IODP Expedition 384: Engineering Testing

Site U1554 Summary

Background and Objectives

The main objective of International Ocean Discovery Program (IODP) Expedition 384, Engineering Testing, was to test drilling, reaming, and coring equipment in igneous ocean crust. Operational schedule changes related to some major *JOIDES Resolution* repairs, as well as the travel restrictions imposed by the COVID-19 pandemic, provided an opportunity to conduct additional operations. Given the short notice and preparation time, the IODP JRSO decided to insert an assessment of the advanced piston corer (APC) core orientation tools and procedures during Expedition 384.

Geographic orientation of APC cores relative to geographic north before they are cut, using magnetic orientation tools deployed in the core barrel, has been routinely performed for many years. The tool currently used is the Icefield core orientation tool; the FlexIT tool was used in the past and is also available. However, recent experience has shown that these measurements are unreliable, working consistently on some expeditions and failing repeatedly on others. The objective on Expedition 384 was to investigate the origin of the problem by assessing the procedures and the equipment used for orienting the cores under more controlled conditions than is typically possible during expeditions when the focus is on maximizing core recovery. We planned to recover APC cores in three adjacent holes to a depth of 70 m below seafloor to obtain a sufficient number of orientation measurements that could be compared with the paleomagnetic measurements in the stratigraphically correlated cores.

The site chosen for the primary engineering objective, proposed Site REYK-13A, happened to have a companion site <100 km away, proposed Site REYK-06A, which had the requisite young sediments expected to be good paleomagnetic recorders based on results from nearby drift sediments cored ~150 km to the northeast on ODP Leg 162. The paleomagnetic declination for these Brunhes-age sediments should average to approximately due north, providing the reference declination against which the orientation tools can be tested.

Operations

Operations at Site U1554 (proposed Site REYK-06A) began after the 1100 nmi transit from Kristiansand, Norway, which ended at 0629 h on 27 July 2020 when we established dynamic positioning. The average speed of the transit was 11.6 kt.

An 11⁷⁄₁₆ inch advanced piston corer/extended core barrel (APC/XCB) bit was made up with a 136.8 m long bottom-hole assembly (BHA) and the drill string was deployed at 1445 h. The pipe stands were measured and cleared of rust during deployment. Hole U1554A was started at 2300 h with a 5.7 m long mudline core. The calculated water depth was 1870 m. We completed APC coring in Hole U1554A at 0625 h on 28 July with Core 8H to 72.2 m driller's depth below seafloor (DSF), with a recovery of 74.7 m (103%). The ship was offset 20 m to the east and Hole U1554B was completed at 1515 h with Core 8H to 76.0 m DSF, with a recovery of 76.8 m (101%). The ship was offset 20 m to the south and we completed Hole U1554C at 2330 h with Core 8H to 75.0 m DSF, with a recovery of 77.0 m (103%). Core orientation was measured on all cores in each hole. On 29 July the ship was offset once more, this time 20 m west of Hole U1554C, and coring in Hole U1554D began at 0045 h. Here we drilled down to 14 m DSF and cored a single Core 2H from 14 to 23.5 m DSF, with a recovery of 9.72 m (102%). This core was taken for future training and testing purposes on the ship. The drill string was retrieved and cleared the rig floor at 0715 h, ending operations at Site U1554. The rig floor was secured and the ship began the transit to Site U1555 (proposed Site REYK-13A) at 0900 h. Total time spent at Site U1554 was 2.0 d.

Principal Results

General Characterization of the Site U1554 Stratigraphy

The core orientation tests required a set of cores that are characterized with the standard set of shipboard measurements and observations. To that end, all cores from Holes U1554A–U1554D were first measured for magnetic susceptibility (MS) and gamma ray attenuation (GRA) on the Special Task Multisensor Logger (STMSL). The STMSL was configured to perform these measurements as rapidly as possible to allow real-time stratigraphic correlation, which was necessary to provide real-time feedback to the driller and ensure that all coring gaps in a hole are covered by cores in at least one of the adjacent holes. Our coring gaps in Hole U1554A were perfectly covered in cores from both Holes U1554B and U1554C using that method, which allowed construction of a composite depth scale to 83.3 m core composite depth below seafloor (CCSF) and a splice representative of the complete stratigraphic section. All cores from Holes U1554A and U1554B were used except for Core U1554B-5H, which was disturbed throughout and replaced with Core U1554C-5H for the splice. Higher resolution measurements of MS and GRA on the Whole-Round Multisensor Logger (WRMSL), which also included *P*-wave velocity measurements, and on the Natural Gamma Radiation Logger (NGRL), were subsequently performed on all whole-round core sections.

All cores were subsequently split and imaged with both visual light and X-ray. Color reflectance and MS measurements were made using the Section Half Multisensor Logger (SHMSL). A small set of discrete samples were taken from the working section halves for moisture and density and magnetic property measurements. Magnetic remanence was measured on all archive section halves using the superconducting rock magnetometer (SRM). The sediments proved to be high fidelity recorders of the Brunhes normal polarity geomagnetic field, with the exception of Core U1554B-5H, which suffered drilling disturbance throughout. Based on the magnetic polarity, the relative paleomagnetic intensity record, and data from nearby ODP Sites 983 and 984, the sediments in the top 80 m at Site U1554 are younger than ~0.6 Ma, yielding an average sedimentation rate of ~14 cm/ky.

The fine-grained texture of the sediment is remarkably uniform, even across the color transitions between shades of greenish gray and gray, based on smear slide observations. The constituents are dominated by silt-sized particles and ash in the greenish gray layers, as expected for a drift deposit in a volcanic province, and by calcareous nannofossils in the light gray layers. Clay and siliceous microfossils, as well as calcareous nannofossils in the darker greenish gray layers, are subordinate constituents. The ash is mostly dispersed and mixed with the other constituents, and more concentrated in thin, darker greenish gray layers. The sediment is intensely bioturbated as indicated by discrete burrows, particularly at interval boundaries with strong color contrast, by ash pods representing remnants of ash layers, and by pervasive mottling. Most of these sediments can be referred to as silty ash or tuffaceous silt with nannofossils and siliceous microfossils, and the light gray layers as tuffaceous nannofossil ooze.

Core Orientation and Paleomagnetic Measurements

To assess whether the core orientation tools were functioning accurately, we used four different magnetic orientation tools while collecting the 25 APC cores from Holes U1554A–U1554D. Eight cores were collected with FlexIT Tool 0937 and the remaining 17 cores were collected with three Icefield Tools (2007, 2043, and 2052). These tools give a measurement, referred to as the Magnetic Tool Face (MTF) angle, that can be used to determine the orientation of the core.

Following magnetic cleaning using progressive alternating field demagnetization, the mean paleomagnetic direction was estimated for each core. The resulting core mean paleomagnetic declination was used to determine the known orientation of the core, because we know that Brunhes age (0–780 ka) sediments that are good paleomagnetic recorders, like those at Site U1554, will have mean declinations of approximately 0°. The difference between true north and the paleomagnetic declination gives a paleomagnetic reorientation (PMR) angle that can be compared directly with the MTF angle. If the magnetic orientation tool is accurately measuring the core orientation, the difference between the PMR and MTF angles should be negligible relative to the errors in the method, which were expected to be roughly ±15°.

The orientation angles (PDR–MTF) for 20 of the 25 cores differed by <28°, with a mean difference of 8.7° and a standard deviation of 13.9°. Core U1554B-5H was not used in the assessment since it was disturbed throughout. The paleomagnetic directions were clearly disturbed in this core, and the PDR–MTF difference was somewhat larger (34.8°) than observed for the undisturbed cores. The four results obtained with Icefield Tool 2043 were all anomalous, with PDR–MTF differences of 155.3°, 183.6°, 192.6°, and 189.0°. The average of these happens to be 180°, indicating that the tool probably has the sign on a couple of the fluxgate magnetometers or accelerometers backwards or some other misalignment. Given the high and highly variable magnetic fields present on the *JOIDES Resolution*, which inhibit accurate measurement of Earth’s magnetic field direction, we waited until the end of Expedition 384 to test Icefield Tool 2043 on the dock in Kristiansand. The tool performed exactly as it should.

Upon further inspection of the pressure casing and connectors for the tool, we found that the T-slot and snubber connections for Icefield Tool 2043 were aligned opposite of those for Icefield Tools 2007 and 2052. This 180° misalignment explains the anomalous results. In addition, if the Icefield Tool 2043 snubber was used with the other tools, that could also have led to unreliable measurements. Given that this has been a long-term problem, it is difficult to determine when the misaligned part was acquired or if it was misaligned aboard the ship. The part was repaired and Icefield Tool 2043 and the other tools should now perform as expected.