regional tidal model, with current direction coordinated with COVIS observations of plume bending.

The acoustic beam from COVIS encompasses hydrothermal flow at several concurrent in situ instruments of other investigators situated on the Grotto vent cluster. The in situ instruments include the Remotely Activated Water Sampler (RAS), which records a time series of temperature and samples diffuse flow (principal investigator D. Butterfield, National Oceanic and Atmospheric Administration and University of Washington); the Benthic and Resistivity Sensor (BARS), which records a time series of fluid resistivity from which chloride concentration, temperature, and redox potential are estimated within a black smoker vent (principal investigator M. Lilley, University

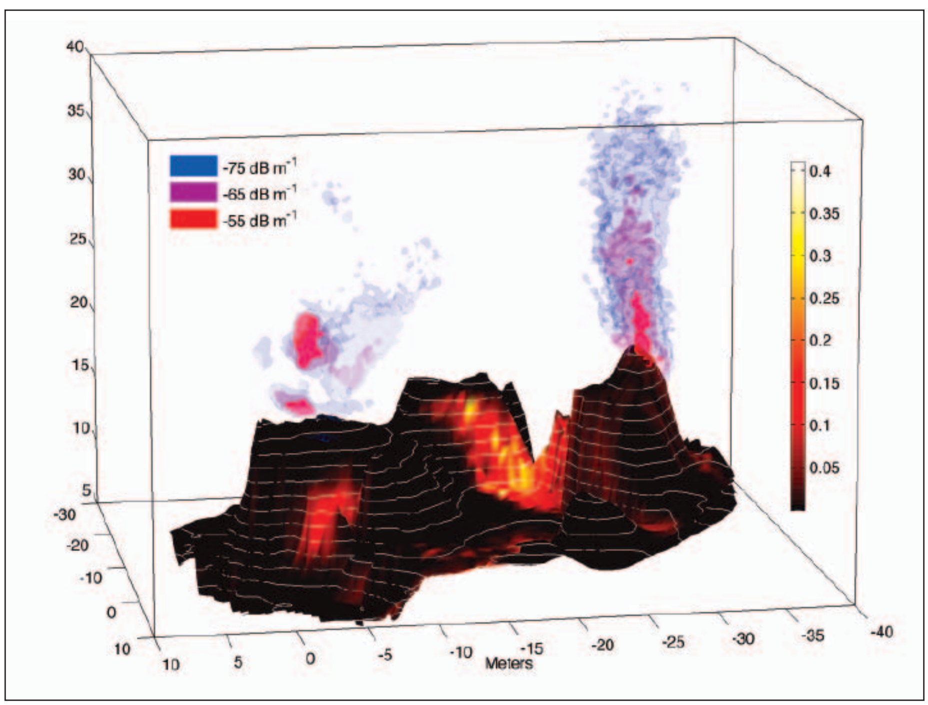

Fig. 1. Cabled Observatory Vent Imaging Sonar (COVIS) acoustic image made at 0600 UT on 11 October 2010, looking south at black smoker plumes and areas of diffuse flow draped over bathymetry of the Grotto vent cluster in the Main Endeavour Field, Juan de Fuca Ridge. The image was made when tidal currents were minimal (e.g., near slack tide). The large plume is from the north tower edifice at the northwestern end, and the smaller plumes are from the northeastern end of Grotto at the in situ experiments. The legend specifies isosurfaces of plume volume scattering strengths (in decibels per meter) related to particle content and temperature-density discontinuities. The vertical color bar gives normalized decorrelation of backscatter (0–1) due to diffuse flow at 0.8-second lag. The plumes decrease in acoustic backscatter intensity as they mix with surrounding seawater with height (in meters) above vents.

of Washington); and a video camera and temperature sensors in an associated diffuse flow ecosystem (principal investigators K. Juniper and K. Robert, University of Victoria). COVIS and the in situ sensors collected data until a cable failure on 27 October 2010, which is scheduled to be corrected during a July 2011 cruise.

Monitoring Hydrothermal Flow

The existing COVIS hydrothermal flow data will be examined with concurrent in situ data to elucidate the response of the hydrothermal system to the prevalent mixed semidiurnal tidal forcing over the existing data period (29 days). Repair of the cable will potentially extend the time series of concurrent COVIS acoustic imagery of hydrothermal flow and in situ measurements to months and years, improving resolution of tidal processes and opening the possibility of recording the response of the hydrothermal system to geologic events (earthquakes and intrusive or extrusive volcanism).

The COVIS team is working to eventually display acoustic images of black smoker plumes, Doppler measurements of vertical flow velocity within the buoyant plumes, and scintillation measurements of the distribution of surrounding diffuse flow in near real time, accessible to the community, on the NEPTUNE Canada Web site (http://neptunecanada.ca). With these data, scientists will be able to monitor the changing state of the hydrothermal system.

Acknowledgments

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NEWS

Metals Shortage Prompts Europe to Seek Solutions

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Headlines about China's temporary suspension of exports of rare earth elements to Japan last year, due to a territorial dispute, brought into sharp focus the heavy dependence of many industrialized countries on imports of critical metals. Concern about the dependence on imports of rare earth elements and other key metals—including iron ore, copper, nickel, and zinc—was the focus of a "great debate" and news briefing at the European Geosciences Union's (EGU) General Assembly held in Vienna, Austria, last month.

There will be little relief over the next 2 years in the way of improved availability or "easier" prices for rare earth elements, according to a 4 May report by the financial services company Goldman Sachs and Partners Australia Pty Ltd. However, the market should come back into balance and prices should soften somewhat beyond 2013 as new mines come online, the report states. The report also states that China currently accounts for more than 95% of global production of a suite of 17 rare earth elements used in a variety of high-tech applications.

At the EGU meeting, geologists and others involved in mining and the mining industry also discussed hurdles affecting mining in general in Europe, including environmental regulations, a "not in my backyard" attitude about mines being developed in specific locations, lengthy permitting processes, and an underfunding of geological surveys in a number of countries over the past several decades. However, the scientists also said a public perception that there could soon be a shortage of metals in the ground available for future use is a fallacy, and they presented ways to overcome hurdles to mining.

Patrice Christmann, manager of the mineral resources strategy division of Bureau de Recherches Géologiques et Minières (BRGM), the French geological survey, said the demand for metals—driven to a large degree by increases in global population and prosperity—is expected to double over the next 15–20 years and will require a significant supply response. Between 2010 and 2050, "humanity will need to produce more minerals of all sorts than were produced since the origin of humanity until 2010," he said.

He said, though, that minerals are there to be found. "Is the world going to run short of mineral resources?" he asked. "Geologically, we have just touched the first few hundred meters below the surface in Europe, for instance. We still have a lot of minerals and metals under our feet that are to be discovered and exploited. It is not an issue of availability, but accessibility."

Lluís Fontboté, with the Ore Deposits Group of the University of Geneva, in Switzerland, and 2012 president-elect of the Society of Economic Geologists, highlighted the misperception that some metals are running out. He pointed to a 1972 Club of Rome report, *The Limits to Growth*, which indicated that some metals would be exhausted by 2000 or 2050. "It's absolutely wrong," he said, adding that while the report was correct in some regards, "on metals, they were not on the right path."

He said that "geological resources are much greater than reserves" but that some people do not understand that distinction. When geological surveys indicate a reserve size, they are only looking at what the mining companies have actually measured rather than what is potentially available to be mined, Fontboté explained. He emphasized that investment is necessary to measure reserves, and mining companies are motivated to make only the investments necessary to ensure their operation.

Fontboté said reserve estimates can fluctuate upward or downward, citing the examples of reserve estimates for copper and zinc over the past several decades. In 1961, prior to the Club of Rome report, copper reserves were thought to extend to 51 years. However, he said, the report spurred governments that were worried about shortages to provide