International Ocean Discovery Program Expedition 397T Scientific Prospectus

Transit and Return to Walvis Ridge Hotspot

William W. Sager
Co-Chief Scientist
Department of Earth and Atmospheric Sciences
University of Houston
USA

Kaj Hoernle
Co-Chief Scientist
GEOMAR Helmholtz Centre for Ocean Research Kiel
Germany

Peter Blum
Expedition Project Manager/Staff Scientist
International Ocean Discovery Program
Texas A&M University
USA

Publisher's notes

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Abstract

During International Ocean Discovery Program (IODP) Expedition 391, the Tristan-Gough-Walvis Ridge (TGW) hotspot track was cored in December 2021–February 2022. Its overarching objective was to recover basaltic rock from TGW edifices to understand the evolution of Walvis Ridge and related guyots. Significant cuts to the Expedition 391 operational plan were necessary as a result of lost time due to COVID-19 mitigation procedures. Because the R/V *JOIDES Resolution* will pass over Walvis Ridge during the transit from Cape Town, South Africa, to Lisbon, Portugal, prior to IODP Expedition 397, the 3 week transit provides an opportunity to drill one or two holes that were planned but not cored during Expedition 391. The transit schedule indicates that ~7 days of ship time will be available for this effort. Coring will be attempted at one or two sites, depending on weather and operational difficulties. The first site to be cored will be proposed Site GT-6A on the flank of the Gough track ridge. If time permits, coring will also be done at proposed Site TT-3A on the Tristan track, completing the proposed transect across the three chains of the Walvis Ridge guyot province. Two operational strategies are planned to address the limited time available. First, the ~164 m thick (Site GT-6A) and ~146 m thick (Site TT-3A) sediment sections will be drilled without coring to ~20 m above basement. Primary Site GT-6A, which is ~1.1 km upslope from alternate Site GT-4A, was specifically proposed because of its reduced sediment thickness.

1. Expedition schedule

At the time of publication of this *Scientific Prospectus*, International Ocean Discovery Program (IODP) Expedition 397T is scheduled to start in Cape Town, South Africa, on 10 September 2022 and to end in Lisbon, Portugal, on 11 October (Figure **F1**; Table **T1**). The plan currently calls for 31

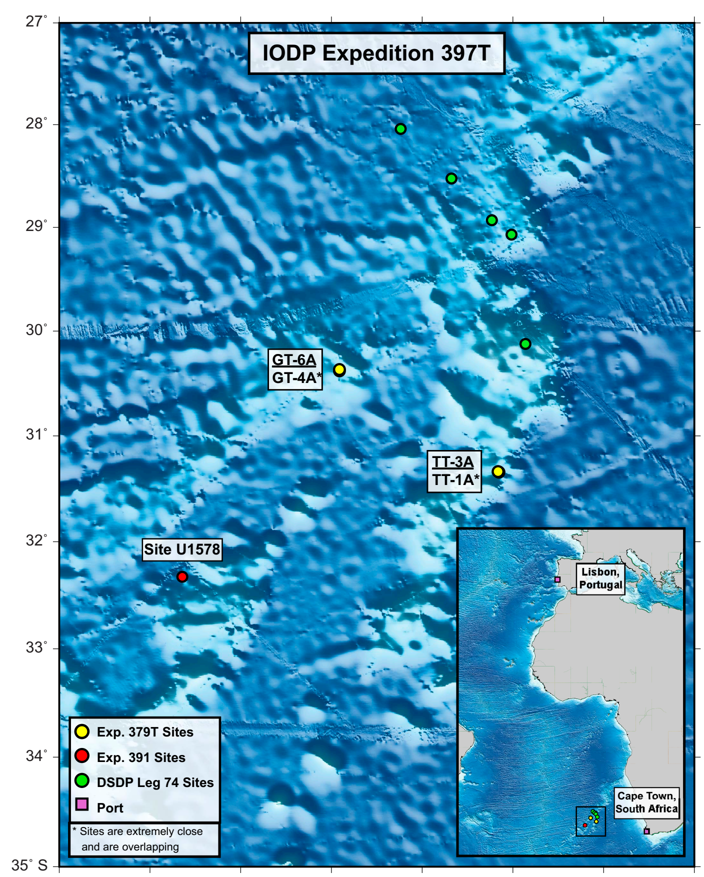

Figure F1. Location of Expedition 397T proposed sites, Site U1578, and Leg 74 sites. Inset: expedition start port (Cape Town, South Africa) and end port (Lisbon, Portugal).

days of operations: ~2 days in port, ~22 days in transit, and ~7 days on site (for the current detailed schedule, see **http://iodp.tamu.edu/scienceops**). Further details about the facilities aboard the research vessel (R/V) *JOIDES Resolution* can be found at **http://iodp.tamu.edu/labs/index.html**.

2. Introduction

Expedition 397T is the transit from Cape Town, the location of a non-IODP tie-up, to Lisbon, the port where IODP Expedition 397 will begin (Figure **F1**). The transit follows a month of tie-up designated as Expedition 397P, with numerous ship and laboratory upgrades planned. Expeditions 397P and 397T are split into equal 1 month durations for personnel and logistical reasons. Given an estimated transit time from Cape Town to Lisbon of 21 days and including 2 days of port call as part of the transit, 7 days were left that could be applied to on-site operations benefiting IODP science.

During IODP Expedition 391 (Walvis Ridge Hotspot), the Tristan-Gough-Walvis Ridge (TGW) hotspot track was cored in December 2021–February 2022 (Sager et al., 2022). Its overarching objective was to recover basaltic rock from TGW edifices to understand the evolution of Walvis Ridge and related guyots. An outbreak of COVID-19 occurred during Expedition 391, requiring *JOIDES Resolution* to return to port for mitigation procedures. The result was a loss of 18 days of ship time and a severe truncation of the expedition science plan. Originally, six sites were planned, with three on the Valdivia Bank oceanic plateau of Walvis Ridge and another three forming a transect across the three lines of seamounts in the Walvis Ridge guyot province. Four sites were drilled during the shortened Expedition 391: three on Valdivia Bank (Sites U1575–U1577) but only one in the guyot province (Site U1578).

Given that the Walvis Ridge Hotspot sites are located on the route for Expedition 397T, the *JOIDES Resolution* Facility Board approved the use of the available time on site to further the objectives of Expedition 391. The additional 7 days of drilling can provide a significant contribution to achieving the most important Expedition 391 science objectives. The plan is to core at the two sites that were dropped owing to time constraints: one on the Gough track seamount chain and the other on the Tristan track seamount chain (Figures **F1**, **F2**). At each site, the plan is to core igneous basement for 50 h, which should span ~100 m of section given the penetration rates achieved on a Center track guyot at Site U1578.

Given the strict time constraints, we selected sites that are located at shallow depths and have minimal sediment cover. Furthermore, we obtained permission from the Environmental Protection and Safety Panel (EPSP) to drill the sediment section without coring to save time. Proposed Site TT-3A was an Expedition 391 alternate site and is located at the top of the Tristan track guyot (Figure **F3**) at a water depth of 1871 m (Figure **F4**). Its sediment cover is less than at other sites on the guyot and is estimated to be ~146 m (this is revised upward from 135 m on site forms because the seismic velocity used to estimate the sediment/basement contact was too low; Figure **F5**). The second proposed site, GT-6A, is at a water depth of 2320 m on the Gough track ridge (Figures **F6**, **F7**). The sediment thickness at Site GT-6A is estimated to be 164 m (Figure **F8**).

3. Scientific background

The scientific rationale for Expedition 397T coring is the same as for Expedition 391. Please see the Expedition 391 *Scientific Prospectus* and *Preliminary Report* (Sager et al., 2020, 2022) for detailed background information.

4. Scientific objectives

The original plan called for three sites on each of three chains of volcanic edifices that occur southwest of the point where Walvis Ridge splits from a single ridge into multiple lines of seamounts and smaller ridges. At nearly the same location, the isotopic characteristics of the seamounts also change. There are at least two distinct isotopic compositions. One signature is similar to that of lavas from Gough Island and edifices in the Gough track stretching from Deep Sea Drilling Project (DSDP) Hole 525A to Gough Island. This signature also occurs through the entire length of Walvis Ridge northeast of the DSDP Leg 74 transect (Hoernle et al., 2015; Homrighausen et al., 2019). The other signature is characteristic of Tristan da Cunha Island and the Tristan track seamounts (edifices between Tristan Island and DSDP Sites 527 and 528). This difference is thought to represent different material source regions in the lower mantle at the edge of the Atlantic large low-shear velocity province. In the proposal, combined published and unpublished data showed that the Center track (intermediate between the Tristan and Gough tracks) might have a distinct geochemical composition (Class et al., 2015). The presence of a third distinct composition requires a more complex source geometry, which would place into question the present model for the origin of zoned plumes. An alternative is that the Center track erupted a mixture of Tristan and Gough lavas, but this hypothesis is difficult to evaluate with the very sparse number of dredged samples from this region because of poor basement exposure.

The Expedition 391 science plan was to core both end-members (Tristan and Gough) and the center. The time constraints because of mitigating a shipboard COVID-19 outbreak required two sites to be eliminated entirely. This loss made it difficult to address one of the two scientific pillars of the expedition. Loss of sites on the Tristan and Gough tracks took away the end-member signatures, making it unclear whether geochemical objectives can be achieved. Thus, the plan for Expedition 397T is to recover ~100 m of basement rocks at proposed Sites TT-3A and GT-6A, which will give robust end-member compositions for the transect.

In addition to these main foci, an Expedition 391 goal was to obtain long igneous sections to help scientists understand the temporal geochemical evolution of single locations along the TGW hotspot track, which is not possible through dredging. Shifts observed in preliminary geochemical

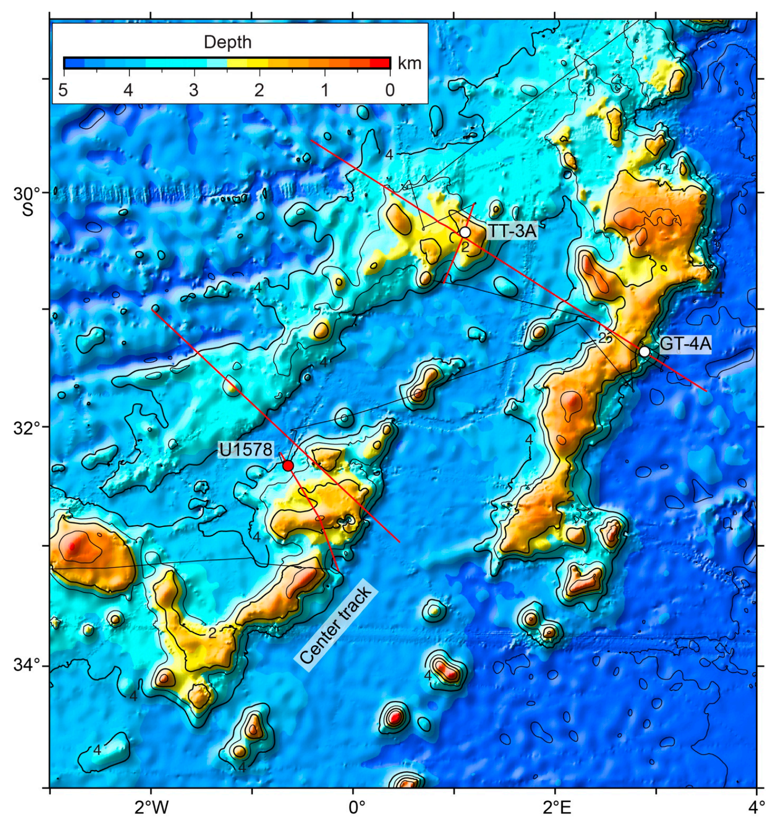

Figure F2. Location of Expedition 391 guyot province sites. Site U1578 was cored during Expedition 391. Proposed Sites TT-3A and GT-4A were not cored. Proposed Site GT-6A will be cored during Expedition 397T instead of Site GT-4A because of thinner sediment thickness (see Figures F6, F7, F8). Black lines = seismic lines, red lines = lines on which these sites are located. Bathymetry is estimated from satellite altimetry.

data from cores from Sites U1575 and U1578 imply changes in magma source through time. Interfingered lava flows and sediments at Sites U1576 and U1578 imply that the cores span a long period of time and that the final eruptions of edifices can take place over an extended time. Such observations can only be made with drill cores provided by *JOIDES Resolution*. Coring the two missing sites will add to the legacy of Expedition 391 and enable a better understanding of TGW volcanism.

Coring at Sites TT-3A and GT-6A will also aid with other Expedition 391 objectives. Another primary objective of the expedition was to compile a record of hotspot paleolatitudes. The rationale is to compare paleolatitude changes over time with models of plume motion and true polar wander (TPW; the shift of the entire mantle relative to the spin axis). Although there is evidence for TPW on other planets and on Earth in the distant past and at present, it has fallen from favor as an explanation for changes in hotspot paleolatitudes for the Late Cretaceous and Cenozoic. Little paleomagnetic data exist currently from Walvis Ridge, but global continental data imply rapid southward motion during the Late Cretaceous, followed by ~5° of northward motion since the latest Cretaceous or early Cenozoic. This northward motion is the opposite of modeled plume motion, but it is the expected shift if some of the ~15° southward shift of the Hawaiian hotspot is caused by TPW. Basalt samples are expected to give the best paleomagnetic record, but critical to that goal is having samples that span >10^5–10^6 y to average paleosecular variations. Having a large number of independent samples of the magnetic field inclination (i.e., measurements that are not close in time) is key to determining paleolatitude with small uncertainty estimates. Coring at Site U1578 produced an excellent section that spans >1 My in duration (Sager et al., 2022), but until paleomagnetic studies are completed, we will not know how well the paleomagnetic field was

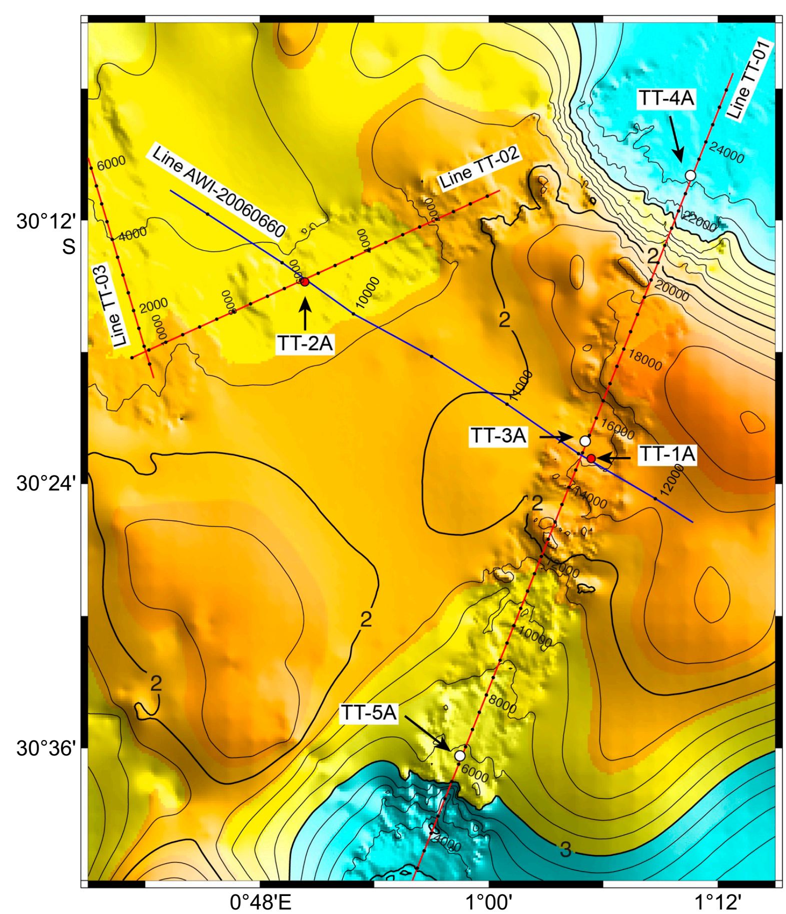

Figure F3. Bathymetry, Tristan track guyot summit showing proposed sites. Proposed Site TT-3A was an alternate site for Expedition 391. It was chosen as a primary site for this expedition because of thin sediment cover and shallow depth. Detailed bathymetry was collected with a multibeam echo sounder, and bathymetry in multibeam gaps is inferred from satellite altimetry.

measured. Proposed Sites GT-6A and TT-3A are expected to provide basaltic lavas similar in age to Site U1578, so new paleomagnetic data from those sites can be used to better determine the latest Cretaceous–earliest Cenozoic paleolatitude. This will increase the likelihood that Expedition 391 goals will be accomplished.

5. Operations plan

The plan is to core ~100 m of basalt at each of the two primary proposed sites, GT-6A and TT-3A (Table T1).

Permission was received to drill without coring through the sediment sections (to ~20 m above basement) to ensure that these primary objectives can be achieved in the 7 days available for on-site operations. Coring showed that the upper sediments are typically soft nannofossil ooze. Similar sediments were cored at Site U1578. Organic geochemistry safety monitoring during Expedition 391 found hydrocarbons to be at the atmospheric background level at all drilled sites, including at Site U1578 (Sager et al., 2022), which represents a depositional setting similar to those of the nearby GT and TT sites. The methane concentration obtained from Hole U1578A, measured at a frequency of one sample per 9.6 m of sediment core, ranged 0–1.13 μL/L. No hydrocarbon gases higher than methane (C_1) were detected. Nearby DSDP Site 526 did not report hydrocarbon concentrations.

A total of 145 and 125 m of sediment will be drilled without coring at Sites GT-6A and TT-3A, respectively, using a center bit installed in the rotary core barrel (RCB) coring bit. The lowermost ~20 m of sediment and the igneous basement will be cored at each site with a single RCB bit for ~40–50 h. Coring at Site U1578 penetrated the basement at ~2 m/h with generally good recovery. This rate implies ~100 m of basement rock can be cored at each site under ideal conditions.

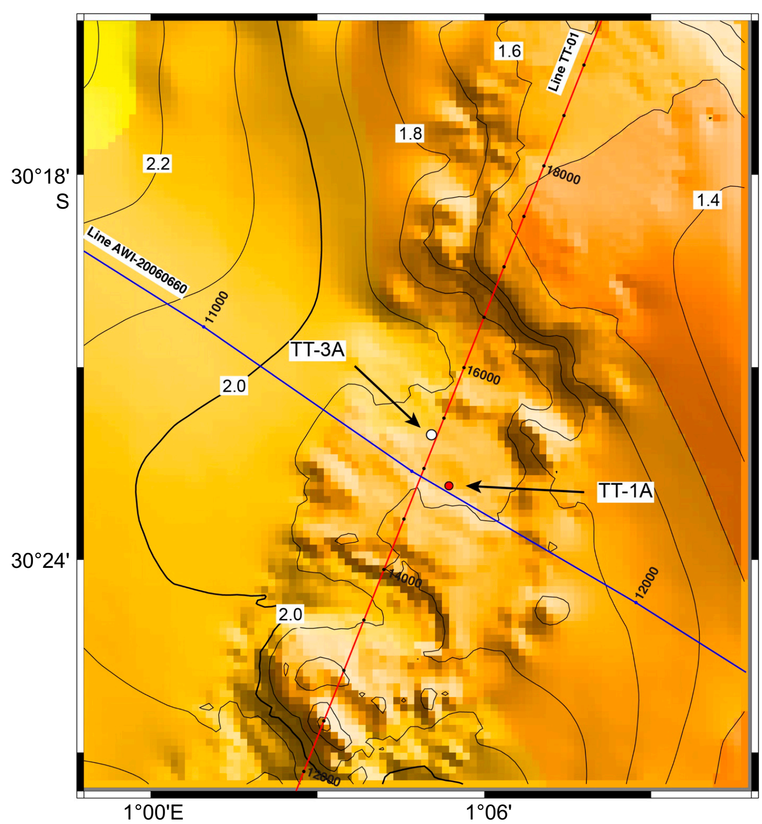

Figure F4. Detailed bathymetry, proposed Site TT-3A. Red and blue lines = site survey seismic lines. Red line is shown in Figure F5. Multibeam bathymetry is plotted along Seismic Line TT-01. Bathymetry elsewhere is estimated from satellite altimetry.

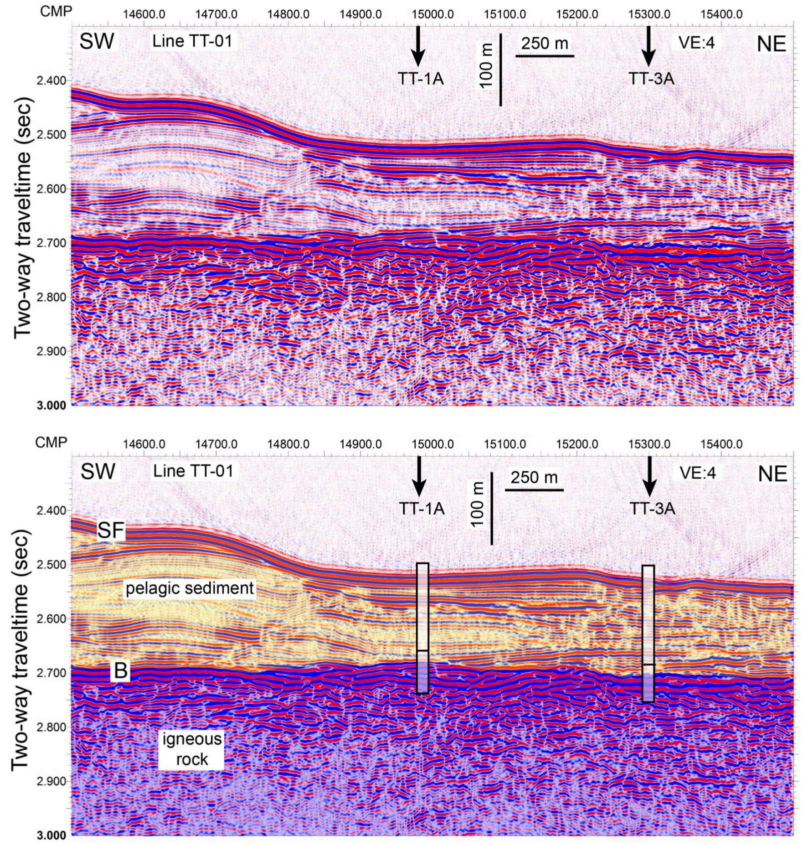

Figure F5. Seismic profile crossing proposed Site TT-3A. Top: uninterpreted data. Bottom: interpretation. Site TT-1A is located on another seismic line and is slightly off this line (see Figure F3). Columns = approximate intervals to be drilled, horizontal line in column = approximate depth at which coring will begin. CMP = common midpoint, VE = vertical exaggeration. SF = seafloor, B = acoustic basement.

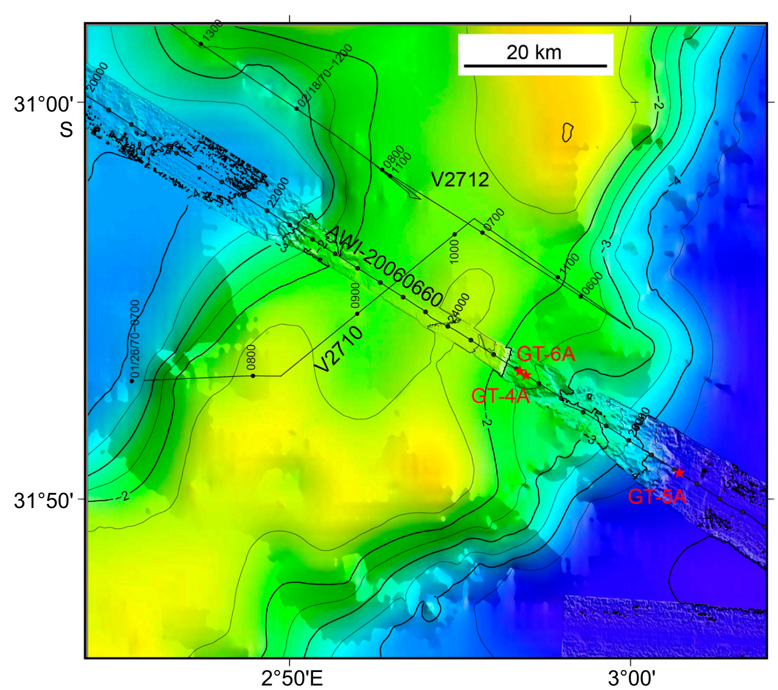

Figure F6. Bathymetry, Gough track ridge showing proposed sites. Multibeam bathymetry appears along seismic line, but elsewhere it is estimated from satellite altimetry.

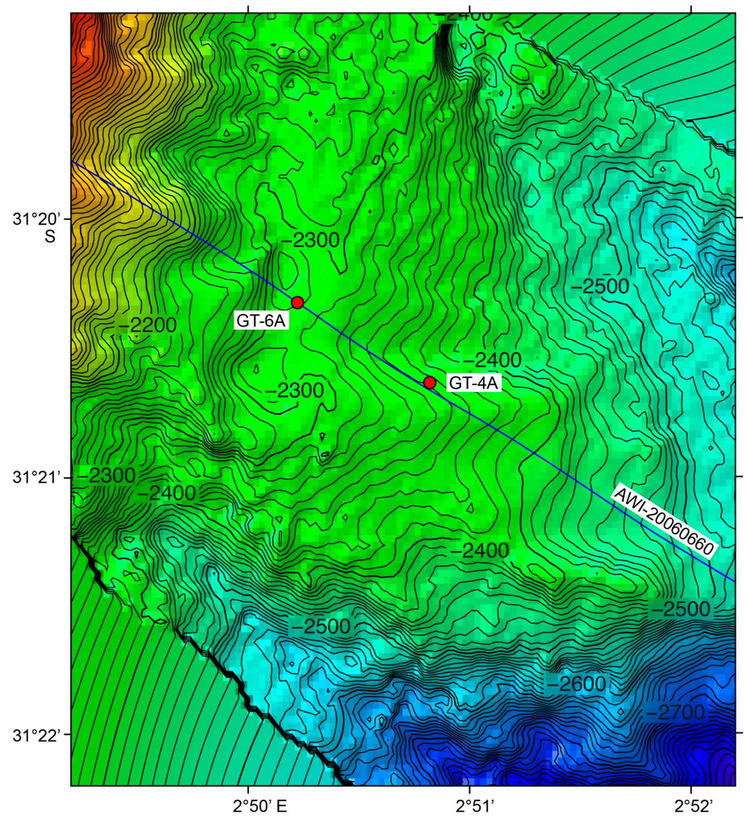

Figure F7. Bathymetry, proposed Sites GT-4A and GT-6A. Bathymetry data is from multibeam echo sounder. Blue line = seismic line shown in Figure F8.

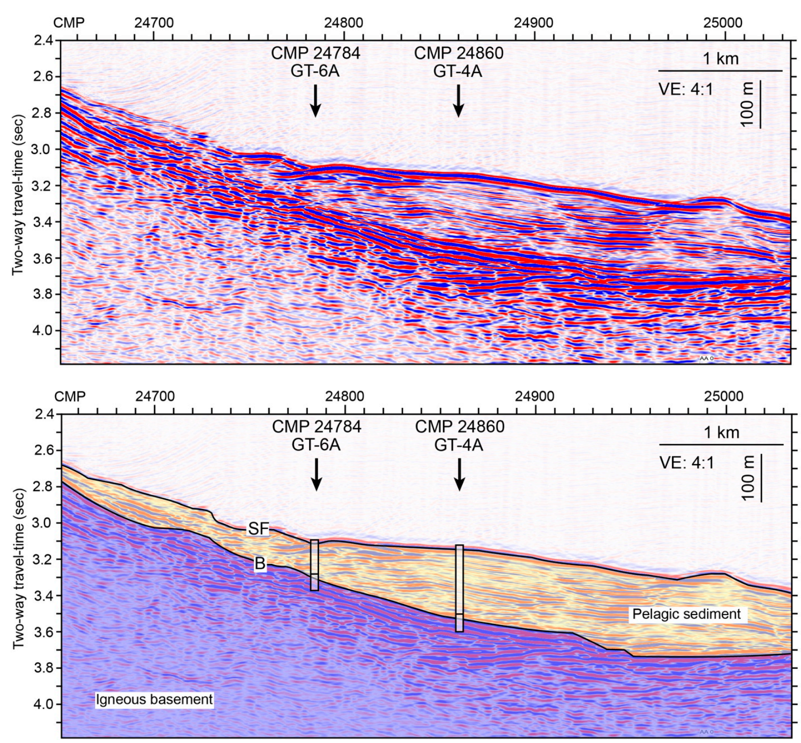

Figure F8. Seismic line crossing proposed Sites GT-4A and GT-6A. Top: uninterpreted data. Bottom: interpretation. Columns = approximate sections to be cored, horizontal line in column = approximate depth at which coring will begin. CMP = common midpoint, VE = vertical exaggeration. SF = seafloor, B = acoustic basement.

Table T1. Operations plan and time estimates, Expedition 397T. * = depth in basement may be extended by shipboard party as deemed necessary. mbrf =meters below rig floor.

Site	Location (latitude, longitude)	Seafloor depth (mbrf)	Operations description	Transit (days)	Drilling/ Coring (days)	Logging (days)
Cape Town			Begin expedition 2	Port call days		
			Transit ~804 nmi to GT-6A @ 10.5 kt	3.2		
GT-6A	31.338700°S	2331	Hole A - Drill ahead to 145 mbsf - RCB core to 264 mbsf (~100 m into basement)	0	3.6	0.0
EPSP	2.836980°E					
to 514* mbsf						
			Subtotal days on site: 3.6			
			Transit ~107 nmi to TT-3A @ 8.0 kt	0.6		
TT-3A	30.368460°S	1882	Hole A - Drill ahead to 125 mbsf - RCB core to 246 mbsf (~90 m into basement)	0	3.2	0.0
EPSP	1.085519°E					
to 550* mbsf						
			Subtotal days on site: 3.6			
			Transit ~4644 nmi to Lisbon @ 10.5 kt	18.4		
Lisbon			End expedition	22.2	6.8	0.0

Port call days:	0.0	Total operating days:	29
Subtotal days on site:	6.8	Total expedition days:	31

Alternate sites

Site	Location (latitude, longitude)	Seafloor depth (mbrf)	Operations description	Transit (days)	Drilling/ Coring (days)	Logging (days)
GT-4A	31.344400°S	2370	Hole A - Drill ahead to 280 mbsf - RCB core to 402 mbsf (100 m into basement)	0	4.0	0.0
EPSP	2.847000°E					
to 652* mbsf						
TT-1A	30.380800°S	1874	Hole A - Drill ahead to 155 mbsf - RCB core to 275 mbsf (100 m into basement)	0	4.3	0.0
EPSP	1.089400°E					
to 498* mbsf						

Proposed Site GT-6A will be drilled and cored first because it is closer to Cape Town. Total time on site estimated by the *JOIDES Resolution* Science Operator is 3.6 days.

The 107 nmi transit to proposed Site TT-3A will take 0.6 days. The total time on site estimated for drilling and coring at Site TT-3A is 3.6 days.

6. Risks and contingencies

The operations plan has no contingency time. Bad weather may allow drilling at only one of the two sites or require that basement penetration be limited at one or both sites to <100 m. These decisions will be made based on the situation encountered.

7. Sample and data sharing

Seven scientists, representing a subgroup of the Expedition 391 science party, were invited to sail on *JOIDES Resolution* during Expedition 397T. They will carry out routine shipboard measurements with a focus on core description, handheld X-ray fluorescence (XRF) measurements, and routine core logging. Paleomagnetic and inductively coupled plasma–atomic emission spectroscopy analyses will be carried out if the scientific and technical staffing levels allow it. In some cases, shore-based science party members may be able to help with data analysis and reporting. All shipboard data will be made available to the entire Expedition 391 science party in near-real time and will be accessible after the expedition on shore. The moratorium period is currently set to end on 17 June 2023; however, a request to extend it was submitted to accommodate Expedition 397T. The site reports generated during Expedition 397T will be integrated into the Expedition Reports section of the Expedition 391 *Proceedings of the International Ocean Discovery Program* volume.

The entire Expedition 391 science party is entitled to samples for personal postexpedition research. Researchers should refer to the IODP Sample, Data, and Obligations Policy and Implementation Guidelines posted on the Web at **http://www.iodp.org/top-resources/program-documents/policies-and-guidelines**. This document outlines the policy for distributing IODP samples and data to research scientists, curators, and educators. The Sample Allocation Committee (SAC; composed of the Co-Chief Scientists, Expedition Project Manager, and IODP Curator on shore and curatorial representative on board the ship) will work with the entire scientific party to formulate a formal expedition-specific sampling plan for shipboard sampling. We intend to take the bulk of the samples on board the ship during Expedition 397T whereby shipboard scientists will take samples on behalf of shore-based scientists. An orchestrated shore-based sampling effort is not planned; however, investigators can contact the Bremen Core Repository (BCR) and arrange for samples to be taken either by the investigator or the repository staff sometime after the expedition.

Scientific party members will be expected to submit research plans and associated sample requests for Expedition 397T, with reference to their original approved plan and request for Expedition 391. Based on the submitted sample requests, the SAC will prepare a tentative sampling plan, which will be revised on the ship based on recovered materials and acquired data as well as communications with all science party members. All sample frequencies and sizes must be justified on a scientific basis and will depend on core recovery, the full spectrum of other requests, and the overall project objectives. The total number of samples for a requester must be in the range of what can be analyzed and published within ~2 y. The SAC will make final decisions regarding each request.

Recovery of critical intervals may result in considerable demand for samples from a limited amount of cored material. These intervals may require special handling, a higher sampling density, reduced sample size, or other strategies. A sampling strategy coordinated by the SAC will be required before critical intervals are sampled. The archive half of each section will be preserved and excluded from sampling for at least 5 y.

At the end of Expedition 397T, the archive section halves will be shipped to the Gulf Coast Repository for potential XRF scanning in January 2023 before being transferred to the BCR for permanent storage. The working section halves will be immediately shipped to the BCR for future sampling.

8. Expedition scientists and scientific participants

The current list of participants for Expedition 397T can be found at **http://iodp.tamu.edu/scienceops/expeditions/walvis_ridge_hotspot.html**.

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Site summaries

Site GT-6A

Priority:	Primary
Position:	31.3387°S, 2.8370°E (Gough track seamount, middle flank)
Water depth (m):	2320
Target drilling depth (mbsf):	264 (164 m sediment, 100 m basement)
Approved maximum penetration (mbsf):	514 (EPSP: depth in basement may be extended by shipboard party as deemed necessary)
Survey coverage:	Common midpoint (CMP) 24784, Seismic Line AWI-20060660 (Figures **F6**, **F7**, **F8**)
Objective(s):	Coring ~100 m of igneous rock for geochemical, geochronologic, paleomagnetic, and other studies
Coring program:	Hole A: Drilling with RCB bit without coring to ~144 meters below seafloor (mbsf) and then proceeding with coring through the sediment/basement contact and ~100 m into the igneous section
Downhole measurements program:	None
Nature of rock anticipated:	Nannofossil chalk overlying basement consisting of basaltic lava flows with possible volcaniclastic or biogenic sediment interbeds

Site GT-4A

Priority:	Alternate
Position:	31.3444°S, 2.8470°E (Gough track seamount, middle flank)
Water depth (m):	2359
Target drilling depth (mbsf):	402 (302 m sediment, 100 m basement)
Approved maximum penetration (mbsf):	652 (EPSP: depth in basement may be extended by shipboard party as deemed necessary)
Survey coverage:	CMP 24860, Seismic Line AWI-20060660 (Figures **F6**, **F7**, **F8**)
Objective(s):	Coring ~100 m of igneous rock for geochemical, geochronologic, paleomagnetic, and other studies
Coring program:	Hole A: Drilling with RCB bit without coring to ~280 mbsf and then proceeding with coring through the sediment/basement contact and ~100 m into the igneous section
Downhole measurements program:	None
Nature of rock anticipated:	Nannofossil chalk overlying basement consisting of basaltic lava flows with possible volcaniclastic or biogenic sediment interbeds

Site TT-3A

Priority:	Primary
Position:	30.3675°S, 1.0842°E (Tristan track seamount, summit)
Water depth (m):	1871
Target drilling depth (mbsf):	246 (146 m sediment, 100 m basement)
Approved maximum penetration (mbsf):	550 (EPSP: depth in basement may be extended by shipboard party as deemed necessary)
Survey coverage:	CMP 215300, Seismic Line TN373-TT-01 (Figures **F3**, **F4**, **F5**)
Objective(s):	Coring ~100 m of igneous rock for geochemical, geochronologic, paleomagnetic, and other studies
Coring program:	Hole A: Drilling with RCB bit without coring to ~126 mbsf and then proceeding with coring through the sediment/basement contact and ~100 m into the igneous section
Downhole measurements program:	None
Nature of rock anticipated:	Nannofossil chalk overlying basement consisting of basaltic lava flows with possible volcaniclastic or biogenic sediment interbeds

Site TT-1A

Priority:	Alternate
Position:	30.3808°S, 1.0894°E (Tristan track seamount, upper flank)
Water depth (m):	1864
Target drilling depth (mbsf):	272 (172 m sediment, 100 m basement)
Approved maximum penetration (mbsf):	498 (EPSP: depth in basement may be extended by shipboard party as deemed necessary)
Survey coverage:	CMP 11576, Seismic Line AWI-20060660 (Figures **F3**, **F4**, **F5**)
Objective(s):	Coring ~100 m of igneous rock at a Tristan track guyot for geochemical, isotopic, geochronologic, and paleomagnetic studies
Coring program:	Hole A: RCB through sediment into basement until bit destruction
Downhole measurements program:	Deploy triple combo, Formation MicroScanner-sonic in two separate logging runs
Nature of rock anticipated:	Recent to early Cenozoic carbonate ooze overlying basaltic lava flows