IODP Expedition 398: Hellenic Arc Volcanic Field

Site U1594 Summary

Background and Scientific Objectives

Site U1594 (proposed Site CSK-07B) is located in the southern basin of the Santorini Caldera. It lies at a water depth of 291 meters below sea level (mbsl). It was drilled to a depth of 51.7 meters below seafloor (mbsf) in a single hole with 94% recovery, before the hole was terminated due to poor stability.

The four caldera sites (U1594–U1597) were planned to sample intracaldera seismic Units S1–S3, to test the published correlations between the two caldera basins, to penetrate below Unit S3 (seismic Unit S4), and to address scientific objectives 1, 4, 5, and 7 of the Expedition 398 *Scientific Prospectus*. The seismic units were thought probably to consist of (S1) muds and sands from cliff mass wasting, (S2) compacted (possibly lithified) sandy volcaniclastics from Kameni Volcano, and (S3) consolidated coarse blocky tuffs, landslide debris, and/or flood gravels. Seismic Unit S4 may be intracaldera tuffs. The goals were to ground truth the different seismic units, document the processes, products, and potential impacts of the Late Bronze Age (LBA) eruption, reconstruct the eruptive history of Kameni Volcano, penetrate below Unit S3, and discover the nature of Unit S4. The combined approach of drilling in the northern and southern caldera basins would enable us to test several hypotheses regarding the LBA caldera-forming eruption of Santorini. By drilling both caldera basins and exploiting our dense seismic reflection coverage, we would gain access to the 3D architecture of the entire caldera fill and better understand the relative roles of downfaulting and downsagging in the LBA caldera collapse. We would also target the question of why the northern basin is 100 m deeper than the southern one, with a thicker seismic Unit S1 but thinner seismic Unit S3. Finally, we would be able to test whether seismic Unit S3 consists of flood debris from the caldera-flooding event, or whether it represents LBA intracaldera tuffs. The intracaldera sites would be used for the microbiological work of objective 7.

Operations

On 22 January 2023 at 1830 h the vessel arrived at Site U1594, in the southern end of the Santorini Caldera. All thrusters were down and secure at 1848 h. The vessel was switched to dynamic positioning (DP) control, starting Site U1594 at 1850 h. The 15.0 nmi transit took 1.8 h at an average speed of 8.3 kt.

The rig crew made-up an advanced piston corer/extended core barrel (APC/XCB) bottom-hole assembly (BHA) with a bit. Hole U1594A (36°23.3368′N, 25°25.0290′E) was spudded on 22

January at 2310 h. Core U1594A-1H was shot from 297.0 meters below rig floor (mbrf), and recovered 4.2 m, establishing the seafloor at 291.0 mbsl.

APC coring continued into 23 January, from Core U1594A-2H to 6H (4.2–51.7 mbsf). Excessive torque was observed, indicating a collapsing hole. The driller worked the drill string, but the tight conditions persisted. The drill string was pulled up with the top drive from 42.2 mbsf to ~100 m above the seafloor. The bit cleared the seafloor at 0350 h.

The decision was made to offset to an alternate site in the southern caldera, proposed Site CSK-08B. The vessel was moved in DP mode, starting the 0.7 nmi passage at 0445 h, marking the end of Site U1594.

Principal Results

Cores from Site U1594 recovered a coherent stratigraphy from 0 to 50.09 mbsf. The site consists of just one hole, Hole U1594A.

The recovered material is unlithified sediment, dominated by volcanic material with minor amounts of mud and tuffaceous mud in the upper 1.5 m. Smear slides for microscopic analyses were prepared to confirm macroscopic descriptions of distinct lithology changes at the section level, such as identification of vitric particles in tuffaceous lithologies or crystals in ash layers. X-ray diffraction (XRD) data were obtained from three interstitial water (IW) squeeze cake sediment residues from Hole U1594A.

It was not possible to measure any structures at Hole U1594A. Although some bedding planes were observed, core-induced disturbance prevented the measurements.

Planktic and benthic foraminifers and calcareous nannofossils were examined from core catcher samples from Hole U1594A to assess the paleoenvironmental conditions of Site U1594. Additionally, benthic foraminifers provided data on paleowater depths and possible dissolution. Very rare planktic and benthic foraminifers were found in core catcher samples in the forms of *Globoturborotalita rubescens* and *Sorites orbiculus*. Additionally, very rare occurrences of the calcareous nannofossils, *Emiliania huxleyi* and *Gephyrocapsa* spp. (small form), were found. This assemblage indicates an age younger than 0.265 Ma, which comes as no surprise given that the Santorini Caldera is filled with sediments younger than ~1630 BCE.

As only one hole was drilled, stratigraphic correlation was not possible at Site U1594.

There is a general trend of increasing *P*-wave velocity and magnetic susceptibility (MS) with increasing depth at Site U1594. Thermal conductivity is lower than typical values for sediments at similar depths. Sediment strength was measured with a pocket penetrometer on the catwalk immediately after sections were cut. Automated vane shear (AVS) measurements were made on working half sections. Because volcaniclastic materials are not suitable for these measurements,

few measurements could be made: one pocket penetrometer and seven AVS measurements. A total of 130 *P*-wave velocity measurements were conducted on working half sections. Discrete measurements of *P*-wave velocity on working half core sections are similar to those measured by the Whole-Round Multisensor Logger (WRMSL). A total of 17 discrete samples were collected for moisture and density (MAD) measurements. Bulk density derived by MAD measurements on discrete samples should be more reliable than gamma ray attenuation (GRA) bulk density data from WRMSL measurements on whole-round cores. However, for both density measures, coring and recovery disturbances may have impacted values.

To determine the geochemistry of the volcanic and tuffaceous materials, four tephra samples were handpicked from various layers within Hole U1594A. Following cleaning, grinding, fusion, and dissolution, the materials were analyzed shipboard for major (Si, Al, Fe, Mg, and Ca), minor (Ti, Mn, Na, K, and P), and trace (Sc, V, Cr, Co, Ni, Cu, Zn, Rb, Sr, Y, Zr, Nb, Ba, Ce, and Nd) elements using inductively coupled plasma–atomic emission spectroscopy (ICP-AES). All of the volcaniclastic units sampled were classified as dacites. Concentrations are reported for all analyzed trace elements, but Ce, Cr, Cu, Nb, Ni, P, Rb, S, and V were below detection limits in the majority of samples. Trace element ratios were used to discriminate broadly between the volcanic centers of Kolumbo, Santorini, and Christiana.

To determine the inorganic constituents of IW, a total of four water samples were taken from the mudline and whole-round squeezing of sediment intervals at Site U1594. Aliquots of IW were used for shipboard analyses, and the remaining water was taken for shore-based analysis, following protocols specified by individual scientists. The retrieved pore waters were analyzed shipboard for salinity, alkalinity, pH, major anions (Cl^-, SO_4^{2-}, and Br^-), major cations (Ca^{2+}, Na^+, Mg^{2+}, and K^+), and major (S, Ca, Mg, K, and Na) and minor (B, Ba, Fe, Li, Mn, P, Si, and Sr) elements.

Three sediment samples were analyzed for bulk geochemistry. All were analyzed for total carbon-hydrogen-nitrogen (CHN) and for inorganic carbon content and carbonate. For the CHN analysis, duplicates were run for ~10% of the sample size to determine analytical reproducibility.

None of the cores recovered at this site were suitable for paleomagnetic analysis.

Due to the instability of the formations encountered, downhole logging was not conducted at Site U1594.