Exploration of the Mid-Cayman Rise

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Discovery of deep-sea hydrothermal vents and associated biological communities on the Galápagos Rift in 1977 was one of the major scientific breakthroughs of the past century, informing our understanding of key issues in the Earth, ocean, and life sciences. More than 100 different vent sites have been found in different ocean basins worldwide since then, and everywhere scientists have looked, new species have been collected. Most recently, scientists were surprised to find that water-rock interactions during hydrothermal circulation at the least volcanically active mid-ocean ridges could give rise to the synthesis of organic compounds in vent fluids that may reveal insight into the origins of life—on Earth and beyond. The August 2011 expedition to the Mid-Cayman Rise, one of Earth's deepest and slowest spreading ridges, followed recent data suggesting there are multiple vent sites present in shallow and deep settings along this ridge axis (German et al., 2010; Connelly et al., 2012).

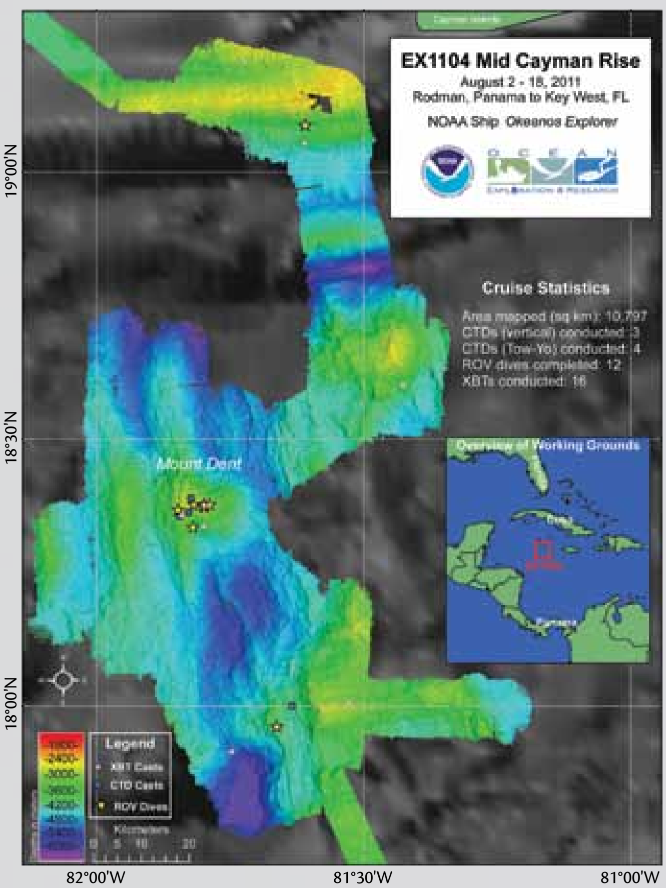

Figure 1. Overview map from the 2011 expedition showing the locations of mapping surveys conducted, ROV dives, and CTD rosette operations.

The expedition focused on mapping the shallow outer "walls" bounding the Mid-Cayman Rise rift valley where long-lived fault-systems lift rocks from deep within Earth's interior to the ocean floor to form oceanic core complexes (OCCs; John and Cheadle, 2010). We also investigated the water column overlying the ridge axis for telltale chemical signals of venting using a CTD rosette, in situ sensors, and onboard gas chromatograph analyses. Finally, we collected detailed ROV seafloor observations (Figure 1), including novel vent sites and the ecosystems they host.

Enabled by satellite and high-bandwidth Internet2 telepresence technology, data and ROV video feeds were transmitted to shore in real time, supporting the participation of an international team of scientists primarily at the University of Rhode Island, but also Woods Hole Oceanographic Institution and NASA's Jet Propulsion Laboratory. Scientists around the world also participated via standard Internet. With only three scientists on board the ship, the shore-based team was an integral part of the expedition, providing comments during daily ROV dives and CTD casts, evaluating transmitted data in real time, and helping to plan and direct daily operations.

Ten ROV dives focused on locating and characterizing the full extent of the Von Damm hydrothermal site and on exploring further afield on Mount Dent to understand its geologic setting. Thanks to input from our UK colleagues, we were able to locate the central spire of the Von Damm hydrothermal field at the start of our first dive and were astonished to find a chimney orifice that was approximately 1 m wide (Figure 2), along with shrimp substantively different in appearance from other Mid-Atlantic Ridge species, but exhibiting features characteristic of shrimp from other known vent sites that host chemosynthetic bacteria.

During the second dive, we documented the first live

Figure 2 (left). ROV *Little Hercules* examining the ~ 1 m diameter vent-orifice at the summit of the Von Damm central spire.

Figure 3 (above). Image of the first live tubeworm photographed at a vent site in Atlantic waters.

Figure 4. Location where active fluid flow, microbial mats, vent shrimp, gastropods, and tubeworms were all observed together at a single site.

tubeworm at an Atlantic hydrothermal field (Figure 3). Our shore-based colleagues confirmed that while these tubeworms were distinct from those seen at hydrothermal vents on the Galápagos Rift, they appeared similar to species found in the Gulf of Mexico, where they live in association with cold hydrocarbon seeps, and at vent fields as far afield as Marsili Seamount off the coast of Italy, and the Lau Basin near Tonga. Continuing our exploration of the Von Damm site we found additional venting sites and tubeworm aggregations. In one location, microbial mats, vent shrimp, tubeworms, and gastropods were all observed coexisting in an area of hydrothermal fluid flow (Figure 4).

A second expedition objective was to understand tectonic processes associated with OCC formation and evolution, and to answer the question: why does the Von Damm field occur where it does? For our investigation, we used ROV cameras to explore the south wall of Mount Dent, located beneath the vent site. Our mission also included an extensive nighttime multibeam program, enabling us to map the bathymetry of three OCCs rising from the rift valley floor.

Toward the end of the cruise, an ROV dive was conducted in the southeast corner of the Mid-Cayman Rise to explore a suspected axial volcanic ridge. The ROV dive revealed interleaved pillow basalts and sheet flows at the first outcrop. There was no evidence of recent volcanic activity, nor active venting or associated vent fauna. Nonetheless, identification of ropey "pahoehoe" lava textures (Figure 5) confirmed that lava emission rates, even on an ultraslow-spreading ridge, can be impressive.

The final ROV dive of the expedition conducted a geological and biological transect from south to north up the interior wall of the North Cayman Fracture Zone. Although fracture zones represent one of the three major types of plate tectonic boundary, they have received relatively little attention, and, as far as we know, this was the first deep-submergence investigation of this particular feature.

This exploratory expedition was extremely productive and successful. We documented the full extent of the Von Damm vent field (approximately 150 m on a side), identified the major sites of active venting, and located new biological communities. Using our CTD and mapping programs, we investigated the fate of fluid discharge from the site, tested for the location of other sites, and investigated geologic processes that underpin hydrothermal venting. This work provides an invaluable legacy for further internationally coordinated research beginning with an ROV *Jason* sampling program in January 2012.

Figure 5. Ropey "pahoehoe" lava textures from more than 3,000 m deep at the Mid-Cayman Rise (above) are identical to those associated with fresh flows at Chain of Craters Road, Hawaii Volcanoes National Park (right).