IODP Expedition 397T: Transit and Return to Walvis Ridge Hotspot

Site U1584 Summary

Background and Objectives

Site U1584 was planned to sample a Gough track ridge to provide basalt samples that would anchor the Gough end of a geochemical transect across the Walvis Ridge Guyot Province. The location was chosen to be slightly younger than the morphologic split in Walvis Ridge, which coincides with the development of different geochemical signatures for the different guyot chains. The major objectives were to core basalt lava flows for major and trace element geochemistry and isotope geochemistry, obtain fresh basalt samples for geochronology, and recover multiple lava units for paleomagnetic inclination studies. Unfortunately, geology disappointed and coring quickly encountered indurated volcaniclastic deposits. Seismic data could not indicate a limit to such deposits and, there being no alternative sites (or enough time to address them), the science team elected to quit Site U1584 and save the unused operations time for the next site.

Operations

Expedition 397T began on 10 September 2022, 0800 h (UTC + 2 h), with the ship tied up at Duncan Dock E, Cape Town, South Africa. All oncoming Expedition 397T personnel, including 22 JRSO staff and eight scientists, moved onto the ship following a four-day hotel quarantine. The quarantine included a PCR and an antigen test according to the COVID-19 mitigation protocol. All personnel tested negative. Once aboard, all shipboard personnel received another COVID-19 PCR test, and all were negative. Port call activities continued, including the loading of 500 mt of fuel and fresh food. COVID mitigation protocols continued to be followed throughout port operations. One more JRSO staff member came on board before the pilot boarded and the ship departed Cape Town on 12 September at 1018 h.

At 0200 h on 15 September, the ship's clock was set back one hour to UTC + 1 h. We completed the 810 nmi voyage from Cape Town and arrived at Site U1584 (proposed Site GT-06A) at 0830 h. The thrusters were deployed and a drill string with a rotary core barrel (RCB) bottom-hole assembly (BHA) and a C-4 coring bit was assembled. At 1630 h the top drive was engaged and a "pig" was deployed to clear potential rust and other obstructions from the drill pipe. We estimated the seafloor at 2313 m below rig floor (mbrf) based on the corrected precision depth recorder (PDR) signal. At 1800 h the first core barrel was dropped from 2310 mbrf and the liner returned empty. The driller had observed a tag at 2315.9 mbrf while lowering the core barrel. For the second attempt, the barrel was dropped from 2315.9 mbrf. The liner returned empty again except for sediment residue smeared all along its length, indicating that the barrel had penetrated the formation but couldn't hold the sediment. At 2005 h we declared the seafloor depth at

2315.9 mbrf and deployed the core barrel. The barrel with center bit had to be deployed twice because no indication of landing was detected the first time. We started to drill down without coring, reaching the target at 141.8 m below seafloor (mbsf) at 0515 h on 16 September. The wash barrel was retrieved and the RCB core barrel was deployed. RCB coring proceeded from Core U1584A-3R through 9R (141.8 to 208.2 mbsf), with core recovery ranging from 0% to 95% (average 36%). The hole was swept with 30 barrels of sepiolite mud after Cores 5R (170 mbsf) and 9R (208.2 mbsf).

At 2215 h on 16 September, we decided to terminate operations at Site U1584 because the seismic basement reflector turned out to be the top of a potentially thick succession of volcaniclastic sediments rather than the desired basaltic lava flows. We retrieved the drill string from Hole U1584A, with the bit clearing the rig floor at 0605 h on 17 September. The rig floor was secured, the thrusters were raised, and we departed Site U1584 at 0700 h.

COVID-19 mitigation protocols continued to be followed with mask wearing, social distancing, and antigen testing of all personnel. Four individuals tested positive after boarding the ship on 11, 13 (2), and 15 September, respectively. They were quarantined until antigen tests on two successive days, starting on day five, were negative.

Principal Results

Lithostratigraphy

A >65 m thick succession of sediments was drilled at Site U1584. It comprises two main lithostratigraphic units: an upper chalky pelagic sediment passing into highly bioturbated sandy silt with clay and foraminifera (Lithostratigraphic Unit I, 141.8–164.84 mbsf), and a lower volcaniclastic-dominated (pumiceous) succession composed of greenish to brown pumice lapilli and varying content of fragmentary lithic volcanic lapilli and blocks, together with infrequent layers of moderately well-sorted scoriaceous ash and small lapilli with rare individual bioclasts toward the base (Unit II, 164.84–207.75 mbsf). No igneous basement was encountered, and the hole was ended at 207.75 mbsf. In Lithostratigraphic Unit I, core recovery increases with sediment consolidation downhole, from ~3% in the chalk (Subunit IA), to 30%–50% in the silty sandstone (Subunits IB and IC). In Lithostratigraphic Unit II, core recovery increases with degree of cementation, from ~25%–40% in the greenish-yellow pumiceous lapillistone (Subunit IIA), to >90% in the olive-brown pumiceous lapillistone and volcanic breccia (Subunit IIB).

Unit I consists of a ~23 m thick succession of bioturbated clayey-nannofossil chalk passing downhole into highly bioturbated, pale brown to reddish silty sand with varying amounts of carbonate, with minor volcaniclastic intercalations including a few coarser beds of vitric and lithic ash. The unit is highly bioturbated throughout, effectively erasing any original bedding or sedimentary structures. Unit I was subdivided into three subunits based on significant compositional or color changes in the clayey-silty sand unit (i.e., rapid change from pale brown

to reddish-brown at the base of a tephra band at Interval U1584A-4R-CC, 16 cm), together with a change to a finer more silt and carbonate-rich composition.

- Subunit IA (142.10–150.80 mbsf) recovered 5 to 8 cm long pieces and gravel-sized fragments of consolidated pale pinkish-grey bioturbated clayey-nannofossil chalk ($CaCO_3$ content ~40%–60%), interpreted as a pelagic deposit.
- Subunit IB (150.80–153.64 mbsf) is a succession of consolidated/lithified pale brown clayey bioturbated silty sand, potentially up to ~10 m thickness, with volcaniclastics and foraminifera ($CaCO_3$ content ~25%–30%). This subunit is interpreted as background pelagic carbonate sedimentation with siliciclastic, silt-sized intervals deposited by turbidity currents.
- Subunit IC (153.64–164.84 mbsf) consists of ~11 m of lithified reddish-brown silty sandstone with foraminifera, volcaniclastic and clay components, and lower $CaCO_3$ content (~20%). The subunit is heavily bioturbated with infrequent layers of moderately well-sorted medium sand and gravel and rare shell bioclasts. The relative amount of background pelagic sedimentation decreases relative to siliciclastic, silt- to sand-sized deposition, possibly from turbidity currents.

Unit II consists of >43 m thick, dominantly volcaniclastic succession of lapillistone containing varying proportions of green to reddened (oxidized) pumice mixed with altered basaltic lithic fragments (see Basaltic Clast Summary below). The boundary between Units I and II is abrupt, but not preserved (Interval U1584A-5R-4, 64 cm). Two subunits are recognized within Unit II based on a change in component proportions in the upper part of Core U1584A-5R and increasing downhole lithification by a mixture of interstitial altered ash and zeolite.

- Subunit IIA (164.84–193.60 mbsf) is a ~20 m thick unstratified succession of green pumice lapilli fragments, with a downward increasing component of basaltic lithic fragments and irregular-shaped blocks set in a matrix of fine-grained gray “ash-like” material, calcite, and zeolite. Two crudely graded intervals from coarser lapilli with volcanic blocks to smaller pumice lapilli with infrequent lapilli-sized basaltic volcaniclasts can be recognized.
- Subunit IIB (193.60–207.75 mbsf) is a >14 m thick lithified olive-brown volcanic breccia consisting of unstratified oxidized pumiceous lapillistone and brown volcaniclastics with blocks in roughly equal proportions. The subunit is characterized by a downhole reduction in dominant clast size, and a greater frequency of subrounded pumice lapilli with rare rounded, internally zoned lapilli; it has a greater bulk density than Subunit IIA (see Physical Properties). Hole U1584A ended within this unit at 207.75 mbsf.

Deposition of the succession indicates a change from volcaniclastic dominated succession in which the main preserved eruptive products are highly vesicular pumice with basaltic lithic fragments and fine ash. Basaltic fragments include occasional cobble or block-sized fragments. The degree of alteration and rounding of pumice clasts deceases upward, and observable crude

layering may have been caused by eruptive pulsing. The later overlying sediments are fine to medium clayey sands passing upward into lower energy (deeper water?) ash clayey silts with concomitant decrease in volcaniclastic component, and finally into pelagic chalks with a minimal clastic component. These contain infrequent thin and dispersed ash (silt- and sand-sized) layers, most likely turbidites.

Basaltic Clast Summary

In Unit II of Hole U1584A, basalt clasts range in diameter from <1 cm up to 6 cm. These clasts show a range in mineralogy and porphyritic and aphanitic textures. No volcanic glass was observed. The highly-phyric clasts typically contain abundant olivine phenocrysts (8%–10%) with some pyroxene (1%–3%). All olivine is partly to completely altered to iddingsite while the pyroxenes display varying degrees of alteration. Moderately and sparsely-phyric basalt clasts have lower olivine abundances (0%–7%) with more plagioclase phenocrysts (0%–5%). Pyroxene is often present in low amounts (0%–2%). Aphyric clasts are also present only as a minor component. Texturally, olivine is found as single crystals or small crystal clusters. Plagioclase phenocrysts range from blocky crystals to elongate crystals with variable degrees of alteration to sericite. Pyroxene is present in thin tabular crystals with only minor visible alteration. Vesicle abundance varied widely, with some vesicle free clasts and others containing up to 30% vesicles. Vesicles commonly contain alteration minerals ranging from a thin zeolite lining to being completely filled with calcite.

Biostratigraphy

Expedition 397T did not have any biostratigraphers on board and we therefore have no data on the age of the sediments. Samples were taken for a micropaleontological assessment after the expedition.

Paleomagnetism

Cores from Hole U1584A did not offer much potential for accomplishing paleomagnetic objectives for Expeditions 391 and 397T. No basaltic basement was cored, and the section of basal sediments that might produce reliable paleomagnetic data was short. Much of the section was volcaniclastic breccia, which is expected to be a poor magnetic recorder because the glassy matrix has low magnetization and basalt clasts are randomly oriented, so no coherent inclination record can be obtained. Superconducting rock magnetometer (SRM) measurements were made on all available material (Cores U1584A-4R, 5R, and 7R to 9R; Core 6R was empty). These measurements found that the basal sediments in Cores U1584A-4R and 5R, containing calcareous clay and chalk, have moderate and coherent magnetization intensities, but deeper volcaniclastic cores have generally low intensities, interrupted by high intensity spikes from basalt clasts. Discrete sample measurements augment and reinforce this picture. The coherent magnetization in the calcareous clay unit gives a consistent positive magnetic inclination which is interpreted to record a reversed magnetic polarity.

Sediment Geochemistry

Sediment samples were analyzed to determine the weight percent (wt%) of $CaCO_3$, total carbon (TC), total inorganic carbon, total organic carbon (TOC), and total nitrogen (TN). At Site U1584, seven samples were collected from Cores U1584A-3R through 5R. In Lithostratigraphic Subunit IA, $CaCO_3$ content is moderate, with a mean of 55.7 ± 15.6 wt%. The mean calcium carbonate content then decreases to 23.7 ± 3.7 wt% and 22.4 ± 10.3 wt% in Subunit IB and Subunit IC, respectively. TOC shows a general decrease from Subunit IA (0.26 ± 0.1 wt%) to Subunit IC (0.07 ± 0.1 wt%). Therefore, TC contents are nearly identical (within error) to total inorganic carbon. Subunit IA has subtly higher TC (6.5 ± 1.5 wt %) than Subunits IB and IC (3.2 ± 0.5 wt% and 2.8 ± 1.5 wt%, respectively). TN contents are below the instrumental detection limits for all samples.

Four representative basalt clasts (4–6 cm) found in volcaniclastic sediment from Site U1584 were analyzed for major and select trace element compositions using inductively coupled plasma–atomic emission spectroscopy (ICP-AES). Three samples from Site U1584 are basalt and one is basalt trachyandesite, and all four samples are alkaline. The basalt clasts from Site U1584 have a narrow range in SiO_2 (45.02–46.40 wt%), TiO_2 (2.05–2.54 wt%), K_2O (1.46–1.73 wt%), but wide range of MgO (2.23–9.50 wt%). The clasts span a range of Mg# (22.8–62.4) and show decreases in TiO_2, Al_2O_3, and Sr and an increase in Ni with increasing Mg#. Though compositionally heterogeneous, the samples from Site U1584 all have higher K_2O, Al_2O_3, Ni, and Sr than the samples from Expedition 391 sites.

Physical Properties

Whole-round core logging included the measurement of gamma ray attenuation bulk density, pass-through magnetic susceptibility (MS), and natural gamma radiation (NGR). The whole-round section surfaces of igneous rocks and some breccias were also imaged in four quadrants. After splitting, the section halves were imaged and measured the diffuse color spectrophotometer and a point magnetic susceptibility (MSP) meter. Discrete samples were measured for moisture and density (MAD) and *P*-wave velocity.

The results can be broken down into two categories based on how well they correlated with the two main lithologic units: a mud and sand dominated lithified sediment in Unit I, and a lapillistone in Unit II, with an increasing proportion of volcanic lithic fragments downhole. NGR, MS, MSP, and *P*-wave velocity correlated with the lithographic units, showing distinct changes between the units. NGR, MS, and MSP values increase slightly downhole from Subunit IB to Subunit IC, where they reach their highest relative values. Continuing downhole from Subunit IC to Subunit IIA, values decrease significantly, from ~25 to 16 counts/s (NGR) and ~700 to 50 SI (MS, MSP). From the top of Unit IIA and through Unit IIB, NGR, MS, and MSP remain relatively constant, with a gradual decrease in their values towards the bottom of the hole. *P*-wave velocity behaves inversely to MS and NGR, increasing towards the bottom of Subunit IIB (~1770 to 3600 m/s). Bulk density measurements (GRA, MAD) and porosity remain

consistent through the lithologic boundary. Density measurements stay consistent from Subunit IB through Subunit IIA and sharply increase going into Subunit IIB (~1.77 to 2.28 g/cm^3). Porosity stays at its highest value from Subunit IB through Subunit IIA and decreases in Subunit IIB, from ~56% to ~27%.