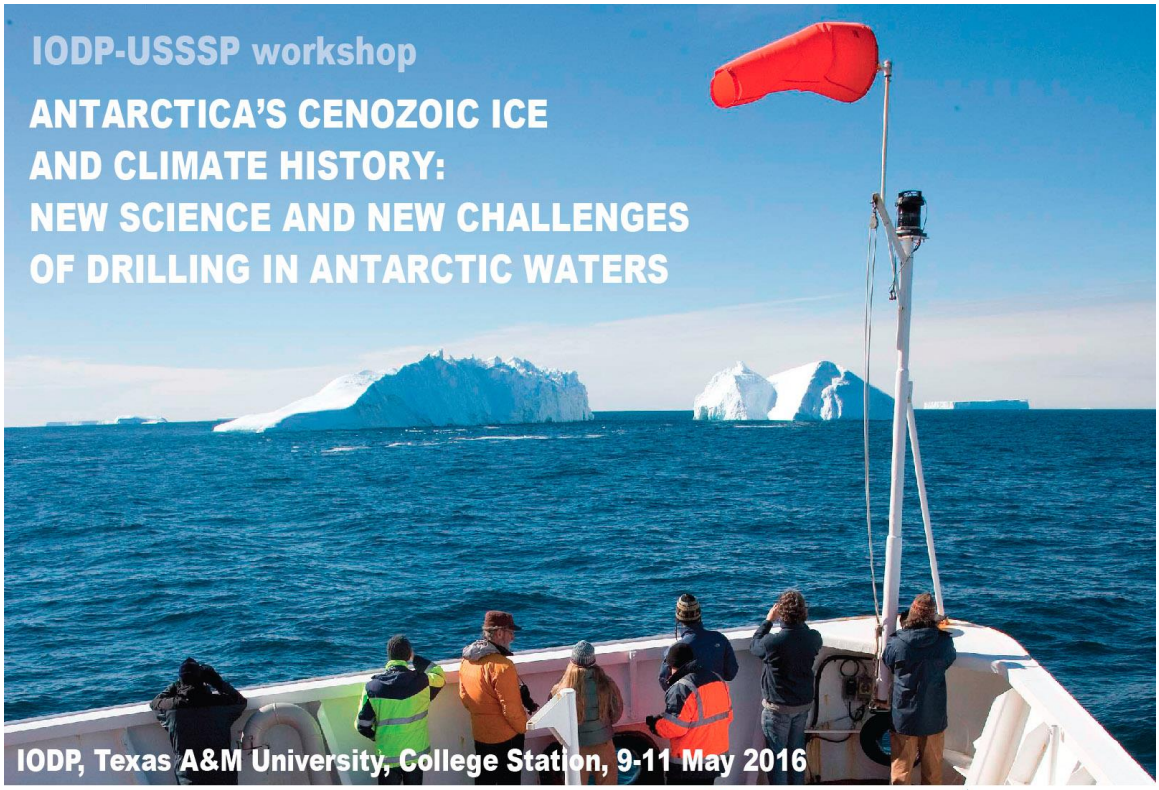


U.S. SCIENCE SUPPORT PROGRAM

ECORD EUROPEAN CONSORTIUM FOR OCEAN RESEARCH DRILLING

IODP INTERNATIONAL OCEAN DISCOVERY PROGRAM

Workshop US/local organizing committee:

- Trevor Williams (IODP, Texas A&M University, College Station)
- Denise Kulhanek, (IODP, Texas A&M University, College Station)
- Amelia Shevenell, (University of South Florida, Tampa)
- Dave Harwood, (University of Nebraska-Lincoln)
- Sean Gulick (University of Texas Institute for Geophysics, Austin)

Workshop International committee:

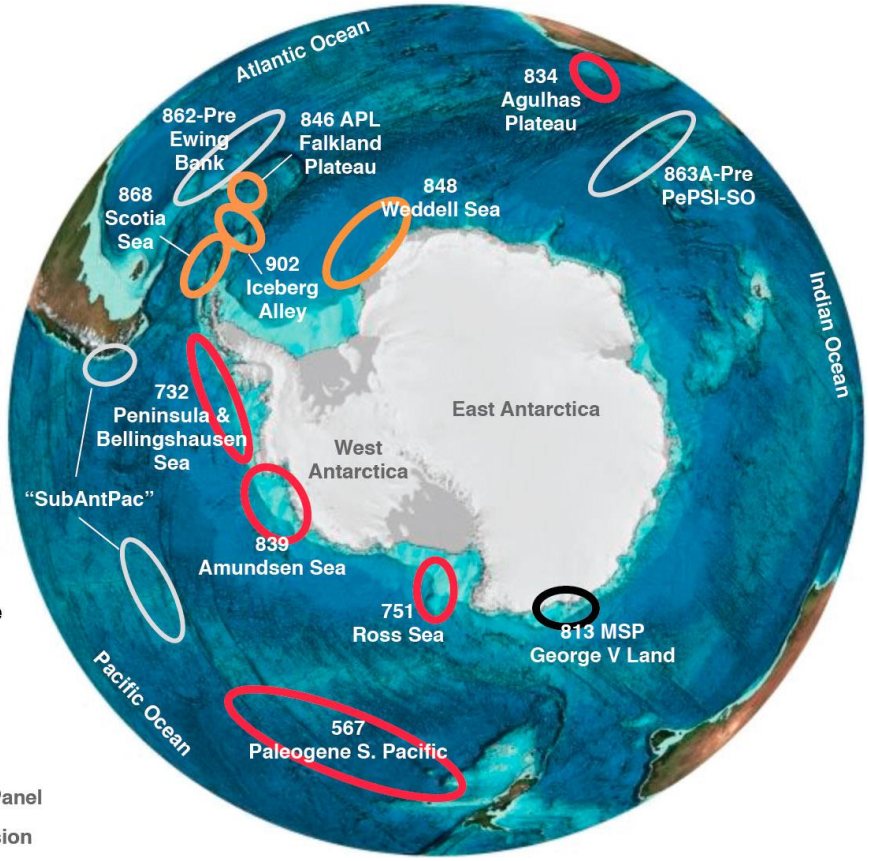
- Trevor Williams (lead proponent and co-chief of IODP-MSP proposal IODP-813 (now Expedition 373); workshop PI)
- Rob McKay (Victoria Univ. of Wellington, NZ), lead proponent of IODP-751 (now Expedition 374)
- Karsten Gohl (AWI, Germany), lead proponent of IODP-839 (now Expedition 379)
- Jim Channell (Univ. of Florida, USA) lead proponent of IODP-732
- Laura De Santis (OGS, Trieste, Italy) SCAR/PAIS co-chair, co-proponent of IODP-751 (now Expedition 374)
- Rob Larter (BAS, Cambridge, UK) co-proponent of IODP-732

SUMMARY

One of the most significant and pressing challenges for climate predictions is to resolve the unknown contribution of continental ice sheets to future sea-level rise. The marine-based West Antarctic Ice Sheet (WAIS), with much of its bed >1000 meters below sea-level, has the potential to provide a major contribution to sea-level rise over the next century and beyond. Therefore, understanding underlying processes, thresholds, and magnitudes of previous WAIS retreats and collapses, when global temperature and atmospheric CO_2 levels were higher than today, is essential to guide numerical model improvement and better predict future sea-level rise. These scientific issues are highlighted in Climate and Ocean Change Challenges 1 and 2 of the 2013-2023 IODP Science Plan and the Denver-2012 prioritization of that plan by the US IODP community.

The USSSP and MagellanPlus-funded Antarctica's Cenozoic Ice and Climate History workshop (Texas A&M University, May 9-11, 2016) is part of a coordinated plan developed since 2009 by the Past Antarctic Ice Sheet Dynamics (PAIS) research program through the Scientific Committee on Antarctic Research (SCAR; www.scar.org), an International Council for Science (ICSU) committee, to stimulate Antarctic Margin Drilling Proposals. The workshop discussed the status of the Antarctic and Southern Ocean proposals currently in the IODP review system and highlighted the requirement of geographically diverse drilling transects because recent observation and modeling studies reveal a heterogeneous response of the Antarctic Ice sheet to oceanic and atmospheric forcing.

Three drilling proposals (751 in the Ross Sea; 839 in the Amundsen Sea; and 732 in the Bellingshausen Sea and Antarctic Peninsula), approved by the Scientific Evaluation Panel and under consideration for scheduling by the *JOIDES Resolution* Facility Board (JRFB) at the time of the workshop, form a coherent West Antarctic Margin Portfolio of drillsites, that will illuminate the spatial and temporal variations of past Antarctic Ice Sheet dynamics and guide model skill for future predictions, by: 1) reconstructing the orbital-scale Cenozoic dynamics of the WAIS, 2) identifying drivers and their thresholds, especially of ocean forcing, for past WAIS retreat, and 3) assessing relationships between the Antarctic cryosphere, ocean circulation, and global climate. This is particularly timely because the 2015 UN Climate Change Conference in Paris requested that IPCC write a special report by 2020 to assess the climate impacts of climate stabilization at +2°C and +1.5°C and response of Antarctic Ice Sheets will comprise an important component of this report. The IODP expeditions will provide near-field ice sheet data to complement and constrain the far-field sea level and paleoceanographic data obtained by expeditions in the Southern Ocean.



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

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

The workshop also addressed problems related to implementing drilling expeditions around Antarctica, like the presence of sea ice, and proposed a strategy in a report to the JRFB to drill the three WAIS proposals over three successive austral summer field seasons. The decision of the JRFB at their meeting, held in the week following the workshop, was that the Ross Sea proposal is now scheduled in early 2018, the Amundsen Sea proposal is scheduled for early 2019, and the planned ship track returns to the South Atlantic and possibly Antarctica such that the Antarctic Peninsula proposal 732 could be drilled in early 2020. This is partly dependent upon the readiness of proposals in the South Atlantic Ocean, and indeed there are several South Atlantic proposals in the IODP system. The PAIS program is now engaging actions to stimulate and help these proposals to progress.

During the workshop some classic DSDP, ODP and IODP Antarctic sediment cores were laid out and examined, so that the participants could see some of the material on which much of the scientific knowledge of Antarctic climate history is based. The core examination also enabled direct conversations between young scientists and more senior scientists (many of whom worked on the cores and in the seismic data tied to these cores), transmitting expertise, generating ideas,

and encouraging the young scientists to join the Antarctic drilling community by applying for future IODP expeditions.

The workshop organization and the US participation was funded by USSSP. MagellanPlus supported the participation of 8 European lead/co-proponents of IODP proposals, early and mid-career scientists and 3 PhD students. A total of 84 participants attended the workshop, including early career to senior scientists, students, expedition proponents and IODP operators.

Contacts:

- Trevor Williams (IODP-JRSO, Texas A&M University, College Station, Texas), williams@iodp.tamu.edu
- Denise Kulhanek (IODP-JRSO, Texas A&M University, College Station, Texas), kulhanek@iodp.tamu.edu
- Laura De Santis (Istituto Nazionale di Oceanografia e Geofisica Sperimentale –OGS, Trieste, Italy), ldesantis@inogs.it

OBJECTIVES

The overarching goal of this workshop was to develop an integrated science plan for the upcoming scheduled and proposed scientific drilling expeditions to Antarctic waters. At the time of the workshop, six IODP Mission-Specific Platform and *JOIDES Resolution* drilling proposals for Antarctic waters were either scheduled (proposal 813), at a Facility Board (proposals 732, 751 and 839), or at the Science Evaluation Panel (e.g. prop. 812, 848, 862, etc.).

In particular the aim of the workshop was to: 1) review the science objectives of the drilling proposals currently in the IODP review system; 2) identify geographic areas and age windows that can best provide insight into Antarctic ice sheets under warm climates; 3) Put this in context of the IODP science plan and the broader context (SCAR, IPCC); and 4) Write a meeting summary to be submitted to the *JOIDES Resolution* Facility Board prior to their next meeting.

Another workshop goal was to review the sea ice and weather information that can be used to: (a) plan drilling expeditions, and (b) to make at-sea decisions, in order to conduct safe drilling operations in Antarctic waters. What are the best weather windows for each proposed expedition? Are more resources needed?

Examination of classic IODP Antarctic sediment cores formed the third major objective of the workshop.

PROGRAM

Monday 9 May (Room 110/111, Koldus Building, Texas A&M University)

Proposed IODP Antarctic and Southern Ocean drilling; common themes and overview of science plans.

9:00 Introduction to the workshop agenda and objectives (Trevor Williams)

9:15 A short history of past Antarctic scientific drilling (Frank Rack)

9:30 Introduction to the IODP proposal system (David Mallinson)

10:15 *Presentations on Antarctic and Southern Ocean proposals at the JR Facility Board*:

IODP-751. Ocean-ice sheet interactions and West Antarctic Ice Sheet vulnerability: clues from the Neogene and Quaternary record of the outer Ross Sea continental margin (Rob McKay et al.).
IODP-839. Development and sensitivity of the West Antarctic Ice Sheet tested from drill records of the Amundsen Sea Embayment (Karsten Gohl et al.).
IODP-732. Sediment drifts off the Antarctic Peninsula and West Antarctica (Jim Channell, Rob Larter, et al.).
IODP-567. Paleogene South Pacific APC Transect: Heat Transport and Water Column Structure During an Extreme Warm Climate (Debbie Thomas et al.).

1:00 *Updates on Antarctic and Southern Ocean drilling proposals*:

IODP-813-MSP. George V Land and Adélie Land shelf sediments (Trevor Williams, Carlota Escutia, et al.). MSP expedition scheduled for Dec 2017 to Feb 2018.
IODP-848. Late Neogene to Quaternary ice-sheet and sea-level history of the Weddell Sea, Antarctica (Mike Weber et al.). At IODP Science Evaluation Panel (SEP).
IODP-847. Plio-Pleistocene reconstruction of ice-sheet, atmosphere, and ocean dynamics in Iceberg Alley (Mike Weber et al.) Resubmitted to SEP, 1 April 2016.
IODP-868 Scotia Sea (Javier Hernandez Molina et al.);
Drake Passage (Gisela Winckler for Frank Lamy et al.);
Agulhas Plateau (Gabi Uenzelmann-Neben et al.);
IODP-MDP-863 ISOLAT (Minoru Ikeraha for Peterson et al.).

2:30 Ice sheet modeling (Rob DeConto)

3:00 Sea level and Glacial Isostatic Adjustment (GIA) (Jacky Austermann)

3:15 Carbon dioxide, temperature, and ice volume over the Cenozoic (Amelia Shevenell)

3:30 Discussion: Where to drill and which ages, events, and high-CO_2 scenarios to target?

Tuesday 10 May (Room 110/111, Koldus Building / IODP-GCR)

Drilling in a harsh polar environment: sea ice, icebergs and weather assessment; planning for the unexpected.

9:00 Introduction to the ice and weather session (Trevor Williams)

9:15 Satellite imagery of ice conditions (Michael Cloutier, PGC)

9:45 Weather: forecasts of temperature, wind, and sea state; typical seasonal changes; available weather forecast and re-analysis products:
- Frank Nitsche – ice monitoring on the *RVIB N.B. Palmer*
- Karsten Gohl – sea ice monitoring on the Polarstern
- Gary Action – hazard management on Leg 178 (Ant. Peninsula) and in Baffin Bay.
- Trevor Williams – Daily visual and microwave radar images for expedition planning.

1:00 Five-minute presentations about each of the sets of sediment cores to be shown at the GCR in the afternoon:

1. Sites 272, 271 (Miocene-Pliocene Ross Sea shelf) Examples of clast-rich silty clay, clast-free diatomite (MMCO age?), structureless mud. *Relating to IODP-751, 839*.
2. Site 270 (Oligocene-Miocene Ross Sea shelf) Examples of marine transgression, diamictite, shallow marine mudstone, glacial rythmites). *Relating to IODP-751, 839*.
3. Sites 1096 and 1101 (Pleistocene Peninsula continental rise sediment drifts) Including MIS interglacials 5, 9, and 31. *Relating to IODP-732.*
4. Sites 1097 and 1103 (late Miocene-Pliocene Peninsula shelf) Examples of diamictites, proglacial debris flows, and ice-distal muds. *Relating to IODP-751, 839*.
5. Sites 1171 (S Tasman Rise) and 1218 (equatorial Pacific) Eocene-Oligocene transitions.
6. Site 689 (Eocene to Pliocene at Maud Rise) Antarctic ice sheet evolution through time.

7. Site U1361 (Wilkes Land continental rise) Pliocene sedimentary cycles - diatom-rich and silty clay alternations, ice-rafted debris, provenance from Wilkes subglacial basin.
8. Site 742 (Prydz Bay) Pliocene ice retreat in shelf sediments: diatomite and diamictite.
9. Micropaleontological examples from the IODP collection in the microscope room.
10. Sites 1098 and 1099 (Palmer Deep, Peninsula) Late-Pleistocene and Holocene Antarctic sediments showing ice retreat, calving bay facies, and laminations.
11. Site 1166 (Cretaceous-Eocene Prydz Bay shelf) Examples of organic and mica-rich siltstone, and pre-glacial to glacial unconformity. *Relating to IODP-813.*

Examination of Antarctic sediment cores in the Gulf Coast Core Repository.

3:00 Orientation to the IODP and GCR.

The sediment cores were organized into eleven stations (core tables), each focusing on a different Antarctic location or time interval. Groups will contain a mix of experienced and junior scientists. At each sediment core station, maps, seismic profile, data etc. provided the setting.

3:30 In parallel: breakout group to discuss the letter for the JOIDES Resolution Facility Board.

4:45 Introduction to how to make a good application for IODP expeditions (for students).

Wednesday 11 May (IODP / Gulf Coast Repository)

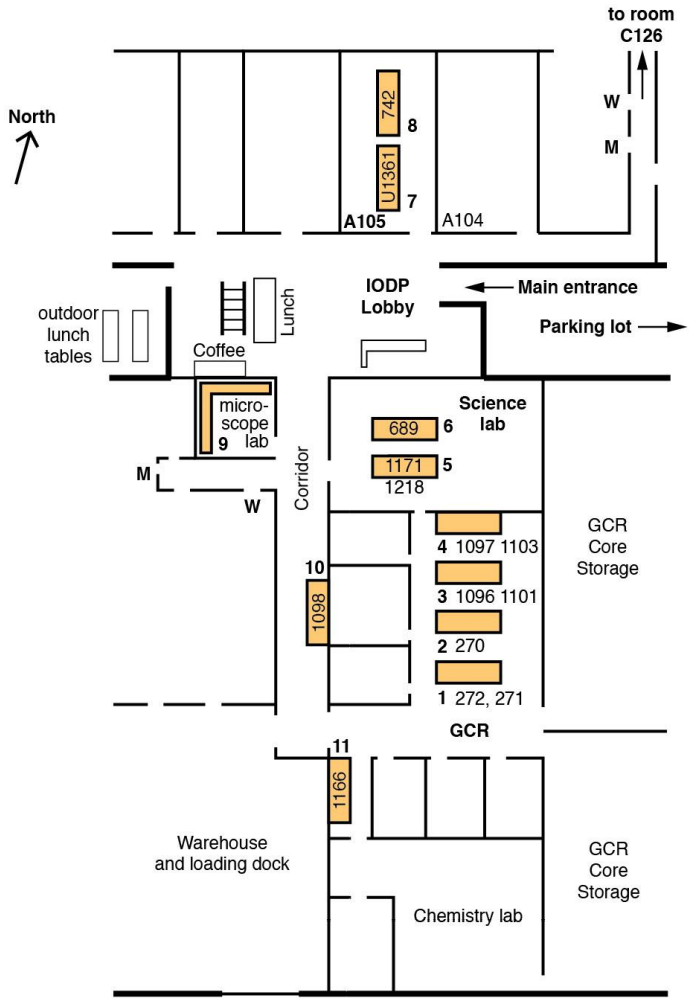
9:00 Guided examination of Antarctic sediment cores in the Gulf Core Repository.

10:45 Four breakout groups to facilitate discussion about Antarctic drilling strategy, proposal strategy,

1:00 Plenary session recap and wrap-up.

2:00 Tours of the Gulf Coast Repository core store and facilities; smear slide classes.

5:00 Meeting close



IODP/GCR sediment core workshop layout illustrating the number of the core sites shown in the different rooms

OUTCOME

The main outcome was a report that was delivered to the *JOIDES Resolution* Facility Board three days after the workshop, from the US and International workshop steering committees (members listed on the front page of this report). The report contains a community-endorsed portfolio implementation strategy to successfully drill the WAIS margin. While each of the three proposals (751 Ross Sea; 839 Amundsen Sea; 732 Peninsula and Bellingshausen Sea) has alternate sites to help mitigate risks associated with drilling in proximity to ice, the workshop report suggests investigation of a broader and more flexible approach in which sites from one expedition could be used as alternate sites for another in the case of a heavy sea-ice year, since sea-ice conditions cannot be predicted at the time when expeditions are scheduled. Ideally, the portfolio would be drilled over three successive austral summer field seasons.

The decision of the JRFB during the meeting held the week after the workshop is that the Ross Sea proposal is now scheduled in early 2018, the Amundsen Sea

proposal is scheduled for early 2019, with the possibility of future drilling in the Southern Ocean and Antarctic waters (prop. 732) as early as the following season, pending mature drilling proposals in the South Atlantic.

Another outcome of the workshop was a summary of sea ice and weather monitoring products that can be used for planning and operating drilling expeditions in Antarctic waters. The list is growing as new computer models and satellite sensors are developed. Most of these products are freely available online. The workshop participants also heard presentations about sea-ice and weather management on polar research vessels using new sea-ice satellite imaging and weather forecasts. This will aid in the development of a common set of guidelines that may be used across the range of proposed expeditions and will ensure the most reliable risk assessments on which to base scheduling and operational decisions.

Another outcome of the workshop is the legacy of the Antarctic sediment core master class. Senior scientists with different skill presented and discussed with early career researchers and students a wide range of sediment facies from past DSDP, ODP and IODP legs, from continental shelf to rise around the Antarctic margin. These facies are expected to be recovered from the sites that will be drilled in 2018-2019 and beyond and the experience gained during the workshop will be useful to those young (and less young) scientists who will apply to sail on scheduled and pending expeditions, and will continue to be involved in the next generation of drilling proposals.

Day 2 and 3: Discussion of archive Antarctic sediment cores from the IODP Gulf Coast Core Repository

FUTURE PLANS

The Antarctica's Cenozoic Ice and Climate History workshop is part of a coordinated plan developed since 2009 by the Past Antarctic Ice Sheet Dynamics (PAIS) research program through the Scientific Committee on Antarctic Research (SCAR; www.scar.org), an International Council for Science (ICSU) committee, to stimulate Antarctic Margin Drilling Proposals. Future plans are to replicate such kinds of meetings to continue fostering drilling proposal submission, data-modelling integration, informing the community, and attracting and training students.

A PRAMSO (Palaeoclimate Records from the Antarctic Margin and Southern Ocean) workshop will be held on Saturday morning (from 9 am to 1 pm), 20 August 2016, in Kuala Lumpur (Malaysia) as a side meeting of the SCAR-OSC conference http://scar2016.com/side-meeting-schedule.php. About 30-40 participants are expected to attend this workshop, which is organized by Carlota Escutia (CSIC-Univ. of Granada, Spain) and Laura De Santis (OGS, Trieste, Italy), with support from the SCAR/PAIS program. The PRAMSO workshop's agenda can be downloaded from http://www.scar.org/pais/pais-news. The

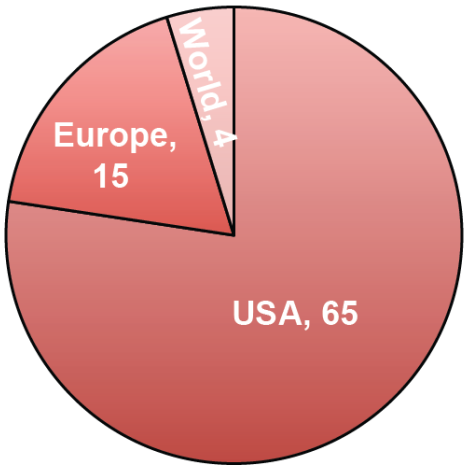
workshop aims to update the scientific community about ongoing activities related to drilling projects from the Antarctic continental margins and Southern Ocean. Talks will present expected scientific results from the scheduled expeditions, alternate sites strategy, staffing, problems to solve before sailing (e.g. ice-breaker support). There will be also presentations on Antarctic drilling proposals that are at the IODP Science Evaluation Panel (SEP). The presentations should indicate what steps are needed to improve the proposals and how PAIS can help the proponents to achieve final SEP approval. Finally there will be presentations on new ideas/areas for future drilling, recent results and plans for site surveys, scientific gaps and geographical areas to address in future proposals.

Similar workshops will also be organized in the future during the PAIS conference that will be held in Trieste (Italy), on 10th-16th September 2017 and the SCAR-OSC conference 2018.

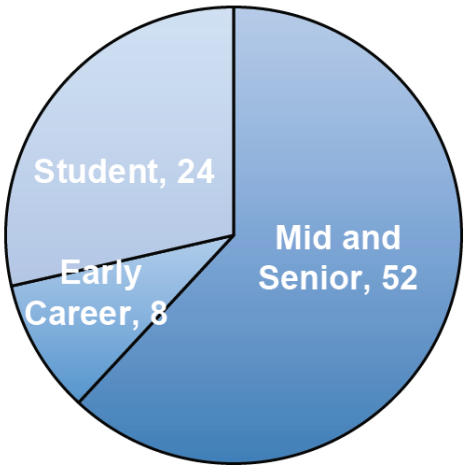
LIST OF PARTICIPANTS (HIGHLIGHTING EARLY STAGE RESEARCHERS).

The workshop organization and US participation was funded by USSSP. MagellanPlus supported the participation of European lead/co-proponents of IODP proposals, early and mid-career scientists and PhD students. A total of 84 participants attended the workshop, including early career to senior scientists, students, expedition proponents and IODP operators.

Where the participants were from



Career stage of the participants



NAME	INSTITUTION
Gary Acton	Sam Houston University, USA
John Anderson	Rice University, USA

Jeanine Ash	UCLA, USA
Jacqueline Austerman	Harvard University, USA
Phil Bart	Louisiana State University, USA
Sjoerd Berends	Siem Offshore, USA
Rachel Bertram	Imperial College London, UK
Steve Bohaty	NOC, Southampton, UK
Imogen Browne	University South Florida, USA
Jim Channell	University Florida, USA
Brad Clement	Texas A&M University, USA
Michael Cloutier	Polar Geospatial Center, Minneapolis, USA
Jason Coenen	Northern Illinois University, USA
Ellen Cowan	Appalachian State University, USA
Rob DeConto	University of Massachusetts, USA
Laura De Santis	OGS Trieste, Italy
Justin Dodd	Northern Illinois University, USA
Eugene Domack	South Florida University, USA
Carlota Escutia	Instituto Andaluz de Ciencias de la Tierra, Spain
Sarah Feakins	University of Southern California, USA
Andrew Fraass	Smithsonian Institution, USA
Karsten Gohl	AWI, Bremerhaven, Germany
Michelle Guitard	University of South Florida, USA
Anna Ruth Halberstadt	Rice University, USA
David Harwood	University of Nebraska, Lincoln, USA
Daniel Hauptvogel	University of Houston, USA
CD Hillenbrand	British Antarctic Survey, UK
Katharina Hochmuth	AWI, Bremerhaven, Germany
Minoru Ikehara	Kochi University, Japan
John Jaeger	University of Florida, USA
Tom Janecek	NSF, Washington DC, USA
Denise Kulhanek	Texas A&M University, USA
Rob Larter	British Antarctic Survey, UK
Bridget Lee	University of California Riverside, USA
Chris Lowery	University of Texas Institute for Geophysics, USA
Melissa Luna	Wesleyan University, USA
David Mallinson	East Carolina University, USA
Mitch Malone	Texas A&M University, USA
Ellen Martin	University of Florida, USA
Yasmina Martos	British Antarctic Survey
Rob McKay	Victoria University of Wellington, New Zealand
David McInroy	ESO, Edinburgh, UK
Jennifer Middleton	Harvard University, USA
Yuribia Munoz	University of Houston, USA
Frank Nitsche	Lamont Doherty Earth Observatory, USA
Suzanne O'Connell	Wesleyan University, USA
Elisabetta Olivo	OGS Trieste, Italy
Sandra Passchier	Montclair State University, USA
Molly Patterson	University of Massachusetts, USA
Stephen Pekar	Queens College CUNY, USA
Michelle Penkrot	University of Florida, USA
Frank Rack	University of Nebraska, Lincoln, USA
Brendan Reilly	Oregon State University, USA

Delaney Robinson	University of Houston, USA
Alan Rooney	Harvard University, USA
Yair Rosenthal	Rutgers University, USA
Ari Salabarmada	Instituto Andaluz de Ciencias de la Tierra, Spain
Howie Scher	University of South Carolina, USA
Reed Scherer	Northern Illinois University, USA
Amelia Shevenell	South Florida University, USA
Lauren Simkins	Rice University, USA
Catherine Smith	University of South Florida, USA
Joe Stoner	Oregon State University, USA
Debbie Thomas	Texas A&M University, USA
Ellen Thomas	Yale University, USA
Gabi Uenzelmann-Neben	AWI, Bremerhaven, Germany
Kara Vadman	University of South Florida, USA
Tina van de Flierdt	Imperial College London, UK
Jonathan Warnock	Indiana University of Pennsylvania, USA
Sophie Warny	Louisiana State University, USA
Mike Weber	University of Köln, Germany
Jo Whittaker	University of Tasmania, Australia
Trevor Williams	Texas A&M University, USA
Gisela Winckler	Lamont Doherty Earth Observatory, USA
Wenshen Xiao	Tongji University, China
Mingyu Yang	University of Nebraska, Lincoln