FY21 Annual Report

International Ocean Discovery Program

JOIDES Resolution Science Operator

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National Science Foundation

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Cover photograph shows the bridge of the *JOIDES Resolution* illuminated by aurora borealis over the Norwegian Sea. Photo credit: Sandra Hermann and IODP JRSO.

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Mitch Malone

Director
International Ocean Discovery Program
JOIDES Resolution Science Operator
Texas A&M University

Mitch Malone was appointed Director of the International Ocean Discovery Program at Texas A&M University in 2021. Malone began working for the Ocean Drilling Program as a Staff Scientist in 1995, and after transitioning into the Integrated Ocean Drilling Program as a Staff Scientist in 2003, he held the positions of Supervisor of Science Support (2004–2006), Manager of Science Operations (2006–2011), Acting Director (2008), and Assistant Director and Manager of Science Operations (2011–2021). During Malone's tenure, he has sailed on 10 Ocean Drilling Program and Integrated Ocean Drilling Program expeditions. Malone earned his B.A. in Geography from the University of Texas at Austin (1986) and his M.S. (1989) and Ph.D. (1995) in Geology from Duke University. He is on the Graduate Faculty at Texas A&M University in the Department of Geology and Geophysics and the Department of Oceanography. Malone was an Associate Editor of the *Journal of Sedimentary Research* from 1999 to 2004.

Gary Acton

Assistant Director and Manager of Technical & Analytical Services
International Ocean Discovery Program
JOIDES Resolution Science Operator
Texas A&M University

Gary Acton was appointed Assistant Director of the International Ocean Discovery Program at Texas A&M University in 2021 and Manager of Technical and Analytical Services in 2017. Acton worked for the Ocean Drilling Program as a Staff Scientist (1995–2003), University of California-Davis as a Research Scientist (2003–2013), and Sam Houston State University as an Associate Professor (2013–2017). He has sailed on 14 scientific coring expeditions. Acton earned his B.S. in Geology from Indiana University (1984), M.S. in Geophysics from University of Arizona (1986), and Ph.D. in Geosciences from Northwestern University (1990). He has served on the ODP Site Survey Panel, the US Advisory Committee for Scientific Ocean Drilling, and the IODP Science Evaluation Panel, and was selected as an IODP US Science Support Program Distinguished Lecturer (2014–2015). Acton served as Secretary of the Geomagnetism-Paleomagnetism Section of the American Geophysical Union from 2008 to 2010 and was elected a Geological Society of America Fellow in 2016.

Historical perspective

From October 2020 through September 2021, the international marine research collaboration called the International Ocean Discovery Program (IODP) monitored subseafloor environments and explored Earth's history and dynamics as recorded in seafloor sediments and rocks. IODP built on the earlier successes of the Deep Sea Drilling Project (DSDP), Ocean Drilling Program (ODP), and Integrated Ocean Drilling Program, which revolutionized our view of Earth's history and global processes through ocean basin exploration.

The Integrated Ocean Drilling Program and IODP expanded on the predecessor programs through the use of multiple drilling platforms operated by three implementing organizations (IOs) to achieve the Program's goals. The riserless research vessel *JOIDES Resolution*, a research facility managed for IODP by Texas A&M University (TAMU) as the *JOIDES Resolution* Science Operator (JRSO), continues to expand the global sampling coverage and disciplinary breadth that were characteristic of DSDP and ODP. The riser drilling vessel *Chikyu*, operated by Japan's Center for Deep Earth Exploration (CDEX), allows extended drilling for several months at a single location. Mission-specific platforms operated by the European Consortium for Ocean Research Drilling (ECORD) Science Operator (ESO) allow drilling in environments unsuitable for either the *JOIDES Resolution* or the *Chikyu*, such as locations near the shoreline in shallow-water areas and in climatically sensitive or ice-covered regions. Consistency from one expedition to the next is ensured through provision of an Expedition Project Manager/Staff Scientist from the IO responsible for operating the expedition's platform.

Each IODP platform provider utilizes a Facility Board to make decisions on the effective use of its drilling facility in fulfilling the objectives of the IODP Science Plan, "Illuminating Earth's Past, Present, and Future," and each of the IOs provides liaisons with appropriate expertise to interact with the Facility Boards and other Program working groups and task forces. The *JOIDES Resolution* Facility Board (JRFB) is informed by advisory panels—the Science Evaluation Panel (SEP) and the Environmental Protection and Safety Panel (EPSP)—to evaluate the science, sites, environmental protection, and safety of hypothesis-driven science expedition proposals aligned with principal research themes outlined in the IODP science plan.

IODP facilities are funded by three platform providers (the US National Science Foundation [NSF], Japan's Ministry of Education, Culture, Sports, Science and Technology [MEXT], and ECORD) with financial contributions from the People's Republic of China Ministry of Science and Technology (MOST); the Interim Asian Consortium, represented by the Korea Institute of Geoscience and Mineral Resources (KIGAM); the Australian and New Zealand IODP Consortium (ANZIC) funded by the Australian Research Council (ARC) and GNS Science (New Zealand); and the Ministry of Earth Sciences (MoES), India. Together, these agencies represent 22 participating nations whose scientists are selected to staff IODP research expeditions conducted throughout the world's oceans.

The *JOIDES Resolution* dockside.

Contents

1. Executive summary

Texas A&M University (TAMU) acts as manager and science operator of the research vessel *JOIDES Resolution* as a research facility for the International Ocean Discovery Program (IODP). Administrative services in support of *JOIDES Resolution* Science Operator (JRSO) activities are provided by the Texas A&M Research Foundation (TAMRF) through the TAMU Sponsored Research Services (SRS).

JRSO scope of work

As the science operator of the *JOIDES Resolution* research facility, JRSO provides wireline coring and logging services along with technical, science, operations, engineering, and information technology (IT) support; curates core materials; develops data applications and manages digital databases; and publishes preexpedition and postexpedition reports and results. In addition, JRSO produces and publishes technical documentation and program plans, completes legacy work (e.g., producing scientific publications), conducts long-lead planning work in preparation for expeditions scheduled for future fiscal years, and provides all necessary clearances and environmental assessments for IODP expeditions conducted by JRSO. All of these Program activities are conducted in accordance with direction provided by the Program's advisory panels and the *JOIDES Resolution* Facility Board (JRFB), as outlined in approved Annual Program Plans.

On behalf of JRSO and as outlined in this Annual Report, TAMRF contracted with ODL AS for the services of *JOIDES Resolution* and with Schlumberger Technology Corporation (Schlumberger) for the provision of downhole logging equipment and engineering support.

FY21 overview

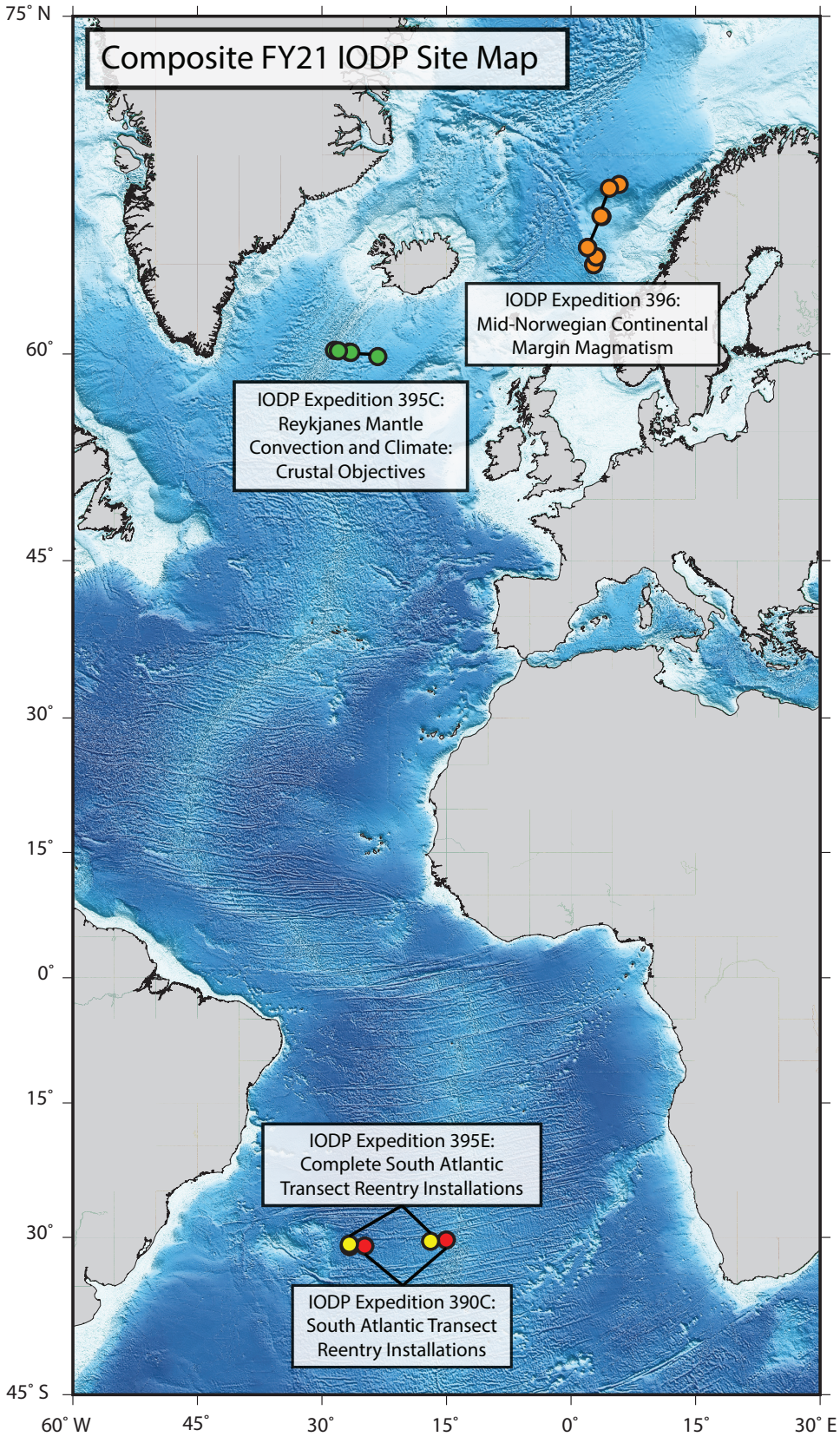
During fiscal year 2021, JRSO successfully completed one expedition and made coring, logging, and operational advances for three scheduled expeditions when science parties could not be mobilized due to the pandemic. Postexpedition research on the collected cores from the completed expedition will improve our understanding of the nature, causes, and climatic implications of the northeast Atlantic continental breakup. Studies are also under way on cores collected as part of three scheduled expeditions, with the goal to improve our understanding of variations in crustal alteration with time,

IODP JRSO FY21 expedition summary

Expedition	Operations time (days)	Distance traveled (nmi)	Sites (number)	Holes (number)	Meters cored	Cores recovered (number)	Core recovery (%)	Holes logged (number)
390C: South Atlantic Transect Reentry Installations	61	8,079	4	11	1,097	128	79	0
395E: Complete South Atlantic Transect Reentry Installations	61	8,097	4	7	190	27	97	0
395C: Reykjanes Mantle Convection and Climate: Crustal Objectives	62	840	5	11	2,867	406	85	5
396: Mid-Norwegian Continental Margin Magmatism	60	2,291	10	21	3,562	502	57	11
Totals	**244**	**19,307**	**23**	**50**	**7,716**	**1,063**	**85**	**16**

Note: Operations time = time on site (does not include transits, waiting on weather, or breakdown time).

FY21 expedition sites.



interactions between mantle plumes and mid-ocean ridges, paleoceanographic conditions and their relation to climate change, and sizes of global biomasses and microbial responses to aging of ocean crust.

Travel restrictions related to the novel Coronavirus Disease 2019 (COVID-19) pandemic impacted all JRSO staff, scientists, and crew. JRSO and ODL AS followed the COVID Mitigation Protocols Established for Safe JR Operations (COPE) developed for operations during the pandemic, and revised operations plans were developed as needed. FY21 Expedition 395P (Complete South Atlantic Transect [SAT] Reentry Installations) was postponed to the Expedition 395E window because of COVID-19 cases on board the ship. Expedition 395 (Reykjanes Mantle Convection and Climate) was postponed, and the decision was made to conduct a revised set of prioritized coring and logging operations focused on the crustal objectives without a science party on board. JRSO was able to use down time from postponed expeditions to install reentry systems at five of the six SAT primary sites (Expeditions 390C and 395E).

This IODP JRSO FY21 Annual Report details these accomplishments and other activities undertaken in support of NSF Cooperative Agreement OCE-1326927 during the period from 1 October 2020 through 30 September 2021.

2. Expedition operations

Expedition 390C: South Atlantic Transect Reentry Installations

The SAT is a multidisciplinary scientific ocean drilling project that comprises two IODP expeditions (390 and 393: SAT 1 and 2). These expeditions were originally scheduled for 2020–2021 but were postponed because of the global COVID-19 pandemic. The six primary sites for the SAT expeditions form a transect perpendicular to the Mid-Atlantic Ridge on the South American plate, overlying crust ranging in age from 7 to 61 Ma. Basement coring will increase our understanding of how crustal alteration progresses over time across the flanks of a slow/intermediate spreading ridge and how microorganisms survive in deep subsurface environments. Sediment will be used in paleoceanographic and microbiological studies.

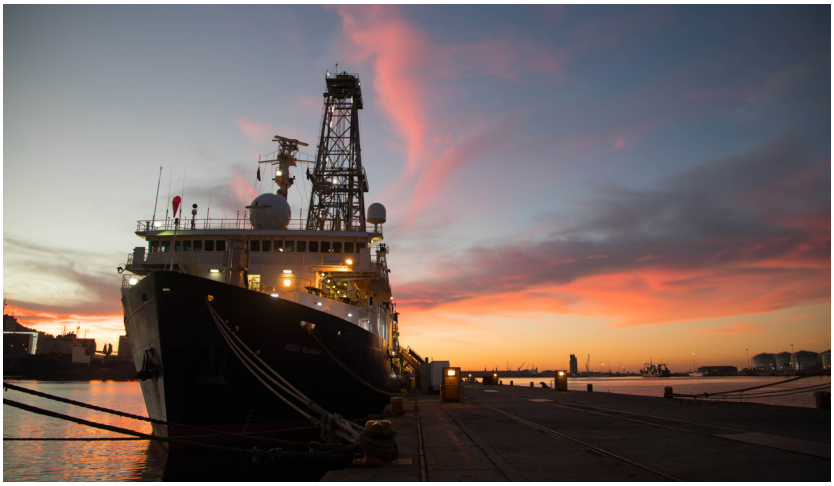
During Expedition 390C (5 October–5 December 2020), which took place with limited JRSO staff and no science party, *JOIDES Resolution* occupied a subset of sites proposed for the postponed SAT expeditions.

From left: Preparing cores for cutting into sections on the catwalk. Close-up of the coulometer cell after an analysis. Loading samples into the CHNS autosampler.

The objectives were to core one hole at each site with the advanced piston corer/extended core barrel (APC/XCB) system to determine depth to basement and for gas safety monitoring and to install a reentry system with casing through the sediment to between ~5 m above basement and <5 m into basement in a second hole. A single APC/XCB sediment hole was cored to the contact with hard rock material at four of the six sites, and reentry systems with casing were successfully installed at three sites. Two failed attempts at drilling in casing and a reentry system into hard rock at Site U1558 indicate that the Dril-Quip running tools are incompatible with the drill-in approach in hard rock because the mechanical release mechanism does not work when the casing string weight cannot be fully removed from the running tool. Therefore, at Sites U1558 and U1559, casing was installed to ~10 m above basement. Site U1557 has a thick sediment cover (564 m) that requires two casing strings to reach basement; a single 16 inch casing string was installed to 60 meters below seafloor (mbsf) at this site during Expedition 390C. These operations will expedite basement drilling during Expeditions 390 and 393 and increase the probability that several sites can be established as legacy holes.

Expedition 395E: Complete South Atlantic Transect Reentry Installations

The Expedition 395E window (6 April–6 June 2021) was originally planned to complete remediation work on Expedition 304/305 (Oceanic Core Complex Formation, Atlantis Massif 1 and 2) Hole U1309D and conduct engineering testing. However, these objectives were postponed to accomplish the objectives of the cancelled Expedition 395P to finish installing the SAT reentry systems. Expedition 395E also took place with limited JRSO staff and no science party, and the Co-Chief Scientists and Expedition Project Manager (EPM) assisted with operational and science decisions from shore. Expedition 395E cored to basement at Site U1560, on the second youngest crust of the transect, for gas safety monitoring and to establish depth to basement. We installed reentry systems to basement at Sites U1560 and U1556 using the hydraulic release tool system and completed the casing plan at Site U1557 by first deepening the hole and installing a second casing string. Enough operation time remained to core an alternate site, U1561, where basalt was found at the unexpectedly shallow depth of 46 mbsf. Reentry systems have now been installed at all but one of the SAT primary sites. Description and additional analysis of the cores collected during Expeditions 390C and 395 will be conducted by the science parties during SAT Expeditions 390 and 393.



From left: The *JOIDES Resolution* docked in Cape Town, South Africa, with the sunset in the background. Securing a reentry funnel to the HRT (hydraulic release tool) base.

Expedition 395C: Reykjanes Mantle Convection and Climate: Crustal Objectives

Expedition 395C (6 June–6 August 2021) was scheduled following the second postponement of Expedition 395 due to the COVID-19 pandemic. This operational activity focused on drilling, coring, and downhole logging operations at sites where the primary objectives are related to mantle convection and crustal composition (Sites U1554, U1555, U1562, U1563, and U1564), and a reentry system was installed at Site U1554. Expedition 395C took place with limited JRSO staff and no science party except for the EPM. The Expedition 395 Co-Chief Scientists and science party assisted with operational and science decisions from shore. More than 2,400 m of core was recovered from the five sites. The majority of the typical expedition measurements were made at sea by JRSO technical staff. In addition to routine physical properties track measurements, the staff were able to collect samples for moisture and density, carbonate, X-ray diffraction, inductively coupled plasma–atomic emission spectroscopy, and thin section analyses. Interstitial water and microbiology samples were collected for shipboard and postcruise measurements, and paleontology samples from core catchers and split cores were collected and shipped to the Expedition 395 biostratigraphers. No core description took place during Expedition 395C; the science party will complete this work postexpedition. Most of the operations for the paleoceanographic-focused Sites U1554 and U1564 were deferred to the rescheduled Expedition 395.

Expedition 396: Mid-Norwegian Continental Margin Magmatism

Expedition 396 (6 August–6 October 2021) revisited the mid-Norwegian margin 36 y after Ocean Drilling Program (ODP) Leg 104. Following the COPE protocol, Expedition 396 took place with a reduced science party and technical group based on the status of the pandemic and vaccine availability prior to the expedition.

Volcanic passive margins are an end-member of continental rifted margins and are believed to originate from the breakup of a continent under the influence of a mantle plume. In spite of 40 y of research into this process, it is still unknown how excess magmatism is produced and what controls its surprisingly short duration. Expedition 396 was planned to provide the necessary observations to parameterize comprehensive 3-D numerical models that will allow identification of the relative importance of different

From left: Sawing a piece of hard rock core to create working and archive halves. Using a hand lens to observe a benthic foraminifer sticking out of the mud. Running the Section Half Multisensor Logger (SHMSL).

tectonomagmatic processes. Drilling also tested the predictions of volcanic seismic facies models and elucidated the role of breakup volcanism in rapid global warming. Secondary objectives related to the onset of the meridional overturning circulation in the North Atlantic Gateway and the potential to use the breakup basalt province to store carbon dioxide on industrial scales were also addressed. During Expedition 396, 10 sites were drilled on the Vøring and Møre margins. Boreholes targeted the breakup volcanic successions as well as the overlying postrift sediments and the underlying synrift sediments. In conjunction with the wealth of reflection seismic data collected by the hydrocarbon industry during the past 40 y, the new core and logging data will provide an unprecedented picture of the formation of a large igneous province during the opening of an ocean basin.

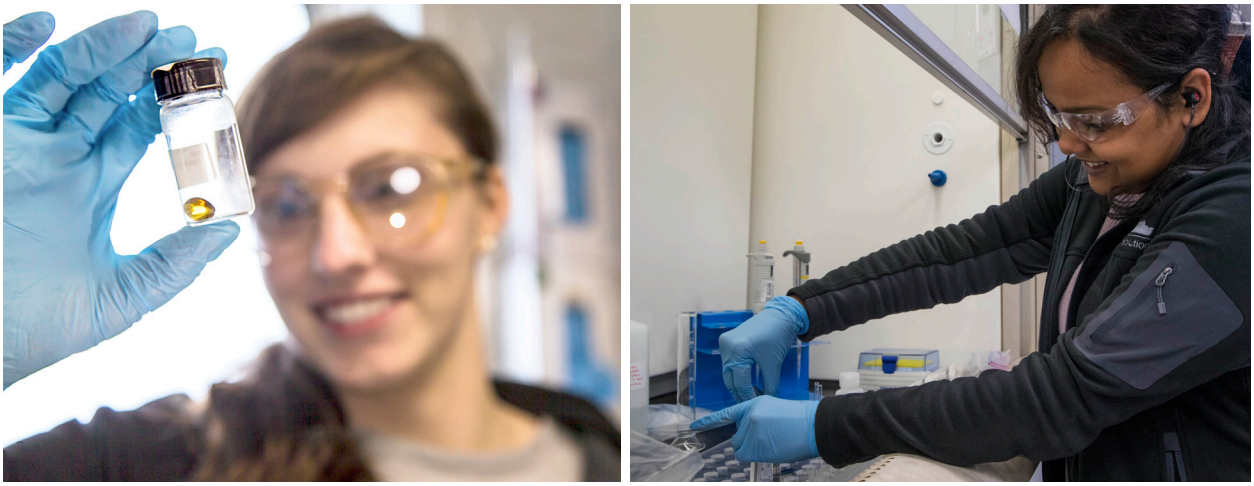
3. Management and Administration

JRSO's organizational structure directly reflects the responsibilities specified by NSF for technical and scientific management, administration, and operation of *JOIDES Resolution*, including planning, coordinating, overseeing, reviewing, and reporting activities. The TAMU portion of the organization consists of four departments: Science Operations (SciOps); Technical & Analytical Services (TAS); Development, Information Technology, & Databases (DITD); and Publication Services (Pubs). Managers of these departments report to the JRSO Director, who is responsible for JRSO's overall management and performance. The Human Resources and Curation groups are part of the Director's Office.

On-site administrative staff members dedicated to JRSO support are overseen by a General Manager who reports to the Executive Director of TAMU SRS. This separate reporting chain ensures that the administrative unit retains the independence to ensure regulatory compliance while working directly with JRSO staff to efficiently implement the Program. The Director's Office and the Administrative Services group combined serve as the Management and Administration group.

Reporting and liaison activities

JRSO reports to and liaises with funding agencies and IODP-related agencies (e.g., JRFB, JRFB advisory panels, Program Member Offices, and other national organizations and facility boards) and participates in facility board, advisory panel, and IODP Forum meetings. Minutes from the facility board meetings are available online (**http://iodp.org/facility-boards**).



From left: A glass bead, melted from sediment, will be analyzed by inductively coupled plasma–atomic emission spectroscopy (ICP-AES). Pipetting interstitial water (IW) split samples.

The JRFB includes liaisons from the European Consortium for Ocean Research Drilling (ECORD) and the Institute for Marine-Earth Exploration and Engineering (MarE3), and the *Chikyu* and ECORD Facility Boards each include a JRSO liaison.

JRSO representatives participated in the Science Evaluation Panel virtual meetings held in January and July and the annual JRFB meeting in June. The JRSO Director and Assistant Director attended a special meeting of the JRFB on 23 November, the US Science Support Program leadership meeting on 8 December, and the American Geophysical Union IODP Town Hall meeting on 15 December. They also participated in monthly meetings of the JRFB Working Group on Science Framework Proposal Requirements and Assessments, a special working group tasked by the JRFB to assess proposal submission guidelines for implementing the new scientific framework. This working group concluded their meetings in May.

Because of COVID-19 travel restrictions, the postcruise editorial meetings for Expeditions 385 (Guaymas Basin Tectonics and Biosphere) and 378 (South Pacific Paleogene Climate) were completed online using collaboration tools. Science Party members were not able to travel to the Gulf Coast Repository (GCR) to participate in sample collection, so the Expedition 378 sample party was conducted by JRSO curation and technical staff. Scientists unable to attend provided sample lists, and samples were mailed to them. JRSO tentatively scheduled the Expedition 395C sampling party to take place at the GCR in May 2022, and the Expedition 396 core description and sampling party is planned for April 2022 at the Bremen Core Repository in Bremen, Germany.

Project portfolio management

M&A managed large cross-departmental tasks and projects through teams using a formal project portfolio management approach to identify, categorize, review, evaluate, select, and prioritize proposed projects. Projects closed, continued, or planned during FY21 are listed below.

JRSO staff completed the Data Asset Management System and SampleMaster Replacement projects and worked on the following projects:

- GEODESC
- X-ray Linescan Core Imager

The White Cliffs of Dover in the morning sun.

- Core Orientation
- QC Data Viewer
- New Rig Instrumentation System
- Digital Asset Management Migration
- Sample and Data Request (SaDR) Replacement Project

4. Subcontractors

The Administrative Services department managed subcontracts with ODL AS for ship services and Schlumberger for wireline logging services. Administrative Services staff reviewed subcontractor invoices prior to payment and ensured financial compliance with cost allowability and other contractual requirements.

JRSO continued to interact with ODL AS and Schlumberger to ensure efficient and compliant operations of the *JOIDES Resolution* and wireline logging operations, respectively.

5. Science Operations

The SciOps department provides scientific and operational planning and implementation for *JOIDES Resolution* drilling expeditions by leading the scoping, planning, and implementation of science expeditions; interacting with and providing technical oversight to the drilling and logging subcontractors; conducting long-range operational planning for out-year JRSO expeditions; and utilizing IODP resources to oversee engineering development projects.

Expedition planning, implementation, and scientific leadership

Because of COVID-19 travel restrictions, preexpedition kick-off meetings for Expeditions 395E, 396, and 392 (Agulhas Plateau Cretaceous Climate) were conducted virtually. Virtual science party meetings were conducted regularly for Expeditions 390C, 396, 391 (Walvis Ridge Hotspot), and 392, and JRSO held small group webinars covering specific topics related to Expedition 392 throughout the spring and summer.

From left: Retrieving a frozen microbiology sample from the liquid nitrogen carrier. Preparing samples for inductively coupled plasma–atomic emission analysis (ICP-AES) analysis.

After the postponement of expeditions because of COVID-19 pandemic travel restrictions, a revised operations plan was developed to drill a single APC hole and install casing and reentry systems at each site in advance of the rescheduled SAT expeditions, which better ensures that target penetration depths can be achieved at all sites and increases the probability that several sites can be established as legacy holes. Expedition 390C started in Kristiansand, Norway, on 5 October and was originally to conclude in Las Palmas, Canary Islands (Spain). However, during the expedition, pandemic conditions in Spain and related restrictions increased. At the same time, South Africa began decreasing restrictions and opening to international travel, so the end port was changed to Cape Town, South Africa, where the expedition concluded on 5 December. After Expedition 390C, Expedition 395P was scheduled to finish installing the reentry systems for the SAT expeditions, but the expedition was canceled because of COVID-19 cases on board the ship. The expedition became a tie-up period (5 December–6 April), and the work was rescheduled to be completed during Expedition 395E (6 April–6 June).

Expedition 395E was previously planned to complete remediation work on Hole U1309D and conduct engineering testing. The JRSO worked with ODL AS to determine if Hole U1309D remediation could be accomplished during Expedition 396T (6 October–6 December). However, critical upgrades planned during this maintenance period, which are required to be completed before starting the scheduled four consecutive South Atlantic expedition sequence (Expeditions 391, 392, 390, 393), prevented rescheduling these tasks.

Expedition 390 and 393 scientists were updated on progress of casing and reentry system installations via a webinar on 4 February, and the micropaleontology laboratory group members were sent samples to construct a preliminary biostratigraphic model. A revised operations plan for Expeditions 390 and 393 was developed to build on the installation of the reentry cones completed during Expeditions 390C and 395E. An addendum to the *Scientific Prospectus* will describe the work left to be completed.

Discussions with the Co-Chief Scientists, the JRFB chair, and NSF resulted in the decision to postpone Expedition 395 but conduct operations that could be accomplished without an onboard science party. The EPM and Co-Chief Scientists developed a revised set of prioritized coring and logging operations that focused on drilling, coring, and downhole logging operations at sites where the primary objectives are related to mantle convection and crustal composition. At the end of the expedition, a casing and reentry

From left: Observing a basalt piece with a hand lens. Soaking a mudline sample in an ethanol-stain mix. Selecting basalt samples for thin sections.

system was installed at one paleoceanographic site (U1554). Full operations at the sites focused on paleoceanographic and paleoclimatic research were deferred to the rescheduled Expedition 395.

The Expedition 396 *Scientific Prospectus* was completed and published in February. The Ultrasonic Borehole Imager tool was confirmed with Schlumberger for Expedition 396, in addition to the already-planned Expedition 395C. Following the current COPE protocol, the expedition took place with a reduced science and technical party complement based on the current status of the pandemic and vaccine availability.

A reduced measurement plan was created for Expedition 391 in case the COPE protocol had to be implemented with a reduced science party. Minor updates were made to the site coordinates related to reassessment of the navigation data, and an addendum to the *Scientific Prospectus* was published in February.

Expedition staffing

Expeditions 390C, 395E, and 395C took place with limited JRSO staff and no shipboard science parties. The Co-Chief Scientists and EPMs assisted with operational and science decisions from shore. Expedition 396 took place with a reduced science party that included the Co-Chief Scientists, the EPM, a Norwegian observer, and 16 scientists.

Logistics support

Operational ship supplies were acquired and shipped preceding all FY21 expedition port calls.

Clearance/Environmental permitting/Risk management

JRSO submitted the Expedition 396 marine scientific research (MSR) application to the US State Department on 5 February, and the US State Department submitted the application and diplomatic note on 17 February. One scientist expressed interest in collecting microbiological data, so Nagoya Protocol requirements were reviewed. NSF approved the Environmental Evaluation (EE) required for Expedition 396 acoustic activity associated with check shot surveys. Authorization from Norway to conduct research in the Norwegian Exclusive Economic Zone was obtained on 1 June.

IODP JRSO FY21 expedition science staffing breakdown

	Expedition				
Member country/consortium	**390C**	**395E**	**395C***	**396****	**Total**
United States Science Support Program (USSSP)	0	0	11	11	22
Japan Drilling Earth Science Consortium (J-DESC)	0	0	1	2	3
European Consortium for Ocean Research Drilling (ECORD) Science Support and Advisory Committee (ESSAC)	0	0	10	11	21
Korea Integrated Ocean Drilling Program (K-IODP)	0	0	0	0	0
IODP-China	0	0	2	2	4
Australia/New Zealand IODP Consortium (ANZIC)	0	0	0	0	0
India Ministry of Earth Science (MoES)	0	0	1	1	2
Total Science Party Participants	**0**	**0**	**25**	**27**	**52**

Notes: * = all scientists were shore based. ** = nine scientists were shore based. Only JRSO staff sailed during Expeditions 390C, 395E, and 395C.

New MSR clearance applications were required for Expeditions 391 and 392 after the expeditions were rescheduled. JRSO submitted a new MSR for Expedition 391 to the US State Department on 13 May, and the US State Department submitted the application and diplomatic note to the Namibian government on 1 June. JRSO met virtually with Namibian officials in August to explore possible additional requirements and, as requested, began developing an expanded outreach plan. The Expedition 392 MSR application was submitted to the US State Department on 27 July, and the US State Department submitted the application and diplomatic note to the South Africa government on 5 August.

Education/Outreach support

No outreach events were conducted during port calls on *JOIDES Resolution* because of restrictions related to COVID-19. During the expeditions, JRSO staff made social media posts on Facebook and Twitter, conducted video outreach events, and facilitated Facebook Live events with expedition scientists. Shore-based outreach officers assisted with activities during Expeditions 395C and 396.

JRSO scientists mentored eight college students this year through staff scientist science engagement activities, which culminated in presentations of students' work at the TAMU Geology & Geophysics research symposium and the TAMU student research week. JRSO Staff Scientists also co-supervised two Ph.D. students and two M.S. students, served on the committees of seven Ph.D. students and three M.S. students at TAMU and TAMU Galveston, taught GEOS 210 (Climate Change), taught undergraduate research classes for B.S. students, and taught the First Year Experience course (GEOS 101-501) in the TAMU College of Geosciences.

JRSO scientists contributed to IODP outreach efforts by participating in the Virtual School of Rock, TAMU College of Geosciences GeoX camp, Outreach Officer training, North Carolina Science Olympiad, TAMU Geosciences Living-Learning Community, Coastal Ocean Environment Summer School in Ghana (COESSING), and TAMU Oceanography Research Experience for Undergraduates program. JRSO scientists also assisted with the continued implementation of the NSF-funded *JOIDES Resolution* Pop-Up/Drill Down Exhibit, taught in a high school AP Environmental Science class, and gave a remote talk to faculty and students of the National University of Mexico. In addition, one JRSO scientist was a webinar speaker at the "Demystifying the IODP Proposal Process for Early Career Scientists" workshop.

From left: Sunset. Calibrating the Section Half Multisensor Logger (SHMSL) at expedition end.

One staff scientist trained and mentored graduate students while sailing on a research cruise collecting water and multicore sediment samples from the Gulf of Mexico as part of an NSF-funded grant, and one staff scientist trained and mentored graduate students while continuing work on an NSF-funded project to make scientific ocean drilling data more accessible and useable.

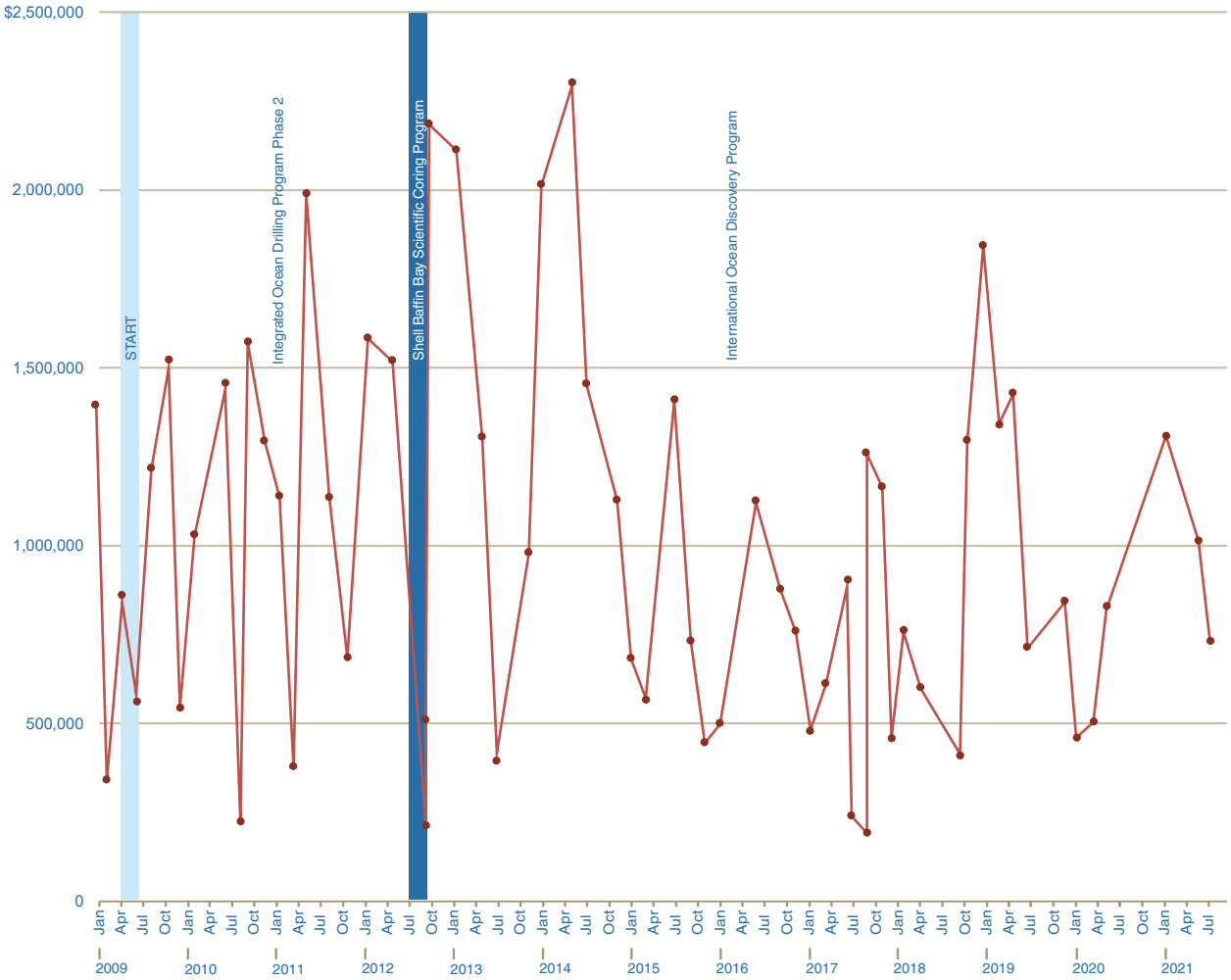
Legacy documentation

Copies of documents and reports produced by JRSO on behalf of IODP, including expedition science and operations reports were archived electronically.

6. Technical and Analytical Services

The TAS department facilitates core flow and oversees laboratories. TAS stocks the shipboard laboratories; operates scientific measurement equipment and provides support to shipboard scientists; provides a supervisory and reporting structure for seagoing JRSO personnel; educates customers regarding laboratory and general shipboard safety; maintains, repairs, and develops scientific equipment at sea; provides support for downhole tools and measurements; works to ensure quality assurance/quality control of measurements made in the shipboard laboratories; and supports shore-based laboratories.

Actual ship fuel costs FY09–FY21. **View chart data.**



Analytical systems

During the tie-up periods, JRSO staff repaired and recoated the core-splitting table, sanded and resurfaced wooden countertops throughout the laboratories, created a nonslip floor area in the chemistry laboratory, repaired and painted the core reefer and gym floors, installed a new television and entertainment system in the gym to make it compatible with the rest of the ship's entertainment system, and reupholstered the gym benches.

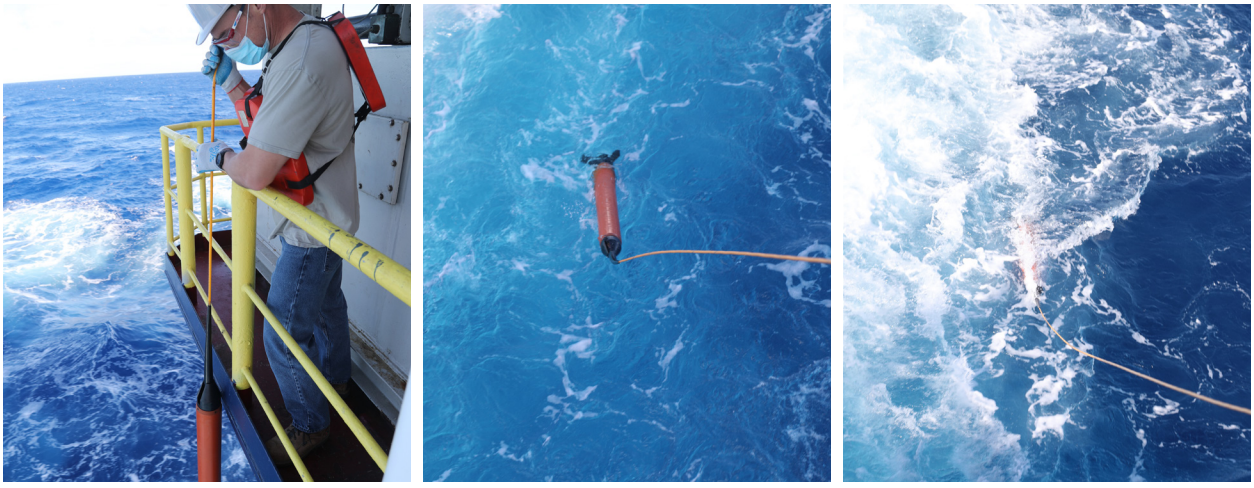
JRSO conducted experiments with a rented Specim hyperspectral imaging logger this year to evaluate the technology as a possible replacement for the contact-based integration sphere color reflectance method. This technology could address one of the recommendations of the 2016 Color Workshop report to eliminate the spectral distortion caused by the GLAD Wrap film that covers each core section half. The experiments were encouraging, prompting JRSO to leverage the rental fee to purchase an FX10 camera at a reduced price and begin constructing its own core logger for the camera using materials on hand.

New equipment acquired for the shipboard laboratories included

- Two epifluorescence microscopes capable of fluorescence/darkfield work as well as differential interference contrast to replace failing microscopes in the microbiology and microscopy laboratories;
- A hyperspectral camera (Specim FX10e) for making non-contact color reflectance measurements;
- Components for completion of the X-ray LineScan Core Imager (XSCAN), including a Hamamatsu TDI X-ray Linescan Camera; and
- A Knudsen Chirp 3260 Dual Channel Echosounder to replace the failing SyQuest Bathy2010 system.

Laboratory working groups

The Geochemistry and Microbiology, Geology, Geophysics, and Curation and Core Handling laboratory working groups (LWGs) include internal technical and science staff members and external members from the IODP science community who review cruise evaluations, expedition technical reports, and issue management communications to develop advice on corrective actions and potential developments on *JOIDES Resolution* and on shore. The LWG technical and science leads attend Issues Management Team meetings to help management better prioritize the LWG efforts. The LWGs provided advice on equipment



Lowering the magnetometer to be towed behind the ship.

acquisition and upgrades, improvements to methodologies and measurements, improvements to laboratories, additional procedural documentation, and ongoing quality assurance work during FY21.

Shipboard laboratory support

More than 5,000 core sections were processed through the shipboard laboratories during the FY21 expeditions, and more than 21,000 samples were taken. Shipboard technical staff and expedition scientists made well over 2 million shipboard measurements on FY21 samples and placed more than 14,000 images (sections, close-ups, and microimages) in the database archive.

7. Development, IT, and Databases

The DITD department oversees JRSO data collection/storage, management, and archiving; maintains IT infrastructure on ship and shore; develops and maintains instrument-specific software for data acquisition; and manages the Program's extensive databases.

Expedition data services and program-wide data query services

During expeditions, laboratory work aboard *JOIDES Resolution* produces a vast amount of data that are stored in the Laboratory Information Management System (LIMS). LIMS data collected during JRSO 384 (Engineering Testing), 390C, 395E, and 395C were successfully transferred to shore, merged with the cumulative LIMS database, and made available online to participating scientists. More than 48,700 downloads were made from the LIMS database during FY21.

Operation and maintenance

JRSO requested a thorough practice IT security audit in late FY20, and the independent IT assessment was completed in December by a TAMU Provost IT security expert. In response, JRSO strengthened processes and made numerous configuration changes to its information resources on ship and shore, including server and workstation software patches and upgrades throughout the ship. This preparation ensured that JRSO IT achieved the highest marks possible during a very comprehensive TAMU System internal audit conducted from December through May.

From left: Working in the ship's server room. Lightning storm behind the derrick.

JRSO completed its annual TAMU IT risk assessment in September, conducted routine system maintenance, and completed its annual disaster recovery exercise in September.

8. Curation

Core Curation provides services in support of IODP core sampling and curation of the core collection archived at the GCR and also supports the X-ray fluorescence (XRF) core scanning facility at the GCR to provide scanning as Program measurements.

Sampling at the Gulf Core Repository

In FY21, the GCR processed a total of 16,121 sample requests and conducted sample parties for Expeditions 378 and 383 (Dynamics of Pacific Antarctic Circumpolar Current), during which an additional 13,694 and 4,000 samples were taken, respectively. The sample parties were completed onsite by JRSO employees because travel restrictions due to COVID-19 prevented science party participation.

Use of core collection and education and outreach activities

The GCR core collection was used for Program outreach through materials provided for display at meetings and museums, tours of the repository, and educational programs. Visitors to the GCR were limited this year because of COVID-19 restrictions. JRSO staff gave tours of the GCR to 243 visitors, including virtual tours to a TAMU Geology class, students from the TAMU Geosciences Living-Learning Community, undergraduate students from the GeoX camp, and scientists participating in COESSING. A documentary film crew led by Director Sharon Shattuck (Picture a Scientist), in collaboration with TAMU postdoctoral scientist Raquel Bryant, also visited the GCR to shoot footage for a trailer for an upcoming film.

Onshore XRF scanning

More than 1,650 core sections were XRF scanned this year, and 467 cores were processed through the shore-based Section Half Imaging Logger.

From left: A full core rack waiting for core logging and splitting. Collecting a headspace sample from the lower part of the core. Measuring a hard rock section half in the Section Half Multisensor Logger (SHMSL).

9. Publication Services

The Pubs department provides publications support services for JRSO expeditions and editing, production, and graphics services for all required reports and scientific publications as defined in the JRSO cooperative agreement with NSF. IODP publications for FY21 included JRSO quarterly and annual reports; *Scientific Prospectuses* for JRSO and ECORD Science Operator (ESO) expeditions; *Preliminary Reports* for JRSO and MarE3 expeditions; *Proceedings of the International Ocean Discovery Program* volumes for JRSO expeditions; Data Reports for USIO, JRSO, MarE3, and ESO expeditions; and the *Proceedings* of the Oman Drilling Project volume.

Shipboard publications support and postexpedition editorial meetings

Publications Specialists sailed during JRSO expeditions to coordinate shipboard reports. During postexpedition editorial meetings, Publications staff coordinate science reviews of all expedition reports content and assist meeting participants with editing prior to publication. In FY21, virtual postexpedition editorial meetings were conducted for Expeditions 385 and 378 using Google Drive collaboration tools.

IODP scientific publishing and publication coordination

IODP Pubs produced and published 3 *Scientific Prospectuses*, 3 *Preliminary Reports*, and 4 Expedition Reports volumes. During FY21, IODP Pubs also tracked postcruise research for 64 Integrated Ocean Drilling Program and IODP Expeditions and published Expedition Research Results for 8 expeditions, including 12 data reports. In addition, peer-reviewed postcruise research result publications related to 26 expeditions were added to the publications database. IODP Program publications are indexed on Google Scholar, and IODP Pubs is a member of the Committee on Publications Ethics.

Web services

IODP Pubs hosts web services for expeditions, publications, and legacy programs. In addition to internal JRSO web page updates and additions, new content is regularly added to IODP expedition web pages at **http://iodp.tamu.edu/scienceops/expeditions.html**. All Deep Sea Drilling Project (DSDP), ODP, Integrated Ocean Drilling Program, and IODP Program scientific publications are accessible online at the IODP Publications and legacy websites. Volumes are available as disk images or zip files so users

View from the helideck.

can download the expedition reports portion of any IODP *Proceedings* volume. There were more than 100,000 visits to the IODP Publications website during FY21.

Bibliography and citation management

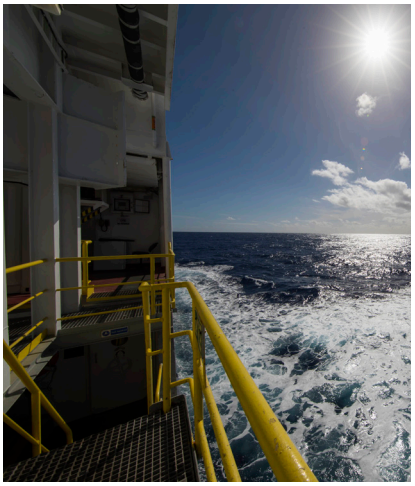
The Scientific Ocean Drilling Bibliographic Database is a subset of the American Geosciences Institute's (AGI) GeoRef database and includes more than 38,600 entries related to IODP and the preceding scientific ocean drilling programs, representing more than 50 years of scientific ocean drilling research. In FY21, more than 8,500 queries were run on the Scientific Ocean Drilling Bibliographic Database, and additional records for more than 4,000 citations were viewed. IODP Pubs works closely with AGI to curate the bibliographic database by identifying and submitting expedition-related research publication citations.

Publications metadata

Metadata for IODP publications are deposited with CrossRef, an official DOI registration agency for scholarly and professional publications. Program publications accessed through CrossRef numbered 90,772 DOI resolutions for Integrated Ocean Drilling Program and IODP publications and 499,712 DOI resolutions for DSDP and ODP publications.

IODP Pubs also participates in CrossRef's cited-by linking; open reference initiative; text and data mining; ORCID, license, and funding registration; and CrossMark metadata validation services. IODP Pubs deposited 28 chapters from Integrated Ocean Drilling Program and IODP *Proceedings* volumes into ScienceOpen, a professional networking research platform for scholars and publishers. The IODP collection can be viewed at **https://www.scienceopen.com/collection/IODP_Publications**. In addition, IODP Pubs deposited more than 4,000 records from expedition-related research published in outside literature into the Expedition Research Results collection, which can be viewed at **https://www.scienceopen.com/collection/8b0582f6-47bf-4988-b90a-8533135e6fcc**.

IODP Pubs also contributed publications metadata for the same Integrated Ocean Drilling Program and IODP *Proceedings* chapters to TAMU's Symplectic Elements database, which feeds data to Altmetric.com, a platform that enables monitoring of online activity surrounding academic research.



From left: Heading into calm seas. The argon plasma from the inductively coupled plasma (ICP) torch is so bright that it lights up the spray chamber from above. An Atlantic white-sided dolphin jumping out of the water.

Legacy and archiving

Peer-reviewed postcruise research result publications related to 34 legacy expeditions were added to the publications database this year.

IODP Pubs uses Archive-It to save publications to the Internet Archive, a long-term archive specializing in full website backups. The complete IODP publications website is available at the Internet Archive, including full content from all Integrated Ocean Drilling Program and IODP volumes, and regular crawls incrementally update the archive with new files. In addition, the archive houses legacy publication sites for DSDP and ODP. At the end of FY21, the JRSO archive collection contained 1.5 TB of data and more than 7.4 million documents. The archive can be viewed at **https://archive-it.org/collections/9148**.

Progress reporting

JRSO operations and management reports were submitted to NSF for the following quarters:

- Fourth quarter of FY20 (July–September 2020) on 12 November 2020
- First quarter of FY21 (October–December 2020) on 8 February 2021
- Second quarter of FY21 (January–March 2021) on 11 May 2021
- Third quarter of FY21 (April–June 2021) on 9 August 2021

All reports are available at **http://iodp.tamu.edu/publications/reports.html**.

From left: A breaking wave at sunrise. Processing samples for palynological studies.

URL list

IODP JRSO website: **http://iodp.tamu.edu**

IODP Program Member Offices: **http://www.iodp.org/about-iodp/program-member-offices**

JOIDES Resolution Facility Board and Panels: **http://www.iodp.org/facility-boards**

IODP Science Support Office: **http://www.iodp.org/program-organization/science-support-office**

IODP JRSO FY21 Annual Program Plan: **http://iodp.tamu.edu/publications/PP/IODP_JRSO_FY21_APP.pdf**

IODP JRSO FY21 Quarterly Reports: **http://iodp.tamu.edu/publications/reports.html**

COVID Mitigation Protocols Established for Safe JR Operations (COPE): **http://iodp.tamu.edu/scienceops/JR_COVID-Mitigation-Protocols.pdf**

Illuminating Earth's Past, Present and Future: The Science Plan for the International Ocean Discovery Program 2013–2023: **https://www.iodp.org/about-iodp/iodp-science-plan-2013-2023**

IODP expedition schedule: **http://iodp.tamu.edu/scienceops/index.html**

IODP expedition information: **http://iodp.tamu.edu/scienceops/expeditions.html**

LIMS Reports: **https://web.iodp.tamu.edu/LORE/**

IODP expedition data: **https://zenodo.org/communities/iodp**

Gulf Coast Repository: **https://iodp.tamu.edu/curation/gcr/index.html**

Core database: **http://iodp.tamu.edu/tasapps**

Sample requests: **https://iodp.tamu.edu/curation/samples.html**

IODP scientific publications and expedition-related citation lists: **http://publications.iodp.org**

Scientific Ocean Drilling Bibliographic Database: **http://iodp.americangeosciences.org/vufind**

2020 Scientific Ocean Drilling Bibliographic Database and Publication Impact Report: **http://iodp.tamu.edu/publications/AGI_studies/2021_Pub_Impact.pdf**

IODP Publications ScienceOpen page: **https://www.scienceopen.com/collection/IODP_Publications**

IODP expedition-related outside literature ScienceOpen page: **https://www.scienceopen.com/collection/8b0582f6-47bf-4988-b90a-8533135e6fcc**

IODP Publications Internet Archive collection: **https://archive-it.org/collections/9148**

DSDP digital collection: **https://babel.hathitrust.org/cgi/mb?a=listis&c=1930557976**

HathiTrust ODP digital collection: **https://babel.hathitrust.org/cgi/mb?a=listis&c=1868324439**

DSDP volumes: **http://www.deepseadrilling.org/**

ODP volumes: **http://www-odp.tamu.edu/publications/**

"Legacy" site: **http://odplegacy.org**