FALL 2016

# 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

**December**

**12-16** American Geophysical Union Fall Meeting (IODP Town Hall, 14 December)
San Francisco, CA USA

**January**

**10-12** Science Evaluation Panel
La Jolla, CA USA

**18-20** U.S. Advisory Committee for Scientific Ocean Drilling
Austin, TX USA

**23-25** USSSP Workshop: Demystifying the IODP Proposal Process for Early Career Scientists
Austin, TX USA

**March**

**6-10** ECORD Training Course 2017: Virtual Drillship Experience
Bremen, Germany

**8-9** ECORD Facility Board
Hannover, Germany

**15-16** *Chikyu* IODP Board
Kobe, Japan

**April**

**23-28** European Geophysical Union Meeting
Vienna, Austria

**May**

**2-3** Environmental Protection & Safety Panel
College Station, TX USA

**16-17** *JOIDES Resolution* Facility Board
Arlington, VA USA

**20-25** Japan Geophysical Union – American Geophysical Union Joint Meeting
Chiba, Japan

**22-23** IODP-ICDP Workshop: New England Freshwater Resources
Woods Hole, MA USA

*Letter From the USAC Chair*

# Denver II: A Critical Step to Renewal of the *JOIDES Resolution* Facility

Dear Colleagues,

As we begin to prepare for the American Geophysical Union (AGU), an annual milestone in our research lives, please reserve time to attend the International Ocean Discovery Program (IODP) Town Hall meeting. The day, Wednesday (December 14, 2016), is a change from previous years, and the hope is that the new day will limit conflicts with other events.

The focus of the Town Hall meeting is renewal of funding for the *JOIDES Resolution*, the U.S. riserless drilling vessel. Recall that the program is approved through 2023, but U.S. funding for the facility must be requested to continue drilling for the second five-year period of the International Ocean Discovery Program. Support for the request must come from you, the IODP community.

All users of the JR facility, from all IODP member nations, are asked to respond to a short survey on how successful the JR has been in fulfilling the IODP Science Plan 2013-2023. All comments and concerns are welcome, and are critical in demonstrating need. The survey will also focus on your experiences in the first five years. It will kick off at the Town Hall and close in spring of 2017.

Survey results will provide the foundation for a U.S. community workshop, Denver II, to be held in September of 2017. The primary goal of Denver II is to provide the National Science Foundation (NSF) with the information needed for the request to U.S. government agencies for renewal. Denver II will be led by a steering committee tasked with summarizing the community response and preparing a report for the NSF. The Denver II effort should not be confused with the IODP New Ventures in Exploring Scientific Targets (INVEST) conference in 2009, which drew from massive international participation and focused on development of the IODP science plan, or Denver I, a U.S. initiative to prioritize implementation of the drilling efforts.

While at AGU, stop by the United States Science Support Program and other IODP booths to learn more about upcoming opportunities and, as always, share your concerns.

Please make the time to attend the Town Hall, and to take the survey. Your input really is critical.

Sincerely,

Beth Christensen
Chair, U.S. Advisory
Committee for Scientific
Ocean Drilling (USAC)

# IODP Expedition 370 Explores the Temperature Limit of Deep Subseafloor Life in the Nankai Trough off Muroto, Japan

## From the *DV Chikyu*

**Verena Heuer, Fumio Inagaki, Yuki Morono, and Expedition 370 Scientists**

In the course of nearly 50 years of scientific ocean drilling, microbial communities have been found everywhere, even in sediments below the nutrient-poor ocean gyres, in basement rocks, and at depths of ~2.5 km. Presumably, the subseafloor contains as many microbial cells as all the water in the global oceans. Its exact size is still a matter of debate. So far, we know neither which factors pose ultimate limits to life in the subseafloor, nor where the bottom of the deep biosphere is located. By addressing these challenging questions, International Ocean Discovery Program (IODP) aims to shed light on one of the largest continuous ecosystems on Earth.

Possibly, life ceases at a certain depth where sediments and rocks become too hot because of geothermal heating. But what is this depth exactly? How do the composition, activity and size of microbial communities change with increasing temperatures? And how does temperature influence the habitat and biosphere-geosphere interactions? Expedition 370 "T-Limit" aims to retrieve samples and data that will help to answer these questions.

On September 13, 2016, *DV Chikyu* left Shimizu port in Japan in order to establish Site C0023 in the vicinity of ODP Sites 808 and 1174 in the Nankai Trough. The site is located ~125 km offshore the Cape Muroto of Shikoku Island, and the water depth is 4.8 km. The site is situated in the protothrust zone of the accretionary prism where the subseafloor heat flow is particularly high. The geothermal gradient is about four times steeper than elsewhere, but still gradual enough for the establishment of distinct, thick depth horizons (>100 m) with suitable conditions for psychrophilic (optimal growth temperature range: <20°C), mesophilic (20-43°C), thermophilic (43-80°C) and hyperthermophilic (>80°C) microorganisms. The latter have been found to grow in hydrothermal vent fluids at temperatures up to ~120°C. In subseafloor environments, the temperature limit of life is expected to be much lower and a lack of sufficient energy to support cell repair mechanisms might be the reason for it. At Site 1174, a decreasing trend of microbial cell concentrations was observed with increasing depth down to 600 m below seafloor (~80°C; Figure 1); however, the bottom of the deep biosphere remains to be explored.

In order to investigate the putative biotic-abiotic transition zone, Expedition 370 aims to enter up to ~130°C sediments at 1.2 km below the seafloor. Since the *JOIDES Resolution* visited Site 1174 for ODP Leg 190 almost 16 years ago, analytical methods have advanced tremendously, particularly in cell quantification, molecular microbiology, and molecular and isotopic geochemical techniques. For example, during ODP Leg 190, a shipboard microbiologist counted the number of microbial cells using microscopy on board, for which the minimal quantification limit was ~60,000 cells per $cm^3$. Using automated fluorescent image-based counting techniques, super-clean room technology, and strict contamination control, Expedition 370 scientists are now prepared to detect cell concentrations as low as a few cells per $cm^3$. The sensitivity of other microbiological and geochemical techniques has advanced in a similar fashion, and the multidisciplinary team of scientists involved in Expedition 370 is equipped with an innovative toolbox for the interrogation of microbial life and geobiological processes at the biotic-abiotic transition zone.

For the successful application of such technologies, quality assessment and quality control (QA/QC) of core samples is crucial. Since Site C0023 is located in close vicinity to the Kochi Core Center (KCC), where super-clean room facilities

and first class analytical equipment are available, some important core samples are transferred via helicopter from *Chikyu* to KCC, where the shore-based group of expedition scientists takes sub-samples for in-depth microbiological investigations and conducts time- and oxygen-sensitive analyses with cutting-edge technology. Understanding the limits of deep life and the biosphere through the Expedition 370 T-Limit project will be fostered with support of the Deep Carbon Observatory (DCO).

In order to investigate the impact of temperature on life in the deep subseafloor biosphere, information on *in situ* temperatures is very important. For the generation of robust downhole temperature data, coring operations at Site C0023 will be followed by the installation of a temperature sensor string. In this manner, Expedition 370 will also help to better characterize the overall hydrothermal regime of the Nankai Trough subduction zone.

**References Cited**

Shipboard Scientific Party, 2001. Site 1174. *In* Moore, G.F., Taira, A., Klaus, A., et al., *Proc ODP, Init Repts*, 190: College Station, TX (Ocean Drilling Program), 1-149.

More information:
http://bit.ly/1rSKlVc;
http://bit.ly/2gNhRrX

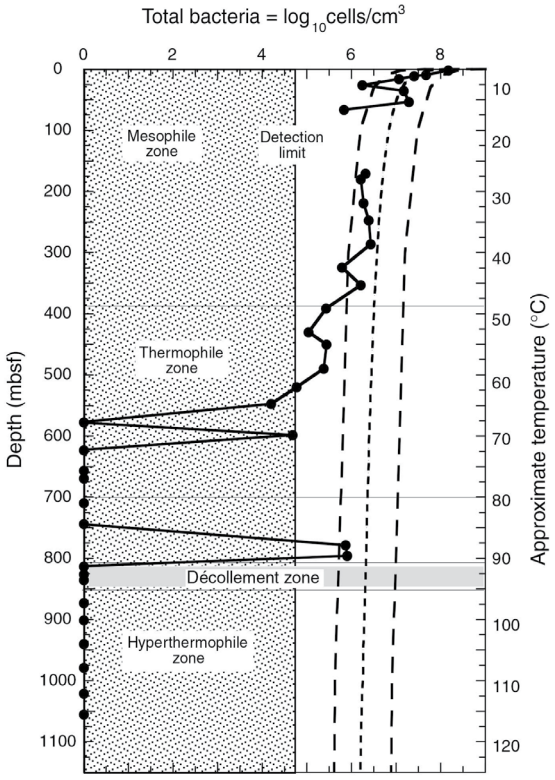
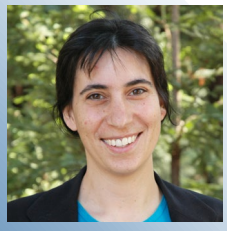



Figure 1. Depth and temperature distribution of total bacterial populations in sediment samples from Holes 1174A and 1174B. For full figure caption, see Shipboard Scientific Party (2001).

# 2017-18 Ocean Discovery Lecture Series

For over twenty years, the Ocean Discovery Lecture Series (formerly the Distinguished Lecture Series) has brought the exciting results and discoveries of scientific ocean drilling to academic research institutions and informal learning centers. The roster of 2017-18 Ocean Discovery Lecturers will focus on topics such as climate change, tectonics, gas hydrates, paleomagnetics and more.



## Emily Brodsky
**University of California Santa Cruz**
*The Stress on a Fault During an Earthquake*

## Mark Reagan
**University of Iowa**
*The early history of the Izu-Bonin-Mariana subduction system as revealed by diving and drilling*

## Tim Collett
**US Geological Survey, Denver**
*From Research to Discovery – The History and Future of Marine Gas Hydrate Research*

## Howie Scher
**University of South Carolina**
*Chasing ice through space and time – Reconstructing polar ice sheets through the Cenozoic using the marine sediment record*

## Cecilia M. HcHugh
**Queens College, CUNY and the Graduate Center of CUNY**
*Pleistocene seismic sequences may result from eustasy but can they be used for global correlations? New insights from the Canterbury Basin, New Zealand"*

## Joseph Stoner
**Oregon State University**
*Reversals, excursions, past intensity & secular variations: Insights into the drivers of geomagnetic change & new magneto-stratigraphic opportunities through IODP drilling (New results from Southern Alaska Margin IODP Exp 341)*

# School of Rock aboard the *JOIDES Resolution*

## by George Hademenos, Physics Teacher, Richardson High School, TX

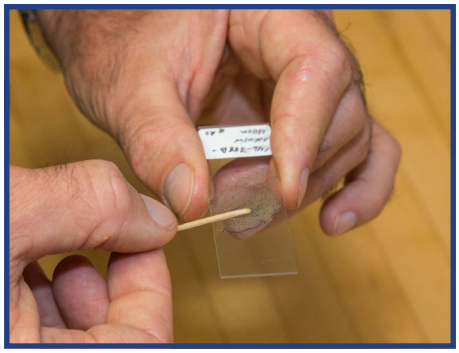
This summer, I officially became an alumnus of the School of Rock (SOR) after spending a week aboard the *JOIDES Resolution* (JR) docked in Cape Town, South Africa. This was truly one of the most exceptional professional development opportunities I have taken part in during my 15 years of teaching physics. How exceptional? Let me explain: Top Five Reasons for Being a Proud Alumnus of the School of Rock.

**1. Opportunity to learn about the science conducted aboard the JR.**

A research vessel 470 feet in length with 8.8 miles of pipe on board, the JR uses a 147-foot derrick structure to propel increments of pipe through a 22-foot diameter hole in the bottom of the ship, and into ocean depths with the goal of acquiring core samples below the ocean floor. The elements of STEM involved in all aspects of the operations, data collection and core analysis conducted aboard the JR provides teachers with a wide spectrum of opportunities and possibilities to enlighten and inspire the next generation of scientists.

**2. Faculty were masters of their trade.**

The geoscience content and hands-on laboratory techniques were presented by two very knowledgeable faculty members: Dr. Larry Krissek from Ohio State University and Dr. Sandy Turner from University of California at Riverside. An example of a hands-on activity included learning the techniques needed to collect and properly wash a sediment sample from a core, how to take a prepared sample and create a smear slide, and a microscope activity involving prepared slides of protists.



**3. Field excursions were beyond amazing … and informative, too.**

On Day 3 of the workshop, our itinerary included several hikes exploring the geology of Cape Town, led by two local geology experts from the University of Cape Town: John Compton and John Rogers. The day began with a hike from Three Anchor Bay to Sea Point Contact (the end point of Charles Darwin's journey on the *Beagle* in 1836), followed by a hike to Signal Hill and Tafelberg Road (providing a breathtaking view of the South African landscape), and ending with a hike to one of the New Seven Wonders of the World – Table Mountain.

**4. Content was teacher-focused and classroom-relevant.**

The underlying objective of any teacher professional development opportunity is not necessarily content-driven (e.g., "How much new information will I learn?") but rather application-focused ("How can I engage my students in the classroom with this information utilizing a hands-on, inquiry-based approach?"). One activity that embodied the challenges in ocean drilling involved a straw and multi-layered cake. Teachers could easily conceptualize the objectives and challenges of the scientific initiatives conducted aboard the JR and then consume the core samples upon completion of the activity. Who knew that geology could be so tasty too?

**5. Established a network of colleagues and life-long friends.**

The SOR is not an exclusive opportunity for geology teachers but rather for all science teachers looking for ways to integrate geology into their curricula. In fact, the 2016 SOR class of 16 participants was very diverse, consisting of teachers both novice and veteran, formal and informal, coming from the United States, Europe and Africa. We have a group Facebook page and look forward to remaining connected and exchanging ideas for years to come.

# Expedition 361 Tracks the Agulhas Current System and Southern African Climate History


## Sidney R Hemming, Ian R Hall, Leah LeVay, and Expedition 361 Scientists


The ocean around Southern Africa is a key location in which to examine connections between the greater Agulhas Current system and past global ocean circulation and climate variability as well as its links to human evolution. Variations in Agulhas warm water transport along the southeast African continental margin foster exchanges of heat and moisture with the atmosphere that influence southern Africa regional rainfall. The Southern Ocean is also an important location to study the Last Glacial Maximum bottom water temperature-salinity profile. Expedition 361 drilled six sites in the southwest Indian Ocean and South Atlantic in February and March 2016 (Figure 1).

Expedition 361 follows a number of research cruises in the Indian Ocean that have been targeting complementary aspects of paleoceanography, and collectively these cruises should yield an extraordinary improvement in our understanding of the ocean-climate system through the Plio-Pleistocene. The expedition made major strides toward fulfilling its science objectives, tapping exceptionally intact archives back to the late Miocene at four of the sites. The sedimentological characteristics range from highly terrigenous near the Zambezi (Site U1477) and Limpopo (U1478) Rivers and in the Natal Valley (U1474) to carbonate rich in the northern Mozambique Channel (U1476), the Agulhas Plateau (U1475), and the Cape Basin (U1479). Nannofossils and foraminifers provided well-developed shipboard biostratigraphies that are in accord with paleomagnetic and diatom stratigraphies (Figure 2, next page). All of the studied fossil groups show a mixture of tropical, subtropical convergence, and temperate or subpolar species in the southernmost sites, and changes through time in these assemblages will provide important constraints on the dynamics of the Agulhas system. The records sampled on Ex-

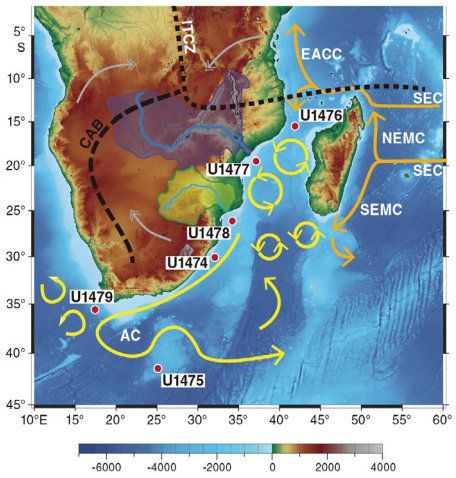



Figure 1. Expedition 361 site locations. Yellow and orange arrows = main surface ocean currents, gray arrows = main pathways of moisture supply to the African continent from the northwest Atlantic (via Congo) and the northwest and southwest Indian Ocean, dashed lines = approximate position of the Intertropical Convergence Zone (ITCZ) and Congo Air Boundary (CAB) (adapted from Reason et al., 2006), purple shaded area = Zambezi Catchment, green shaded area = Limpopo Catchment. AC = Agulhas Current, SEC= South Equatorial Current, SEMC = South East Madagascar Current, NEMC = North East Madagascar Current, EACC = East Africa Coastal Current. From Hall et al. (2016).

**Expedition 361 Science Party**

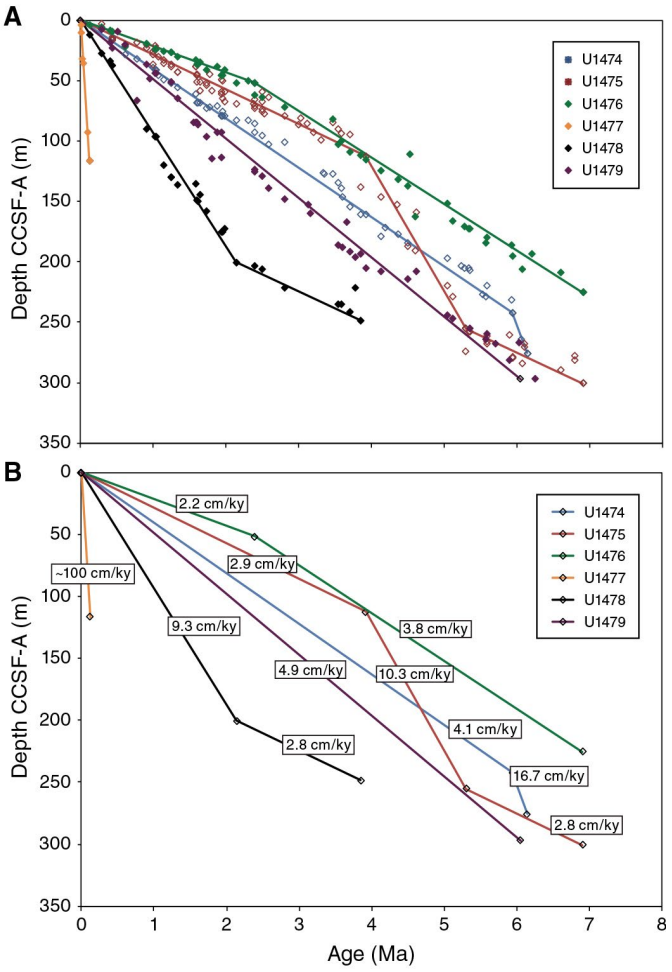



Figure 2. Age-depth relationships, Sites U1474–U1479. A. Time estimates based on a mixture of major planktonic foraminifer, calcareous nannoplankton, diatom, and paleomagnetic datums. B. Implied sedimentation rates. From Hall et al. (2016).

pedition 361 hold significant potential to investigate the connections between southern African terrestrial climates and southeast Indian Ocean heat budgets, and notably the links to the cultural evolution of early modern humans.

**Site U1474** is located in the headwaters of the fully constituted Agulhas Current and provides the opportunity for high-resolution climate reconstructions through the past 6.2 million years.

**Site U1475** is located in the Agulhas Retroflection and near the sub-tropical front, and can yield records of connections between the Agulhas Current system and productivity and deepwater circulation through the last 7 million years.

**Site U1476** is located on the Davie Ridge at the northern end of the Mozambique Channel in a region with low productivity and with equilibrium ocean-atmosphere $CO_2$. Its apparently cyclic deposits hold significant potential to investigate the connections between southern African terrestrial climates and southeast Indian Ocean heat budgets, and thermocline and deepwater variability that will likely lead to insights into the development of the Indonesian Throughflow and aridification of east Africa as well as $pCO_2$ over the past 6.9 million years.

**Site U1477** is located near the Zambezi River and has an average sediment accumulation rate of ~1 m/ky. This extreme accumulation rate was a surprise and led to recovering only ~120 kyrs of sediment record from the Zambezi catchment, rather than the expected 2 million year record; instead, it can yield extremely high-resolution reconstructions of terrestrial climate and thermocline characteristics during the last glacial cycle.

**Site U1478** is located near the Limpopo River and is ideally situated for climate reconstructions of faunal, biogeochemical, and terrigenous tracers that are characteristic of the upper reaches of the Agulhas Current through the past 4 million years.

**Site U1479** is located in the Cape Basin in the pathway of the so called "Agulhas Leakage," allowing temporal comparisons to be made between changes in the export of salt between the Indian and Atlantic Oceans with deepwater circulation variability through the past 7 million years. The Agulhas Leakage is thought to be a significant component of the global themohaline circulation by contributing to mode changes and variability of the Atlantic Meridional Overturning Circulation (AMOC) and thus climate variability in the North Atlantic region and beyond.

The records obtained from Expedition 361 will allow us to document how the Agulhas Current has varied with changing climates of the Plio-Pleistocene, in association with transient to long-term changes in tectonics, high-latitude climates, tropical heat budgets, and the monsoon system. In addition to connecting Agulhas Current variability with southern Africa rainfall patterns and river runoff, they will provide insights into the dynamics of the Indian-Atlantic gateway circulation with changing wind fields and migrating ocean fronts, as well as connections between Agulhas Leakage and ensuing buoyancy transfer and shifts of the AMOC during major ocean and climate reorganizations. The pore water acquired for the ancillary project letter will provide temperature, salinity, and density structure of the last glacial maximum ocean with interstitial water samples, collected at Sites U1474 (3045 m water depth), U1475 (2669 m), U1476 (2165 m), and U1478 (488 m).

**References Cited**

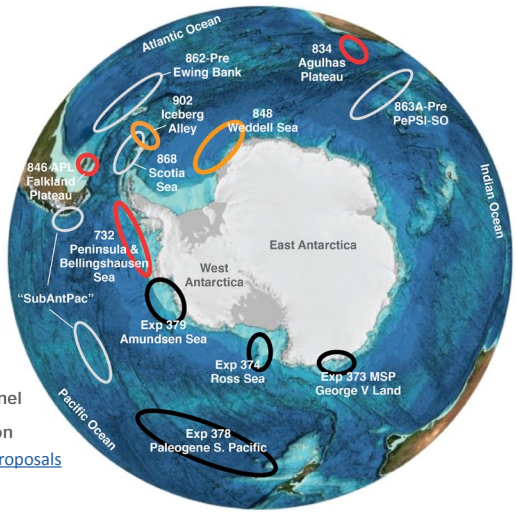
Hall, I.R., Hemming, S.R., LeVay, L.J., and the Expedition 361 Scientists, 2016. *Expedition 361 Preliminary Report: South African Climates (Agulhas LGM Density Profile).* International Ocean Discovery Program.

# Workshop Report: Antarctica's Cenozoic Ice and Climate History, New Science, and New Challenges of Drilling in Antarctic Waters

**Trevor Williams, Denise Kulhanek, Amelia Shevenell, David Harwood, Sean Gulick, Rob McKay, Karsten Gohl, Jim Channell, Rob Larter, and Laura De Santis**

Antarctic and Southern Ocean marine sediments contain records of ice sheet dynamics and warm climates of the past. Understanding underlying processes, thresholds, and magnitudes of previous ice retreat and collapse in a variety of locations, when global temperatures and atmospheric $CO_2$ levels were higher than today, is essential to constrain numerical models and improve predictions of future sea-level rise. These scientific objectives are highlighted in the Climate and Ocean Change Challenges 1 and 2 of the 2013-2023 International Ocean Discovery Program (IODP) Science Plan. At the time of the workshop, several proposals to collect Antarctic sediment records were in the IODP review system, but had not yet been scheduled for drilling. This workshop built on a broad effort to develop Antarctic margin drilling proposals led since 2009 by the Past Antarctic Ice Sheet Dynamics (PAIS) research program of the Scientific Committee on Antarctic Research (SCAR).

The workshop was held at Texas A&M University on May 9-11, 2016, and brought together 84 senior, mid and early career Antarctic marine geologists and other experts to: (1) gain an overview of the current proposals and what IODP drilling can bring to our understanding of Antarctic ice sheet retreat (and hence sea level rise) under warm climates; (2) review sea ice and weather monitoring and forecasting products that can be used to plan drilling expeditions and make at-sea operational decisions; and (3) examine existing sediment cores from the Gulf Coast Repository that have revealed Antarctica's past glaciological history. Outcomes of the workshop included the following:




**Antarctic and Southern Ocean drilling proposals in the IODP review system. Status, July 2016:**

- Scheduled
- at Facility Board
- at Science Evaluation Panel
- Pre-proposal or in revision

www.iodp.org/proposals/active-proposals

**(1)** A plan submitted to the *JOIDES Resolution* Facility Board (JRFB) describing a portfolio of West Antarctic margin drill sites, based on IODP proposals 751 (Ross Sea), 839 (Amundsen Sea), and 732 (Antarctic Peninsula and Bellingshausen Sea). The West Antarctic Ice Sheet (WAIS) is particularly susceptible to retreat because much of it is grounded below sea level. The portfolio's objectives are to: (a) reconstruct the Neogene-Quaternary orbital-scale dynamics of the WAIS; (b) identify drivers of ice instability and their thresholds, especially of ocean forcing, for past WAIS retreat; and (c) assess relationships between the Antarctic cryosphere, ocean circulation, and global climate. These objectives are critical for improving paleo-calibrated model-ensemble simulations of Antarctica's future response to business-as-usual greenhouse gas emissions, which currently estimate ~0.6 m to ~1 m of sea-level rise by the end of this century.

The range of uncertainty is due to assumptions about the sensitivity of Antarctica's ice sheets to warm Pliocene conditions. At the May 2016 JRFB meeting, the Ross Sea and Amundsen Sea proposals were scheduled for drilling as Expedition 374 (2018) and Expedition 379 (2019), joining the planned George V Land MSP Expedition 373 (see Figure).

**(2)** Sea ice is an operational hazard for Antarctic drilling. However, imagery from optical and radar satellite instruments has improved significantly over the last 10 years and can be used to show daily extents of sea ice and typical ice evolution through the drilling season, which allows best planning of dates, ship tracks, and drill sites. Workshop presentations showed examples of sea ice and weather data, including their use at sea on the *RV N.B. Palmer* and *RV Polarstern*. Global and Antarctic regional weather forecasts and archives of daily weather data can be used to anticipate weather conditions both before an expedition and for operational planning during an expedition. Most of these products are freely available online from NASA, the European Space Agency, the US Naval Research Laboratory, and other agencies.

**(3)** During the workshop, classic Deep Sea Drilling Project, Ocean Drilling Program, and IODP Antarctic sediment cores were laid out in the core repository so that participants could examine the sediments on which much of the scientific knowledge of Antarctic climate evolution is based. Core examination also enabled conversations between early career scientists and more senior scientists (many of whom did the original work on the cores), transmitting expertise, stimulating new ideas, and encouraging the early career scientists to join the Antarctic drilling community by applying for future IODP expeditions and writing new drilling proposals.

In summary, the workshop emphasized the value of a coordinated approach to Antarctic scientific drilling to recover the requisite ice-proximal geological data to understand cryosphere evolution and help models predict the rate and magnitude of sea-level rise that would result from Antarctic ice sheet retreat.

For more information about the Antarctic Ice and Climate History Workshop, visit the workshop webpage at http://usoceandiscovery.org/workshop-antarctic-ice-climate/.

## Onshore-Offshore Drilling and Sampling to Understand Freshwater Resources along the New England Continental Shelf: An IODP-ICDP Workshop

**May 22-23, 2017, Woods Hole, MA USA**

To understand the dynamics of onshore-offshore hydrologic systems, this workshop will focus on the coupling between glacial dynamics, sea-level variations, and groundwater flow for the U.S. Atlantic continental shelf.

Workshop Goals: (1) Develop measurement plans for geology, geophysics, geochemistry, and microbiology across the shoreline and shelf; (2) Prioritize onshore and offshore operations and depths; and (3) Formulate specific plans for pursuing external funds.

Application deadline: February 17, 2017
For details about participation, visit
http://usoceandiscovery.org/workshop-ne-freshwater-resources

Questions? Contact Brandon Dugan (dugan@mines.edu)

IODP INTERNATIONAL OCEAN DISCOVERY PROGRAM U.S. SCIENCE SUPPORT PROGRAM icdp

# Education and Outreach from the Crater of Doom

**by Kevin Kurtz**

Dinosaurs. Asteroids. Mass extinctions. Children's authors. Expedition 364: Chicxulub K-Pg Impact Crater had it all.

For two months during the spring of 2016, Expedition 364 scientists went to the Gulf of Mexico to drill into the Chicxulub Crater for the first time ever from sea. Since this expedition promised to help us learn more about the asteroid impact that 66 million years ago wiped out 75% of species on Earth, including the non-avian dinosaurs, it has drawn attention from news outlets around the world.

The Chicxulub Crater drilling site was located in waters that were too shallow for the *JOIDES Resolution* (JR) or the *Chikyu* to drill, so the drilling was conducted on a mission-specific platform that was operated by the European Consortium for Ocean Research Drilling (ECORD). The expedition occurred on the modified *Liftboat Myrtle*. During two months of drilling, it was able to drill to a depth of 1334.69 meters below sea level and recover 839.55 meters of core from the crater (which was actually 100% recovery, as they were not trying to recover anything during the first 500 meters of drilling).

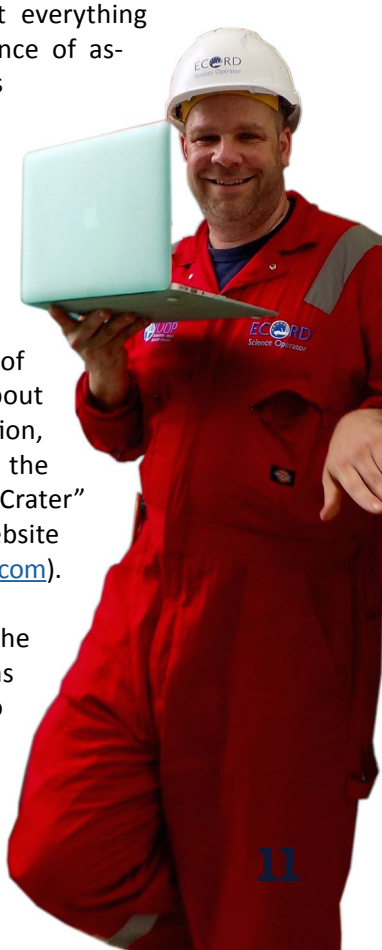
Though the *Liftboat Myrtle* was set up to drill, it was not equipped to do all of the necessary core description. Thus, this phase of the expedition had to wait until the fall. First the cores were shipped to the Bremen Core Repository in Germany. Then on September 21st, 2016, thirty-one scientists and a large support team came to Bremen to spend a month describing and sampling the cores.

I joined the expedition to do outreach and education during both the offshore and onshore phases. I was onboard the *Liftboat Myrtle* for a few days in early May and then came to the University of Bremen with the science party for two weeks in late September and early October.

I am a children's author and science educator who lives in Rochester, New York. I have been involved with International Ocean Discovery Program (IODP) outreach and education since 2009, when I was one of the educators on the JR for that year's School of Rock workshop. Since then, I have been involved with many IODP outreach projects, including writing two children's e-books about IODP science; one, titled *Uncovering Earth's Secrets*, about the JR and the other, titled *Where Wild Microbes Grow*, about IODP scientists discovering life in the seafloor. [Both can be downloaded for free at http://joidesresolution.org/node/2998]

My job during both the offshore and onshore phase of the expedition was to observe and learn from the Chicxulub K-Pg Impact Crater scientists and then share what I learned with students and the general public. One of the main ways I did this was by writing a series of posts for both the JR website (http://joidesresolution.org/blog), and ECORD's blog for Expedition 364 (http://bit.ly/1Ykz7DF).

I wrote about everything from the science of asteroid impacts to comparing expeditions on the JR with expeditions on a mission-specific platform (find a full list of my posts about the expedition, with links, on the "Dinosaur Crater" page of my website www.kevkurtz.com).



Thanks to the Internet, I was also able to do a series of live video events with school

groups both while I was on the *Liftboat Myrtle* and at the University of Bremen labs. Using a laptop and the web-based application Zoom (similar to Skype), I was able to give students brief tours of the ship and some of the labs and other spaces where the Chicxulub scientists were working. Students were then able to ask questions and hear the scientists' answers. I was able to do ten of these programs on the *Liftboat Myrtle* and twenty-six programs at the University of Bremen and reached over 1,900 students from ages 7 to 21 years old, who were very excited to be able to interact with scientists while the science was happening. (Also the dinosaur and asteroid impact connection definitely added to the coolness factor.)

The Chicxulub K-Pg Impact Crater expedition was an amazing experience. I am very grateful to have had the opportunity to see firsthand cores that provide evidence of one of the most cataclysmic events in Earth's history while also observing the process that allows us to gain new scientific knowledge. It also was a true joy working with such a diverse group of enthusiastic, creative, and knowledgeable people. I look forward to sharing my experience of the Chicxulub K-Pg Impact Crater expedition with both kids and adults for many years to come.

*"I am very grateful to have had the opportunity to see firsthand cores that provide evidence of one of the most cataclysmic events in Earth's history while also observing the process that allows us to gain new scientific knowledge."*

## IODP Innovators

# Bill Crawford

*What is your role on the* JOIDES Resolution*?*

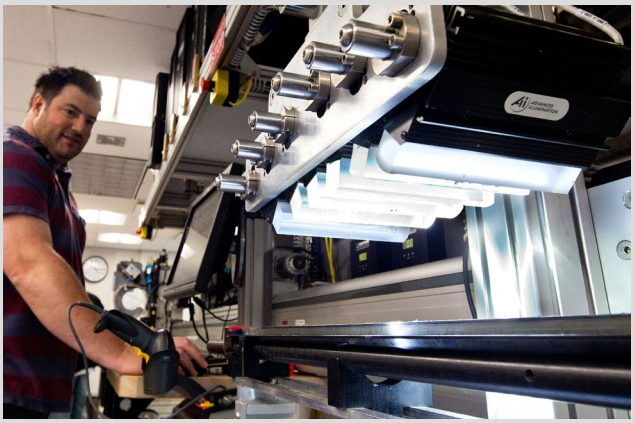
They call me an "imaging specialist." I've always called myself a photographer. I got a degree in photography in 1976 and it was something I've wanted to do all my life. I do still photos that help record the history of the mission. I also do special requests from the scientists, who may want me to take a particular piece of core and photograph it, using different lighting techniques to enhance the features which allows them to better describe it.

*How does imaging the core help scientists describe it better than looking at the actual sample?*

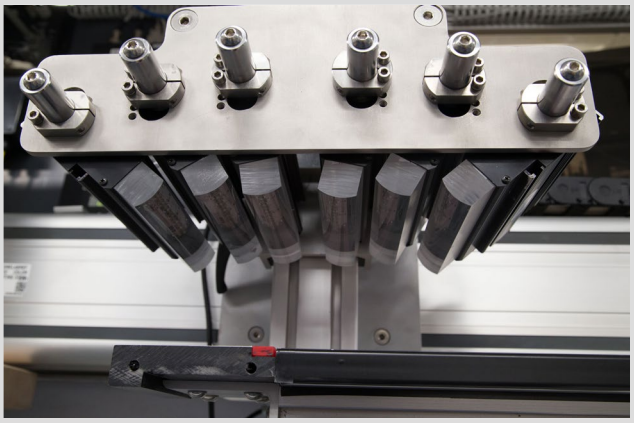
You can only tell the shape of an object by the light that is reflected from it. So we can somewhat change the shape of things by the light, how we present the light to the object. The lighting from the scanner is straight down and shadowless. I feel that if you really want to see the shape of something, you've got to have the shadows to have that texture.

*How did you get involved with the International Ocean Discovery Program (IODP)?*

I had a studio for about 24 years. Photographers are horrible business people and although I was able to have a business for 24 years, it came to a crashing end. It just so happens that during that tremendous time of stress in my life, this other door opened and I was able to get this job.



*Section Half Image Logger (SHIL)*



*Array of LED Lights on the SHIL*

*How many years have you been with the program?*

I joined in April of 2004.

*Can you talk about how imaging technology on the JR has changed in that time, and how it's influenced the science?*

Back in the day we had a dark room and E-6 (slide) processing. We had the ability to do black-and-white film processing and black-and-white printing. To record those images for the archive half, we put all of the sections of one core on a table and raised them up off the floor with a lift system, and in the ceiling was a view camera which was loaded to shoot 4 x 5 inch transparencies.

*There was actually a darkroom on the ship?*

You bet. Then we of course had the refit of the ship in 2007-2009. We did away with the wet chemistry and we went to all digital. Now, we were lucky that the digital technology had matured to the point where we could begin to use it. How do you take a digital camera and record to the clarity of that beautiful 4 x 5 sheet film? You know that's a pretty tough thing to do. I wasn't involved in this at the beginning of the wet chemistry era, I was involved with it at the end, but IODP began the task of designing a scanner to do the recording of each of those archive core sections. The scanner uses a "Line Scan Camera," and it's very different from the camera that you normally use, even professionally. Instead of having a postage stamp-looking sensor array of pixels, the Line Scan Camera uses only one line of pixels. The system builds the image by stacking this one line of pixels side by side as the camera travels down the length of the core. I don't have the number that represents how tiny that thing is, but it's one line of pixels about twenty five hundred across. And this camera at full resolution renders the image at 425 pixels per inch at one hundred percent of original size. Each core section 150 cm long will be rendered in a file size of 160 MB. You place these seven or eight sections side by side and the scanner easily far exceeds the resolution of the sheet film. A typical expedition will gather 500 GB of images just from this scanner alone.

Several technologies came together to make this work. We found some LED lights that were in a long strip that had a lens on the front of them and it produced a beam five millimeters across by a hundred millimeters long. Unlike halogen lights, you can change the power of LEDs up or down to get a certain luminance and it doesn't change the color temperature. That's really important to what I was doing. My job was to ensure that as you go deeper in the core, there was no falloff of light. The lighting task when dealing with the relatively flat and even sediment cores is not a huge problem. The challenge is illuminating evenly the broken bits and crevasses which are found when we harvest hard rock samples. The solution came in the form of an array of six lights with the outside pair lighting the uppermost surface, the middle pair illuminating to about 15 mm below the surface, and the center pair bathing the bottom of the core with the correct amount of light. Each of these beams has a center. I was able to feather these together or paint what I needed with the different strokes of light at the different density to paint the whole core from top to bottom. And the reason I was able to do that is because I was only dealing with one line of pixels and it created a masking device. I was only looking at one line of pixels so what was happening outside of that didn't matter. If you had tried this crazy lighting with any kind of camera but what I used, if you'd tried crazy lighting with any kind of luminance other than LEDs, it wouldn't have worked.

*How have your imaging innovations pushed the science forward in a way traditional photography could not?*

The digital technology has allowed me to photograph something and put it immediately in the scientists' hands. Whether they use it for their reports or blow that image up and start looking at details and

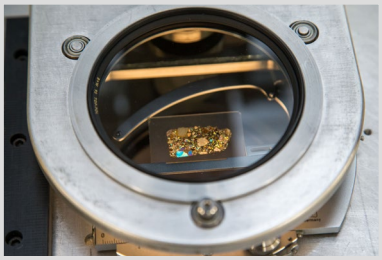
describing the core, they can see things in digital photography that perhaps even the naked eye can't.

It helps them so tremendously. I look at their reports, and I look at the images that I helped with, and frankly I just grin ear to ear because I see the benefit of good photography and how it is helping the science.

*Are there any other lighting or imaging methods you have developed in your time on the JR?*

We take rocks, cut and polish them until they become the thickness of hair (thirty microns), making a "thin section" - then you can look through that rock. You're seeing the crystals. You take that sample and look through it with a light source with a polarized filter. Linear polarization is kind of like looking through a picket fence. Now, if you take another picket fence and you turn it ninety degrees, it covers each thing up and light won't pass through it. When you turn two polarizing filters in this manner, you have a state that is called cross polarization. You could stick your finger between those two filters and not see anything. But place that thin section between the filters and you see colors like a kaleidoscope. You see these crystals glow. What happens is the light bends as it strikes the crystal, which allows it to go through the second filter. How far the light departs from its original axes determines the color of the glow. A trained petrologist can look at that and tell you what mineral it is by the color. Microscopes have been doing this for all these years - what they couldn't do is get a photograph of the whole thing quickly at once. The field of view of a microscope is so small, full sized images were being built by stitching them together in Photoshop or some other similar program. This was tedious and time consuming. Well, I took a look at their problem and said, "OK, let's look at what the microscopes are doing." Then I also looked at the light itself. Did that light path have to be protected? Did it have to be baffled? Did it have to be in its own dark chamber for that light to be good? Were there any restrictions on the distance between the polarizing filters? The answer was no. I built this thing and it has been a tremendous success. For the first time, scientists were able to get full polarized images quickly and easily of the whole thing.

*Petrographic Image Capture and Archiving Tool (PICAT)*



*Thin Section in the PICAT view finder*

*That sounds like a real breakthrough.*

It's just a light source, two filters, and a camera. And it's connected to a computer, so I'm able to project what the camera is seeing to a big computer screen. And now everyone sees the features at the same time. It's a big teaching tool. Now, one of the things that is unique is that if you rotate the sample you get these kaleidoscopes of color that appear and disappear. That's called birefringence - another thing scientists use to determine what mineral they have when using a microscope. I saw that they were turning the sample. Well guess what, when you do that, you lose orientation and you don't know what's the top and what's the bottom of that slide! I wanted the orientation to stay with the axes and orientation of the camera. Through testing, I realized there was little difference between turning the filters in unison and turning the sample. Leave the sample alone and turn the filters locked together, and it does the same thing. When this was introduced on the ship, Rodey [Batiza, former NSF Program Director] said, "It took a damned photographer to figure this out!" He said, "Son, not only have you hit a home run but it was the bottom of the ninth and the bases were loaded, there were two outs and you knocked it out of the park." To be honest, I had no idea of the impact this gadget would have.

*What is the name of the apparatus?*

True to form, the project had to have a name. We call it a Petrographic Image Capture and Archiving Tool (PICAT). Acronyms annoy me. I would rather call it a thin section viewer.

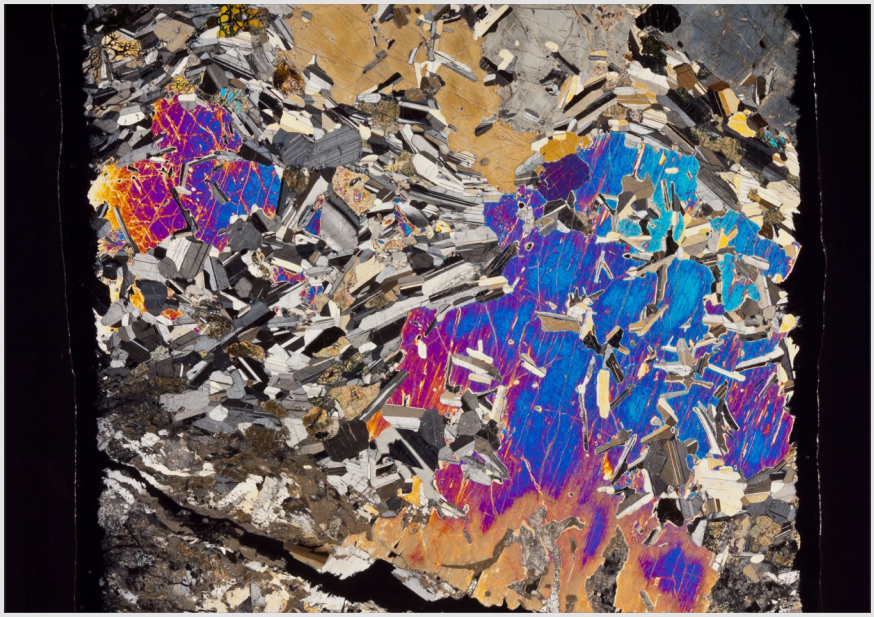
*Is there anything else you'd like to add?*

The JR is the best-equipped floating geology lab in the world. In fact it may be the best-equipped geology lab in the world, period. The program (IODP, ODP, DSDP) is so rich in its history. It's all here, and I'm thrilled and excited to be a part of it. How do I keep from not being bored to tears after doing twenty-five [expeditions]? The answer to that is it might appear repetitive to me, but it's the first time for you. It's my job to make those scientists' first time the best. We do science that's important, but there's something far greater, in my opinion, than the science that we do, and that's the mentoring of those young minds. We are passing the baton, so to speak. They get immersed for two months out here and they're doing science, they don't have TV commercials, video games or other

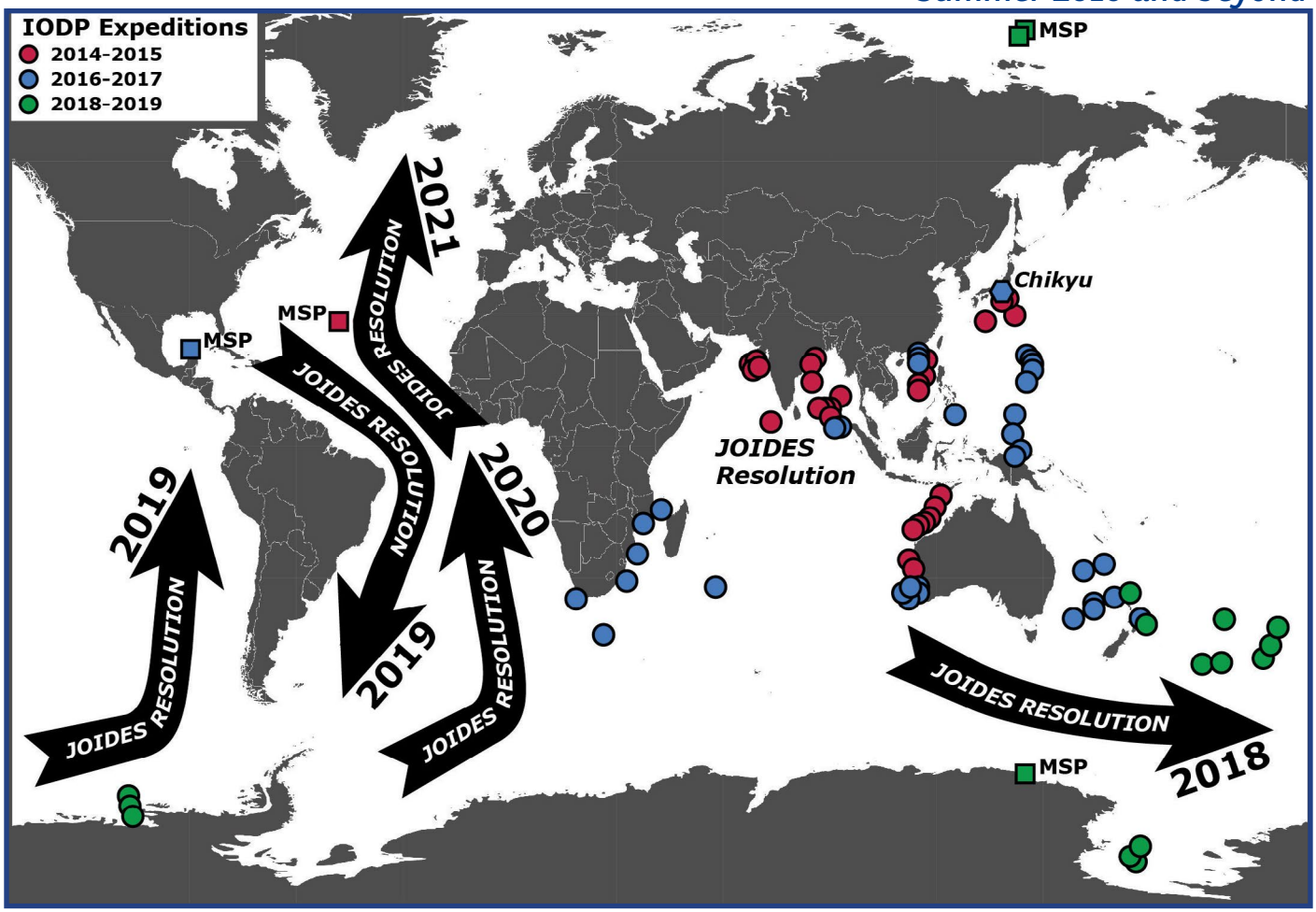
distractions and they're shown the right way to do it.

Someone once said, "Nature loves to hide." My wish is to help the scientists through photography reveal some of Nature's shyness. Come sail with us and if you do, your life will change. It's almost guaranteed.

My job is very visible. It requires me to interface with just about everyone on the ship. My images are obviously visible. It's the non-visible that makes the program as good as it is. It's those people behind the scenes that make the program great! I am just a tiny part of this effort. They are the ones who are the heroes in my opinion.



## The *JOIDES Resolution* Ship Track: Summer 2016 and beyond




Map modified with permission from the IODP-JRFB

# 2016 - 2019 IODP EXPEDITION SCHEDULE

| Platform | # | Expedition | Dates | Ports |
|---|---|---|---|---|
| | 370 | T-Limit of the Deep Biosphere off Muroto | 09/13/16 - 11/23/16 | Shimizu, Japan - Kochi, Japan |
| | 363 | Western Pacific Warm Pool | 10/06/16 - 12/08/16 | Singapore - Guam |
| | 366 | Mariana Convergent Margin | 12/08/16 - 02/07/17 | Guam - Hong Kong |
| | 367 | South China Sea Rifted Margin A | 02/07/17 - 04/09/17 | Hong Kong - Hong Kong |
| | 368 | South China Sea Rifted Margin B | 04/09/17 - 06/11/17 | Hong Kong - Shanghai, China |
| | 371 | Tasman Frontier Subduction Initiation and Paleogene Climate | 07/27/17 - 09/26/17 | Townsville, Australia - Hobart, Australia |
| | 369 | Australia Cretaceous Climate and Tectonics | 09/26/17 - 11/26/17 | Hobart, Australia - Fremantle, Australia |
| | 372 | Creeping Gas Hydrate Slides and Hikurangi LWD | 11/26/17 - 01/04/18 | Fremantle, Australia - Wellington, New Zealand |
| | 374 | Ross Sea West Antarctic Ice Sheet History | 01/04/18 - 03/08/18 | Wellington, New Zealand - Wellington, New Zealand |
| | 375 | Hikurangi Subduction Margin | 03/08/18 - 05/05/18 | Wellington, New Zealand - Auckland, New Zealand |
| | 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 | Wellington, New Zealand - Papeete, Tahiti |
| | 379 | Amundsen Sea West Antarctic Ice Sheet History | 01/18/19 - 03/20/19 | Punta Arenas, Chile - Punta Arenas, Chile |

*Chikyu*
*JOIDES Resolution*