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Continued Exploration of the Santorini Volcanic Field and Cretan Basin, Aegean Sea

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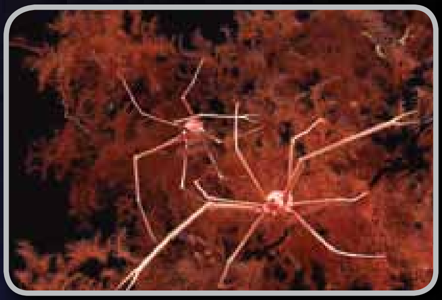

New Frontiers in Ocean Exploration

The E/V *Nautilus* and NOAA Ship *Okeanos Explorer* 2011 Field Season

GUEST EDITORS | KATHERINE L.C. BELL, KELLEY ELLIOTT, CATALINA MARTINEZ, AND SARAH A. FULLER

Continued Exploration of the Santorini Volcanic Field and Cretan Basin, Aegean Sea

By Katherine L.C. Bell, Paraskevi Nomikou, Steven N. Carey, Eleni Stathopoulou, Paraskevi Polymenakou, Athanasios Godelitsas, Chris Roman, and Michelle Parks

The Hellenic Volcanic Arc lies in the southern Aegean Sea, formed by subduction of the African Plate below the European Plate. The Santorini complex, the most active volcanic center in the Hellenic Arc in recent times, is composed of three volcanic areas along the northeast-southwest Kameni and Kolumbo lines (Figure 1): the Kolumbo Volcanic Rift Zone in the northeast, Santorini in the center, and the Christiana islet group and submarine domes in the southwest (recent work of author Nomikou and colleagues). In 2011, we investigated the Santorini volcanic complex, as well as the back-arc Cretan Basin, continuing work that began in these regions in 2006 (Sigurdsson et al., 2006; Carey et al., 2011).

Kolumbo, which last erupted explosively in 1650 CE, is the largest volcano of the Kolumbo Volcanic Rift Zone. Its submarine cone is 3 km in diameter, and its crater floor is 500 m deep. In 2006, an active hydrothermal system venting hot gases and fluids at temperatures exceeding 200°C was discovered in the crater (Sigurdsson et al., 2006). In 2010, gas and geological samples were collected (Carey et al., 2011), and high-resolution mapping using multibeam, structured light, and stereo imagery was carried out (Roman et al., 2010b). In 2011, we returned to Kolumbo to focus on: (1) biogeochemical sampling of geological deposits, bacteria, water, and gases that exist in and around the hydrothermal vent field, and (2) high-resolution mapping of the hydrothermal vent field. We also tested two new gas sampling devices that are currently in development by URI Ocean Engineering Intern Mike Filimon.

In total, we collected 26 rock and sediment samples (with bacteria), 10 Niskin water samples, and 14 gas samples from the Kolumbo vent field. Samples of red-orange and white-grey bacterial mats from the crater floor were collected for metagenomic exploration of these newly discovered habitats in collaboration with the Joint Genome Institute, US Department of Energy. The first analytical data using pyrosequencing and illumina sequencing technology showed that a highly diverse microbial community inhabits this environment. Active and extinct chimneys are built of Fe, Pb, Cu, and Zn sulfides, and Ba and Ca sulfates. Iron-rich minerals and some arsenic-sulfur minerals

Figure 1. Swath bathymetry map of Santorini's volcanic field.

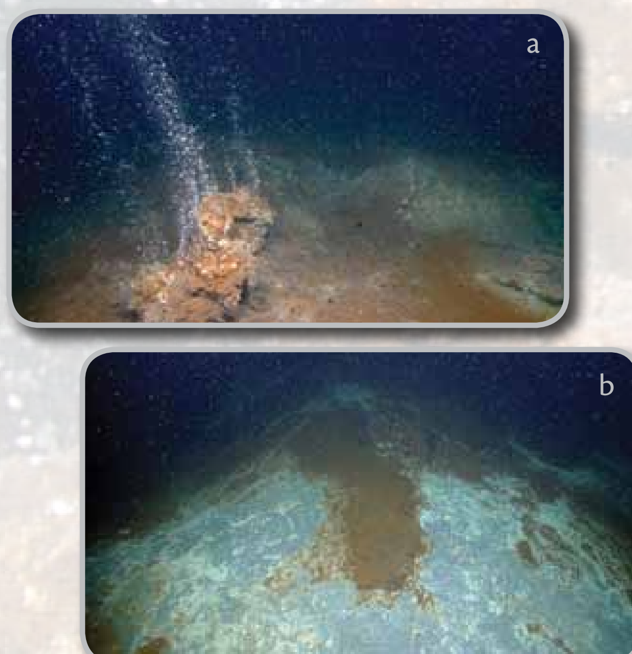

Figure 2. We are able to use different survey techniques to map out distributions of (a) bubbling and (b) nonbubbling vents inside the crater of Kolumbo Volcano.

Figure 3. *Hercules* collects a push core of a yellow bacterial colony and sediment from the hydrothermal vent field in the northern basin of Santorini.

Figure 4. *Hercules* inspects a large fracture on the slope of the Christiana domes.

Figure 5. Unidentified mounds in the Cretan Basin are a few meters in diameter, approximately 1 m high, and commonly have a small crater at the top.

that may be of biogenic origin cover some of the Kolumbo chimneys. Initial studies also indicate possible microbial microtextures in the cores of the chimneys (Kilias et al., 2011). Gas samples collected in 2010 showed that 99% of the gas being emitted from the hydrothermal vents is composed of CO_2 (Carey et al., 2011). Not surprisingly, preliminary onboard analysis of water samples in 2011 shows pH levels lower than average; detailed chemical analysis is currently in progress.

Kolumbo mapping efforts focused on two new ways to visualize active physical processes (Figure 2). First, we mapped the hydrothermal vent field and actively bubbling vents at high resolution. Second, we tested the use of structured light mapping over areas venting hot water without bubbles ("shimmery" water). The observed refraction of light can be used to visualize these venting areas (see pages 42–45). The preliminary results of both techniques were excellent, and we anticipate that these maps will contribute to a better understanding of Kolumbo's geological activity, and demonstrate the use of mapping temporal changes in biogeological systems. These techniques should also be useful in other exploratory applications.

Our work inside Santorini caldera focused on two regions: the hydrothermal vent field in the northern basin (Figure 3), and the north and east slopes of Nea Kameni Island. The low-temperature vent field in the northern basin, first discovered in 2006, is composed of small (1–4 m) mounds covered in yellow bacteria. Sediment samples were collected here to compare the microbial community to that in nearby Kolumbo. Since January 2011, interferometric synthetic aperture radar and GPS measurements[1] collected on the Kameni islands and Thera suggest caldera-wide uplift occurs at a fairly constant rate. This continued inflation may indicate the influx of new magma beneath Nea Kameni. ROV exploration along the northern slopes of Nea Kameni revealed lava flows and fractured lava blocks that were formed during the 1707–1711 and 1925–1928 CE eruptions. At the top of a volcanic dome, east of Nea Kameni, we also discovered a crater with shimmery water.

The Christiana group of four small islets belongs to a stand-alone volcanic cone that domed the seafloor at the junction of a pair of fault zones trending NNW-SSE and NNE-SSW. A group of submarine domes near the Christiana islets occur at an average depth of 500 m and are believed to be of volcanic origin (recent work of author Nomikou and colleagues). Until now, no visual observations had been made on the submarine domes; we conducted several *Hercules* dive transects up their slopes to study their origin, history, and relationship with the rest of the Santorini volcanic complex. We found evidence of faulting (Figure 4)—cliffs up to 100 m tall, and small colonies of yellow, presumably sulfur-reducing hydrothermal bacteria, as well as abundant benthic megafauna, including sponges, corals, sea cucumbers, and urchins.

The final area of interest was the Cretan Basin in the Sea of Crete, where we discovered an area of pockmarked mounds in 2006. Our goal in 2011 was to map the region with side-scan sonar to determine the geographic extent of the mound area, followed by visual reconnaissance with *Hercules*, and to collect sediment samples to investigate how these features formed (Figure 5). Unfortunately, failure of the side-scan system prevented us from carrying out the planned mapping, but we collected push cores from several of the mounds, and analysis is in progress.

[1] GPS measurements have been collected as a collaborative project that includes the University of Oxford, the National Technical University of Athens, the Georgia Institute of Technology, and the University of Patras.