

IODP Expedition 398: Hellenic Arc Volcanic Field

Site U1596 Summary

Background and Scientific Objectives

Site U1596 (proposed Site CSK-06B) is located in the northern basin of the Santorini Caldera. It lies at a water depth of 382 meters below sea level (mbsl) and consists of Holes U1596A and U1596B with 91% and 87% core recovery, respectively.

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 volcanoclastics 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

The dynamic positioning (DP) move to Site U1596 from Site U1595 was completed at 0330 h on 24 January 2023 while the crew completed assembling the bottom-hole assembly (BHA). At 0430 h, the BHA was lowered and Hole U1596A (36°26.5378'N, 25°22.5130'E) was spudded at 0650 h. Core U1596A-1H recovered 3.9 m and seafloor depth was calculated at 382.0 mbsl. Coring continued through Core 5H at 41.9 meters below seafloor (mbsf), the final depth for U1596A. Excessive torque was encountered before shooting Core 6H. The decision was made to pull out of the hole and offset to primary proposed Site CSK-05C.

The drill string was pulled from 32.4 mbsf to approximately 80 m above the seafloor. The DP move started at 1102 h, ending Site U1596.

On 3 February, the ship revisited Site U1596 and arrived on location 50 m northwest of Hole U1596A at 1615 h. The 4.8 nmi DP move from Site U1595 took 1.7 h at a speed of 2.8 kt. The advanced piston corer/extended core barrel (APC/XCB) BHA was assembled. Hole U1596B (36°26.5568'N, 25°22.4875'E) was spudded at 1915 h. A recovery of 4.2 m in Core U1596B-1H gave a calculated mudline at 381.9 mbsl. APC coring continued to Core 5H at 42.2 mbsf, the final depth for the hole.

The drill string was pulled clear of the hole with the top drive. On 4 February at 0105 h, the bit cleared the rotary table at 0105 h and the drill floor was secure at 0145 h. The vessel was brought under bridge control at 0148 h. All thrusters were brought up and secured. The sea passage to Site U1600 started at 0154 h, ending Site U1596.

Principal Results

Cores from Site U1596 recovered coherent stratigraphy from 0 to 40.62 mbsf. The recovered material is unlithified sediment, dominated by volcanic material with minor amounts of mud and tuffaceous mud in the upper 8 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 U1596A and two IW squeeze cake sediment residues from Hole U1596B.

It was not possible to measure any structures at Site U1596. Although some bedding planes were observed, core-induced disturbance prevented the measurements.

No calcareous nannofossils or benthic foraminifers were found in core catcher samples; however, very rare planktic foraminifers were found in the forms of *Orbulina suturalis*, *Globigerina bulloides*, *Neogloboquadrina pachyderma*, and *Globigerinita glutinata*. Additionally, rare Radiolaria, Bryozoa, and ostracods were found, though biological remains were of insufficient quantity to permit paleoenvironmental analyses.

To establish the composite depth scale, Holes U1596A and U1596B were analyzed for their physical properties using the Whole-Round Multisensor Logger (WRMSL) for magnetic susceptibility (MS) and gamma ray attenuation (GRA) and the gamma ray track (for natural gamma ray [NGR] intensity), as well as core photos. Similar to Site U1595, correlation was very challenging at this site and only the MS data allowed several reliable correlations, while NGR and GRA density measurements were strongly overprinted by the irregular distribution of core material in cores with low recovery and a high content of water. Both holes recovered the mudline and Core U1596B-1H was used as the initial anchor for stratigraphic correlation. From

thereon, we attempted to determine the relative depth offset of each core by establishing affinities between the holes based on the maximum correlation of all measured physical properties. Once the composite depth scale was established, selected sequences from Holes U1596A and U1596B were spliced to create the most complete and representative section possible.

There is a general trend of increasing *P*-wave velocity with increasing depth at Site U1596. 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 section splitting. Automated vane shear (AVS) measurements were made on working half sections. Because volcanoclastic materials are not suitable for these measurements, few measurements (seven AVS measurements and three pocket penetrometer measurements) could be made.

A total of 107 and 110 *P*-wave velocity measurements were conducted on working half sections from Holes U1596A and U1596B, respectively. Discrete measurements of *P*-wave velocity on working half core sections are similar to those measured by WRMSL measurements on whole-round cores. *P*-wave velocity increases with depth. A total of 15 discrete samples were collected for moisture and density (MAD) measurements from Hole U1596A. Bulk density derived by MAD measurements on discrete samples should be more reliable than GRA data from WRMSL measurements on whole-round cores; however, in both cases coring and recovery disturbances may have impacted measured values. The cored depth at this site is too shallow to identify systematic trends with depth.

To determine the inorganic constituents of IW, a total of five water samples were taken from the mudline and whole-round squeezing of sediment intervals at Site U1596. Aliquots of IW were used for shipboard analyses, and the remaining water was taken for shore-based analysis. 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. Salinity was 40‰ throughout the hole.

Headspace gas analyses were performed at a resolution of one sample per full-length core (9.5 m advance) throughout Hole U1596A. The aim was to monitor the presence and abundance of C1–C3 hydrocarbons as part of the standard IODP safety protocol. A total of nine headspace gas samples from this hole were analyzed by gas chromatography (GC). Methane, ethane, and propane concentrations are below the detection limit. Concentrations of heavier hydrocarbons (*iso*-butane, *n*-butane, and *n*-pentane, etc.) were below the detection limit throughout.

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

Microbiological analysis was conducted on two whole-round samples from Hole U1596B. The whole-round samples were split into 25 subsamples. Most of the microbiological analyses will be conducted on shore, but first culturing experiments indicate the presence of the iron oxidizing bacterium *Mariprofundus ferroxydans*.

Due to the instability of the formations encountered, downhole logging was not conducted at Site U1596.