

IODP Expedition 376: Brothers Arc Flux

Site U1531 Summary

Background and Objectives

Site U1531 (proposed alternate Site LC-1A) is located on the saddle between the Lower and Upper Cones of Brothers volcano at 34°52.7767'S, 179°4.2241'E about 380 m northeast of seismic Line Bro-3 in a water depth of 1355 m. This site likely sits between the margins of the upflow zones of both the Upper and Lower Cones because there is no detectable magnetic low in this area. The Lower Cone hydrothermal vent field includes vents that discharge the most Fe- and Mg-rich fluids sampled at Brothers volcano to date, although there is no evidence for venting at the saddle. The main objective of Site U1531 was to drill and core to ~300 m to sample the various volcanic cycles that comprise the Lower Cone, as well as to intersect the upflow zone of metal-rich fluids.

Operations

We implemented operations in five holes at Site U1531 (proposed alternate Site LC-1A). Holes U1531A, U1531B, and U1531E were drilled on the saddle stretching between the Lower and Upper Cone of Brothers volcano. Holes U1531C and U1531D were on the summit of the Lower Cone. Hole U1531A is located at 34°52.7767'S, 179°4.2241'E, in a water depth of 1354.9 m. In this hole, we conducted rotary core barrel (RCB) coring from the seafloor to 15 m with poor recovery of 1.0 m (7%). Any further advancement was impossible due to very poor hole conditions that led to a stuck drill string several times. We then RCB cored in Hole U1531B, which is located at 34°52.7721'S, 179°4.2111'E, in a water depth of 1351.9 m. Coring in Hole U1531B penetrated from the seafloor to 26 m and recovered 4.0 m (15%). However, poor hole conditions in blocky/fragmented lava deposits prevented us from further deepening. We then offset the vessel ~110 m northeastward to the summit of the Lower Cone to Hole U1531C at 34°52.7239'S, 179°4.2586'E, in a water depth of 1306.9 m. In this hole, we RCB cored from the seafloor to 28.4 m and recovered 2.3 m (8%) with tight hole conditions throughout coring; we decided to abandon Hole U1531C at 28.4 m. We then decided to deploy a reentry system with a short, 16 m long casing string to establish a stable hole for reaching deeper coring and logging objectives. We drilled in casing in Hole U1531D at 34°52.7228'S, 179°4.2606'E, in a water depth of 1306.9 m at the summit of the Lower Cone. After the pilot bit drilled to the target depth of 19 m, we released the reentry system from the drilling assembly (mud motor, underreamer, drill bit), but we were unable to pull the drilling assembly clear of the casing string, as the underreamer arms did not completely retract. After several hours of attempting to free the reentry system, we started pulling the drill string and attached reentry system out of the hole and back to the vessel. While we were retrieving the casing-reentry system assembly, it unfortunately

dropped off in sight of the moonpool, with our position above the bottom part of Lower Cone slope in its transition to the surrounding southeastern caldera floor. We then moved back to the saddle between Lower and Upper Cone and made up another drilling assembly to drill in 16 m of casing in Hole U1531E, which is located at 34°52.7591'S, 179°4.2344'E in a water depth of 1355.0 m. We drilled the casing in to 17.9 m. We then conducted another test of the CDEX turbine-driven coring system (TDCS), which washed down (drilled without coring) to 17.9 m to start coring in Hole U1531E. We could not advance any deeper as the TDCS core barrel got stuck in the bottom-hole assembly and could not be retrieved. After the TDCS test, we RCB cored from 17.9 to 39.6 m and recovered only 0.8 m (4%). At this point, the blower motor in the top drive failed. We decided not to repair it at this time due to our remaining scientific priorities and the approaching end of the expedition. Our final operation at Site U1531 consisted of a downhole temperature measurement with the Elevated Borehole Temperature Sensor (ETBS) memory tool. It recorded a maximum temperature of ~5°C at 20 m. A total of 264.25 h or 11.01 d were recorded while on Site U1531.

Principal Results

Igneous Petrology and Volcanology

At Site U1531, one igneous unit was observed in Holes U1531A (0–1.14 m), U1531B (0–21.97 m), U1531C (0–23.75 m), and U1531E (17.90–34.95 m). Several cores were also recovered during hole cleaning (ghost Cores U1531E-2G to 4G). Igneous Unit 1 consists of an unaltered to slightly altered plagioclase-pyroxene phyric dacite lava intercalated with unconsolidated ash, ash with lapilli, and lapilli tephra with ash. The moderately to highly vesicular dacite lava contains glomerocrysts and phenocrysts of plagioclase, ortho- and clinopyroxene, and Fe-Ti oxides in a cryptocrystalline and hypocrySTALLINE groundmass. Volcaniclastic material is mainly composed of unaltered vitric clasts and crystals that are likely fragments of the dacite lava, and subordinate lithic components. The composition of the dacitic lavas and pyroclastic rocks from Site U1531 is typical for those of the youngest dacitic magmas erupted at Brothers volcano.

Alteration

One alteration type was identified at Site U1531 based on an alteration assemblage identified through a combination of macroscopic and microscopic descriptions, and X-ray diffraction (XRD) analyses. Alteration Type I is classified as slightly altered and has an alteration mineral assemblage of smectite, iron-oxyhydroxide, zeolite, pyrite, and rarely native sulfur. Alteration occurs as infilling and lining of vesicles as well as smectite replacing the glassy matrix.

Structural Geology

The main structures at Site U1531 include volcanic fabrics and fractures. Volcanic fabrics were observed in all holes and are well developed, ranging from weak to strong. There are only three intervals across Site U1531 that are isotropic. Fabrics are defined by elongated vesicles, plagioclase microlites, and to a lesser extent plagioclase phenocrysts and glomerocrysts. Vesicles have aspect ratios between 5 and 15. Hole U1531C is the only hole where fabric orientation was measured with dips that range from moderate to steep. A few pieces in Hole U1531C have lineations defined by vesicles; all plunges are subparallel to the dip. Several core pieces from all holes have microfractures delineated by the growth of halite and gypsum in the laboratory after pieces were cut and dried. Discrete fractures are best preserved in Hole U1531C. Fractures range from shallow to steep and are typically marked by secondary minerals such as native sulfur or iron-oxyhydroxide.

Geochemistry

Unaltered to slightly altered lavas and tephra from Igneous Unit 1 represent typical dacites, with 62.3 to 65.0 wt% SiO₂, and Na₂O + K₂O contents ranging from 6.5 to 6.9 wt%. They are essentially similar in major and trace element composition to fresh dacites from Site U1529 and Hole U1527A (Igneous Unit 1 at those sites) and confirm the low compositional range previously reported for dacites at Brothers volcano. Total carbon (TC) and sulfur concentrations are generally low (<250 μg/g and <300 μg/g respectively), except in one sample with ~1900 μg/g. Low total sulfur is consistent with previously reported data for dacitic glass in Brothers volcano and suggest minimal influence of magmatic volatile input in selected samples. Nevertheless, relatively high concentrations of H₂ and acid volatile sulfide were detected in some intervals consistent with discharging magmatic gases through the volcanic pile.

Paleomagnetism

Only three core sections recovered from Site U1531 (i.e., Hole U1531C) had oriented pieces that could be measured in the cryogenic superconducting rock magnetometer. In addition, we selected five discrete samples from the working-half core sections for detailed measurements of anisotropy of magnetic susceptibility, alternating field and thermal demagnetization, as well as isothermal remanent magnetization experiments. As expected from fresh dacites, the natural remanent magnetization intensities are large. Magnetic directions from these samples have inclinations of approximately -60°, suggesting a very young age for the primary magnetization component. The shape of the thermal demagnetization curve indicates that these samples contain pure magnetite and titanomagnetite with variable Ti content.

Physical Properties

Physical properties measurements made on limited, fragmented core recovered from Holes U1531A, U1531B, U1531C, and U1531E are consistent with the range of expected values for

fresh dacitic lavas and tephra, and are similar to those for fresh volcanoclastic material from the Igneous Unit 1 at Sites U1527 to U1529. There is no clear difference in physical properties between material recovered from the summit of the Lower Cone and material recovered from the saddle, although interpretation is significantly limited by the low recovery, fragmented nature of the core, and limited number of oriented pieces.

Downhole Measurements

The ETBS memory tool was deployed in Hole U1531E after about 24 h without circulation. It recorded a maximum temperature of 5.2°C at 20 m which is similar to the bottom seawater temperature.

Microbiology

One whole-round sample of moderately vesicular dacite lava was collected from Hole U1531C for microbiological analysis. Sample aliquots were taken and preserved for shore-based DNA and RNA analyses, as well as prokaryotic and viral counting and activity measurements.