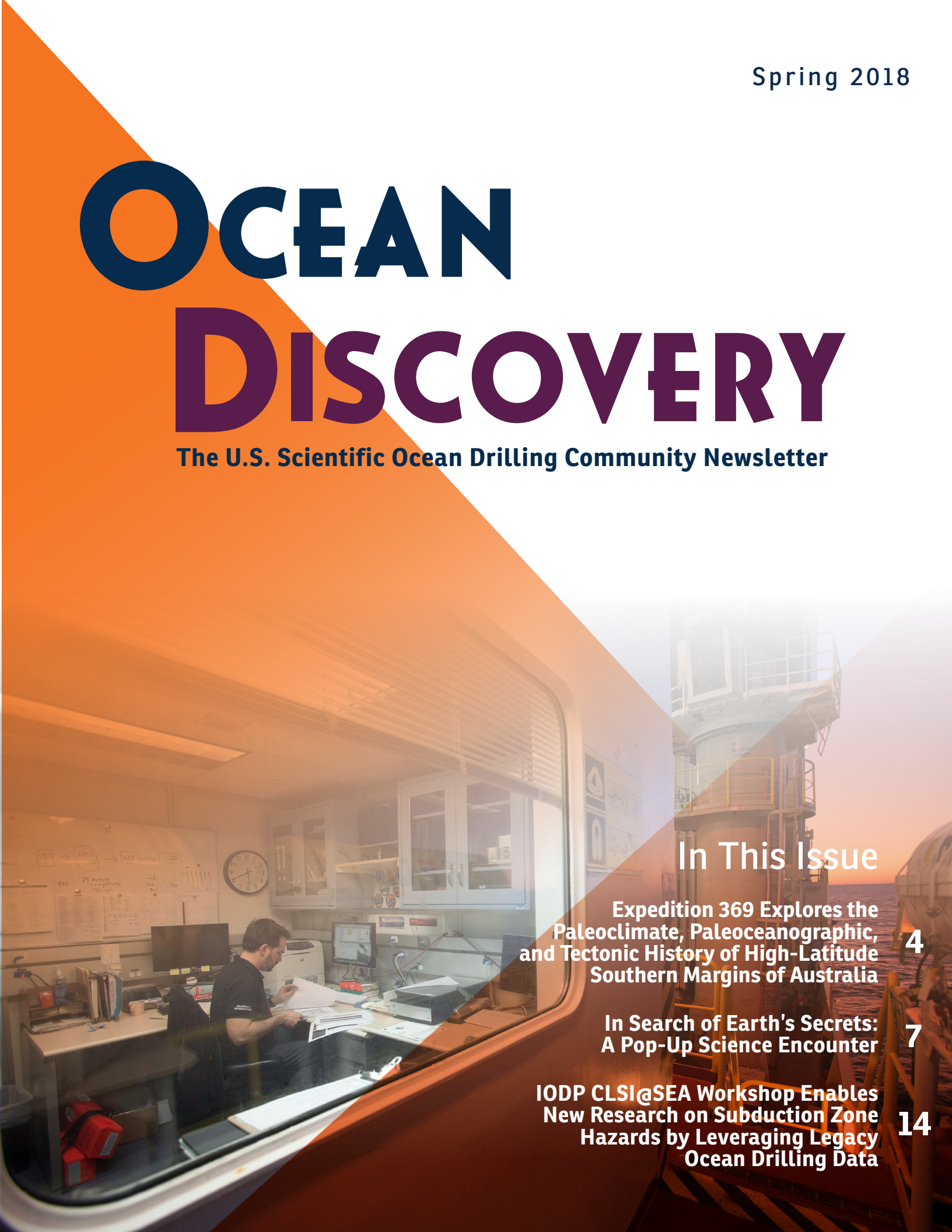
Spring 2018

Ocean Discovery

The U.S. Scientific Ocean Drilling Community Newsletter



In This Issue

The International Ocean Discovery Program (IODP) is an international research collaboration among roughly two dozen countries to advance scientific understanding of the Earth through drilling, coring, and monitoring the subseafloor. The U.S. Science Support Program (USSSP) supports the involvement of the U.S. scientific community in IODP and is funded by the U.S. National Science Foundation (NSF). IODP utilizes multiple drilling platforms to carry out its missions: the riserless *JOIDES Resolution*, managed by Texas A&M University; the riser-equipped *Chikyu*, operated by the Center for Deep Earth Research (CDEX), a subdivision of the Japan Agency for Marine-Earth Science and Technology (JAMSTEC); and various mission-specific platforms operated by the British Geological Survey on behalf of the European Consortium for Ocean Research Drilling (ECORD). For more information, visit: www.iodp.org.

To contact the editor of Ocean Discovery, email: jspencer@LDEO.columbia.edu; or call 845-365-8785

For more information about USSSP, visit: usoceandiscovery.org/what-is-usssp

CALENDAR

May

15-16 — ***JOIDES Resolution* Facility Board**
Alexandria, VA

June

26-28 — **Science Evaluation Panel**
Potsdam, Germany

June 30 - July 6 — **Petrophysics Summer School**
Leicester, UK

July

5-13 — **Te Kura Kōhatu: School of Rock**
JOIDES Resolution & Auckland, New Zealand

24-26 — **U.S. Advisory Committee for Scientific Ocean Drilling**
New York, NY

August

6-10 — **Workshop: Polar Marine Diatoms**
Milford, IA

September

3-14 — **ECORD Summer School 2018: Sub-seafloor fluid transport and gas hydrate dynamics**
Bremen, Germany

4-6 — **Environmental Protection and Safety Panel**
College Station, Texas

19-21 — **IODP Forum**
Goa, India

25-27 — **Workshop: Scientific Exploration of the Arctic and North Pacific**
Mt. Hood, OR

Letter from the USAC Chair

Dear U.S. Ocean Drilling Community,

Congratulations to us, the ocean drilling community, as we celebrate 50 years of scientific ocean drilling. It is not a stretch to say that over the past 50 years, scientific ocean drilling has been the primary mechanism by which researchers have studied the history of Earth system change, and it remains so today. Ocean drilling's longevity is a testament to the vision and leadership within our community and its legacy continues to grow because of your vigilance in implementing technological advancements that have improved core quality and recovery.

To prepare for the next phase of IODP (2019-2023), my predecessors John Jaeger and Beth Christensen organized and convened the *JOIDES Resolution* Assessment Workshop (JRAW) last fall. More than 80 scientists met in Denver over three days to distill the input from 876 survey responses submitted by the greater ocean drilling community. The JRAW report has provided valuable input to the National Science Foundation (NSF) and will assist NSF in making the case to the National Science Board for continued funding of the *JOIDES Resolution* through 2023. I encourage you to take a moment to read through it (http://usoceandiscovery.org/workshop-jr-assessment/).

High-quality scientific proposals have been the hallmark of the previous 50 years of ocean drilling. So too, the future of ocean drilling depends on the continued submission of excellent proposals. Seismic imaging of the sub-seafloor is the lifeblood for our community; it is the only means by which we can study deep crustal environments, identify drilling targets, and assess potential safety hazards. NSF recently released a Dear Colleague Letter (https://www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf18061) outlining a new approach for marine seismic capabilities to the U.S. research community. While still supporting a broad portfolio of marine seismic research, the letter announces that NSF is planning to phase out the *Marcus G. Langseth*, a unique workhorse of the U.S. academic fleet for seismic data acquisition. Portable seismic systems on UNOLS vessels can provide imaging for shallow objectives and collaboration with our international partners can provide some deep capabilities. However, the IODP Forum has noted that insufficient capability exists globally and within the U.S., and the *Langseth* remains the sole global academic vessel capable of imaging deep crustal objectives.

Make no mistake, NSF's decision regarding the *Langseth* and the provisional plans for seismic data acquisition will make it more difficult to obtain these critical data to sustain ocean drilling into the future. As a community, we need to work with NSF over the next two years to develop a plan that, at a minimum, keeps seismic data acquisition at the status quo. As your representatives, USAC will continue the dialog with NSF, voicing your concerns as a community, and urging NSF to remain committed to ocean drilling via the funding of marine seismic data acquisition proposals. As the ocean drilling community enters the next 50 years of exploration of the Earth beneath the seafloor, we should not only heed the lessons of the past, but also look forward to deployment of the most cutting-edge technology. This includes not only new developments in drilling, but also state-of-the-art imaging of new subsurface targets in advance of drilling.

Sincerely,

James Wright
Chair, U.S. Advisory Committee
for Scientific Ocean Drilling

Expedition 369 Explores the Paleoclimate, Paleoceanographic, and Tectonic History of High-Latitude Southern Margins of Australia

Brian Huber, Richard Hobbs, Kara Bogus and the Expedition 369 Scientists

Understanding the tectonic and depositional history of the Great Australian Bight (GAB) and Mentelle Basin (MB; adjacent to Naturaliste Plateau) is key to reconstructing the Cretaceous and Cenozoic climate changes and ocean dynamics during the last phase of breakup among remnant Gondwana continents. Sediments recovered from IODP Expedition 369 (Australia Cretaceous Climate and Tectonics) sites in both regions will provide a new perspective on Earth's temperature variation at subpolar latitudes (60°–62°S) during the rise and fall of the mid-Cretaceous and early Eocene hothouse climates, and ensuing paleoceanographic and biotic changes. They will also provide constraints on the timing of rifting, the nature of the breakup, and subsequent subsidence of the margins.

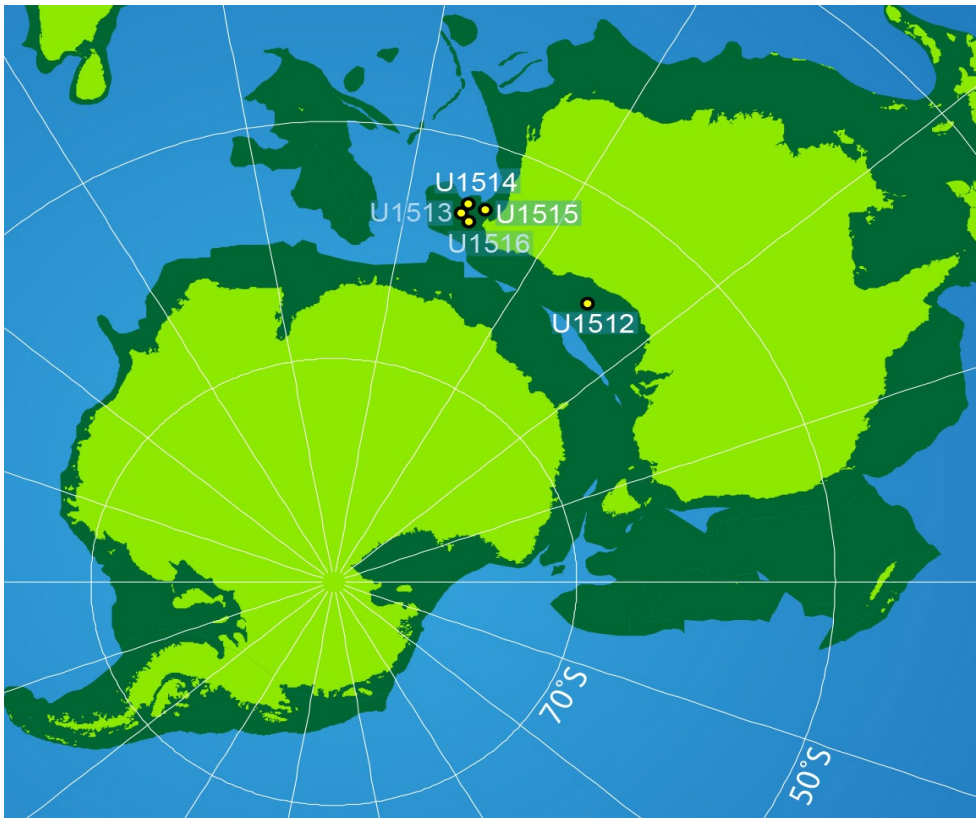


Figure 1. Paleogeographic reconstruction (from Ende et al., 2017) of the southern polar region for 90 Ma showing the location of Expedition 369 Site U1512 in the Great Australian Bight and Sites U1513–U1516 in Mentelle Basin. Final separation of Australia and Antarctica along the South Tasman Rise occurred at ~45 Ma.

Although several exploration wells were drilled in the GAB prior to Expedition 369, no continuous cores had been obtained from the Turonian to recent sequence. Therefore, little was known about the history of the Australo-Antarctic Gulf (Southern Ocean) opening, as it widened northward and ocean communication with the Indian Ocean extended eastward toward the land connection between Tasmania and East Antarctica. Furthermore, most knowledge of the MB stratigraphy has been based on basin-wide correlation of sedimentary units drilled at Deep Sea Drilling Project (DSDP) Site 258, which was spot-cored with only 22% average sediment recovery and no recovery of underlying basalt flows or pre-breakup units. As a result, understanding of the Cretaceous–Paleogene paleoceanographic and paleoclimatic history of the southeast Indian Ocean region and the tectonic history of the MB remained poorly understood.

The cored material and data obtained from Sites U1512–U1516 (Figure 1) will achieve all the primary scientific objectives for Expedition 369, as discussed below. The water depths and core recovery for each site are summarized in Table 1.

Investigate the timing and causes for the rise and collapse of the Cretaceous hot greenhouse and how these affected the climate-ocean system and oceanic biota: The recovered Cretaceous sediments are thermally immature and yield well-preserved foraminifera at Sites U1512–U1514 and U1516, minimizing the likelihood that diagenetic overprints will compromise paleoceanographic and paleotemperature signals. The most continuous Cretaceous climate record, which ranges from the middle Albian through the earliest Campanian (~28 Myr), comes from Site U1513, adjacent to the original DSDP Site 258. Analysis of Cenomanian sediments yielding good microfossil preservation at Sites U1513, U1514, and U1516 will fill a critical temporal gap in the climate record at southern high latitudes. Moreover, good core recovery and microfossil preservation in portions of the Turonian–Coniacian and/or late Albian at Sites U1512 to U1514 and most of the Santonian–early Campanian at Site U1513 will significantly improve reconstructions of the climatic and oceanographic changes that span the rise and fall of the hot Cretaceous greenhouse climate.

Determine the relative roles of productivity, ocean temperature, and

ocean circulation at high southern latitudes during Cretaceous Oceanic Anoxic Events (OAEs): A major goal of Expedition 369 was to obtain stratigraphically complete and well-preserved sediment records spanning OAE 2 (~93.8 Ma) and OAE 1d (~100.2 Ma). These short-lived (<1 Myr) episodes of enhanced deposition of organic carbon are associated with a global carbon isotope excursion and high rates of species turnover (e.g., Jenkyns et al., 2017). Complete and well-preserved microfossil assemblages and laminated black shale beds were recovered from the OAE 2 (Figure 2) and OAE 1d intervals at Sites U1513, U1514, and U1516. Geochemical measurements of the sediment and foraminifera through the OAEs should determine whether volcanic events linked with ocean warming and increased plankton productivity provided the mechanism for enhanced organic matter preservation in these intervals. Results will significantly advance understanding of the cause and effects of these possibly global anoxic events.

Identify the main source regions for deep-water and intermediate water masses in the southeast Indian Ocean and how these changed during Gondwana breakup: εNd analyses will be used to trace sources and circulation patterns of deep-water masses (and thus changing connections between basins), as well as local weathering inputs and potential global influences such as hydrothermal input from large igneous province volcanism. For the Cenomanian in general and the OAE 2 interval in particular, εNd patterns obtained from sediments cored at Sites U1513 and U1516 will provide a geographically distant test between competing volcanic and circulation models developed for the North Atlantic. The increasing importance of the Southern Ocean as a deep-water source can be temporally constrained by comparing εNd values and trends in the MB cores to values documented elsewhere. Finally, the timing and regional importance of the opening of the Tasman Gateway and the evolution of Antarctic circulation patterns across the Eocene/Oligocene boundary can be determined from εNd values obtained from sediment cores at Site U1514 in the northern MB.

Characterize how oceanographic conditions changed at the MB during the Cenozoic opening of the Tasman Passage and restriction of the Indonesian Gateway: The Cenozoic sedimentation in the MB is particularly sensitive to northward and southward movements of Antarctic waters and changes in oceanic gateway passages that connect the western equatorial Pacific Ocean with the Indian Ocean. Study of Eocene deposits recovered at Sites U1514 and U1516 will further our understanding of the oceanographic and climatic consequences of the opening of the Tasman Gateway. The Miocene and Pliocene sediments recovered from Sites U1513, U1514, and U1516 will be used to establish the timing, magnitude, and rates of climate and ocean circulation changes that affected the Australian continent and the southeast Indian Ocean region as the seaway between Australia and Antarctica widened and deepened and the Indonesian Passage became more restricted.

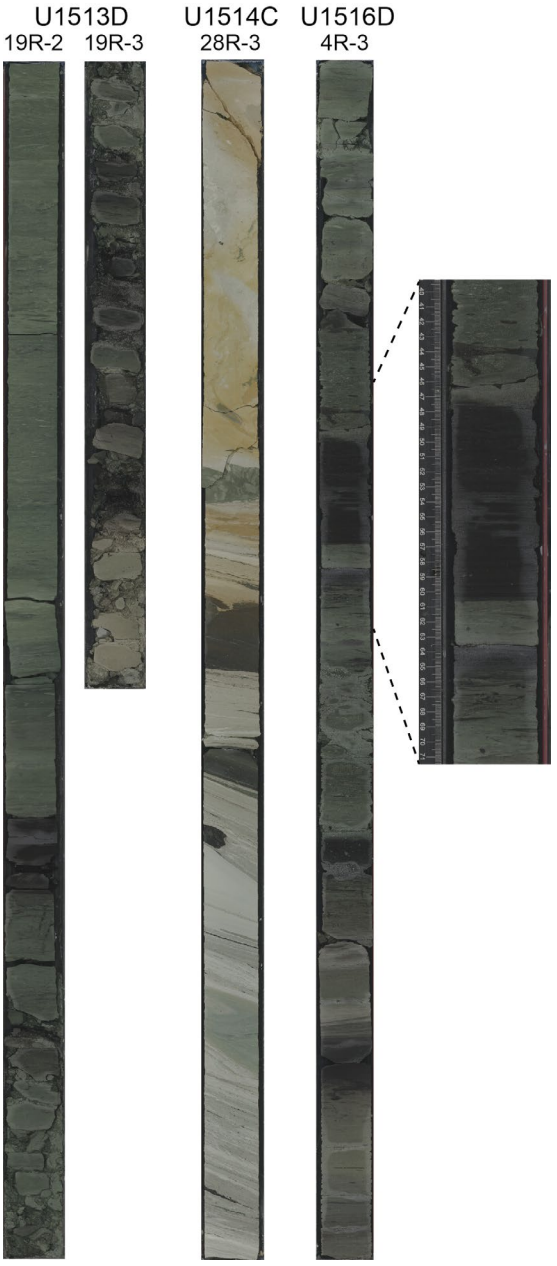


Figure 2. Core-sections spanning the Cenomanian-Turonian boundary interval (~94 Ma) and containing black shale beds from OAE 2 in Holes U1513D, U1514C, and U1516D. The disturbed beds in Hole U1514C are from within a detachment zone that occurred during a more recent slumping event. The enlargement from Section U1516D-4R-3 shows a 13 cm-thick laminated black shale bed containing 14% total organic carbon content.

Resolve questions on the volcanic and sedimentary origins of the basin and provide vital stratigraphic control on the age and nature of the pre-breakup succession: Sampling the pre-breakup sediments was achieved at Site U1515. The margin-wide breakup unconformity was crossed at 364 m CSF-A, and coring sampled a series of carbon-rich claystones interspersed with poorly cemented sandstone in a fault-bounded segment of the eastern MB. These claystones are believed to have been deposited during the Early Jurassic rifting of Eastern Gondwana. Tilting of these sediments is indicative of a later rifting event in the Jurassic.

Our deepest hole (U1513E) recovered ~70 m of volcanic material overlain by volcaniclastic sediments. Shipboard analysis identified extrusive flow sequences intercalated with sedimentary breccia beds, diabase dike intrusions, and a mix of subaerial and marine flows, which suggests the basalts were deposited close to sea level. Although the basalt sequences are highly altered, Ar/Ar dating should constrain the ages of the flows and the dike. Results will be com-

Site	Water Depth (m)	Cored (m)	Recovered (m)	Avg. Recovery	Logging
U1512	3071	700.8	631.86	90%	1512A
U1513	2789	1137.8	777.07	68%	1513A, D, E
U1514	3838	591.9	518.12	88%	1514C
U1515	850	517.1	93.62	18%	
U1516	2676	605	476.99	79%	
Total		**3552.6**	**2497.66**	**69%**	

Table 1. Summary of depths, core recovery and logging achieved at sites drilled during IODP Expedition 369.

pared with a recent compilation of basalt samples from both nearby dredges and samples of the Bunbury basalt.

All Expedition 369 sites contribute to improving the stratigraphic control of the regional reflection seismic data, which record the rifting of both India and Antarctica from Australia. Site U1512 provides a reference point for the current interpretations in the GAB and similarly U1513-U1516 will further constrain interpretation of the MB. Erosional hiatuses and faults in the sedimentary succession can now be dated and linked with episodes of uplift, erosion, and subsidence, which in turn can be linked to the wider tectonic and thermal events on this margin.

Additional details of the expedition can be found in the preliminary report (Huber et al., 2018).

References Cited

Ende, C. v. d., White, L.T., and van Welzen, P. (2017), The existence and break-up of the Antarctic land bridge as indicated by both amphi-Pacific distributions and tectonics. Gondwana Research, 44, 219-227.

Huber, B.T., Hobbs, R.W., Bogus, K.A., and Expedition 369 Scientists (2018), Expedition 369 Preliminary Report: Australia Cretaceous Climate and Tectonics, International Ocean Discovery Program. doi:10.14379/iodp.pr.369.2018.

Jenkyns, H.C., Dickson, A.J., Ruhl, M., and van den Boorn, S.H.J.M. (2017). Basalt-seawater interaction, the Plenus Cold Event, enhanced weathering and geochemical change: deconstructing Oceanic Anoxic Event 2 (Cenomanian–Turonian, Late Cretaceous). Sedimentology, 64, 16-43.

Schlanger Fellows 2018-2019

Meet our 2018-2019 Schlanger Ocean Drilling Fellows! Each of the recipients will receive a $30,000 award to conduct IODP-related research during the 2018-2019 academic year. Additional information on their projects can be found at http://usoceandiscovery.org/schlanger-fellows-2018-2019

Allison Cluett

University at Buffalo,
State University of New York

Hydroclimate of Southern Greenland during interglacials of the past 600,000 years based on terrestrial leaf wax biomarker isotopes preserved in ocean sediments

Colin Jones

University of Rhode Island

Oceanographic controls on mid-Holocene nutrient consumption at Palmer Deep, West Antarctic Peninsula

Megan Mullis

Texas A&M University,
Corpus Christi

Active microbial community survival in Mariana Forearc sediments

Sarah Trubovitz

University of Nevada

What drives plankton evolution?: An investigation of the paleoenvironmental impacts on radiolarian macroevolution using the contrasting histories of tropical and polar Neogene oceans

In Search of Earth's Secrets: A Pop-Up Science Encounter

In February, the U.S. Science Support Program (USSSP)—in collaboration with IODP, Consortium for Ocean Leadership, Rutgers University, University of Hawaii, and a variety of libraries and youth-serving organizations—launched the traveling exhibit, *In Search of Earth's Secrets: A Pop-Up Science Encounter.* Independently funded by a grant from the U.S. National Science Foundation to USSSP's Sharon Cooper, *Earth's Secrets* aims to bring the exciting cutting edge science of the ocean drilling programs, and Earth science in general, to communities nationwide. Its goals include especially bringing science and scientists to those traditionally underserved and with less access to world class science resources throughout the United States.

Earth's Secrets consists of a 45-foot (13.7 m) inflatable replica of the *JOIDES Resolution*, inside of which a video wall presentation explores some of scientific ocean drilling's greatest stories of discovery. The video was produced by the team at Netherlands-based ScienceMedia. In addition to the inflatable JR, the exhibit includes six interactive kiosks, each focusing on a science or engineering topic addressed by the drilling program, including subseafloor microbiology, microfossils as Earth history storytellers, drilling technology, earthquakes and tsunami, extinction of the dinosaurs, and more. In addition, a 30 x 15 ft (9 x 4.5 m) floor map of the ocean floor invites visitors to step **into** the ocean and explore its many unique and surprising features.

The exhibit is set to visit three communities in 2018: Martinsville, VA, New Brunswick, NJ, and Queens, NY. During each visit, program staff first work with Girl Scouts and other youth-serving organizations to train them on the content and operation of the exhibit. Later, during public events, these young people serve as docents and facilitators for the exhibit. In between larger public events at museums and outdoor spaces, the kiosks "live" at libraries and other venues where they are available for deeper exploration by visitors.

The *Earth's Secrets* exhibit tour began in early February in the community of Martinsville, in the Southwestern foothills of Virginia. The first stop was at the Virginia Museum of Natural History (VMNH), a key partner on the project. The museum hosted the training event for the local Girl Scouts from the Virginia Skyline Council who would become volunteer docents for the exhibit. Seventeen girls with the rank of Cadette, Senior, and Ambassador participated in the training, with the goals of immersion in the science content and preparing them to facilitate interpretative experiences with the concepts presented in the exhibit. The VMNH also hosted the first events the girls worked—a Council wide "lock-in" for Girl Scout Brownies and Juniors and an *Earth's Secrets* celebration open to the public that was enjoyed by over 400 visitors.

Taking advantage of the portability of the exhibit design, the kiosks were next distributed to another key partner, the Blue Ridge Regional Library (BRRL) system, a collaborative consisting of five branches.

Club Teen Center, and the local chapter of the National Society of Black Engineers (NSBE). It then traveled to Reynolds Homestead (RH), a historical community engagement center administered by Virginia Tech in neighboring Patrick County. Hosted for nearly two weeks, RH education staff presented programs for a variety of student group field trips, including a high number of rural and Title I schools, and a festival and open house for the public. Nearly 400 visitors from the region were engaged there.

Innovation Learning program, a Verizon Foundation initiative, spent a day exploring the exhibit. PHCC is one of five community colleges in the nation to launch a pilot program for training future female leaders in the science, technology, engineering and math fields.

While the 2018 sites are set, the project is requesting applications for new communities to serve as hosts for the project in 2019, 2020 and 2021. Information, schedule and more can be found at www.insearchofearthssecrets.com. For more information, feel free to contact Sharon Cooper at scooper@LDEO.columbia.edu.

A culminating celebration brought the whole exhibit back together and brought in over 800 patrons, more than had ever been at that branch for any one-day event before!

The exhibit then spent time at New College Institute (NCI), a higher education institution in Martinsville, where it was enjoyed by high school students from three of NCI's clients: the Academy of Engineering and Technology, the Boys and Girls

The final stop was at the Manufacturing, Engineering, and Technology (MET) Complex at Patrick Henry Community College (PHCC). The exhibit was open to the public for several days and visited by science, technology and engineering students and faculty. Also, girls involved in the Verizon

Brothers Volcano: A Window Into Volatile Flux, Metal Transport, and Conditions for Early Life at a Submarine Arc Volcano

Susan E. Humphris and Cornel E.J. de Ronde

Volcanic arcs are the surface expression of magmatic systems that result from the subduction of mostly oceanic lithosphere at convergent plate boundaries. Arcs with a submarine component include intraoceanic arcs and island arcs that span almost 22,000 km on Earth's surface. Submarine arc magmatic-hydrothermal systems are driven by crystallization of magmas produced through partial melting of mantle that is fluxed by volatiles released from the subducting slab, resulting in magmas that are enriched in volatiles by an order of magnitude compared with mid-ocean ridge basalts. The degassing of these arc magmas gives rise to extraordinary phenomena, such as discharge of liquid CO_2 and the formation of liquid "lakes" of sulfur on the seafloor (de Ronde et al., 2015). The high metal contents and very acidic fluids discharging from these hydrothermal systems are thought to be important analogs for many of the porphyry copper and epithermal gold deposits exploited on land today. Although these systems might seem to be some of the most hostile environments for life, diverse animal and microbial communities are commonly observed in such systems.

What are the fundamental underlying processes that distinguish hydrothermal systems in arc volcanoes from those in spreading environments? Brothers volcano in the Kermadec arc is an excellent example of a submarine arc hydrothermal system and has been the focus of a continuing series of studies. An IODP workshop in 2012 identified Brothers volcano as the top candidate worldwide for arc volcano drilling to further our understanding of mineral deposit formation along arcs, the subseafloor architecture of these volcanoes and their related permeability, and the relationship between the discharge of magmatic fluids and the deep biosphere.

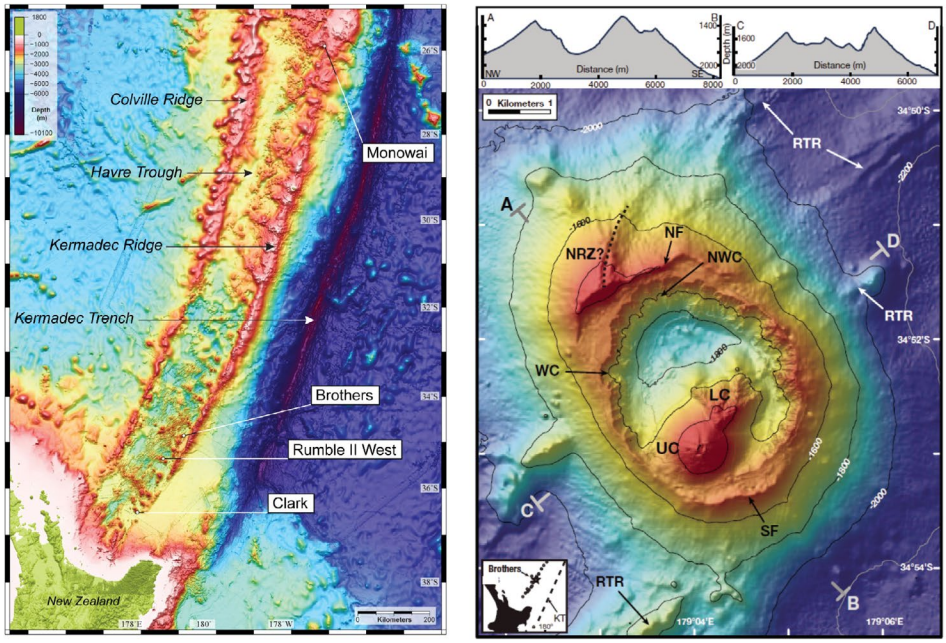


Figure 1. (A, Left): Location map of the Kermadec arc and trench showing the location of Brothers volcano. (B, Right): Detailed bathymetry (contour interval is 200 m) of Brothers volcano and surrounds. Letters designate North fault (NF), South fault (SF), North rift zone (NRZ), Upper Cone (UC), and Lower Cone (LC), NW Caldera (NWC), W Caldera (WC), and regional tectonic ridge (RTR). Letters A-B and C-D are endpoints for the bathymetric cross sections shown in the top panels.

Brothers volcano is a caldera volcano along the active Kermadec volcanic arc front (Figure 1A). The base of the volcano rises from a depth of ~2200 m to a continuous caldera rim at 1540-1320 m. The caldera floor has a basal diameter of 3–3.5 km and averages 1850 m in depth. An elongate northeast–southwest, 1.5–2 km wide and 350 m high post-collapse cone occurs within the caldera, with a satellite cone conjoined with its northeast flank (de Ronde et al., 2005).

Of particular note is the existence of two distinct types of hydrothermal systems at Brothers volcano. Six hydrothermal fields, five active and one inactive, have been identified on the caldera walls and atop the two cones rising up from the caldera floor (Figure 1B). The three active caldera sites are characterized by high-temperature (up to 302°C) venting of relatively gas-poor, moderately acidic fluids through Cu-Au-rich sulfide chimneys. In contrast, the two active vent fields at the summits of the Upper and Lower Cones discharge lower-temperature (≤120°C), volatile-rich, very low-pH (to 1.9) fluids, and are characterized by native sulfur chimneys and extensive Fe-oxyhydroxide crusts (de Ronde et al., 2005; 2011).

Microbial communities sampled from one of the caldera wall sites are characterized by an abundance of slightly thermophilic and hyperthermophilic chemolithoautotrophs, as observed in typical high-temperature hydrothermal vent environments of mid-ocean ridge and backarc basin systems (Takai et al., 2009). However, microbial communities from the cone sites exhibit a diversity of bacterial lineages, with potential psychrophilic and thermophilic sulfur- and iron-oxidizing chemolithotrophs found in the magmatic volatiles-rich hydrothermal environments of submarine arc volcanoes (Stott et al., 2008). The existence of two distinct hydrothermal microbial ecosystems occurring together within a sin-

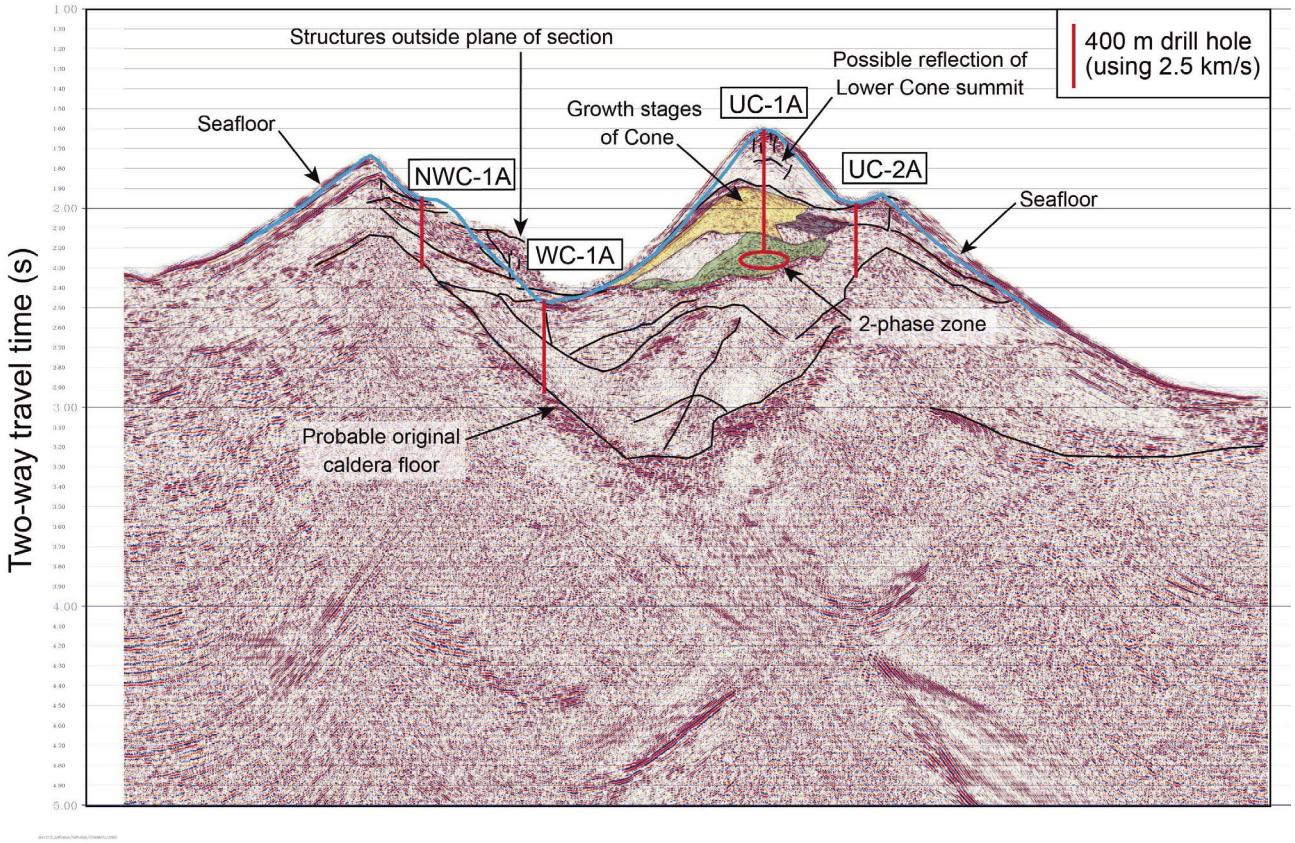


Figure 2. Seismic section across Brothers Volcano showing the growth stages of the caldera and the proposed IODP drill sites. Blue line is the seafloor derived from bathymetric data.

gle caldera—showing a clear niche segregation in response to both physical and chemical differences in the hydrothermal fluids—is currently globally unique.

IODP Expedition 376 (Brothers Arc Flux) will drill and log three primary sites to depths between 400-800 mbsf: one site on the rim of the caldera (Site NWC-1A), another on the floor of the caldera (Site WC-1A), and a third on the summit of the Upper Cone (UC-1A) (Figure 2). These three sites represent discharge zones of geochemically distinct fluids, thereby providing access to critical zones dominated by magma degassing and high-temperature hydrothermal circulation over depth ranges considered crucial in the development of multiphase mineralizing systems.

Coring and logging during Expedition 376 will reveal the mechanisms and extent of fluid-rock interactions and their consequences for mass transfer of metals and metalloids into the ocean. Downhole fluid sampling will be conducted in an attempt to characterize the magma chamber–derived volatile phase to test model-based predictions that it is either a single-phase gas or a two-phase brine-vapor. Finally, we will assess the diversity, extent, and metabolic pathways of microbial life in this extreme, metal-toxic, and acidic volcanic environment.

IODP drilling will be complemented by shallow (<200 mbsf) drilling using the MeBo seafloor drill rig from the *R/V Sonne* at a time yet to be scheduled. Cores with good recovery in the shallow part of the section are required to explore aspects of the hydrogeology, including the flux of metals to the seafloor, the permeability of the volcanic rock, fluid flow and seawater entrainment, mineral zonation, and their effects on microbial community development and habitability. Strategically, this shallow MeBo coring will allow IODP to bypass coring in the shallow sections if necessary and set up the holes for casing required to stabilize the drill holes for deep coring. Together, these two expeditions represent the first comprehensive study of the internal structure of a hydrothermally active intraoceanic arc volcano.

References Cited

de Ronde, C.E.J., Hannington, M.D., Stoffers, P., et al., 2005. Evolution of a submarine magmatic-hydrothermal system: Brothers volcano, southern Kermadec arc, New Zealand. Econ. Geol., 100, 1097-1133.

de Ronde, C.E.J., Massoth, G.J., Butterfield, D.A., et al., 2011. Submarine hydrothermal activity and gold-rich mineralization at Brothers volcano, Kermadec arc, New Zealand. Mineralium Deposita, 46, 541-584.

de Ronde, C.E.J., Chadwick, W.W., Jr., Ditchburn, R.G., et al., 2015. Molten sulfur lakes of intraoceanic arc volcanoes. In Rouwet, D., Christenson, B., Tassi, F., and Vandelbroulemuck, J. (Eds.), Advances in Volcanology: Volcanic Lakes. Nemeth, K. (Series Ed.): Berlin (Springer-Verlag), 261–288.

Stott, M.B., Saito, J.A., Crowe, M.A., et al., 2008. Culture-independent characterization of a novel microbial community at a hydrothermal vent at Brothers volcano, Kermadec arc, New Zealand. J. Geophys. Res. 113:B08S06.

Takai, K., Nunoura, T., Suzuki, Y., et al., 2009. Variability in microbial communities in black smoker chimneys at the NW caldera vent field, Brothers volcano, Kermadec arc, Geomicrobiol. J., 26, 552–569.

A general bibliography related to this article can be found in the Expedition 376 Scientific Prospectus at: https://bit.ly/2tcbZjt.

Reddit Science "Ask Me Anything"

Reddit is a massive online community that encourages discussion of a broad range of topics, including politics, culture, hobbies, and more. The subreddit dedicated to science, r/Science, supports a series of "Ask Me Anything" (AMA) sessions in which users submit and "upvote" questions they wish to have addressed by active researchers. The stated goal of the r/Science AMA series is "to encourage discussion and facilitate outreach while helping to bridge the gap between practicing scientists and the general public." Reddit AMAs are an opportunity for dynamic, interactive Q&A sessions and have allowed IODP scientists to engage with a diverse audience of students, science enthusiasts, and the general public.

Included here are samples from the Expedition 374 AMA that illustrate the types of questions that have been asked and the overall spirit of the community. AMA sessions are scheduled for specific times but promoted in advance, allowing members of the Reddit community to compile, vote, and comment on questions. The sessions are then archived permanently at the Reddit Journal of Science: https://www.reddit.com/r/science/.

More background on the Reddit Science AMA series and guidelines for hosting your own can be found at http://bit.ly/2prDscb.

Q: What is your biggest challenge in working there?

A: The cold water proved to be the most challenging during this expedition. We had an ice observer to help us avoid coming to close to ice, but the ice was not very thick and did not pose a problem. The cold water affected the functioning of one of our propellers. After 5 weeks, the problem was significant enough to force us back to port in New Zealand.

Q: So far, what has been the most interesting discovery you have made with these cores?

A: The most mind boggling fact for many of us has been to see how much material we found down here in the Ross Sea that shows us the interplay of atmospheric and ocean temperatures, ice sheet growth and decay, ocean circulation (the way the water moves around the oceans), and the building of the modern sea floor around here. If we look many million years back in time, what is now the deep sea was shallow ocean, and some of the shallow ocean was land. We see evidence for this in our cores, and can't wait to work out all the details about the stories when we get back home.

Q: So how bad is the ice sheet really? It seems every year I read that the models are off and that it is accelerating melt more than we can predict. Also have you all seen any pattern of this in the past? Thanks.

A: Understanding the response of the large ice sheets in Greenland and Antarctica to global warming and rising atmospheric carbon dioxide concentrations is a complex topic. Some areas of the ice sheets are more vulnerable to changing environmental conditions, and some are less. To give an example, when the ice is in direct contact with the ocean, it can melt from above (atmosphere) and below (ocean), which makes the melting go faster. This happens at the moment in some parts of the Antarctic ice sheet. With every year of research, we collect more data that document this change in more detail, and this is why you keep hearing "new facts" on it. The bottom line is that we have known for quite a while that the ice sheets are changing, we just keep learning more about the details and processes on how it happens. Is it really bad? Well, if we continue to warm our planet it could lead to a lot of the ice on the poles disappearing. This is going to raise sea level to a level that many people living in coastal areas are affected. This is not going to happen overnight, but we really need to understand the exact mechanisms and rates at which this is going on, to make sure we know what our future will look like.

Q: Any proof of climate change in your samples collected?

A: Absolutely. The main reason we went down here is to document the changes in the past we were quite certain happened. And that's what we did. We found many layers of sediment that changed in their color and composition (chemistry, physical properties, magnetics, biological assemblage). In some of our cores these changes happened over longer timescales of hundreds of thousands of years, and in some they happen much quicker. Detailed work back home will hopefully help us to add a lot of knowledge and understanding on climate change, and in particular about the Antarctic ice sheets and how they reacted to it and maybe influenced it.

Q. Is global warming real and if so, how much is man-made?

A. Climate change is real and continuously happening. The goal of Expedition 374 is to study that climate change back about 20 million years ago. Back then, humans were not around to change the climate, but the climate was changing and sometimes very rapidly. The ice sheet that currently covers Antarctica has changed in size numerous times over the past 20 million years. It has shrunk and grown in size owing to many factors: some related to Earth's orbit relative to the sun, some related to greenhouse gas variations, some related to plate tectonic motions, ocean circulation, and other factors. Although Expedition 374 is not studying current climate change, the results can help understand what is causing current climate change. Yes, current climate change is being driven by man-made activities, of that there is abundant evidence from many scientific studies. Other natural processes are involved. One of the goals of this and other science ventures that look at climate, is to unravel what all the processes are and how important each of them is at different times in Earth's past and future.

Education & Outreach Activities

©AMNH/R. Mickens. Sun-Earth Day

Winter/Spring 2018 AMNH Events

Dinos After Dark Back by popular demand, the American Museum of Natural History organized a second "Dinos After Dark" event on February 1, 2018. Chris Lowery, Postdoctoral Fellow at the Institute for Geophysics at the University of Texas at Austin and paleontologist on IODP Expedition 364, presented a lightning talk entitled "The Chicxulub Impact and the End Cretaceous Mass Extinction." The sold out adults-only event, attended of 680 visitors, provided after-hours access to the museum's fossil halls.

An Evening for Educators with Yair Rosenthal and Steve Midgley Deviating from the traditional "single-presenter" format, the focus of this year's Educator Evening was a unique moderated panel discussion including Yair Rosenthal (Distinguished Professor, Rutgers University) and Steve Midgley (Operations Superintendent, JRSO), which reached 201 educators. The discussion spoke to the impressive technology available on the JR, the amazing and varied science that can be performed with the facility, how the science needs shape the technology development, and how the technology enables the science.

Milstein Science Series: Ocean Technology The Milstein Science Series has been a feature event of the museum for over eight years. On February 25, 2018, the series continued the tradition, highlighting the technology used to explore the ocean floor. IODP scientist Beth Orcutt presented her work as a microbial biogeochemist in the "Meet the Experts" mainstage program and interacted one-on-one with attendees afterwards. There was also a ship-to-shore broadcast from IODP Expedition 374 on the big screen, where over 7,000 attendees "visited" the JR.

Sun-Earth Day On March 24, 2018, USSSP participated in Sun-Earth Day at the museum. Visitors discovered how scientists onboard the *JOIDES Resolution* use microfossils to study past events in Earth's history as it relates to climate change. The display included hands-on activities and the chance to peer through a microscope to view microfossil specimens.

Conferences

NSTA The Education and Outreach department represented the USSSP-IODP program at the annual meeting of the National Science Teachers Association (NSTA) March 13-18, 2018 in Atlanta, Georgia. The USSSP staff was joined at the exhibit booth by recent Onboard Outreach Officers from Expeditions 371 and 376, and a recent School of Rock alumus. The staff also participated in a number of share-a-thon presentations providing information for informal educators and high school and middle school educators.


©AMNH/R. Mickens. Sun-Earth Day

Ocean Sciences Meeting Recent Onboard Outreach Officers and USSSP staff made several presentations at the bi-annual AGU/ASLO Ocean Sciences Meeting in Portland, OR held on February 11-16. Describing their experiences at sea—particularly connecting with shore-based audiences through the live events program—Kristen Weiss and Stephanie Sharuga enthusiastically represented the program. There was significant interest in upcoming opportunities to sail and participate in art/science collaborations onboard. USSSP staff also presented a poster on innovative at-sea experiences.

European Geosciences Union USSSP-IODP staff attended the 2018 EGU General Assembly held April 8-13 in Vienna, Austria. During the meeting, staff assisted at the joint IODP/ECORD/ICDP exhibit booth, answering questions from the conference attendees. Staff also made presentations and distributed educational material to some of the more than 80 teachers involved in the Geophysical Information for Teachers (GIFT) workshop, which included educators from Europe, the U.S., India and the Philippines. "Major Events that Shaped the Earth" was the theme of this year's EGU GIFT. In addition, a poster about overall U.S.-based education and outreach efforts was presented in a session about IODP education and outreach. A number of posters were also presented in several education sessions by former JR Education Officers, showcasing their use of IODP data in their classrooms over the years.

Ocean Discovery Lecture Series

The 2017-2018 Ocean Discovery Lecture Series wrapped up in May with the lecturers visiting a total of 47 venues around the country, reaching nearly 1,000 faculty members, graduate and undergraduate students, and general public attendees. In addition to giving a presentation at the host institution, the lecturers frequently spent additional days visiting with students and faculty members in informal settings for advice and mentoring.

Emily Brodsky, from the University of California, Santa Cruz, focused her talk on the 2011 Tohoku earthquake that resulted in the devastating tsunami that took more than 23,000 lives and inflicted massive damage along the northeast coast of Honshu. The JFAST project drilled into this fault zone just over a year after the event in an effort to understand the physical mechanisms of large slip during earthquakes.

Tim Collett, from the U.S. Geological Survey, spoke about the history and future of marine gas hydrate research. His talk highlighted IODP's great strides in understanding the geologic controls on the formation, occurrence, and stability of marine gas hydrates and the technologies needed to carry out this research.

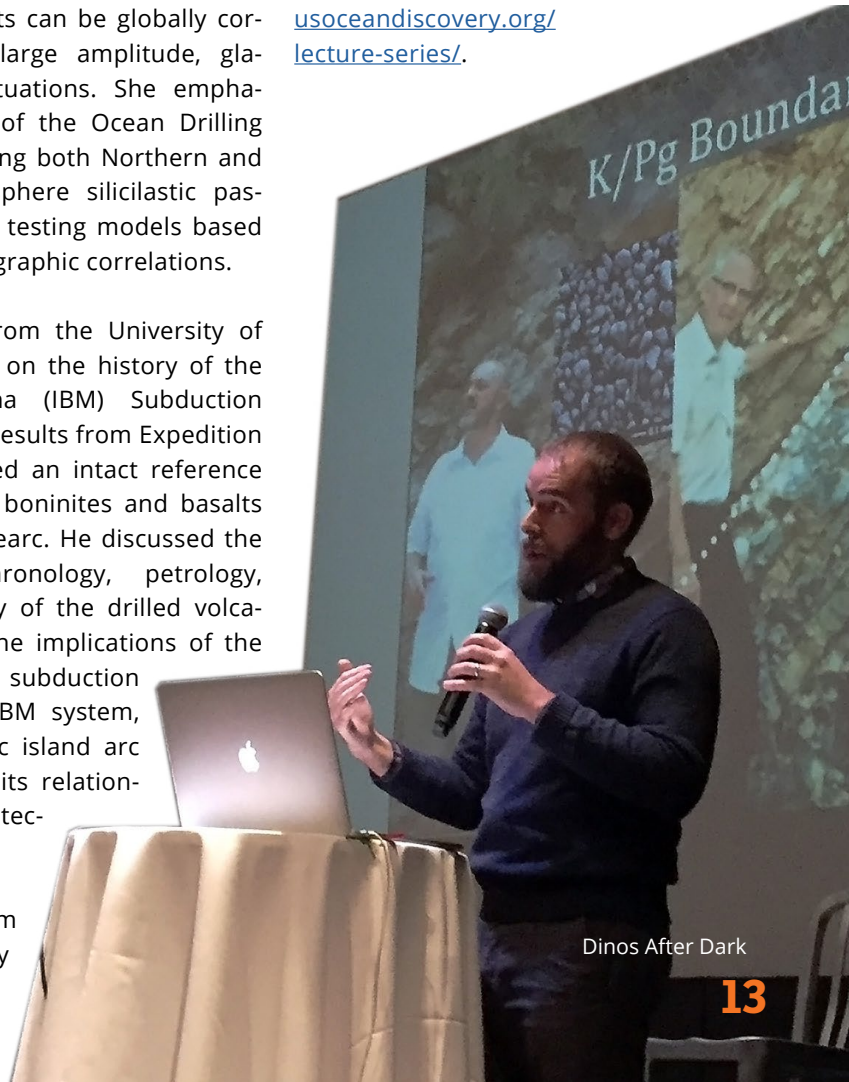
Cecilia McHugh, from Queens College CUNY, analyzed whether continental margin sediments can be globally correlated during large amplitude, glacio-eustatic fluctuations. She emphasized the work of the Ocean Drilling Program in drilling both Northern and Southern Hemisphere siliciclastic passive margins for testing models based on seismic stratigraphic correlations.

Mark Reagan, from the University of Iowa, presented on the history of the Izu-Bonin-Mariana (IBM) Subduction System and the results from Expedition 352, which drilled an intact reference section through boninites and basalts in the Bonin forearc. He discussed the geology, geochronology, petrology, and geochemisty of the drilled volcanic rocks, and the implications of the research on why subduction started in the IBM system, how this oceanic island arc developed, and its relationship to global tectonics.

Howie Scher, from the University of South Carolina, discussed the polar ice sheets through the Cenozoic using marine sediment records. Dr. Scher presented evidence that precursor glaciations preceded the widespread development of ice-sheets on Antarctica, in addition to new results from Expedition 342 (Newfoundland Drifts) that indicate an episode of glacial weathering on Greenland in the earliest Oligocene.

Joseph Stoner, from Oregon State University, detailed the geomagnetic insights and magnetostratigraphic opportunities provided through IODP drilling with results from Expedition 341 (Southern Alaska Margin).

The Ocean Discovery Lecture Series consistently receives positive feedback for its ability to bring distinguished IODP researchers to campuses and institutions that otherwise might not be able to afford them. For more information on the current or past series, or to find out how you can apply to host a lecturer for the future series, visit: http://usoceandiscovery.org/lecture-series/.



Dinos After Dark

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IODP CLSI@SEA Workshop Enables New Research on Subduction Zone Hazards by Leveraging Legacy Ocean Drilling Data

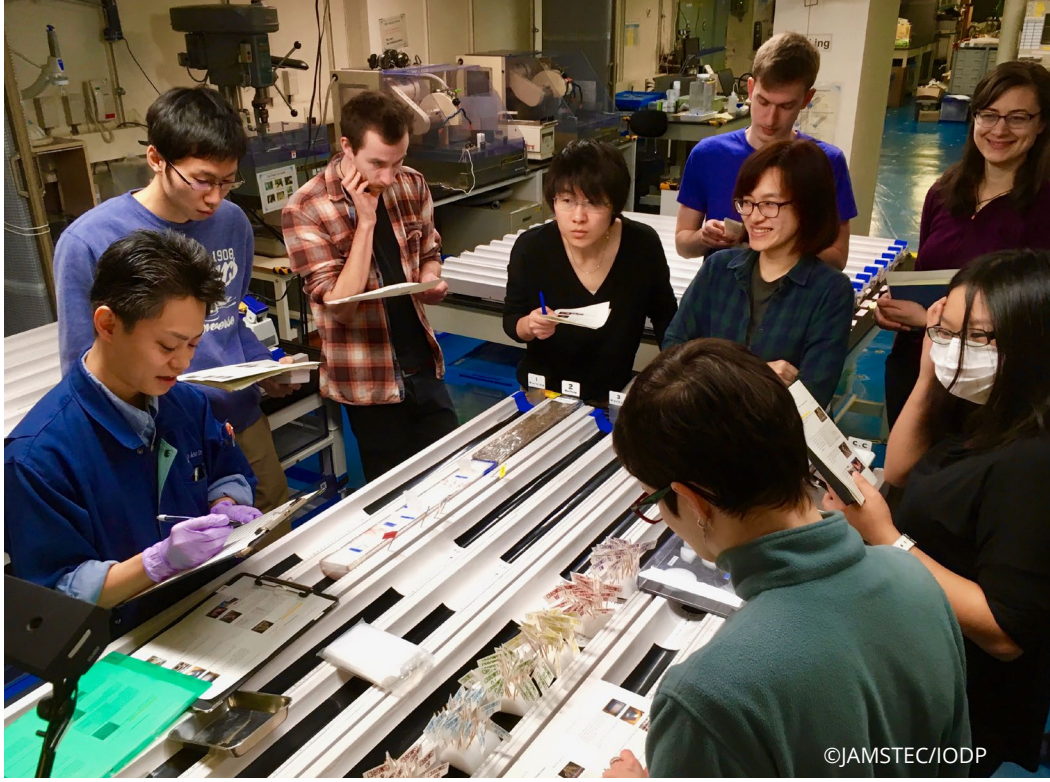
Christine Regalla, Gael Lymer, Rina Fukuchi, and the CLSI@Sea participants

The first Core-Log-Seismic Integration at Sea (CLSI@Sea) workshop, organized by the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) on board the IODP *D/V Chikyu*, brought together senior scientists and early career researchers in January and February 2018 to develop new, interdisciplinary approaches to use legacy ocean drilling, logging, and seismic data to address outstanding questions regarding the processes that lead to seismogenic and tsunamigenic slip in the shallow portion of subduction zones. Subduction plate boundaries are host to the world's largest magnitude earthquakes and can generate tsunami with catastrophic impacts on populated coastal regions, such as occurred in 2004 in Sumatra and 2011 in Northeast Japan. Recent recognition of seismic slip to the trench and documentation of shallow slow slip and tremor have motivated new deep-sea drilling investigations and real-time monitoring of the *in situ* physical and chemical properties of subduction zones. However, existing archives of cores and borehole log data from previous ocean drilling expeditions also provide a precious repository of data available to address new research questions with state-of-the-art analytical techniques.

The CLSI@Sea workshop focused on bringing together scientists with diverse backgrounds to integrate IODP data from four sites across the Nankai trench, previously visited as part of the Southwest Japan, Nankai Trough Seismogenic Zone Experiment (NanTroSEIZE). The workshop included 8 senior scientists serving as workshop mentors, along with 14 students and early career researchers, and 3 staff scientists, collectively representing 7 countries and 17 institutions. A central goal of CLSI@Sea was to connect these mentors and workshop participants, exchange knowledge, and collaborate to work on common scientific questions. This was enabled by a series of research seminars from mentors and presentations by workshop participants, which helped promote lively scientific discussions in a cordial, focused atmosphere. Teamwork between mentors, participants, and IODP staff fostered the efficient development of individual and collaborative research and publication plans, and highlighted the need for multi-disciplinary collaborations that integrate data across different spatiotemporal scales.

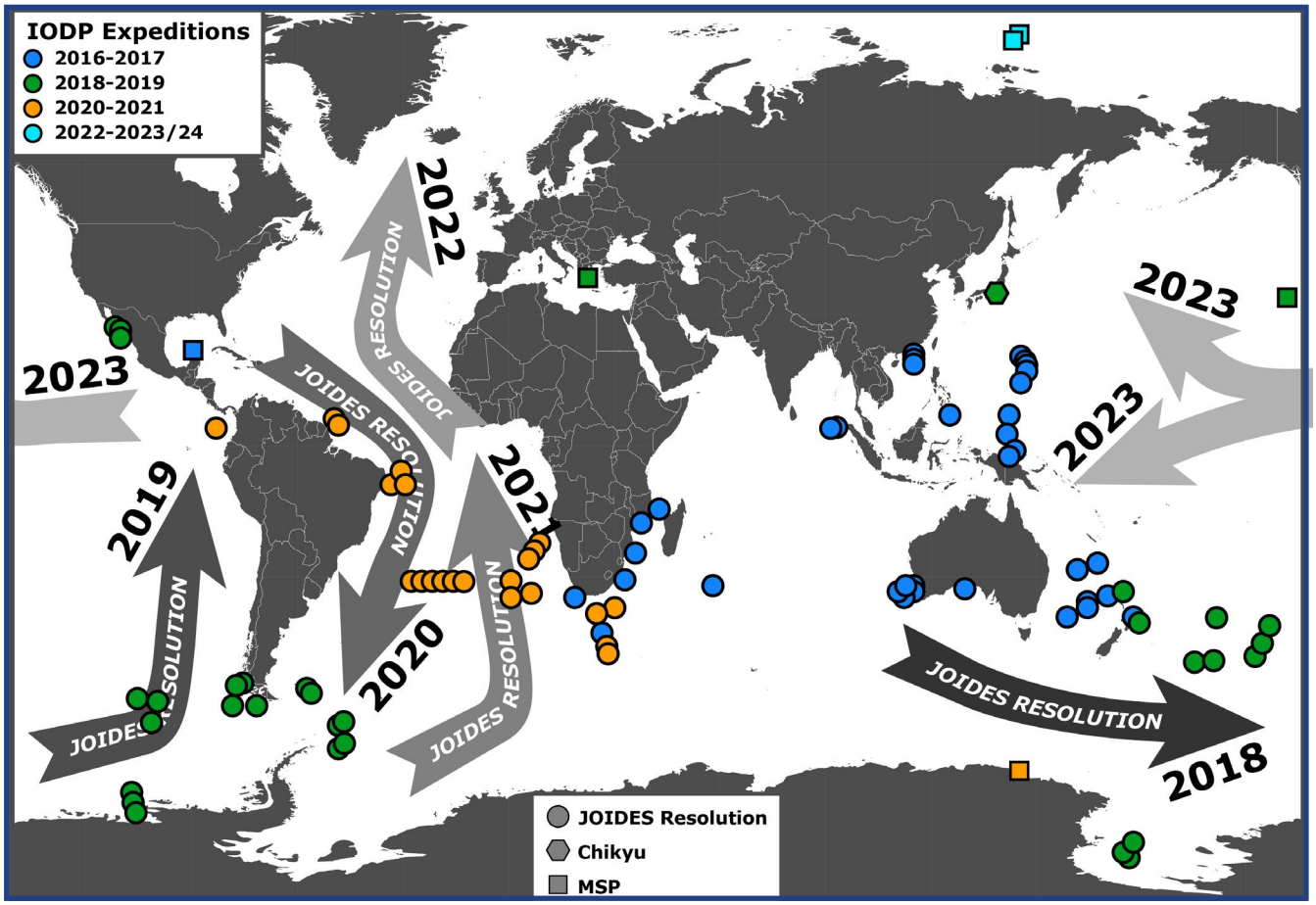
Three unique aspects of the workshop contributed to productive research and educational outcomes. First, the workshop was held on board the *Chikyu* concurrent with IODP Expedition 380, allowing participants to interact with expedition scientists installing a long-term borehole monitoring system (LTBMS) at the same sites where the workshop's

research was focused. This opportunity provided the potential to align workshop and borehole observatory goals. Second, expedition and site survey data from previous NanTroSEIZE expeditions across the Nankai Trough axis and deformation front were made available to workshop participants on the ship. Logging data, drilling parameters, and seismic data were loaded to ship servers, and well-preserved cores from across the prism toe were temporarily transferred from the Kochi Core Center to the Chikyu, enabling participants to perform new description, sampling, and analyses. Third, workshop participants were granted access to the drilling vessel laboratory facilities and software for their research while at sea. Participants received training from laboratory technicians and staff scientists, and were able to utilize ship time to produce new sample measurements and data analyses.



In addition to facilitating the development of individual research projects, the CLSI@Sea workshop led to a synthesis of data and formulation of key outstanding research questions that will be published as a summary report in the journal *Scientific Drilling*. Post-cruise meetings are being planned to enable continued international collaboration between workshop participants and research mentors and provide updates on post-workshop research progress. In summary, the remarkable productivity of this workshop demonstrated the research and educational value of organizing a CLSI@Sea program, with outcomes transportable to a variety of scientific disciplines and research areas.

The *JOIDES Resolution* Ship Track: From Summer 2016 and Beyond



Map modified with permission from the IODP-JRFB

2018 - 2021 IODP EXPEDITION SCHEDULE

Platform	#	Expedition	Dates	Ports
	**376**	Brothers Arc Flux	05/05/18 - 07/05/18	Auckland, New Zealand - Auckland, New Zealand
	**378**	South Pacific Paleogene Climate	10/14/18 - 12/14/18	Lyttelton, New Zealand - Papeete, Tahiti
	**358**	NanTroSEIZE: Plate Boundary Deep Riser 4	10/7/18 - 3/21/18	Shimizu, Japan - Shimizu, Japan
	**379**	Amundsen Sea West Antarctic Ice Sheet History	01/18/19 - 03/20/19	Punta Arenas, Chile - Punta Arenas, Chile
	**382**	Iceberg Alley and South Falkland Slope Ice and Ocean Dynamics	03/20/19 - 05/20	Punta Arenas, Chile - Punta Arenas, Chile
	**383**	Dynamics of Pacific Antarctic Circumpolar Current	05/20- 07/20	Punta Arenas, Chile - Valparaiso, Chile
	**385**	Guaymas Basin Tectonics and Biosphere	09/19 - 11/19	San Diego, California - San Diego, California
	**384**	Panama Basin Crustal Architecture (504B) & Engineering Testing	02/20 - 03/20	TBD
	**387**	Amazon Margin	04/20 - 05/20	TBD
	**388**	Equatorial Altantic Gateway	08/20 - 09/20	TBD
	**390**	South Atlantic Transect 1	10/20 - 11/20	TBD
	**391**	Walvis Ridge Hotspot	12/20 - 01/21	TBD
	**392**	Agulhas Plateau	02/21 - 03/21	TBD
	**393**	South Atlantic Transect 2	04/21 - 05/21	TBD

Chikyu
JOIDES Resolution