**Kolumbo Submarine Volcano: A National Underwater Treasure for Greece**

Nomikou P.[1], Carey S.[2], Kilias S.[1], Bell K.L.C.[2], Godelitsas A.[1], Argyraki A.[1], Polymenakou P.[3], Stathopoulou E.[4], Bejelou K.[1], Perros I.[5], Argyrou A.[6]

[1]*University of Athens, Department of Geology and Geoenvironment, Panepistimioupoli Zografou, 15784 Athens, Greece.*
[2]*Graduate School of Oceanography, University of Rhode Island, Narragansett,USA.*
[3]*Hellenic Centre for Marine Research, Institute of Marine Biology, Biotechnology and Aquaculture, Gournes Pediados, P.O.Box 2214, Gr 71003, Heraklion Crete, Greece.*
[4]*University of Athens, Department of Ghemistry, Panepistimioupoli Zografou, 15784 Athens, Greece.*
[5] *University of Athens, Pedagogical Department of Primary Education, Greece.*
[6] *Photographer, Kamari, 84700, Santorini, Greece.*

Santorini volcano, of the active Hellenic volcanic arc, is among the most famous volcanoes in the world, being the site of numerous explosive eruptions over the last 600,000 years. It is particularly well known for the Minoan eruption (~1615 BC) which is thought to have had a significant impact on the Minoan civilization in the eastern Mediterranean Sea. Millions of people visit Santorini each year to view its stunning volcanic vistas. But few people know that just offshore of the northeastern part of Santorini, at only a few hundred meters beneath seawater surface, lies another volcano, Kolumbo (Fig.1) (Nomikou, 2003; Nomikou et al., 2012b). This is an active submarine volcano that last erupted in 1650 AD (Fouque, 1879) and caused significant damage and fatalities on the island of Thera as a result of gas discharges and tsunamis (Dominey–Howes et al. 2000; Nomikou et al., 2012b). Recent exploration of Kolumbo volcano using ROVs and submersible have revealed a fascinating underwater landscape rich in unique geological and biological features (Carey et al., 2011).

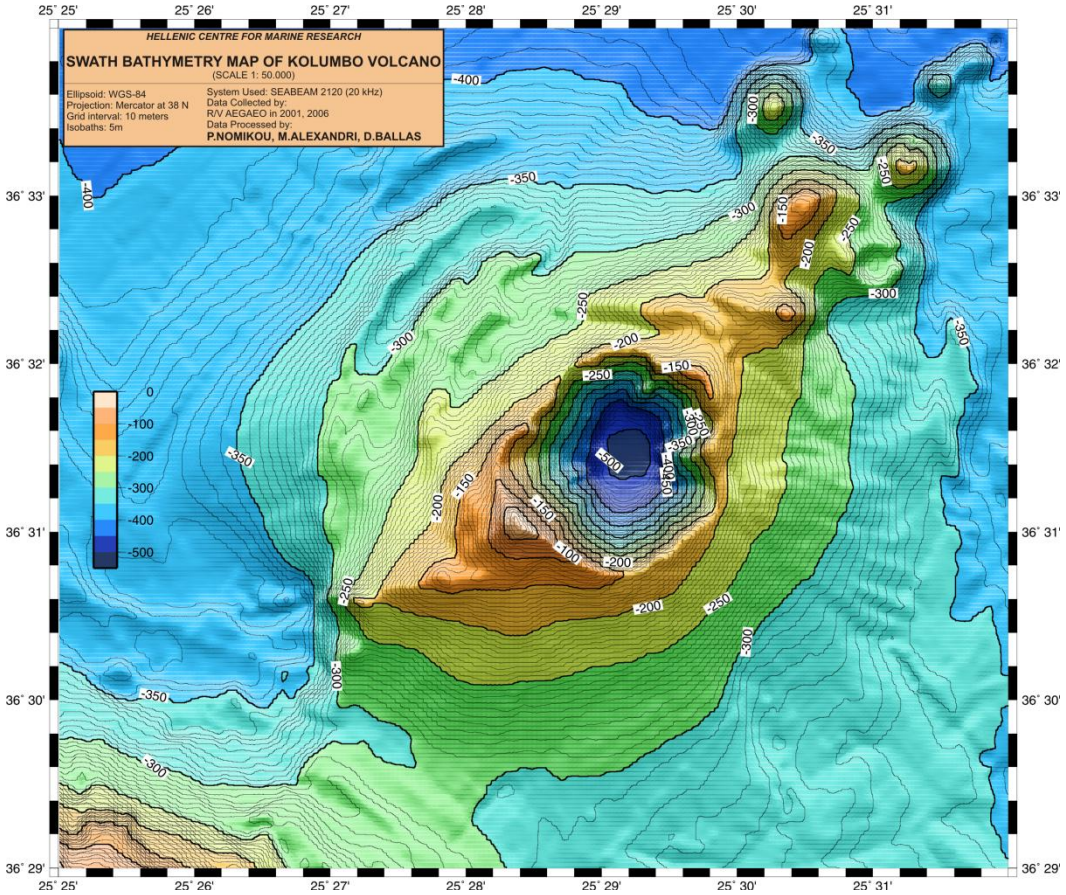


**Figure 1:** Swath bathymetric map of Kolumbo volcano using 5m isobaths (Nomikou et al., 2012b).

Kolumbo thus serves as a special “Underwater Physical Laboratory” within which scientists spanning a wide range of disciplines can observe and study processes that have been recognized in few other places throughout the world’s oceans. On the floor of Kolumbo’s crater, hot volcanic fluids and gases are being discharged through the seafloor to form spectacular chimneys and mounds (Fig. 2) made up of minerals rich in Fe, Zn, Pb, Au, Ag and other metals (Kilias et al., 2011). These hydrothermal vents, first discovered in 2006 (Sigurdsson et al., 2012), represent a potential economically important ore deposit actively being formed on and below the Aegean sea floor, triggered by the dynamic interaction of seawater, hot volcanic rocks, and microbial activity. The hydrothermal vents are the sites of extensive bacterial colonization (Fig. 3). Virtually the whole of their surfaces covered by microbial mats of fascinating colors made of extremophile and acidophile microbes and minerals with a fascinating range in color and textures which live under extreme toxic metal rich conditions of high temperature (~100$^0$C), and acidic waters. They thrive on the sulfur-, iron- and other metal-rich fluids as a source of energy for their survival and may provide important insights into how life evolved during early Earth history.

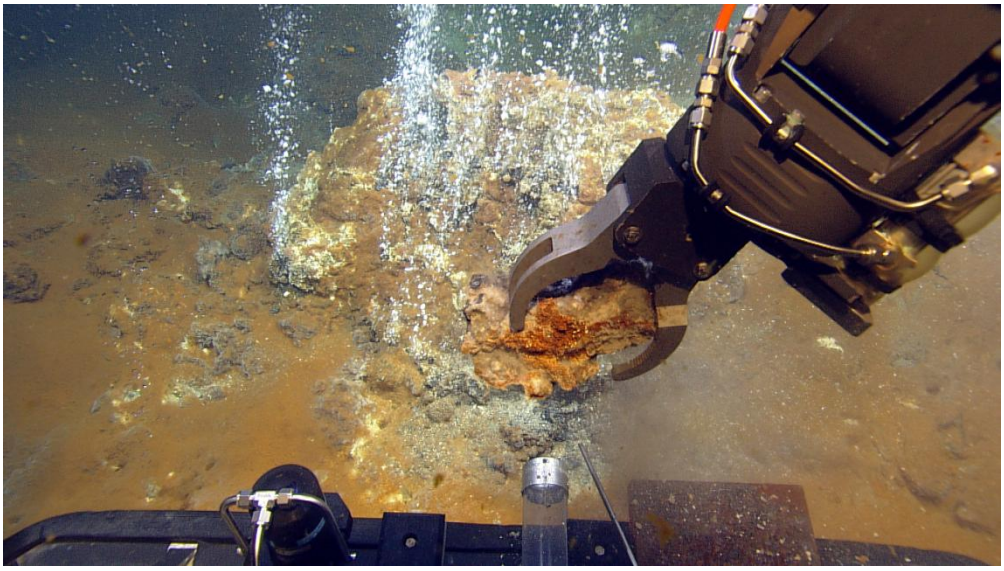

**Fig. 2:** Sampling with the manipulator arm of ROV Hercules from a hydrothermal vent mound discharging both fluids and gases (220$^o$C).

Fig. 3: Streams of white bacteria spreading along the crater floor of Kolumbo volcano.

Even though Kolumbo lacks any vent eukaryotic fauna like deep sea mussels, bythograeid and galatheid crabs, barnacles, large actinians (sea anemones), and gastropods that are found at other vent fields like Sunrise, at the upper part of carter walls many different kind of fishes have been found (Fig. 4).

**Fig. 4:** Eel at the inner crater walls of Kolumbo Volcano at 170m depth.

Just as the caldera of Santorini provides breathtaking views of vertical cliffs carved into mutlticolored volcanic rocks, the walls of Kolumbo's crater are the sites of equally spectacular underwater landscapes (Fig.5) (Carey et al., 2011; Nomikou et al., 2012a). Similar volcanic processes have created thick sequences of volcanic ash and lava that have been sculptured by waves, ocean currents, and earthquakes.

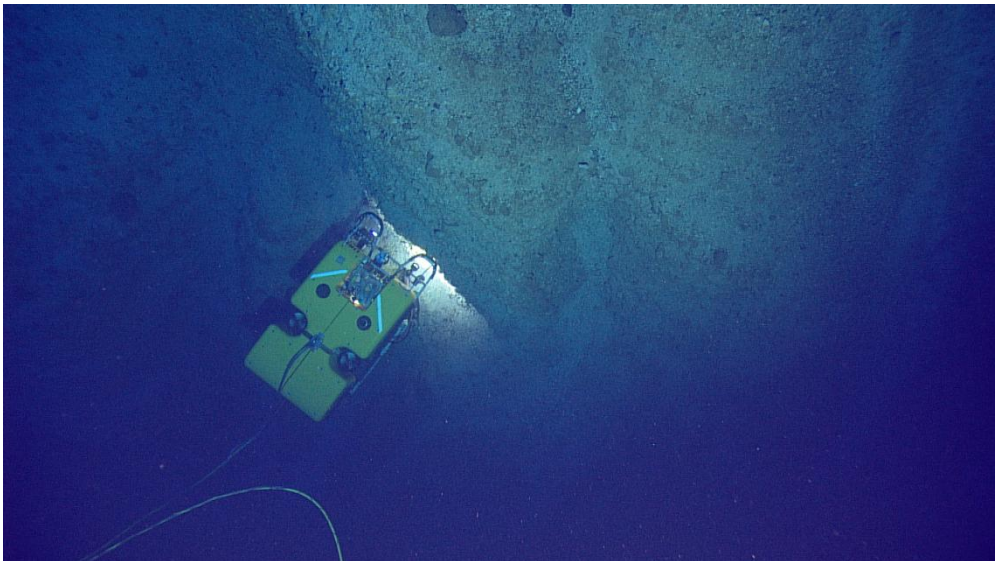

**Fig. 5:** Remotely operated vehicle Hercules examines a vertical pumice wall in the crater of Kolumbo submarine volcano.

Despite it's great natural beauty, Kolumbo is an active volcano that lies in close proximity to a major tourist destination in Greece. Recent studies have shown that there is more earthquake activity beneath Kolumbo than there is beneath Santorini (Bohnhoff et al., 2006; Dimitriadis et al., 2010). The observed metal enrichment underscores the importance of shallow submarine geothermal activity as a potential source of toxic metals in areas exploited by fishing. Kolumbo is therefore an important site for monitoring signs of impending volcanic and

geothermal activity such as changes in the temperature, gas flux, and distribution of hydrothermal vents on the crater floor (Fig.6). Kolumbo's unique assemblage of geological, biological, and hazard phenomena distinguish it as a unique underwater site that deserves special recognition. Creation of a Special Research Area (SRA) would facilitate the scientific exploration of this site and help assure the preservation of key features and resources.

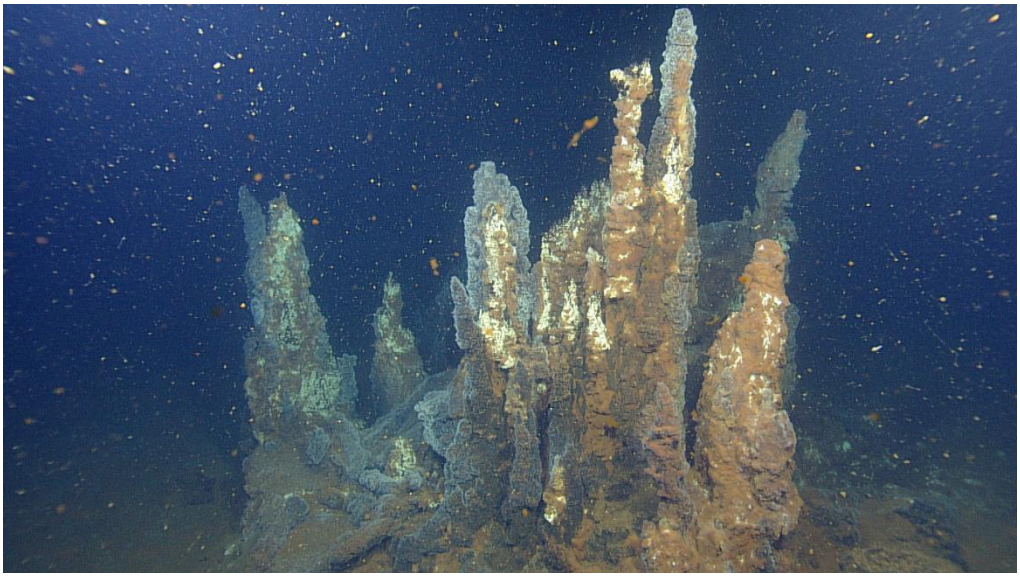

**Fig. 6:** Field of multiple inactive and active sulfide/sulfate, spires up to 2 m high on top of a hydrothermal mound with spire fragments, draped by Fe-bacteria mats on the floor of Kolumbo submarine volcano (500m depth.)

Some of the objectives associated with a SRA would be to: 1). Coordinate scientific research at Kolumbo through a process of academic oversight, 2). Encourage an evaluation of resources and special features that would be used to direct future research projects, 3). Stimulate the distribution of information about Kolumbo through a research database, symposium, and the internet.

**References**


Bohnhoff, M., Rische, M., Meier, T., Becker, D., Stavrakakis, G., Harjes, H.P. (2006). Microseismic activity in the Hellenic Volcanic Arc, Greece, with emphasis on the seismotectonic setting of the Santorini–Amorgos zone. Tectonophysics 423, 17-33.

Carey S., Bell K. L. C., Nomikou, P., Vougioukalakis, G., Roman, C., Cantner, K., Bejelou, K., Bourbouli, M., Martin Fero J. (2011). Exploration of the Kolumbo Volcanic Rift Zone. Oceanography, Vol.24, No. 1, Supplement, "New Frontiers in Ocean Exploration" The E/V Nautilus 2010 Field Season. March 2011, p. 24-25.

Dimitriadis, I., Papazachos, C., Panagiotopoulos, D., Hatzidimitriou, P., Bohnhoff, M., Rische, M., Meier, T., (2010). P and S velocity structures of the Santorini-Coloumbo volcanic system (Aegean Sea, Greece) obtained by non-linear inversion of travel times and its tectonic implications. Journal of Volcanology and Geothermal Research 195, 13-30.

Dominey-Howes, D.T.M., Papadopoulos, G.A., Dawson, A.G., (2000). Geological and historical investigation of the 1650 Mt. Columbo (Thera Island) eruption and tsunami, Aegean Sea, Greece. Natural Hazards 21 (1), 83– 96.

Kilias S., Nomikou P., Godelitsas A., Polymenakou P., Stathopoulou E., Carey S. (2011): Interdisciplinary mineralogic, microbiological and chemical studies of active Koloumbo shallow submarine arc-related hydrothermal vent field, Aegean Sea: preliminary results. William Smith Meeting: Remote Sensing of volcanoes & Volcanic processes: integrating observation & modeling, 4-5 October 2011, London, p.51.

Nomikou, P. (2003). Santorini and Nisyros: Similarities and differences between the two calderas of the modern Aegean Volcanic Arc. CIESM Workshop on "Human records of recent geological evolution in the Mediterranean Basin-historical and archaeological

evidence" Santorini 22-25 October 2003, Greece. CIESM Workshop Monographs n24, p.103-108.

Nomikou P., Carey S., Papanikolaou D., Croff Bell K., Sakellariou D., Alexandri M., Bejelou K. 2012a: Submarine Volcanoes of the Kolumbo volcanic zone NE of Santorini Caldera, Greece. Global and Planetary Change 90-91 (2012) 135-151. doi:10.1016/j.gloplacha.2012.01.001.

Nomikou P., Carey S., Croff Bell K., Papanikolaou D., Bejelou K., Cantner K., Sakellariou D., Perros I. 2012b: Tsunami Hazard Risk of a future volcanic eruption of Kolumbo submarine volcano, NE of Santorini Caldera, Greece: Natural Hazards. DOI:10.1007/s11069-012-0405-0.

Sigurdsson H., Carey S., Alexandri M., Vougioukalakis G., Croff, K., Roman C., Sakellariou D., Anagnostou C., Rousakis G., Ioakim C., Gogou A., Ballas D., Misaridis T., and Nomikou P. (2006). "Marine Investigations of Greece's Santorini Volcanic Field", EOS, Vol 87 N. 34, 22 August 2006.