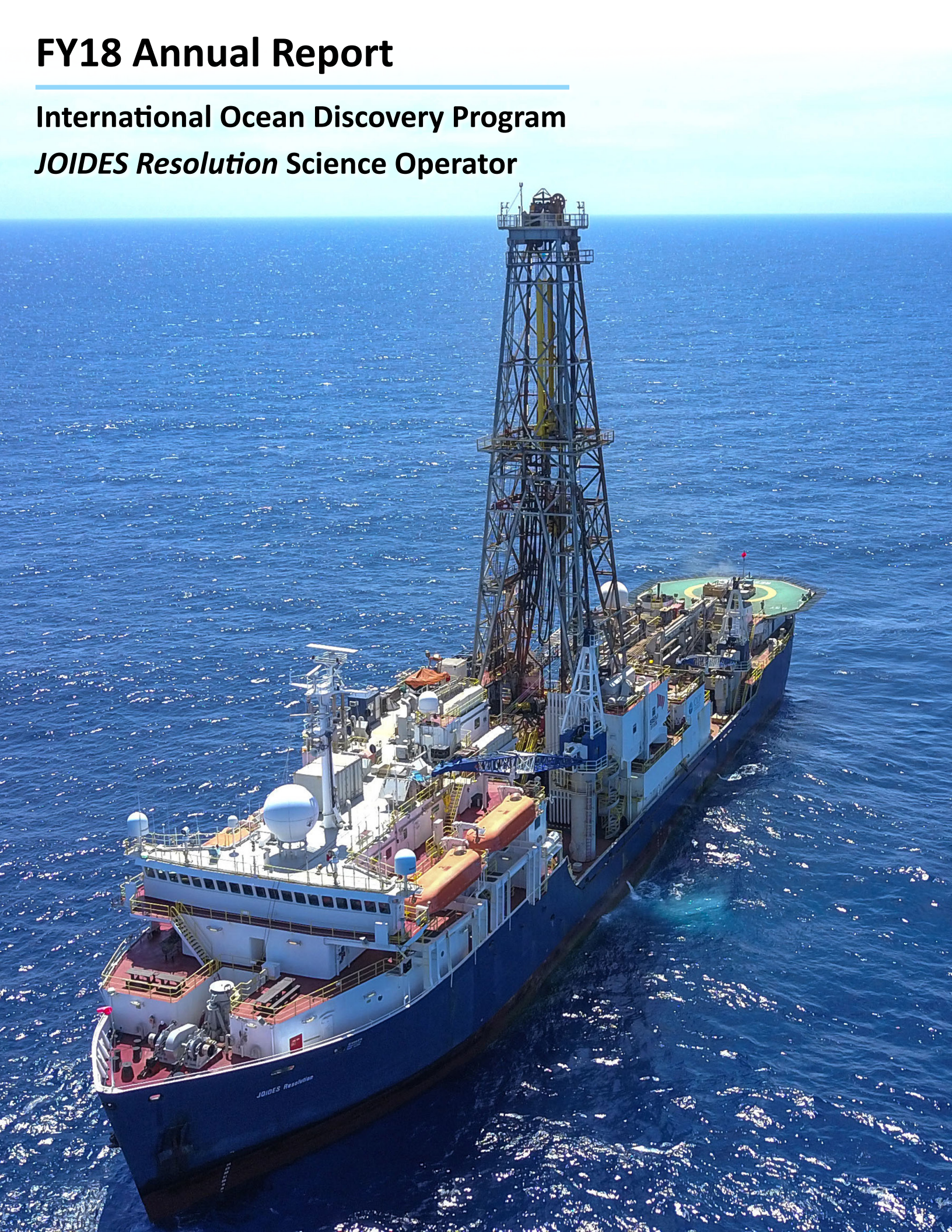
FY18 Annual Report

International Ocean Discovery Program

JOIDES Resolution Science Operator



FY18 Annual Report

International Ocean Discovery Program

JOIDES Resolution Science Operator

National Science Foundation

Cooperative Agreement OCE-1326927

1 October 2017–30 September 2018

PUBLISHER'S NOTES

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- Ministry of Earth Sciences (MoES), India
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Brad Clement

Director,
International Ocean Discovery Program,
Texas A&M University

Brad Clement was appointed Director of the International Ocean Discovery Program at Texas A&M University in August 2009. Clement previously chaired the U.S. Science Advisory Committee and has a long history of involvement with the Program, having sailed on four expeditions, worked as an Ocean Drilling Program Staff Scientist, and served on the JOIDES Ocean History Panel. Clement earned his B.S. in Geology from the University of Georgia (1979) and his M.A. (1981) and Ph.D. (1985) in Geology from Columbia University. He previously served as Associate Program Director for the Ocean Drilling Program in the National Science Foundation's Ocean Sciences Division from 2001 to 2003, as a Professor in the Department of Earth and Environmental Science at Florida International University from 1988 to 2009, and as Adjunct Associate Professor of Geophysics at Texas A&M University from 1984 to 1988. Clement was Associate Editor of the Journal of Geophysical Research and has served on several American Geophysical Union committees.

Mitch Malone

Assistant Director and Manager of Science Support,
International Ocean Discovery Program,
Texas A&M University

Mitch Malone was appointed Assistant Director of the International Ocean Discovery Program at Texas A&M University and Manager of Science Operations in 2011. 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), and Acting Director (2008). 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 has also been an adjunct faculty member in the Texas A&M University Departments of Geology and Geophysics since 1996 and Oceanography since 2005. Malone was an Associate Editor of the Journal of Sedimentary Research from 1999 to 2004.

Historical perspective

From October 2017 through September 2018, 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 *JOIDES Resolution* Facility (JRF) Science Evaluation Panel (SEP) and the JRF 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 Coordination for Improvement of Higher Education, Brazil (CAPES); 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 26 participating nations whose scientists are selected to staff IODP research expeditions conducted throughout the world's oceans.

Celebrating 50 years of scientific ocean drilling.

Contents

1. Executive summary

Texas A&M University (TAMU) acts as manager and science operator of the research vessel (R/V) *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) department.

JRSO scope of work

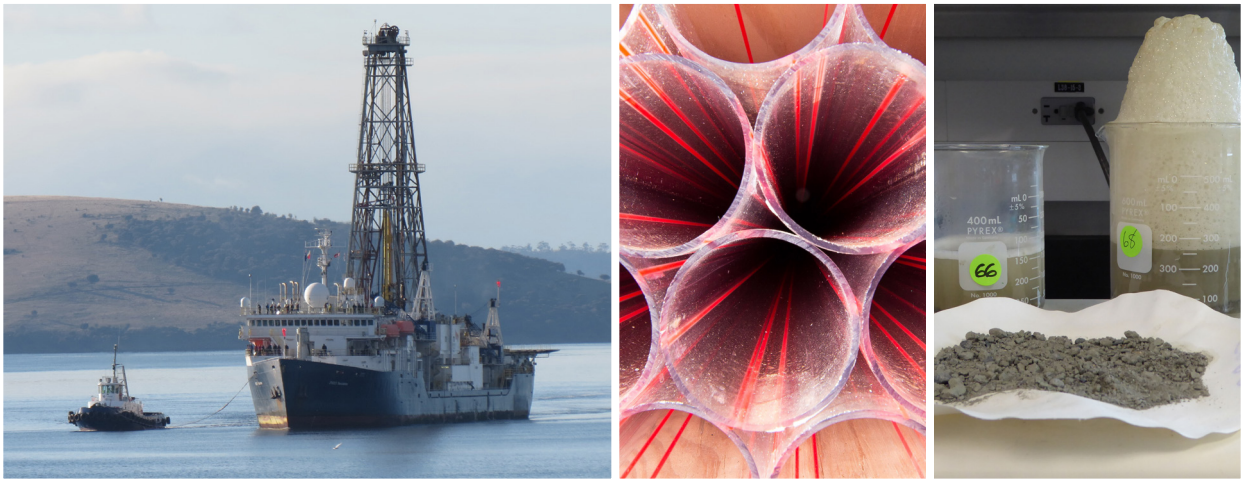
As the science operator of the *JOIDES Resolution* research facility, the JRSO provides wireline coring and logging services along with technical, science, operations, engineering, and information technology (IT) support; curates core materials; develops data applications and manages digital databases; and publishes pre-expedition and postexpedition reports and results. All of these Program activities are conducted in accordance with direction provided by the Program's advisory panels and the JRFB and as outlined in approved Annual Program Plans.

The JRSO also carries out postexpedition activities related to IODP expeditions and ongoing operational tasks (e.g., completing reports and technical documentation), completing legacy work (e.g., producing scientific publications), conducting long-lead planning work in preparation for expeditions scheduled for future fiscal years, and providing all necessary clearances and environmental assessments for IODP expeditions conducted by the JRSO.

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

FY18 overview

During fiscal year 2018, the JRSO successfully completed five expeditions that will advance the global understanding of Earth systems and processes. Postexpedition research on the collected sediments from these expeditions will improve our understanding of slow-slip fault event cycles; the relationship between climate and ocean change and the evolution of the West Antarctic Ice Sheet; the fluid-rock



From left: Tugboat guiding the *JOIDES Resolution* into port at Hobart, Tasmania. Core liner. Heating sediment with hydrogen peroxide before extraction of foraminifers.

interaction, transfer of metals, and extent of microbial life in volcanic hydrothermal systems; and the rise and collapse of the hothouse climate and ocean anoxia during the Cretaceous period.

The Co-Chief Scientist review and the National Science Foundation (NSF) Review Panel again culminated in positive feedback that concluded the JRSO is managing the *JOIDES Resolution* facility exceptionally well and receiving effective oversight by the *JOIDES Resolution* Facility Board (JRFB) and NSF. Activities in response to the previous year's facility review included pursuing long-term archiving options for digital program materials and increasing pre-expedition communication with the Science Parties and expedition proponents.

This IODP JRSO FY18 Annual Report details these accomplishments and other activities undertaken in support of NSF Cooperative Agreement OCE-1326927 during the period from 1 October 2017 to 30 September 2018.

2. Expedition operations

The FY18 operations schedule included five expeditions. In addition, the JRSO completed postexpedition activities for five previous expeditions.

Expedition 369: Australia Cretaceous Climate and Tectonics

The tectonic and paleoceanographic setting of the Great Australian Bight and the Mentelle Basin (adjacent to Naturaliste Plateau) offered an opportunity to investigate Cretaceous and Cenozoic climate change and ocean dynamics during the last phase of breakup among remnant Gondwana continents. Sediment recovered from sites in both regions during Expedition 369, Australia Cretaceous Climate and Tectonics (26 September–26 November 2017), will provide a new perspective on Earth's climate variations at subpolar latitudes (60°–62°S) across the extremes of the mid-Cretaceous hot greenhouse climate and the cooling that followed. The recovered basalts and prebreakup sediments will provide constraints regarding the type and age of the Mentelle Basin basement and processes operating during the final breakup of Gondwana.

Well-preserved calcareous microfossil assemblages recovered from different paleodepths will enable generation of paleotemperature and biotic records that span the rise and collapse of the Cretaceous hot greenhouse (including Oceanic Anoxic Events [OAEs] 1d and 2), providing insight to resultant changes in deep-water and surface water circulation that can be used to test predictions from earth system

IODP JRSO FY18 expedition summary.

Expedition	Operations time (days)	Distance traveled (nmi)	Sites (number)	Holes (number)	Meters cored	Cores recovered (number)	Core recovery (%)	Holes logged (number)
369: Australia Cretaceous Climate and Tectonics	42.95	2,687	5	14	3,553.6	417	70	5
372: Creeping Gas Hydrate Slides and Hikurangi LWD	14.03	3,928	4	9	197.9	37	94	6
374: Ross Sea West Antarctic Ice Sheet History	24.48	4,438	5	11	2,478.7	298	52	3
375: Hikurangi Subduction Margin	45.06	1,042	4	14	1,857.2	231	62	1
376: Brothers Arc Flux	48.80	492	6	15	1,244.0	227	18	2
Totals	175.32	12,587	24	63	9,331.4	1,210	53	17

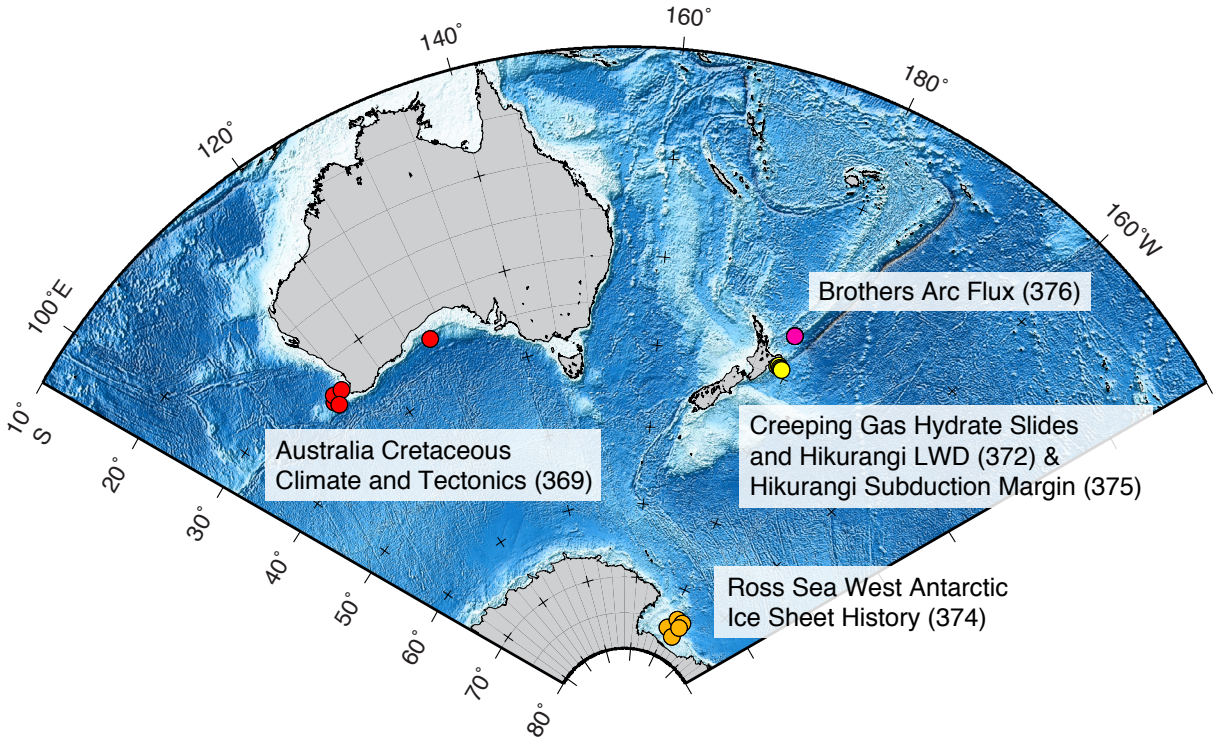
Note: Operations time = time on site (does not include transits, waiting on weather, or breakdown time).

models. Paleotemperature proxies and other data will reveal the timing, magnitude, and duration of peak hothouse temperatures and any cold intervals that could have allowed growth of a polar ice sheet. Understanding the paleoceanographic changes in a regional context provides a global test of models of Cenomanian–Turonian oceanographic and climatic evolution related both to extreme Turonian warmth and the evolution of OAE 2. Data from the sites will also be used to reconstruct the mid-Eocene–early Oligocene opening of the Tasman Gateway and the Miocene–Pliocene restriction of the Indonesian Gateway; both passages have important effects on global oceanography and climate. Finally, the Lower Cretaceous volcanic rocks and underlying Jurassic(?) sediments cored in different parts of the Mentelle Basin will provide information on the timing of different stages of the Gondwana breakup. The recovered cores should provide sufficient new age constraints to underpin reevaluation of the basin-wide seismic stratigraphy and tectonic models for the region.

Expedition 372: Creeping Gas Hydrate Slides and Hikurangi LWD and Expedition 375: Hikurangi Subduction Margin

Slow-slip events (SSEs) involve transient aseismic slip on a fault (lasting weeks to years) at a slip velocity intermediate between plate tectonic rates and those required to generate seismic waves. Only since the advent of dense, plate boundary–scale geodetic networks in the last ~15 years has the importance of these events as a significant mode of fault slip been recognized. The observation of SSEs and associated seismic phenomena (e.g., tremor and low-frequency earthquakes) along subduction megathrusts worldwide has ignited one of the most dynamic fields of current research in seismology.

In FY18, the JRSO undertook the first scientific drilling at the Hikurangi subduction margin, an area well suited for examining shallow SSEs at subduction zones. Expedition 372, Creeping Gas Hydrate Slides and Hikurangi LWD (26 November 2017–4 January 2018), combined two research topics: SSEs on subduction faults and actively deforming gas hydrate–bearing landslides. The expedition focused on a set



of experiments in the creeping part of the Tuaheni Landslide Complex (TLC), cored through the TLC and gas hydrate stability zone with almost complete recovery, and conducted temperature and pressure tool deployments. The expedition acquired excellent logging-while-drilling (LWD) data at three subduction-focused sites on the Hikurangi margin.

Expedition 375, Hikurangi Subduction Margin, sailed from 8 March to 5 May 2018. During the expedition, two complex, nested subseafloor observatories were installed to monitor deformation and characterize changes in thermal, hydrological, and chemical state during multiple SSE cycles. Cores recovered during the expedition reveal a surprising diversity of lithologies entering the subduction zone, including clastic trench fill material, carbonate-rich pelagic sediments, and a thick volcaniclastic sequence. Coring across an active shallow thrust fault provided new insights into the fault architecture, small-scale structural features, physical properties, and pore fluid geochemistry of an active fault that may be involved in SSEs. The approach of targeted spot coring was successful in obtaining samples necessary to interpret observatory pressure and temperature data and to extract quantitative information about in situ stress state from wellbore breakouts deeper than ~590 meters below seafloor (mbsf). Temperature measurements in the hole cored with the advanced piston corer (APC) system were also successful and provided valuable constraints for models that will define the thermal structure of the subduction zone and the temperature regime of the SSE source region.

Together, Expeditions 372 and 375 implemented a complex, linked data sharing and sampling plan that spanned two expeditions and involved several shore-based investigators and a high volume of sample requests for mission-critical postexpedition studies of rock properties, composition, structures, and deformation.

Expedition 374: Ross Sea West Antarctic Ice Sheet History

The marine-based West Antarctic Ice Sheet (WAIS) is currently retreating because of shifting wind-driven oceanic currents that transport warm waters toward the ice margin, resulting in ice-shelf thinning and accelerated mass loss of the WAIS. Numerical ice sheet models indicate that the sector from the outer continental shelf to rise in the eastern Ross Sea is highly sensitive to changes in ocean heat flux. Expedition 374, Ross Sea West Antarctic Ice Sheet History (4 January–8 March 2018), drilled a latitudinal and depth transect of five drill sites in this sector, aiming to resolve the relationship between climatic and oceanic change and WAIS evolution through the Neogene and Quaternary. The expedition was designed for optimal data-model integration and will enable improved understanding of the sensitivity of Antarctic Ice Sheet mass balance during warmer-than-present climates (e.g., the Pleistocene “super interglacials,” the mid-Pliocene, and the late early to middle Miocene).

Expedition 374 recovered high-quality records spanning the early Miocene to late Quaternary. Coring on the continental shelf penetrated the Ross Sea seismic Unconformity RSU4 and will yield depositional reconstructions of past glacial and open-marine conditions that will provide unprecedented insight into environmental change on the Antarctic continental shelf during the early and middle Miocene. Cores recovered from an upper Miocene to Pleistocene sequence of glacial and glaciomarine strata from the outer shelf will be used to date seismic Unconformity RSU3, which is interpreted to represent the first major continental shelf–wide expansion and coalescing of marine-based ice streams from both East and West Antarctica. A sediment drift located beneath the westerly flowing Antarctic Slope Current (ASC) yielded cores that will provide a record of the changing vigor of the ASC through time, which will enable testing of the hypothesis that changes in the vigor of the ASC represent a key control on regulating heat flux onto the continental shelf and therefore play a fundamental role in ice sheet mass balance.

A Pliocene–Pleistocene sedimentary sequence was cored on the continental rise, together with a complementary Pliocene sequence on the continental slope, on the margins of the Hillary Canyon, which is one of the largest conduits of Antarctic Bottom Water delivery from the Antarctic continental shelf into the abyssal ocean. These ice-distal sites will provide a more continuous record of glacial–interglacial cyclicity and oceanic response to Antarctic Ice Sheet variability. Unfortunately, a mechanical failure of the vessel forced early termination of the expedition before we were able to core middle and lower Miocene sequences on the continental rise.

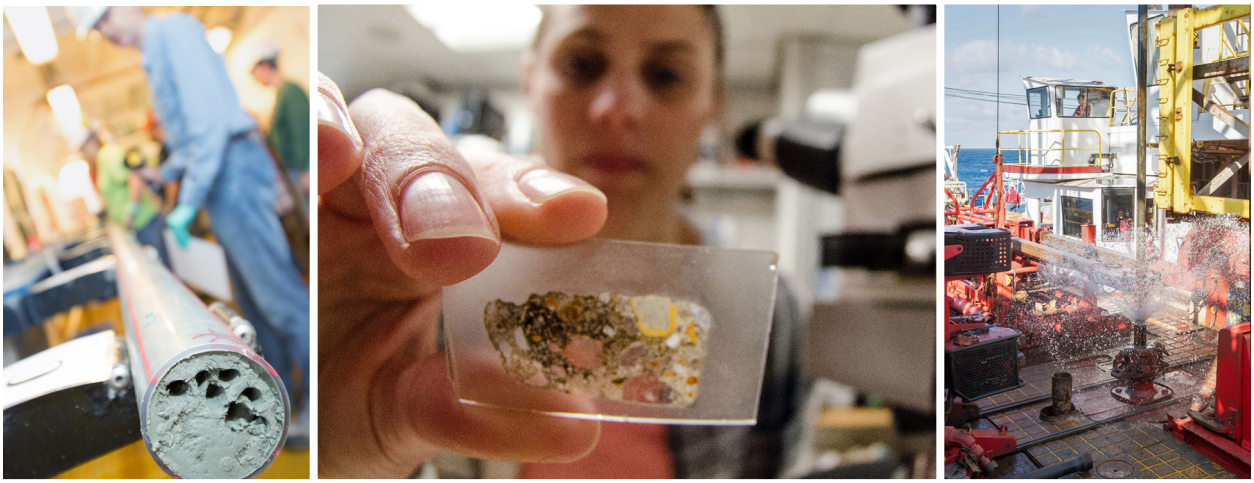
Despite our failure to recover a shelf-to-rise transect for much of the Miocene, a continental shelf-to-rise transect for the Pliocene to Pleistocene interval is possible through comparison of the high-quality records from Expedition 374 sites and legacy cores from the Antarctic Geological Drilling Project.

Expedition 376: Brothers Arc Flux

Expedition 376, Brothers Arc Flux (5 May–5 July 2018), drilled into Brothers volcano in the Kermadec arc aiming to provide the missing link (i.e., the third dimension) in our understanding of hydrothermal activity and mineral deposit formation at submarine arc volcanoes and the relationship between the discharge of magmatic fluids and the deep biosphere. Brothers volcano hosts two active and distinct hydrothermal systems: one seawater influenced and the other affected by magmatic fluids (largely gases).

Cores recovered during Expedition 376 consist of dacitic volcaniclastics and lava flows with only limited chemical variability relative to the overall range in composition of dacites in the Kermadec arc. Pervasive alteration with complex and variable mineral assemblages attests to a highly dynamic hydrothermal system. The material and data recovered during Expedition 376 provide new stratigraphic, lithologic, and geochemical constraints on the development and evolution of Brothers volcano and its hydrothermal systems.

Two tests of a prototype turbine-driven coring system (designed by the Center for Deep Earth Exploration [CDEX] at Japan Agency for Marine-Earth Science and Technology [JAMSTEC]) for drilling and coring hard rocks were also conducted during Expedition 376.



From left: The end of a new core after gas safety samples were taken on the catwalk. Preparing to examine a thin section slide. Pipe trip on the rig floor.

3. Management and Administration

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

The JRSO reports to and liaises with funding agencies and IODP-related agencies (e.g., JRFB, JRFB advisory panels, Program Member Offices [PMOs], 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).

The JRFB includes liaisons from the European Consortium for Ocean Research Drilling (ECORD) and CDEX, and the *Chikyu* and ECORD Facility Boards each include a JRSO liaison. This year, JRSO representatives participated in the Science Evaluation Panel (SEP) meetings in January and June, the ECORD Facility Board meeting in March, the JRFB meeting and an informal meeting of US members/chairs of JRFB panels in May, the US Advisory Committee meeting in August, and the IODP Forum meeting and IODP PMO meeting in September. Senior JRSO staff attended the US Science Support Program (USSSP) leadership meeting on 13 December 2017 at the American Geophysical Union (AGU) Fall Meeting in conjunction with the IODP Town Hall meeting and the Deep Crustal Engineering Working Group meeting held at the JRSO on 16–18 October.

The JRSO hosted the following postexpedition meetings in College Station, Texas (USA):

- JRSO Expedition 371 editorial meeting, 23–27 January
- JRSO Expedition 371 sampling party, 29 January–2 February
- JRSO Expedition 369 editorial meeting, 14–17 May
- JRSO Expedition 369 sampling party, 18–22 May
- JRSO Expedition 374 editorial meeting, 30 July–3 August
- JRSO Expedition 374 sampling party, 4–10 August
- ECORD Science Operator (ESO) Expedition 381 editorial meeting, 10–13 July
- CDEX Expedition 380 editorial meeting, 11 and 12 September

Project portfolio management

M&A managed large cross-departmental tasks and projects through teams using a formal project portfolio management (PPM) approach to identify, categorize, review, evaluate, select, and prioritize proposed projects. Specific PPM projects are described in Section 7.

Facility assessment

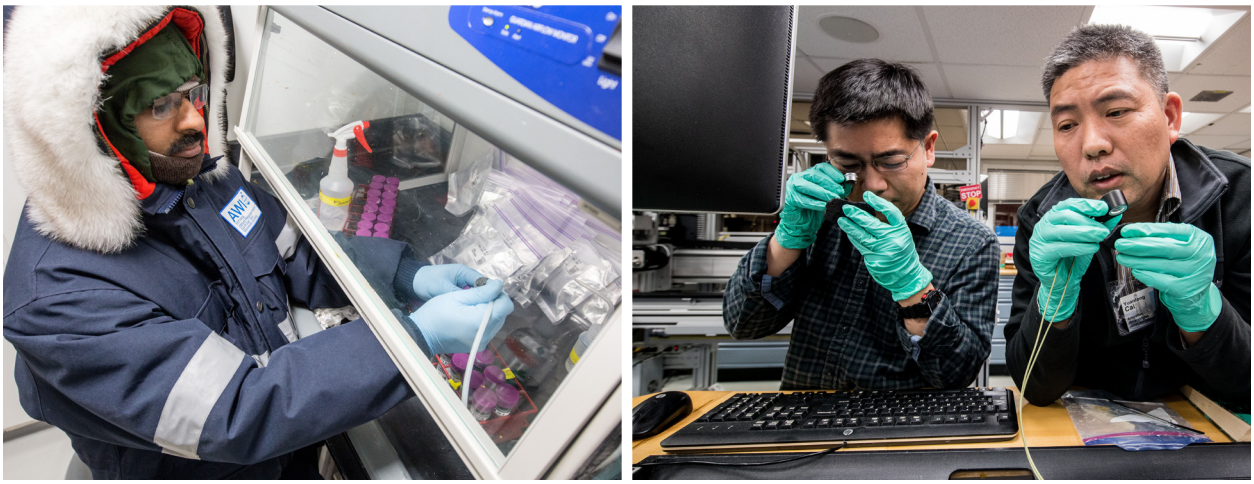
The JRSO hosted two meetings during the second quarter of FY18 to assess JRSO facility performance. The first meeting, held 26 and 27 February 2018, was a Co-Chief Scientist review, during which seven of the ten FY17 expedition Co-Chief Scientists assessed the JRSO's performance in implementing FY17 Expeditions 363 (Western Pacific Warm Pool), 366 (Mariana Convergent Margin and South Chamorro Seamount), 367/368 (South China Sea Rifted Margin), and 371 (Tasman Frontier Subduction Initiation and Paleogene Climate). Their findings were compiled in a report that was presented at the second meeting, an NSF Review Panel for Ocean Sciences site visit held 28 February–2 March to assess the JRSO's performance as a facility in meeting the needs of IODP in fulfilling its Science Plan. The site visit panel concluded that "the facility is being managed superbly well by the JRSO, with effective support from *the JOIDES Resolution* Facility Board and NSF," and the NSF response to the site visit panel report noted that the five FY17 JRSO expeditions addressed 12 of the 14 identified challenges in all four IODP Science Plan themes.

The JRSO received panel recommendations from NSF on 6 April 2018 with guidance for implementation, and the JRFB met in May and fully supported NSF's conclusions and recommendations. Some of the recommendations were addressed during FY18, and others were addressed in the JRSO FY19 Annual Program Plan.

Facility operations risk management recommendations

Proactive use of operational experience

Five of the panel recommendations provide suggestions for mining underutilized data and knowledge that could be used to mitigate operational risk in an aging facility where maintenance costs and breakdowns are likely to increase in the future. NSF agreed with these recommendations and suggested



From left: Subsampling microbiology whole-round samples in the microbiology laboratory cold room. Close work at the core description table.

that the JRSO examine ways to more effectively draw upon operational experience in planning complex operations and convey this information to IODP proposal authors, the SEP, and expedition Co-Chief Scientists during the proposal evaluation and expedition planning processes.

The JRSO committed to continue using the organization's operational experience to assess the feasibility of proposed operations at all stages of the proposal and expedition processes as is practical.

Safety information for panel reviews

NSF tasked the JRSO with including an annual summary of the safety information provided in *JOIDES Resolution* Daily Reports as part of the facility Annual Report to NSF and the JRFB and making this information easily accessible to the panel in future reviews.

The JRSO proposed in the FY19 Annual Program Plan to provide an annual summary of the safety information provided in the daily operational reports.

Enhancement of Science Party support recommendations

Alternate sites for complex/difficult operations

The panel report highlights the need for increasing the number of alternate sites in expedition planning for complex or difficult operations. NSF has confidence that the JRSO, as part of the SEP proposal review watchdog process, will implement this recommendation.

The JRSO proposed in the FY19 Annual Program Plan to work to ensure that a suitable number of alternative sites are included in planned expeditions.

Shipboard availability of site survey data

NSF supports efforts by the JRSO to work with the JRFB and the US Science Support Office to modify site survey policies to ensure that critical site survey data are available on board during every *JOIDES Resolution* expedition for both safety and science support.

The JRSO proposed in the FY19 Annual Program Plan to work to ensure that critical site survey data are available for safety and science support during *JOIDES Resolution* expeditions.

Implementing improvements in science planning

The panel recognizes that the JRSO can enhance science planning for *JOIDES Resolution* operations through better communication of what is possible and what can be realistically done on board the *JOIDES Resolution* during operations. NSF requested that the JRSO examine these recommendations carefully and suggests moving forward with implementing improvements using the task management processes that have been used effectively to improve the shipboard computing environment.

The JRSO committed to continue assessing the feasibility of proposed operations at all stages of the proposal and expedition processes as is practical.

Shipboard X-ray fluorescence core scanning

The panel recommends that the JRSO continue to explore ways to install a whole-core X-ray fluorescence (XRF) core scanner on board the *JOIDES Resolution*. NSF understands the significant laboratory spatial and financial obstacles that must be resolved before this recommendation can be implemented

and requests that the JRSO report to the JRFB the trade-offs and financial requirements needed to implement this recommendation.

The JRSO committed to continue exploring the possibility of providing XRF scanning as a shipboard measurement. Existing XRF core scanners remain too slow to provide meaningful measurements with the limitations of core flow during most expeditions where these measurements would of greatest value.

Outreach collaboration

NSF encouraged the JRSO to continue working with the USSSP and the IODP PMOs to ensure close collaboration between nominated outreach officers and expedition leadership prior to and during expeditions.

The JRSO committed to continuing to facilitate an effective outreach program on board the *JOIDES Resolution*.

Reporting expedition-related publications

NSF requests that the JRSO update and simplify the online form for reporting expedition-related publications by expedition science party members to help ensure IODP Sample, Data, and Obligations Policy & Implementation Guidelines are followed.

The JRSO simplified the process for reporting expedition-related publications by expedition science party members.

4. Subcontractors

The Administrative Services department managed subcontracts with ODL 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.

The JRSO continued to interact with ODL to ensure efficient and compliant operations of the *JOIDES Resolution* and to produce a restatement of the TAMRF/ODL contract, which is intended to simplify the document by removing irrelevant material and condensing amendments into simplified text. JRSO

Welding a reentry funnel.

management met with ODL management at the JRSO in September to discuss upcoming operational issues, renewal efforts, and contract issues.

The JRSO continued to interact with Schlumberger to ensure that wireline logging operations aboard the *JOIDES Resolution* continue in an efficient and compliant manner. The JRSO and Schlumberger worked successfully to streamline travel and shipping activities.

5. Science Operations

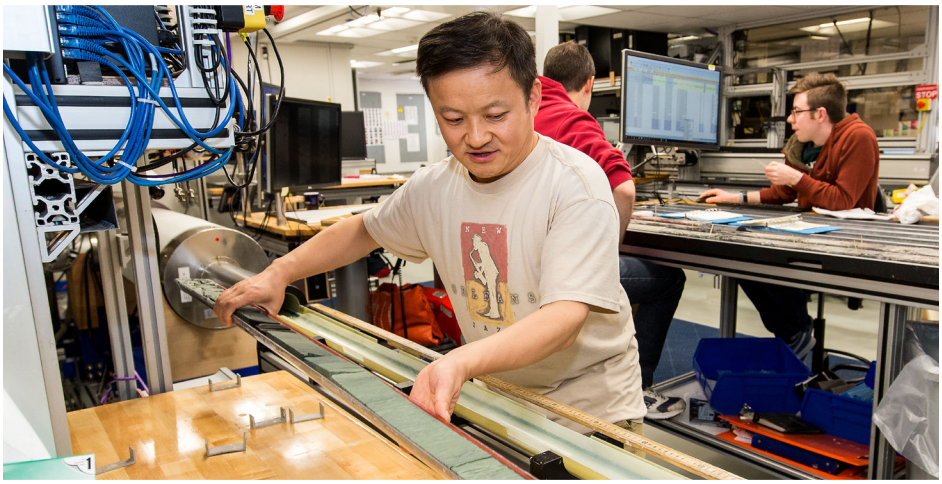
The SciOps department provides scientific and operational planning and implementation for *JOIDES Resolution* drilling expeditions by leading the scoping, planning, and implementation of science expeditions; interacting with and providing technical oversight to the drilling and logging subcontractors; 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

The JRSO hosted the following pre-expedition meetings in College Station:

- JRSO Expedition 378, 6 and 7 November
- JRSO Expedition 379, 1 and 2 November
- JRSO Expedition 382, 8 and 9 February
- JRSO Expedition 383, 26 and 27 April
- JRSO Expedition 385, 3 and 4 September

Routine planning activities occurred for FY18 and FY19 expeditions throughout the year. Videoconferencing and conference calls were held for initial Co-Chief Scientist presentations to the Expedition 379 (Amundsen Sea West Antarctic Ice Sheet History) Science Party and for discussions of bottom-hole assembly (BHA) configuration and data requirements for Expedition 372, observatory issues and research plans for Expeditions 372 and 375, and laboratory requirements and third-party analytical instruments for Expedition 376.



From left: Loading a section half into the cyrogenic magnetometer. Injecting a borehole fluid sample into the H_2S extraction line.

The JRSO began reviewing how to supply basic manual X-ray imaging capability for Expeditions 379 and 382 (Iceberg Alley and Subantarctic Ice and Ocean Dynamics), contracted a service for weather forecasting and began negotiations for an ice imagery agreement for Expedition 379, and worked with Siem Offshore and ODL management to finalize ice management support requirements for Expedition 382.

The US Coast Guard informed ODL that the *JOIDES Resolution* would need to fulfill all requirements of the Mobile Offshore Drilling Unit 1989 Standard to receive permitting for Expedition 386 (Gulf of Mexico Methane Hydrate) in the US Exclusive Economic Zone (EEZ) of the Gulf of Mexico. Given the high costs and insufficient available time for the large number of upgrades required, the JRFB removed Expedition 386 from the *JOIDES Resolution* schedule and forwarded proposals 887-CPP2 and 887-ADD2 to the EFB for consideration of potential implementation as a mission-specific drilling project.

The *JOIDES Resolution* completed what was planned as a routine, required 5-year dry dock in Subic Bay, Philippines. The duration of dry dock was estimated to require 17 days, which included changing out and upgrading the propeller shaft seals. However, ~18 hours after going dry, the wooden portions of the blocking collapsed and the ship dropped ~1 m onto the underlying cement blocks due to the shipyard preparing blocking that was ~5,000 tons under what is required to support the ship. Damage from the incident required replacement of steel in 18 sections of the hull and all the bolts/fasteners (~2,500) in the derrick. Completing the hull repairs and all items originally planned ultimately required 40 days in dry dock. The derrick repairs, which took 2 weeks, were completed in Subic Bay following the dry docking phase.

During dry dock, it was discovered that the *JOIDES Resolution* propellers needed to be replaced. Consequently, the expedition schedule was reorganized because of associated delays with making these repairs, which will be completed in Hong Kong in FY19.

Expedition 378 (South Pacific Paleogene Climate) was deferred to 3 January–4 March 2020 to accommodate the weather window for South Pacific operations. The beginning port will now be in Fiji, and the end port remains in Papeete, Tahiti. The site locations and operations plan remain unchanged. Insertion of a transit from San Diego, California (USA), to Fiji including a short tie up following Expedition 385 (Guaymas Basin Tectonics and Biosphere) was required to return the ship to the South Pacific area of operations for Expedition 378 without impacting operational days for either expedition.

Expedition 379T (the first JR100 expedition) was deferred to the tie-up slot following Expedition 383 (Dynamics of Pacific Antarctic Circumpolar Current). The revised dates and ports will decrease the transit

IODP JRSO FY18 expedition science staffing breakdown.

	Expedition					
Member country/consortium	**369**	**372**	**374**	**375**	**376**	**Total**
United States Science Support Program (USSSP)	10*	10†	10†	11*†	10*†	46
Japan Drilling Earth Science Consortium (J-DESC)	3	3	3	3	3	15
European Consortium for Ocean Research Drilling (ECORD)	10*	8	11*†	8	8	44
Korea Integrated Ocean Drilling Program (K-IODP)	1	1	2	1	1	6
IODP-China	3	2	2	3	2	12
Australia/New Zealand IODP Consortium (ANZIC)	2	5**†	3*†	5*†	4*†	16
India Ministry of Earth Science (MoES)	0	1	1	0	0	2
Coordination for Improvement of Higher Education (IODP-Brazil)	2†	1	1	1	2*	5
Total Science Party Participants	30	29	30	30	27	146

Notes: * = includes one Co-Chief Scientist. ** = includes two Co-Chief Scientists. † = includes international Onboard Education/Outreach Officer. Numbers do not include observers that become part of the Science Party.

time and increase the available operational days relative to the previous position in the schedule, albeit in a less desirable weather window. The expedition plan now anticipates being able to visit 11 sites, assuming no weather delays.

With the insertion of Expedition 378 into the January–March 2020 window ending in Tahiti, Expedition 384 (Panama Basin Crustal Architecture and Engineering Testing) will be impacted with two long transits (from Tahiti to the engineering testing area near Central America and then to Barbados). Consequently, the Panama Basin 769 Ancillary Project Letter (APL) (Hole 504B), which was previously planned as part of FY20 Expedition 384, was moved to the FY19 Expedition 385T transit from Antofagasta, Chile, to San Diego. Enough operational time was available during the transit (~10 days) to also add 921 APL, which is designed to restore nearby Ocean Drilling Program (ODP) Hole 896A. Expedition 384 will now focus only on ~23 days of engineering testing and 25 days of transit.

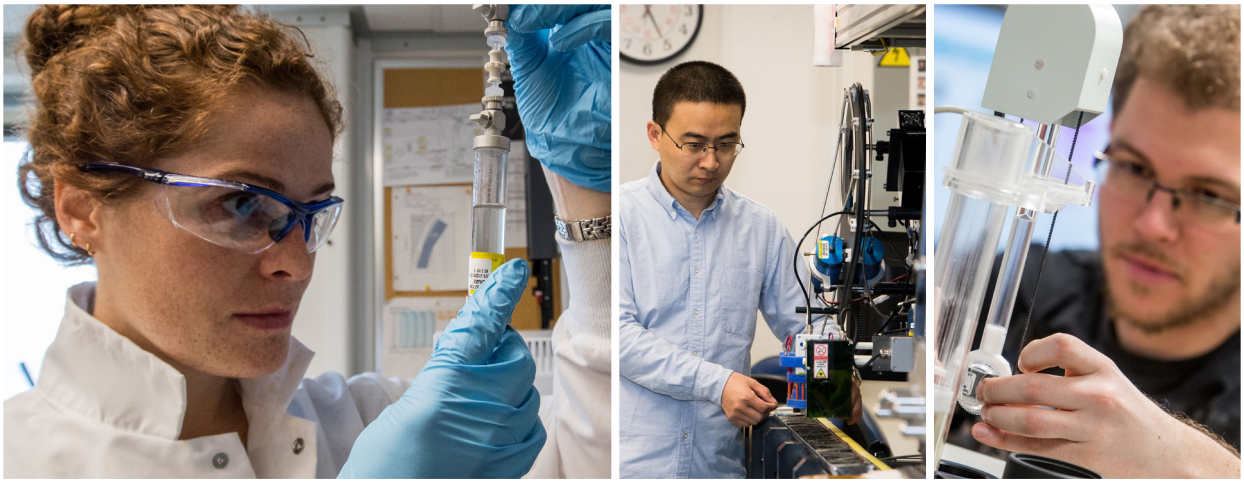
The fabrication and installation of the new propellers were completed about 3 weeks before the ship needed to depart Hong Kong and begin the transit to Punta Arenas, Chile, for the start of Expedition 379. To maximize the amount of time that the facility will be conducting science, Expedition 368X (Return to Hole U1503A [South China Sea]) was added to the schedule. The sole objective of Expedition 368X will be to deepen Hole U1503A, which was cased to 991 mbsf during FY17 Expedition 368 but could not be completed because of the failure of one of the drawworks clutches. Because of the very short lead time, a minimal science staffing model will be implemented to collect ephemeral, safety, and core and wireline logging data only.

Expedition staffing

Science staffing was completed this year for Expeditions 376, 378, and 382, and staffing webinars were conducted for Expeditions 383 and 385.

Logistics support

Supplies, hardware, and equipment were shipped preceding all FY18 expedition port calls.



From left: Measuring the volume of gas in a fluid sample collected downhole. Operating the Section-Half Multisensor Logger. Loading an oriented paleomagnetic cube sample into the Kappabridge KLY-4S.

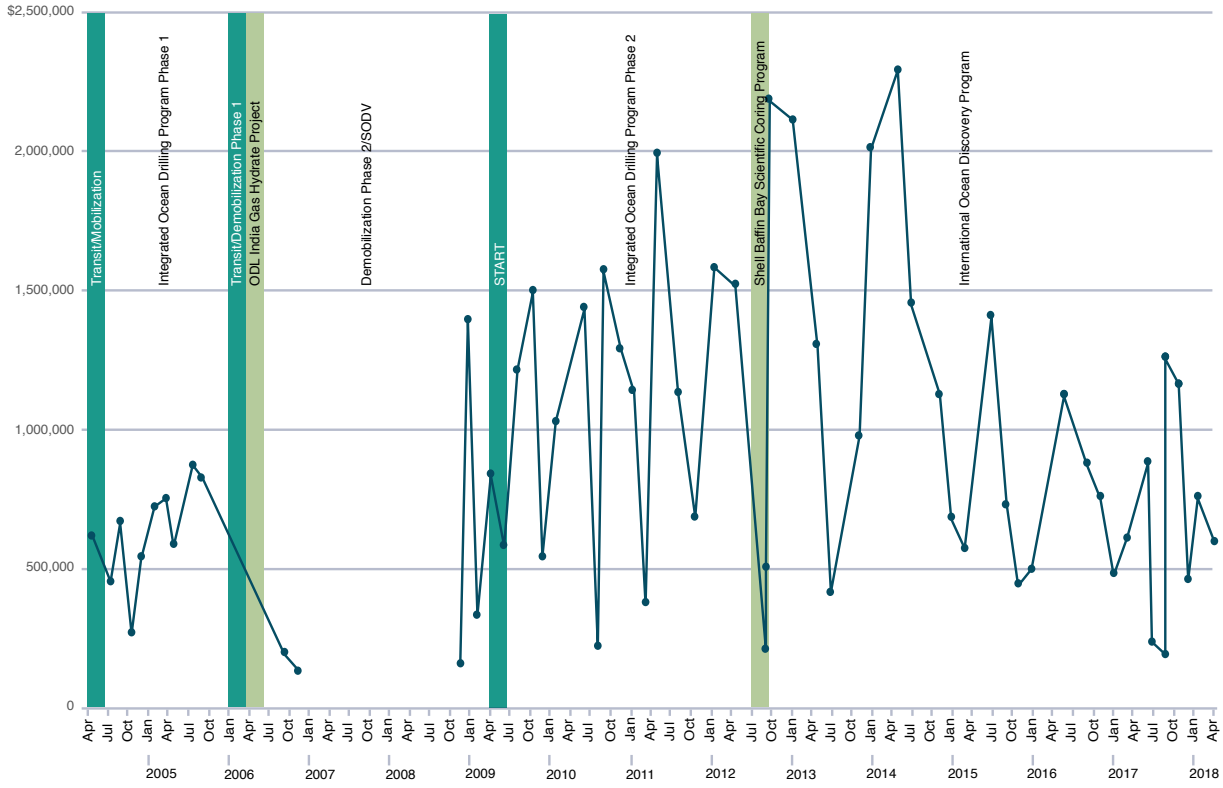
Clearance/Environmental permitting/Risk management

The Environmental Protection and Safety Panel (EPSP) and the TAMU Safety Panel met twice (20 February and 6 September 2018) to review and make recommendations on scheduled expeditions and proposals at the JRFB and to preview selected proposals at SEP. In addition, EPSP and the TAMU Safety Panel reviewed and recommended for approval additional alternate sites and modification requests for Expedition 369, 374, 376, 383, and 382 sites.

The New Zealand government issued authorizations to conduct research in New Zealand waters for Expedition 375 in December, for Expedition 376 in March, and for FY19 Expedition 378 in August. The New Zealand Ministry of Foreign Affairs and Trade also approved two replacement sites for Expedition 376 in June during the expedition. In accordance with the New Zealand EEZ Act, the New Zealand authorization for Expeditions 372, 375, 376, and 378 included a requirement to submit a pre-activity notice to their Environmental Protection Authority (EPA). In addition, other EPA requirements included notifications to parties of interest (e.g., Māori groups) and an initial environmental assessment prior to the expedition, reporting during the expedition, and a postactivity report

NSF completed the Expedition 374 requirements to meet US regulations that implement the Protocol on Environmental Protection to the Antarctic Treaty and its annexes, including issuing a waste permit for Antarctic activities for expeditions with operations in polar waters in FY18 and FY19 (Expeditions 374, 379, 382, and 383) and issuing an environmental evaluation and a radioactive sources (logging tools) usage form for Expedition 374 operations in the Ross Sea. The JRSO submitted the Annual Antarctica Waste Report on 30 March.

Actual fuel costs FY04–FY18.



The JRSO submitted the Expedition 379T (JR100) marine scientific research (MSR) application to the US State Department on 25 May. The MSR application for Expedition 382 was submitted through the US State Department to Argentina and the United Kingdom on 13 August and 21 August, respectively. Several queries from Argentina were received and answered. The JRSO submitted the Expedition 368X application through the US State Department to China and Taiwan on 26 September and 2 October, respectively. A formal letter of intent was submitted to IODP-China on 21 September.

Engineering support

The engineering section continued efforts on a project to replace the obsolescent hydraulic power unit for the vibration-isolated television camera winch. Final parts for the redundant hydraulic power units were delivered to the ship at the Fremantle, Australia, port call. Final installation and connection were completed by the ship's crew during the transit from Auckland, New Zealand, to Subic Bay, Philippines, and initial testing and troubleshooting resolved any issues during the maintenance period. The entire system will be tested at sea during the upcoming transit to Hong Kong.

Education/Outreach support

Shipboard berths were made available to accommodate education and outreach efforts. JRSO staff provided technical support for Onboard Education Officers' live ship-to-shore broadcasting and helped plan and execute public relations and outreach activities during port calls for FY18 Expeditions 372, 374, 375, and 376 and assisted with planning and facilitating the portion of the 2018 School of Rock that took place on board the ship after the Expedition 376 port call. More than 500 students, teachers, media representatives, and government officials toured the *JOIDES Resolution* during port calls in FY18.

JRSO scientists mentored 25 students this year (23 TAMU students and 2 Bryan High School students) through Staff Scientist science engagement activities, which culminated in presentations of students' work at the TAMU Student Research Week and the AGU Fall Meeting in December 2017.

Legacy documentation

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

From left: Sending a live-feed video to a classroom in Japan. Labeling whole-round core sections.

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 (QA/QC) of measurements made in the shipboard laboratories; and supports shore-based laboratories.

Analytical systems

The new *P*-wave logger (PWL) design was implemented on both Whole-Round Multisensor Loggers (WRMSLs). The *JOIDES Resolution* now has two identical multisensor track systems that measure density from gamma ray attenuation, magnetic susceptibility, and *P*-wave velocity. The method for selecting the first *P*-wave arrival from the PWL on the WRMSL was improved, which will increase the number of valid *P*-wave velocities obtained from whole-round measurements.

The Olympus DELTA Premium portable XRF scanner, a fluxgate magnetometer, and an Agico JR-6 spinner magnetometer were repaired by their vendors this year. New equipment installed in the shipboard laboratories included a freeze dryer to replace a malfunctioning unit; a new scintillator to replace a faulty one in the Natural Gamma Radiation Logger (NGRL); a 360° camera to make 3-D images around and under the ship while in dry dock; a new detector for the X-ray diffraction (XRD) system, which was serviced this year; and two additional Ocean Optics QE-Pro spectrophotometers, one for an additional spare on the ship and one for developing a color reflectance system for testing and development on shore.

A mini-project was initiated this year to design and build a compact manual X-ray system for use on high-latitude expeditions, particularly Expeditions 379 and 382. The system will image ~12 cm intervals to ensure overlap between 10 cm imaging regions. TAMU Environmental Health & Safety staff inspected the system with its shielding to ensure that the JRSO met radiation safety requirements for an uncontrolled space. Radiation safety testing will be conducted again on board the ship to ensure the condition of uncontrolled space is met. Test images on a taped-together pair of section halves from Expedition 374 are promising, revealing the ice-rafted debris inside the section.

Laboratory working groups

The Geochemistry and Microbiology, Geology, Geophysics, and Curation and Core Handling laboratory working groups (LWGs) include technical and science staff members and external participants who review cruise evaluations, expedition technical reports, and issues management communications to develop advice on corrective actions and potential developments on the *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 four LWGs provided advice on equipment acquisition and upgrades, improvements to methodologies and measurements, maintenance period activities, and ongoing quality assurance work during FY18.

Shipboard laboratory support

More than 5,000 core sections were processed through the shipboard laboratories during the five FY18 expeditions, and more than 41,000 samples were taken. Shipboard technical staff and expedition scientists made well over 1.6 million shipboard measurements on FY18 samples and placed more than 12,000 images (sections, close-ups, and microimages) in the database archive.

During the transit, dry dock, and tie-up period, TAS installed new air-conditioning units in the science conference room, recarpeted the science conference room and other IODP offices, refurbished the sonar dome and the bio van, installed insulation under the logging office, repaired a leak in the ceiling of the core laboratory, and repaired cracks in the laboratory floors.

In response to the dry-dock incident in which the ship shifted abruptly, TAS staff inspected laboratory systems for damage and found no obvious problems.

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 the *JOIDES Resolution* produces a vast amount of data that are stored in the Laboratory Information Management System (LIMS). LIMS data collected during JRSO Expeditions 369, 371, 372, and 374–376 were successfully transferred to shore, merged with the cumulative LIMS database, and made available online to participating scientists. More than 70,000 downloads were made from the LIMS database during FY18.

Operation and maintenance

The JRSO upgraded shipboard and shore-based Oracle database engines from Oracle 11g to Oracle 12c this year.

From left: Image of the *JOIDES Resolution* derrick captured by drone. Participating in emergency response team training.

Software development

Ongoing efforts completed during the year include projects to develop data structure, uploader, and reports for XRF Core Scanner data; deliver an application with a simple, intuitive user interface to make it easier for technicians and scientists to operate the coulometer and correctly record the results of measurements; and create an uploader to transfer KappaBridge magnetic susceptibility data to the LIMS database and build LIMS Online Report Environment (LORE) reports for viewing and downloading the data.

Project portfolio management

Teams assigned through the JRSO's PPM process plan and implement development projects. Projects closed, continued, or planned during FY18 are listed below.

The JRSO closed the following projects:

- XRF Core Scanner Uploader and Reports
- Coulometer Interface
- KappaBridge Uploader & LORE Reports

The JRSO continued work on the following projects:

- Data Publication
- GEODESC
- DESClogik Replacement
- SampleMaster Replacement

8. Curation

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

From left: Students touring the Gulf Coast Repository during GeoX 2018. An onboard sampling party.

Sampling at the Gulf Coast Repository

In FY18, the GCR processed a total of 16,535 sample requests and hosted sampling parties for Expeditions 371, 369, and 374, during which an additional >12,000, >12,000, and ~20,000 samples, respectively, were taken. In addition, the GCR staff continued work not completed during the Expedition 367, 368, and 363 sampling parties, taking more than 5,000 additional samples.

Use of core collection for 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. This year, the GCR hosted TAMU classes for undergraduate and graduate students and JRSO staff gave tours of the GCR to more than 450 visitors, including Kristian Siem (Siem Offshore, Inc.). The GCR superintendent also made a presentation to the Baylor Research Innovation Collaboration in Waco, Texas (USA).

Onshore XRF scanning

More than 3,800 core sections were XRF scanned this year, and 859 cores were processed through the shore-based Section Half Imaging Logger (SHIL).

Maintenance

The heating, ventilation, and air conditioning in the GCR reefers was replaced this year.

9. Publication Services

The Pubs department provides publications support services for JRSO drilling 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 FY18 included quarterly and annual reports for the JRSO; a *Scientific Prospectus, Preliminary Report,* and *Proceedings of the International Ocean Discovery Program* volume for each JRSO, CDEX, and ESO expedition; and Data Reports for USIO, ESO, and CDEX expeditions that concluded by the end of FY14.

Shipboard publications support and postexpedition editorial meetings

Publications Specialists sailed during all JRSO expeditions to coordinate shipboard reports and visual graphics 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 FY18, JRSO staff in College Station hosted postexpedition meetings for two JRSO expeditions, one CDEX expedition, and one ESO expedition.

IODP scientific publishing and publication coordination

Pubs produced and published 6 *Scientific Prospectuses*, 9 *Preliminary Reports*, and 6 expedition reports volumes for JRSO, CDEX, and ESO expeditions. During FY18, Pubs also coordinated postexpedition publications and published expedition research results content for 14 expeditions, including 21 data reports.

Web services

The JRSO 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 scientific publications are accessible online at the IODP Publications and legacy websites. Volumes are available as disk image or zip files so users can download the expedition reports portion of any IODP *Proceedings* volume.

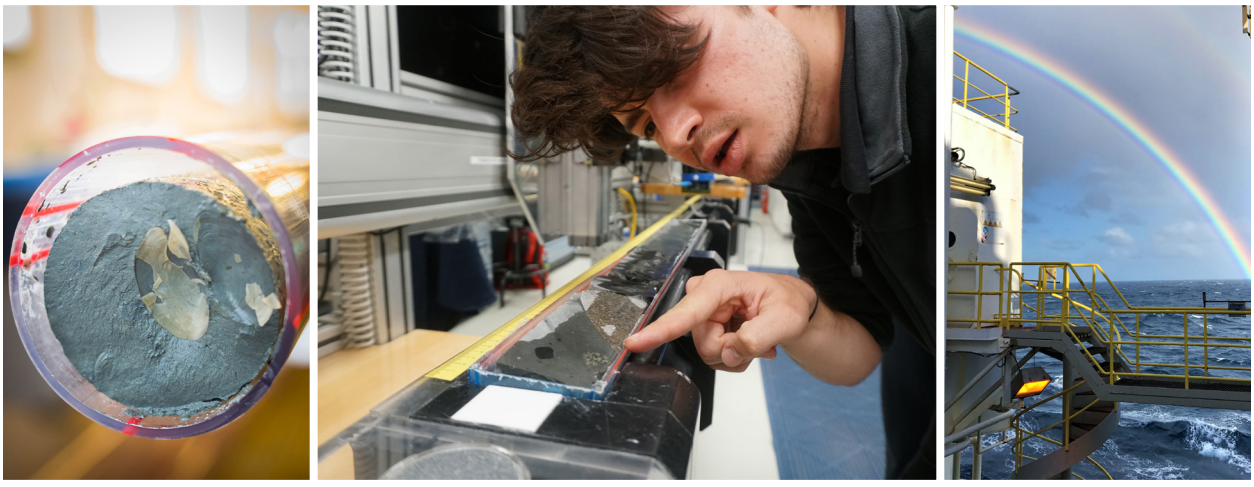
Bibliography and citation management

The Scientific Ocean Drilling Bibliographic Database is a subset of the American Geosciences Institute's GeoRef database and includes more than 35,000 entries related to IODP and the preceding scientific ocean drilling programs, representing nearly a half century of scientific ocean drilling research. In FY18, more than 8,500 queries were run on the Scientific Ocean Drilling Bibliographic Database, and additional records for more than 8,000 citations were viewed.

Publications discoverability

Program scientific publications are accessible through CrossRef, an official digital object identifier (DOI) registration agency for scholarly and professional publications. Program publications accessed through CrossRef numbered more than 110,000 DOI resolutions for Integrated Ocean Drilling Program and IODP publications and more than 149,000 DOI resolutions for DSDP and ODP publications. The JRSO also participates in CrossRef's "Cited-by Linking" and CrossMark validation services.

The JRSO deposited 655 chapters from Integrated Ocean Drilling Program and IODP Expeditions 301–360 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, the JRSO created a companion collection this year containing 2,701 records from expedition-related research published in outside literature. That collection can be viewed at https://www.scienceopen.com/collection/8b0582f6-47bf-4988-b90a-8533135e6fcc.



From left: A bivalve found at a core section break. Preparing to scan an archive-half core section on the Section Half Multisensor Logger. A vivid double-rainbow seen from the catwalk.

Legacy and archiving

The JRSO subscribes to Archive-It, a long-term archive specializing in full website backups. The IODP publications website is now available at Archive-it, with full content from all Integrated Ocean Drilling Program and IODP volumes included, and quarterly crawls incrementally update the archive with new files. In addition, the archive houses legacy publication sites for DSDP and ODP. At the end of FY18, the archive contained 1.1 TB of data and almost 6 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 FY17 (July–September 2017) on 15 November 2017
- First quarter of FY18 (October–December 2017) on 5 February 2018
- Second quarter of FY18 (January–March 2018) on 11 May 2018
- Third quarter of FY18 (April–June 2018) on 3 August 2018

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

Placing a whole-round core section in the storage rack.

URL list

Illuminating Earth's Past, Present and Future: The Science Plan for the International Ocean Discovery Program 2013–2023: http://iodp.org/Science-Plan-for-2013-2023

IODP funding agencies: http://www.iodp.org/funding-agencies

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

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

IODP JRSO FY18 Annual Program Plan: http://iodp.tamu.edu/publications/PP/IODP_JRSO_FY18_APP.pdf

IODP JRSO FY18 Quarterly Reports: http://iodp.tamu.edu/publications/reports.html

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

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

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

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

LIMS Reports: http://web.iodp.tamu.edu/LORE

Sample requests: http:/iodp.tamu.edu/curation/samples.html

IODP scientific publications: http://publications.iodp.org

Proceedings of the International Ocean Discovery Program: http://iodp.tamu.edu/publications/proceedings.html

Expedition-related citation lists: http://iodp.tamu.edu/publications/citations.html

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

2018 Scientific Ocean Drilling Bibliographic Database Report: http://iodp.tamu.edu/publications/AGI_studies/AGI_study_2018.pdf

HathiTrust 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

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

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

Acronyms

AGU	American Geophysical Union
APC	advanced piston corer
APL	Ancillary Project Letter
ASC	Antarctic Slope Current
BHA	bottom-hole assembly
CDEX	Center for Deep Earth Exploration
DOI	digital object identifier
DSDP	Deep Sea Drilling Project
ECORD	European Consortium for Ocean Research Drilling
EEZ	exclusive economic zone
EPA	Environmental Protection Authority (Australia)
EPSP	Environmental Protection and Safety Panel
ESO	ECORD Science Operator
GCR	Gulf Coast Repository
IODP	International Ocean Discovery Program
IT	information technology
JAMSTEC	Japan Agency for Marine-Earth Science and Technology
JRFB	*JOIDES Resolution* Facility Board
JRSO	*JOIDES Resolution* Science Operator
LIMS	Laboratory Information Management System
LORE	LIMS Online Report Environment
LWD	logging while drilling
LWG	laboratory working group
mbsf	meters below seafloor
MSR	marine scientific research
NGRL	Natural Gamma Radiation Logger
NSF	National Science Foundation
OAE	Oceanic Anoxic Events
ODL	Overseas Drilling Limited
ODP	Ocean Drilling Program
PMO	Program Member Office
PPM	project portfolio management
PWL	*P*-wave logger
SEP	Science Evaluation Panel
SHIL	Section Half Imaging Logger
SSE	slow-slip event
TAMU	Texas A&M University
TLC	Tuaheni Landslide Complex
USSSP	US Science Support Program
WAIS	West Antarctic Ice Sheet
WRMSL	Whole-Round Multisensor Logger
XRD	X-ray diffraction
XRF	X-ray fluorescence