Oceanography
Vol. 31, No. 1, Supplement, March 2018

New Frontiers in Ocean Exploration

The E/V *Nautilus*, NOAA Ship *Okeanos Explorer*, and R/V *Falkor* 2017 Field Season

GUEST EDITORS | Nicole A. Raineault, Joanne Flanders, and Amy Bowman

FRONT COVER. A large *Deepstaria enigmatica* scyphozoan jellyfish is imaged up close at 974 m depth off of San Benedicto Island, Revillagigedo Archipelago, Mexico, on E/V *Nautilus* cruise NA092. This specimen, measuring approximately 55 cm across, was approached in almost complete darkness and remained undisturbed for several minutes, at which point it closed its umbrella and turned to present itself in high detail. An intricate network of anastomosing canals, assumed to be part of its digestive tract, is clearly visible. *Image credit: D. Fornari (WHOI-MISO Facility) and OET*

PREFERRED CITATION
Raineault, N.A, J. Flanders, and A. Bowman, eds. 2018. New frontiers in ocean exploration: The E/V *Nautilus*, NOAA Ship *Okeanos Explorer*, and R/V *Falkor* 2017 field season. *Oceanography* 31(1), supplement, 126 pp., https://doi.org/10.5670/oceanog.2018.supplement.01.

Interior of a gas-rich pillow basalt off the west coast of Socorro island, Revillagigedo Archipelago, Mexico, from E/V *Nautilus* cruise NA092. *Image credit: D. Fornari (WHOI-MISO Facility) and OET*

Exploring and Mapping the Revillagigedo Archipelago World Heritage Site in Mexico

By Steven Carey, Karen Wishner, Claus Siebe, Katherine Kelley, Brennan Phillips, Christopher Roman, Megan Lubetkin, and Esmerelda Morales Domínguez

The Revillagigedo Archipelago consists of four volcanic islands located 450 km south of Baja California (Figure 1). The islands are situated at a major convergence of two marine biogeographical regions, the Northeastern and the Eastern Pacific. In particular, this area is where the California and Equatorial Currents mix, creating a complex and highly productive marine environment. Often referred to as "Mexico's Galápagos," the islands are isolated from the mainland and are home to a significant number of endemic species both on land and in the marine environment. The shallow waters around the islands are remarkable for the abundance of large marine predators and pelagic species. Large populations of sharks (hammerhead, silky, and whale), rays, tunas, and turtles attract recreational scuba divers from around the world. In particular, the archipelago hosts the largest aggregations of giant manta rays (*Manta birostris*).

The unique biological, geological, and oceanographic features of the Revillagigedo Islands has led to their designation as a World Heritage Site by UNESCO in 2016. E/V *Nautilus* cruise NA092 was the first to deploy an ROV to explore the deep marine environment surrounding two major islands of the archipelago, Socorro and San Benedicto. Primary focus themes of the cruise included processes of submarine volcanism, characterization of benthic and pelagic fauna, and impacts of the oxygen minimum zone (OMZ) on marine ecosystems occupying the island flanks.

Figure 1. Location of the Revillagigedo Islands (Socorro, Clarion, San Benedicto, and Roca Partida) in the eastern Pacific Ocean. *Basemap from Google Earth, GEBCO*

Submarine Volcanism

The most recent submarine volcanic eruption in the archipelago was in 1993 about 4 km off the west shore of Socorro (Siebe et al., 1995). It is one of only five known submarine eruptions that have produced large floating lava blocks, known as scoria. The scoria eventually broke into pieces, and often were propelled laterally by vigorous steam jets. Despite its surface manifestations, the location of the underwater vent was unknown. With the aid of new multibeam maps of the area, ROV dives explored nine potential target sites. The vent site was located at 275 m water depth on the summit of a small volcanic cone that exhibited an extensive field of white, filamentous bacteria surrounding meter-size scoria blocks (Figure 2). The dives revealed that the amount of large scoria was likely relatively minor and that most eruptive products consisted of glassy volcanic sand. Construction of submarine cones from such material produces structures that are potentially unstable and susceptible to mass wasting, as shown by the presence of collapse scars on many of the slopes.

In deeper water (>1,000 m), the sides of both Socorro and San Benedicto Islands consist of overlapping, flat-topped satellite vents, often with a central depression likely monogenetic in origin. The sides of these structures are quite steep

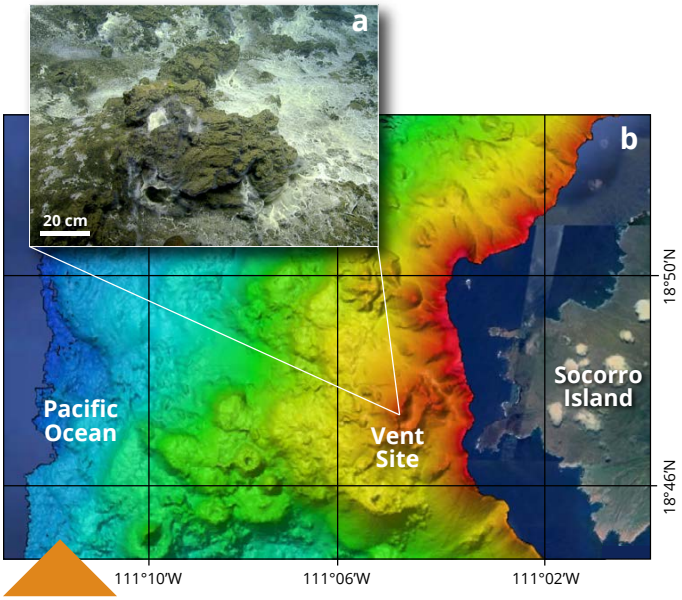
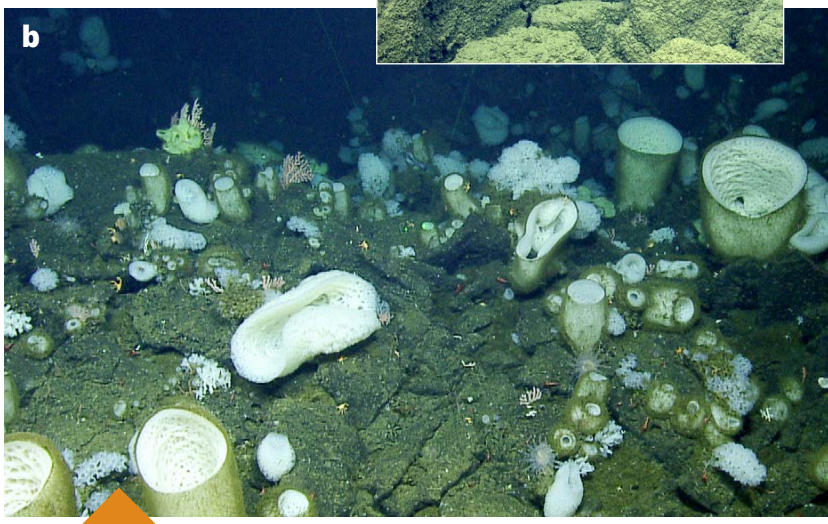


Figure 2. (a) Photo of a scoria block surrounded by white bacterial mats at the summit of the 1993 submarine vent site west of Socorro Island. (b) Map showing the seafloor morphology in the vicinity of the 1993 vent site and the abundance of other circular vents and cones. Multibeam bathymetry from cruise NA089.

Figure 3. Near-vertical pillow lava tubes on the side of a flat-topped volcanic center to the southeast of San Benedicto Island.



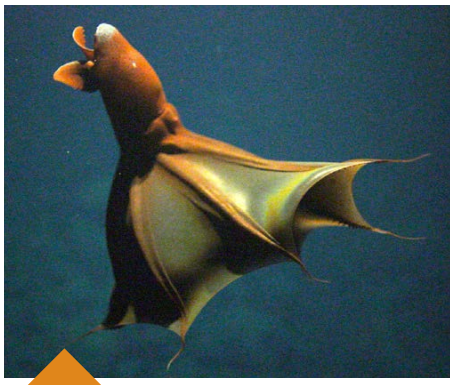


Figure 5. Using a low-light camera equipped with extremely dim lights, a vampire squid (*Vampyroteuthis infernalis*) was observed up close at 1,225 m depth in an apparent relaxed state.

Figure 4. Biological zonation through the oxygen minimum zone. (a) Rocks at 345 m depth in low-oxygen water are covered with a fuzzy biological mat but no larger animals. (b) Abundant diverse sponges and other large epifauna in the Sponge Garden at 851 m depth where oxygen levels are higher.

and consist dominantly of pillow lavas and elongated pillow tubes (Figure 3). Fresh basaltic glass was recovered from some of these vents, suggesting that the frequency of submarine eruptions may be underestimated in the region. Geochemical analyses of the samples will be used to evaluate the origin of the magmas and investigate how volcanism has sustained these active oceanic islands on the Mathematician spreading ridge after abandonment approximately 3.5 million years ago.

Marine Ecosystems and the OMZ

This oceanographic region of the world is characterized by extremely low oxygen at mid-water depths from about 200 m to 800 m. Previous work in 1988 at a nearby seamount (Volcano 7) that penetrated into the OMZ showed benthic faunal zonation along the seamount slope into the low-oxygen water, with the summit devoid of large animals (Wishner et al., 1990, 1995). Our *Nautilus* dives confirmed this basic pattern and provided detailed high-resolution photographic imaging, comprehensive associated physical data, broader depth coverage, and sample collection of key benthic taxa.

ROV transects revealed strong zonation of benthic fauna associated with depth, geological features, and oxygen concentration. On the flanks of Socorro Island, deep regions were characterized by high abundances of colorful corals, crinoids, and big sponges. A spectacular "sponge garden" was observed in a narrow depth zone, where diverse sponges and corals occupied almost every bit of open space (Figure 4b). There were virtually no macrofauna higher up the slope in low-oxygen water, except for occasional sightings of squat lobsters, brittle stars, and fish. At the lowest oxygen level, a fuzzy mat completely covered all surfaces of the substrate (Figure 4a). The extensive white bacterial mat at the 1993 vent site was in this lowest oxygen environment. This may account for the lack of any larger typical vent and seep fauna, such as tubeworms or clams. Even though nutrition for these communities is derived from chemoautotrophic endosymbionts, the larger animals require oxygen to support their metabolism. Vertical zonation on San Benedicto Island was not as dramatic, possibly a reflection of the shorter time for settlement and growth since the creation of this peak in the 1952 eruption of Barcena Volcano. This effect may be compounded by the lack of hard substrate available, as widespread layers of ash were observed on these slopes.

A special low-light camera, designed to image bioluminescence in color and to allow stealthy, less intrusive observation of animals, obtained some dramatic footage. Bioluminescent responses of several planktonic animals were imaged, but none of the deep-sea corals in this region appeared to be bioluminescent. Dimmable lights were used to approach a vampire squid, which appeared initially relaxed with closed arms and then transitioned to a predator-avoidance posture with its arms and glossy webbing expanded (Figure 5).

The results of cruise NA092 have dramatically increased the characterization of the geology and the ecosystems of the deep-sea environment within this newly created World Heritage Site.