Australian and New Zealand IODP Consortium Annual Report 2016

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Compilation by Neville Exon and design by Catherine Beasley

Cover photo: *JOIDES Resolution* at sea. Photo courtesy of John Beck, IODP/TAMU

Back cover photo: Map of Australasian Scientific Ocean Drilling from 1969 to 2016, Courtesy of Geoscience Australia

Australian and New Zealand IODP Consortium

Chairman's Overview

This is the fourth year of the first decade of the IODP, the International Ocean Discovery Program. This is the latest of the deep sea scientific drilling programs that have collectively endured since 1968 - and this year has been another outstanding one, with nine ANZIC scientists and one Education and Outreach officer sailing on IODP expeditions.

Ocean science addresses globally significant problems, with two-thirds of our world covered by oceans. About 60% of Australia's and 95% of New Zealand's territory is offshore. As the world's largest geoscience research program (ocean drilling being the best method of sampling below the ocean floor) the IODP is a broad and vital collaborative effort, continually developing insights into how the Earth has worked, how it is working now, and how it may work in the future. These insights can be of great societal relevance.

Collaboration is central to most science and to its effective application, and few of the world's scientists are based in Australia or New Zealand. With 23 member countries in 2016, involving nearly all the major scientific countries on Earth, we have direct access to, and active engagement with, the world's best scientific minds. Our involvement comes from a roughly 1% contribution to IODP's $US180 million annual international operational budget, and the quality of our scientists lifts our profile.

Australia and New Zealand, through the ANZIC consortium, are important players in this exciting project, with the eager participation of many scientists. We estimate that at least 120 Australians and 40 New Zealanders are working at present on ocean drilling science, and they are respected internationally. Our scientific contribution since IODP began in 2003 has been substantial, with Australians involved in 18.2% and New Zealanders in 3.4% of all publications I have very much enjoyed seeing our 20 ANZIC member universities and research organisations working so well together and with their international counterparts.

Membership of IODP is critical in helping us maintain our leadership in Southern Hemisphere marine research. The Australasian region has seen eight IODP expeditions since late 2009, including two in 2016, and there will be another six expeditions in the region in 2017 and 2018. The generosity of our major partners means that we get a wonderful return on our modest financial investment, with access to assets worth more than $US1 billion.

The *JOIDES Resolution* at the dock in Port Louis, Mauritius. (Credit: Richard Norris & IODP)

Australian and New Zealand IODP Consortium

Over the next seven years, IODP research will cover, among other things: the nature of the Earth's mantle and crust, and the nature of the related deep forces that drive the Earth's tectonics; past and future climate change; the history of life as revealed in sedimentary strata; the nature of the extraordinary microbes found deep in the sediments and volcanic rocks beneath the sea floor; and major natural hazards such as earthquakes, tsunamis, and submarine landslides. An average two-month IODP expedition recovers thousands of metres of sediments and rocks that provide a wonderful store of highly varied information for subsequent investigation.

New Zealanders were the driving force behind five of the six future *JOIDES Resolution* expeditions in the region approved last year, and have been rewarded with six Co-Chief Scientist positions, an amazing achievement. New Zealand sits on top of the great sunken continent Zealandia, which has been in the news recently, and which provides many fascinating targets for ocean drilling.

Outreach activities remain central to our mission, and in the last year these included funding forty bright young university undergraduate students, who attended Marine Geoscience Masterclasses in Perth in February, and in New Zealand in December, designed to inspire the next generation of scientists to work in this exciting research field. We had a highly successful IODP Symposium at the Australian Earth Sciences Convention in Adelaide in June, at which the talks and the associated ANZIC/IODP booth generated considerable interest.

Finally, after six absorbing years it remains for me to say farewell to the Chairmanship of the ANZIC Governing Council, having handed over this responsibility to the distinguished marine scientist Dr Ian Poiner in December. I have found IODP an important and fascinating scientific endeavour that had me hooked early in my term. Over these past years it has been a great pleasure to work with a Council membership of talented and enthusiastic scientists of international calibre. Strong leadership and warm friendship have been provided by the outstanding Program Office team of Neville Exon and Catherine Beasley. I wish Ian Poiner all the very best in his new role as my replacement.

Geoff Garrett and Ian Poiner at ANZIC's Governing Council Meeting December 2016

Dr Geoff Garrett AO,
Chairman of the ANZIC Governing Council and Chief Scientist of Queensland in 2016

Australian and New Zealand IODP Consortium

Program Scientist's Summary

Ocean Drilling in General

Ocean drilling addresses scientific problems of global interest. It explores how the Earth has worked in the past, how it is working now, and how it may work in the future – a big and ongoing task! The International Ocean Discovery Pprogram (IODP) platforms take continuous cores of sediments and rocks from all the world's oceans, at times reaching several kilometres below the sea bed. Two large coring vessels, *JOIDES Resolution* and *Chikyu*, and mission specific alternative platforms, are used to 'ground truth' scientific theories based largely on remote sensing geophysical techniques.

The IODP is the successor to earlier ocean drilling programs – the Deep Sea Drilling Project, the Ocean Drilling Program, and the Integrated Ocean Drilling Program. The present phase of IODP is guided by an internationally agreed science plan.

The many ocean drilling expeditions in our region since 1968 have provided new scientific knowledge of global significance. Hundreds of scientists participate each year, tackling 'big science' questions in fields ranging from climate change to the deep biosphere and plate tectonics. Every expedition in our region not only brings high-technology drilling vessels here, but also about 30 outstanding scientists to work with our participants on issues of great scientific interest.

Australia and New Zealand Consortium

Australia and New Zealand are members of IODP, in our own *Australia and New Zealand IODP Consortium (ANZIC)*. Our IODP scientists work with research teams from around the world, and post-expedition research cooperation often extends far beyond IODP. Our geoscientists and microbiologists are making important scientific contributions, and coring expeditions in our region and elsewhere have improved and will keep improving our understanding of global scientific questions.

Membership of IODP helps us maintain our quality in marine research, and our region's geography, climate, oceanography and plate tectonics make its study vital in addressing various global science problems. The Australasian region has seen a great deal of ocean drilling since 1968, including nine IODP expeditions from 2009 to 2016. Six more regional expeditions will occur in 2017 to 2018. This is a huge credit to our scientists, who have played leading roles in many proposals. One reward is that, from 2010 to 2018, we will have had eight ANZIC scientists in the key role of Co-chief Scientist on seven of the expeditions. These scientists not only helped design the expeditions but play a key role in shipboard decision making, and in post-cruise scientific decisions.

In 2016, the ANZIC consortium consisted of 16 universities, 4 government agencies, and one marine geoscience peak body. Australia is the major ANZIC financial contributor but benefits are shared between our two countries. ANZIC funding of about $A3.3 million for 2016 came from an ARC/LIEF grant of $A2 million, with additional contributions from 15 Australian partners and five New Zealand partners. In 2016, membership expenditure of $US1.8 million gave us eight shipboard places on *JOIDES Resolution*, one on *Chikyu* and one on an alternative platform, plus a variety of other benefits.

In 2016, we paid our annual membership fee to the US National Science Foundation for membership of the US/European consortium and an extra $UD300,000 for additional shipboard positions. Our membership of the Japanese consortium was in abeyance this year although *Chikyu* was again active in IODP science. We very much hope that *Chikyu* will have enough future funding to return in full to its very valuable IODP activities.

Australian and New Zealand IODP Consortium

Australian and New Zealand scientists are remarkably prolific authors of scientific ocean drilling publications. In total (Table 5), nearly 33,000 peer-reviewed ocean drilling publications have appeared since 1968. Australians were involved in nearly 6000 refereed publications (18.2%) and New Zealanders in more than 1100 (3.4%). Table 6 shows that of the total, 544 publications were in the leading science journals *Nature*, *Science,* and *Proceedings of the National Academy of Sciences* with Australians involved in 56 (10.3%) of these and New Zealanders in 19 (3.4%).

Our scientists gain by shipboard and post-expedition participation, by building partnerships with overseas scientists, by being research proponents and co-chief scientists who can steer programs and their scientific emphasis, and by early access to key samples and data. Post-doctoral and doctoral students have opportunities to train in areas of geoscience and microbiology that could not be studied in any other way. For logistical reasons the 2015 Marine Geoscience Masterclass for outstanding undergraduate students from all our university partners was deferred but successfully held in Perth in February 2016. A second successful Marine Geoscience Masterclass was held in New Zealand in December 2016, and this involved extensive land and marine fieldwork. Feedback for both masterclasses, from both students and leaders, was very positive indeed. The aim of the masterclasses is to demonstrate that geology and IODP science can provide exciting futures for undergraduate students, many of whom have not yet decided on their long term careers.

ANZIC's Governing Council has set aside money from the scientific members to support post-expedition research by shipboard participants amounting to $242,300 for eight participants in 2016. Also in 2016 an additional nine grants amounting to a total of $150,000 were made to Australian-led groups, to encourage them to work on interesting problems that can be addressed by studying legacy material (DSDP-ODP-IODP) and hence increase output from our overall investment

in ocean drilling. Work is proceeding under both this and the three previous years' grants, and research papers are starting to be published.

Three marine submissions involving geoscience, IODP and ANZIC were made to the strategically important ***Australian National Research Infrastructure Roadmap*** prepared for the federal government in late 2016. It has been argued for many years that funding of Australian membership of the IODP is similar to the needs of other national groups involved in multinational research using foreign owned infrastructure, and requires more secure, longer term funding. Our submissions drew attention to this necessity for our membership of the IODP, and are available with all others at https://submissions.education.gov.au/Forms/National-Research-Infrastructure-Capability-Issues-Paper-Submissions.

As a result of our submissions, the final version of the Roadmap document, due to go to Government early in 2017, will include a text box highlighting the IODP, as an example of an excellent international research program from which Australia gains a great deal scientifically in a very cost effective manner.

***DV Chikyu* arrives at Kochi prior to Exp 370 (Photo: JAMSTEC)**

Scientific Activities

ANZIC has active members on all key IODP committees. In 2016, eight Australians took part in all *JOIDES Resolution* expeditions (Table 4). The four *JOIDES Resolution* expeditions (see Map 2) were:

- Expedition 361, *South African Climates*
- Expedition 362, *Sumatra Seismogenic Zone*
- Expedition 363, *Western Pacific Warm Pool*
- Expedition 366, *Mariana Convergent Margin*

The alternative platform expedition was:

- Expedition 364, *Chixculub Impact Crater*

The *Chikyu* expedition was:

- Expedition 370, Nankai margin sub-seafloor life.

Three expeditions were of exceptional significance

- Expedition 363 addressed how conditions had varied over the last five million years in the large pool of exceptionally warm water in the western equatorial Pacific that is a major driver of world climate.

- Expedition 364 addressed the nature of the Cretaceous-Cenozoic boundary meteorite impact that wiped out much of earthly life, including the dinosaurs, about 65 million years ago, and allowed mammals to take over the Earth, leading eventually to humanity.

- Expedition 370 addressed the pressure and temperature conditions that limit microbes at great depth below the seafloor, and the nature of the many unusual microbes that survive there.

The Australian Earth Sciences Convention was held in Adelaide in June, with IODP sessions on two days. Five northern hemisphere scientists and eleven ANZIC scientists gave an excellent series of talks. The program enabled us to report to the geoscience community on the various IODP expeditions of the recent past and plans for the future. There was an ANZIC Booth at AESC, and both the talks and the booth generated real interest.

IODP Platforms

JOIDES Resolution funded by NSF, USA

Chikyu, funded by JAMSTEC, Japan

Mission specific platforms
Lift Boat Myrtle, alternative platform in 2016
funded by ECORD
(photo L. Pérez-Cruz, ECORD/IODP)

The Future of IODP

A ten-year phase of ocean drilling, under the name *International Ocean Discovery Program*, commenced in late 2013, and funding is agreed for the *JOIDES Resolution* and the European alternative platforms until late 2023, subject to reviews. Long-term funding for the Japanese deep-drilling vessel *Chikyu* is still under negotiation. Australia is funded through until the end of 2020, and New Zealand expects to remain in ANZIC at least that long.

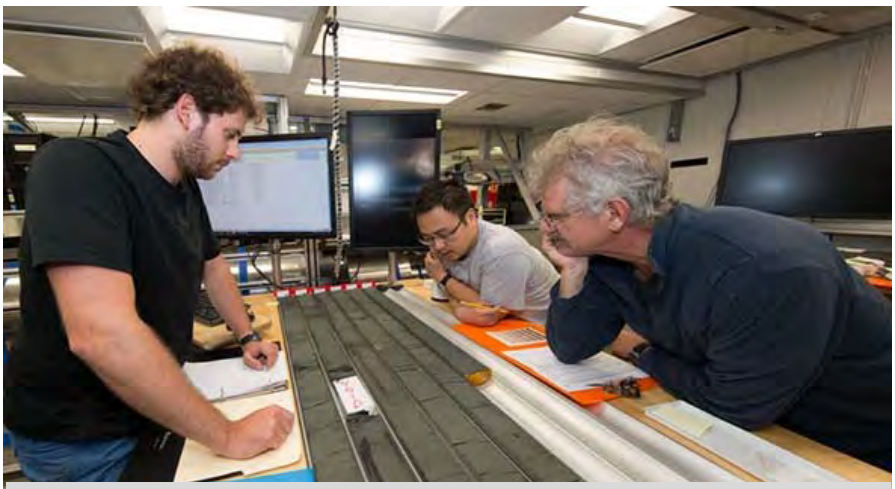
The themes of the new Science Plan – ***Illuminating Earth's Past, Present and Future*** - are:

- Climate and Ocean Change: Reading the Past, Informing the Future
- Biosphere Frontiers: Deep Life and Environmental Forcing of Evolution
- Earth Connections: Deep Processes and their Impact on Earth's Surface Environment
- Earth in Motion: Processes and Hazards on Human Time Scales

The years 2017 and 2018 will be very special for ANZIC, with six *JOIDES Resolution* expeditions in our region, all of high scientific and societal interest, and with very strong ANZIC involvement including a number of co-chief scientists:

- Expedition 369: *Australian Cretaceous Climates* (Naturaliste Plateau)
- Expedition 371: *Tasman Frontier Subduction and Climate* (Lord Howe Rise)
- Expedition 372: *Gas Hydrates and Hikurangi Subduction Margin*
- Expedition 374: *Ross Sea West Antarctic Ice Shelf*
- Expedition 375: *Hikurangi Subduction Margin*
- Expedition 376: *Brothers Arc Flux* (north of New Zealand)

An Australasian IODP Regional Planning Workshop is to be held at Sydney University in June, 2017. This major workshop will cover all the Australian and New Zealand region and is modelled on the earlier, highly successful, Indian Ocean and Southwest Pacific Ocean workshops. It will cover all platform possibilities, but our main aim will be to start the process of writing outstanding proposals to attract *JOIDES Resolution* back into our region around 2022.



On the right, Bradley Opdyke (ANU) with Niklas Meinicke (University of Bergen), Haowen Dang (Tongji University) examining Papua New Guinea cores (Credit: William Crawford)

Australian and New Zealand IODP Consortium

Acknowledgements

All our partners are thanked for their wholehearted support and advice, with special thanks to the members of the ANZIC Governing Council and Science Committee. Our strength is in our breadth of support in the geoscience community. Geoff Garrett has been an imaginative and dynamic Chairman of Governing Council, and New Zealander Rob McKay has been a very active and innovative Chairman of the Science Committee. Special thanks are due to Catherine Beasley for her excellent administrative work and friendship, and to Stuart Henrys as my very active New Zealand counterpart.

We are hugely grateful to the Australian Research Council for their ongoing financial support, and to all our Australian and New Zealand partners for their vital financial and scientific input.

Farewell

This will be my last year as ANZIC Program Scientist, as I plan to step down at the end of August 2017. This role has provided me with great interest since 2008 and I am proud of what I and my colleagues have managed to do in that time. In particular, the two regional IODP workshops – Indian Ocean in 2011, Southwest Pacific Ocean in 2012 – have generated much interest and many successful regional drilling proposals. The forthcoming Australasian IODP workshop is sure to do the same. Another important initiative is the ANZIC legacy volume, covering the first phase of IODP from 2008 to 2013, which contains articles by many of our scientists and will be published in 2017 by ANU Press.

Professor Neville Exon,
Program Scientist

Australian and New Zealand IODP Consortium

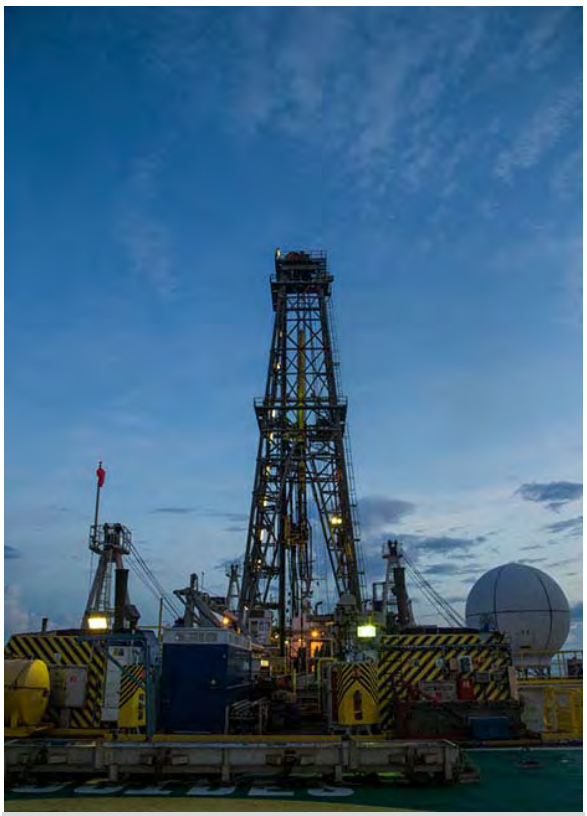
General Report for 2016

ANZIC IODP Organisation

The organizational involvement of Australians and New Zealanders in IODP falls into a number of categories: IODP panels, ANZIC committees, conferences and workshops.

Australian and New Zealand partners in IODP in 2016

The Consortium joined the new phase of IODP in September 2013. Australia was funded for 2016 to 2020 under a new ARC/LIEF grant, and the New Zealand partners funded themselves, with GNS Science paying the lion's share of their costs.



Early morning light shines through the *JOIDES Resolution* derrick. (Credit: William Crawford, IODP JRSO)

Australian IODP partners:

Unfortunately our previous partners, James Cook University, the University of New England and the University of Technology Sydney did not rejoin for 2016-20, but the University of New South Wales is a new partner. Our membership remains very strong and collectively contributing substantially more funds than previously to the annual costs associated with our involvement
in the IODP.

- Australian National University
- CSIRO Earth Science and Resource Engineering
- Curtin University of Technology
- Geoscience Australia
- James Cook University
- Macquarie University
- Monash University
- MARGO (Marine Geoscience Office) which is the marine geoscience peak body
- Queensland University of Technology
- University of Adelaide
- University of Melbourne
- University of New South Wales
- University of Queensland
- University of Sydney
- University of Tasmania
- University of Western Australia
- University of Wollongong

New Zealand IODP partners:

- GNS Science
- University of Auckland
- University of Otago
- Victoria University of Wellington
- NIWA (National Institute of Water and Atmospheric Research)

ANZIC members of IODP committees

ANZIC has participation rights on most IODP Scientific Advisory Structure panels, with ANZIC representatives listed in Table 1.

Table 1: ANZIC Members of IODP Committees in 2016

Committee or Panel	Member	Organisation
***JOIDES Resolution* Facility Board**	Mike Coffin; alternate Gary Wilson *Special scientific adviser* Andrew Roberts	University of Tasmania University of Otago Australian National University
***Chikyu* IODP Committee**	Andrew Heap; alternate Greg Yaxley	Geoscience Australia ANU
***ECORD* Facility Board**	Leanne Armand; alternate Craig Sloss *Special scientific adviser* Stephen Gallagher	Macquarie University Queensland University of Technology University of Melbourne
Science Evaluation Panel	Timothy Naish; alternate Zanna Chase Ben Clennell; alternate Andrew Gorman	Victoria University Wellington University of Tasmania CSIRO University of Otago
Environmental Protection and Safety Panel	David Campin; alternate Suzanne Hurter	Queensland Government University of Queensland
IODP Forum	Neville Exon alternate Richard Arculus	ANZIC Office, ANU ANU

ANZIC Governing Council

The Governing Council (GC) is a steering committee for the Australia-NZ IODP Consortium, and looks after broad policy. Its 2016 membership is listed below. Professor Stephen Eggins, the Director of the Research School of Earth Sciences at ANU is responsible for ANZIC finances.

In March, three major ANZIC meetings were held consecutively to get people together at the very beginning of the 2016-2020 phase of ANZIC. Professor Stephen Eggins hosted two meetings at ANU: a Science Committee meeting and a stakeholders meeting. Andrew Heap hosted a GC meeting at Geoscience Australia on the next day. In September, Associate Professor Oliver Nebel hosted a GC meeting at Monash University Melbourne, and in November Professor Stephen Eggins hosted another meeting at ANU. Two intervening meetings were convened by telephone, and other business was carried out by email.

Table 2: Members of the ANZIC Governing Council in 2016

Person	Position	Institutions	Expertise
Geoff Garrett	Chairman	Queensland Chief Scientist	Metallurgist and science management
Richard Arculus	Lead Chief Investigator of the ARC/LIEF grant	ANU, Canberra	Igneous petrologist. ODP shipboard scientist. IODP co-chief scientist
Ben Clennell	CSIRO representative	CSIRO Petroleum Exploration and Production	Petroleum geologist. ODP shipboard scientist. SEP panel member
David Cohen	University of NSW, Sydney	University of NSW, Sydney	Igneous petrologist and geochemist, mineral exploration
Kelsie Dadd	Australian university representative (Jan-Aug 2016)	Macquarie University, Sydney	Physical volcanologist, sedimentologist. IODP shipboard scientist
Stephen Eggins	ANU representative	ANU, Canberra	Geochemist
Chris Elders	Australian university representative	Curtin University of Technology, Perth	Petroleum geologist, seismic interpreter, margin evolution
Neville Exon	ANZIC Program Scientist	ANU, Canberra	Marine geologist and geophysicist. ODP co-chief scientist
Simon George	Australian university representative (Sept-Dec 2016)	Macquarie University, Sydney	Organic geochemist, IODP Shipboard scientist
Andrew Heap	GA representative	Geoscience Australia, Canberra	Marine geologist and sea bed mapping
Stuart Henrys	Chair, NZ IODP	GNS Science, Wellington, NZ	Marine geophysicist
Robert McKay	ANZIC Science Committee Chair	Victoria University Wellington	Sedimentologist, Antarctic glacial history
Joshu Mountjoy	NZ representative	NIWA, (National Institute of Atmospheric Research), Wellington	Marine Geologist, active techtonics, gas hydates
Oliver Nebel	Australian university representative	Monash University, Melbourne	Igneous petrologist and geochemist
Chris Yeats	Independent expert adviser	NSW Geological Survey Executive Director	Hydrothermal systems. ODP and IODP shipboard scientist
Clive Baldock	ARC Observer (Part year)	Australian Research Council Canberra	Medical physicist
Stephen Buckman	ARC observer (Part year)	Australian Research Council, Canberra	Atomic physicist

ANZIC Science Committee

The Science Committee encourages and assists the development of science proposals, organizes topical workshops, assesses cruise applicants, applicants for IODP panel membership, and applications for special analytical funding, and supports quality speakers to visit Australian and New Zealand research centres. A subcommittee considers applications for post-cruise analytical funding for science party members (shipboard and sampling parties). The committee's revised membership in 2016 is listed below.

Most business was conducted by email or telephone, but the committee met face-to-face at ANU on 15 March. Most of its business was related to assessing applicants for places on forthcoming expeditions. Those deemed suitable were ranked, and their details and our ranking were sent on to the relevant expeditionary planners. In general, our top-ranked applicant was scheduled for each expedition.

Governing Council authorised Science Committee grants for work on material and data from ocean drilling material, which were made from the funds provided by our partners, but excluding ARC/LIEF funds. A small sub-committee dealt with requests for general post-cruise scientific funding (maximum grant of $40,000 per person). Eight shipboard participants were awarded a total of $242,300. The full committee ranked applications in a special call for post-cruise analytical funding to cover legacy ocean drilling material. Eleven scientific groups applied. A total of $150,000 was awarded to nine of the applying groups, with the highest grant being $A20,000 and the lowest being $A10,000.

ANZIC Governing Council November 2016 (L-R) Stephen Buckman (ARC), Ian Poiner (Incoming Council Chair), Neville Exon (Program Scientist), Geoff Garrett (Outgoing Council Chair), Catherine Beasley (ANZIC Administrator), Ben Clennell (CSIRO), Andrew Heap (GA), Chris Yeats (GS NSW) and David Cohen (UNSW)

Table 3: Members of ANZIC Science Committee in 2016

People	Institutions	Expertise
Robert McKay, Chairman	Victoria University, Wellington	Sedimentologist
Leanne Armand	Macquarie University	Micropaleontologist(Diatoms), Southern Ocean geoscience
Irina Borissova	Geoscience Australia	Marine geophysicist and basin studies
Ben Clennell	CSIRO	Petroleum geologist
Mike Coffin	University of Tasmania	Marine geophysicist, large igneous provinces
Chris Elders	Curtin University	Seismic interpretation of continental margins, petroleum geologist
Neville Exon	Australian National University	Marine geologist and geophysicist
Kliti Grice	Curtin University	Organic geochemist
John Moreau	University of Melbourne	Microbiologist
Nick Mortimer	GNS Science, Dunedin	Tectonics, petrologist, SW Pacific, Zealandia and Antarctic regional geologist
Oliver Nebel	Monash University, Melbourne	High temperature geochemist
Joanna Parr	CSIRO	Submarine ore geologist
Gordon Southam	University of Queensland, Brisbane	Microbiologist
Virginia Toy	University of Otago	Structural geologist
Jody Webster	University of Sydney	Carbonate sedimentologist
Greg Yaxley	Australian National University	Igneous petrologist

ANZIC IODP Science

Participants in IODP Expeditions in 2016

ANZIC is entitled to put up to six scientists aboard IODP expeditions each year, and the bulk of these positions are on the US drilling vessel *JOIDES Resolution*. Fifty Australians and ten New Zealanders have been members of a science party between 2008 and 2016. During 2016, eight Australians and one New Zealander took part as scientific members on all the expeditions that spanned the calendar year (rather than the six we were formally entitled to). One Australian education officer also sailed.

The four *JOIDES Resolution* expeditions (see map below) were:

- Expedition 361, *South African Climates and Agulhas Current Density Profile*: the history of the Agulhas Current during the Pliocene–Pleistocene Expedition
- 362, *Sumatra Seismogenic Zone*: the role of input materials in shallow seismogenic slip and forearc plateau development.
- Expedition 363, *Western Pacific Warm pool*: Neogene and Quaternary records of Western Pacific Warm Pool paleoceanography.
- Expedition 366, *Mariana serpentinite mud volcanism: geochemical, tectonic, and biological processes*: examining processes of mass transport within the subduction zone of a non-accretionary convergent margin; and establishing long-term seafloor observatory sites by emplacing cased boreholes at summit (conduit) holes in mud volcanoes.

The alternative platform ECORD expedition was:

- Expedition 364, *Chicxulub Impact Crater*: drilling the Cretaceous-Paleogene impact crater associated with global mass extinctions for a variety of structural, petrological, fluid flow and microbiological reasons.

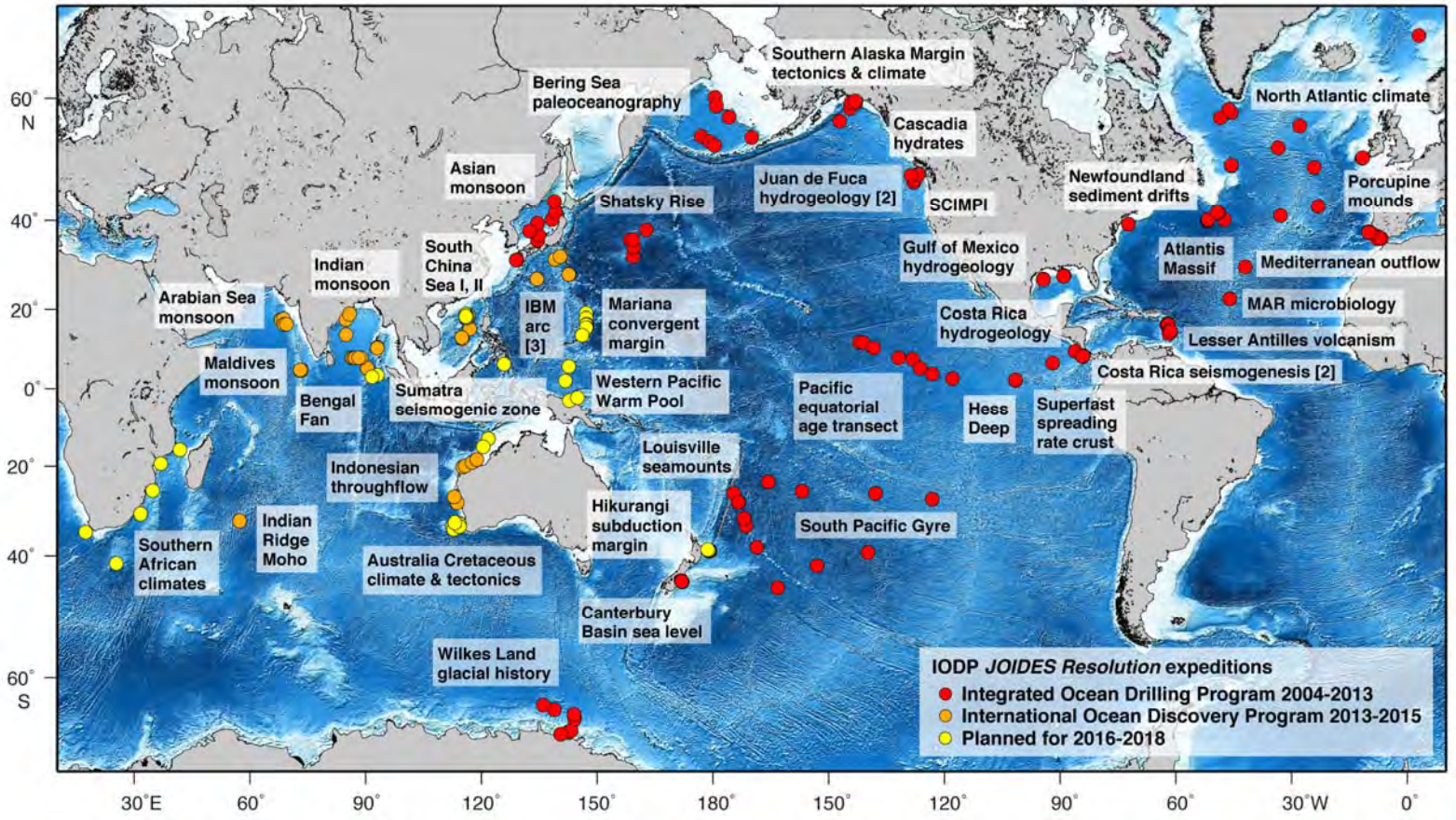
The *Chikyu* expedition was:

- Expedition 370, *Temperature limit of the Deep Biosphere off Muroto*: deciphering factors that constrain the extent of the deep biosphere in a subduction zone.

Jennifer Wurtzel (Australian National University) takes a selfie of the Exp 363 Physical Properties team during initial lab training. With Anna Drury (University of Bremen), Anaïs Schmitt (Université de Nantes), and Jian Xu (Northwest University, China). (Credit: Jennifer Wurtzel & IODP JRSO)

Australian and New Zealand IODP Consortium

Map 1: All JOIDES Resolution IODP Expeditions from 2004 to 2018

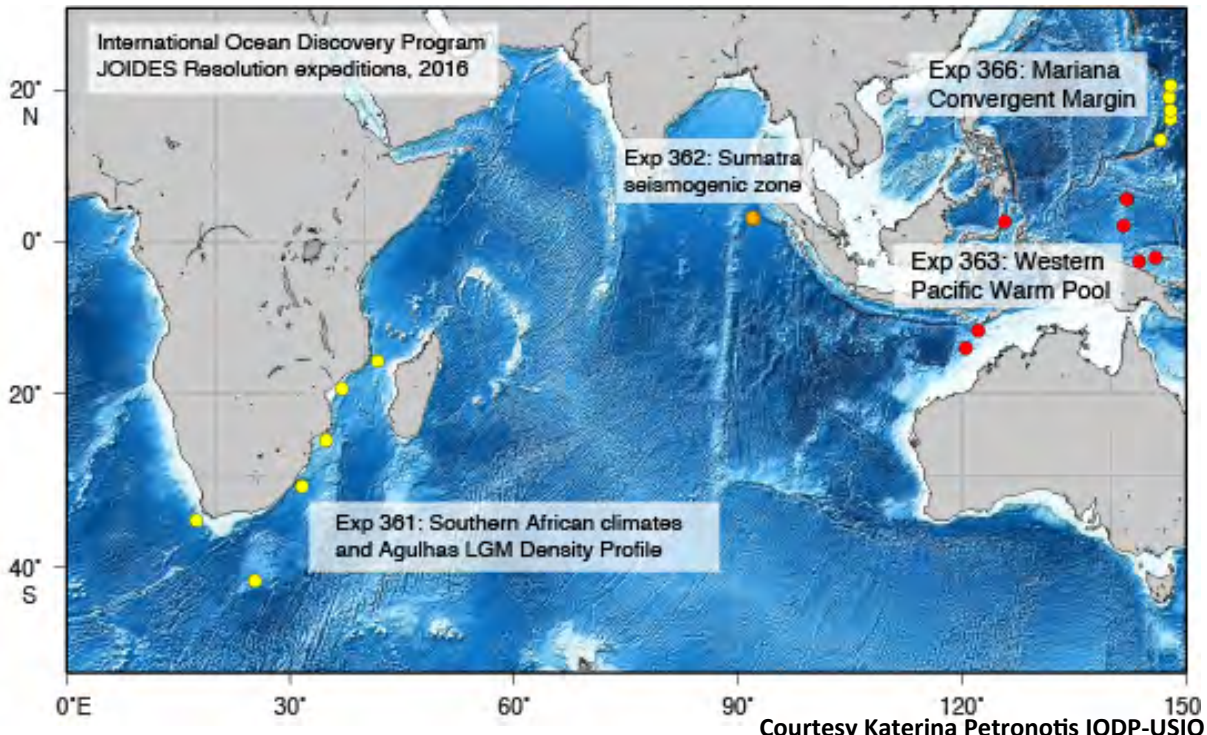


This map (courtesy Katerina Petronotis IODP-USIO) shows JOIDES Resolution expeditions but does not show expeditions on alternative platforms or DV Chikyu.

Table 4: Participants in IODP Expeditions in 2016

Expedition	Date	Participants
361: South African Climates	January 30– March 31, 2016	John Rolison (Otago), inorganic geochemist; Luna Brentegani (QUT), nannofossils
364: Chicxulub Impact Crater (ECORD)	April 5 – May 31, 2016	Marco Coolen (Curtin), organic geochemist aboard ship
362: Sumatra Seismogenic Zone	August 6 – October 6, 2016	Tobias Colson (UWA), physical properties; Sarah Kachovich (UQ), radiolarians
363: Western Pacific Warm Pool	October 6 – December 8, 2016	Brad Opdyke (ANU), sedimentologist; Jennifer Wurtzel (ANU), petrophysicist; Katie Halder, (WA) education officer
370: Chikyu Nankai margin sub -seafloor life	September 10-November 10, 2016	Maija Raudsepp (UQ), shipboard microbiologist
366: Mariana Convergent Margin	December 8, 2016 – February 7, 2017	Emanuelle Frery (CSIRO), sedimentologist

Map 2: JOIDES Resolution IODP Expeditions 2016



Courtesy Katerina Petronotis IODP-USIO

Australian and New Zealand IODP Consortium

Personal reports on IODP Expeditions in 2016

Expedition 361: South African Climates

February and March, 2016

(Luna Brentegani, Queensland University of Technology)

Expedition 361 started its journey from the docks of Port Louis, Mauritius, heading south of Madagascar to collect six long cores along the eastern African margin between the Mozambique Channel down to the Agulhas Plateau, south of South Africa. The aim of the expedition was to recover sediments along the path of the Agulhas Current in order to reconstruct its changes during the past 5 million years. We successfully ended our journey with a total of 5175 m of sediment that covered up to 7 Ma of history.

After an unexpected beginning, waiting for the approval to drill within the Mozambique Channel, the expedition suffered also from the reduction of the scientific crew due to the need of medical attention. These combined events explain why the cores that were first collected are not within the planned northern route of the *Joides Resolution* (JR). Indeed, we first sailed south enjoying the long travelling times between sites. However, when we finally headed north and were able to drill within the Channel, the workload suddenly increased. Sediment description, sample preparation and analysis, data collection and storage, site report writing and editing happened all at once for three sites in a row!

Luna Brentegani (QUT) collecting samples Expedition 361

Luna Brentegani (QUT) and John Rolison (University of Otago) backed up by Exp 361 Staff Scientist, Leah LeVay and Co-Chief Scientists Ian Hall (Cardiff University), and Sidney Hemming (Columbia University). (Credit: Tim Fulton, IODP JRSO)

All in all, the core recovery was excellent and many of the objectives of Expedition 361 will be addressed thanks to the collection of complete sedimentary sequences that span the Late Pleistocene to the late Miocene.

Some of these scientific goals related to:

- Identifying the effects of a changing climate on the Agulhas Current system;
- Determining differences within the Indian-Atlantic gateway through time;
- Observing the behaviour of the Agulhas leakage into the Atlantic Ocean in relation to shifts of the Atlantic Meridional Overturning Circulation (AMOC) as revealed by the recovered sequence.

After the Expedition I participated in the Editorial Meeting and Sampling Party held in College Station, Texas, in October 2016, thanks to ANZIC. As for the future, I hope to find the opportunity to work on the samples that I selected from the sediment sequences. The distribution and calcification of calcareous nannofossils within selected time intervals (1 – 1.5 Ma; Miocene) would help in reconstructing the path of the Agulhas Current and its environmental characteristics. Thanks to the combined effort made on board by the biostratigraphers together with the palaeomagnetists and stratigraphic correlators, we were able to provide reliable dates and age models with relative sedimentation rates for the six recovered cores. Now there is the possibility to continue the investigation by refining the sequences' ages, collecting geological, physical and chemical data, which will enable us to understand the connection between the South Indian and South Atlantic Oceans through time.

Expedition 364: Chicxulub Impact Crater

April and May, 2016

(Marco J. L. Coolen, Curtin University)

The 180 km in diameter impact crater at Chicxulub (Yucatan Peninsula, Mexico) is the largest terrestrial crater on Earth with a well-preserved peak ring and ejecta spread globally. The asteroid impact was associated with the End-Cretaceous extinction event 65.5 million years ago, which destroyed 75% of species world-wide including all non-avian dinosaurs. For the first time in history this expedition cored through much of the peak ring of the Chicxulub impact crater with the central aims to investigate (1) the nature and formational mechanism of peak rings, (2) how rocks are weakened during large impacts, (3) the nature and extent of post-impact hydrothermal circulation, (4) the deep biosphere and habitability of the peak ring, and (5) the recovery of life in a sterile zone. The coring location was ~30 km off the Mexican port city of Progreso and, since the water depth at the coring location was only 17 m, the core could be obtained from a steady platform (i.e., the American lift boat *Myrtle*).

Over a period of two months we obtained an 837 m-long continuous core, with virtually full recovery, spanning the lower 120 m of 618 m of Cenozoic marine sediments and 717 m of underlying peak ring rocks, (Morgan et al., *Science*, 2016). The upper peak ring consists of ~130 m of impact breccia with fragments of impact melt rock. The lower 587m of the peak ring, to the total depth of 1335 metres below sea floor, was formed from uplifted, fractured, shocked, felsic basement rocks.

Marco Coolen approaching to board the *Liftboat Myrtle* (photo EPM, ECORD/IODP).

I participated in the entire offshore expedition as a geomicrobiologist to collect pristine rock samples suitable for DNA analysis, in order to analyse the taxonomic and functional diversity of microbial life that was capable of recolonising the fractured impact rocks after the crater had cooled sufficiently to sustain microbial life. I also collected samples from the overlying marine Paleogene interval. Using molecular biological and biostatistical tools I plan to reveal which fraction of the deep subsurface microbial life underwent little to no selection upon burial and that could inform us about the paleodepositional environment. Using state-of-the-art organic and isotope geochemistry approaches in the laboratory of my colleague and mass extinction expert Kliti Grice at Curtin University, the Cenozoic (and select impact breccia) samples will be analysed further to reconstruct the paleodepositional environment associated with post-impact ecosystem changes. The latter analysis of chemical fossils and their individual stable C, H, S isotopes will also reveal the post-impact fate of taxa that do not preserve as microscopic or macroscopic fossils. Parallel drilling mud samples were obtained and will be analysed as controls for contamination with biomolecules and biomarkers during coring. I was working during the night shift while the other geomicrobiologist, Charles Cockell of the University of Edinburgh, sampled during the day. Charles also collected rocks for microbial cell counts and anaerobic cultivation of the ancient rock microbes.

Life on the boat and the interactions with the other science party and the crew were excellent. We had perfect weather, not even a drop of rain, and plenty of food of course. Space and opportunities to relax were limited, so I used off time to work on papers instead. We had a lot of world-wide media attention during the expedition, as well as some issues with angry local fishermen who feared that we were drilling for oil.

Later in the year I joined the onshore sampling party at the IODP core depository of MARUM at the University of Bremen in Germany where the core was split and described extensively by the entire 31 strong science party. This gave me the opportunity to obtain additional targeted samples such as carbonate veins that were formed at temperatures low enough to sustain microbial life as well as to visit my family in the neighboring country, The Netherlands. Two PhD students at Curtin University (Bettina Schaefer and Danlei Wang) are currently analysing a selection of the recovered samples.

Expedition 364 Science party aboard *Liftboat Myrtle.*

IODP Expedition 362: Sumatra Seismogenic Zone

August to October, 2016

(Toby Colson, University of Western Australia)

On the 6th August, 33 intrepid scientists set sail from the port of Colombo to embark on the Sumatra Seismogenic Zone Expedition 362. The objective was to understand the nature of seismogenesis in North Sumatra through sampling the input materials making their way toward the fault. In 2004 an enormous Mw 9.2 earthquake and tsunami struck North Sumatra and the Andaman-Nicobar Islands, devastating coastal communities around the Indian Ocean. This earthquake, followed by the Japanese earthquake and tsunami in 2011, showed unexpectedly shallow megathrust slip. In the case of North Sumatra, this was focused beneath the distinctive plateau of the Sumatra accretionary prism.

The first drill site (in 4185 m water depth) was U1480, with APC/XCB coring to 815 metres below sea floor (mbsf). Poor core recovery near the base led to a change to the rotary (RCB) bit. A new hole, offset by 20 *m* from the first entry position cored the lower section , and recovery improved as the formation became harder. Site U1480 reached a total depth of 1431.6 mbsf about 15m into the basaltic basement. The lower half of the hole had good core recovery. Unfortunately, although the hole was cased to 750 mbsf, attempts to conduct wireline logging below the casing were not successful.

At the second site (U1481), although the casing was successfully installed in 4178.3 m of water, one of the two brake bearings failed as the drill string was being pulled up to change the bit, an extraordinary occurrence for IODP. So we had to retrieve the drill string and head to Singapore to get a replacement part.

The scientists enjoyed the brief interlude in Singapore, but the transit took valuable time away from drilling. After great work by the drilling contractor, the JR returned to U1481, and re-entered the casing. We washed down to 1150 mbsf and commenced coring. Excellent core recovery was achieved to the total depth of 1500 mbsf, an estimated 50m short of basement. However, the hole was in good condition and a single wireline logging run was successfully conducted returning gamma ray, resistivity, sonic and caliper logs. After the logging run, we were out of time and had to pull the drill string to return to Singapore.

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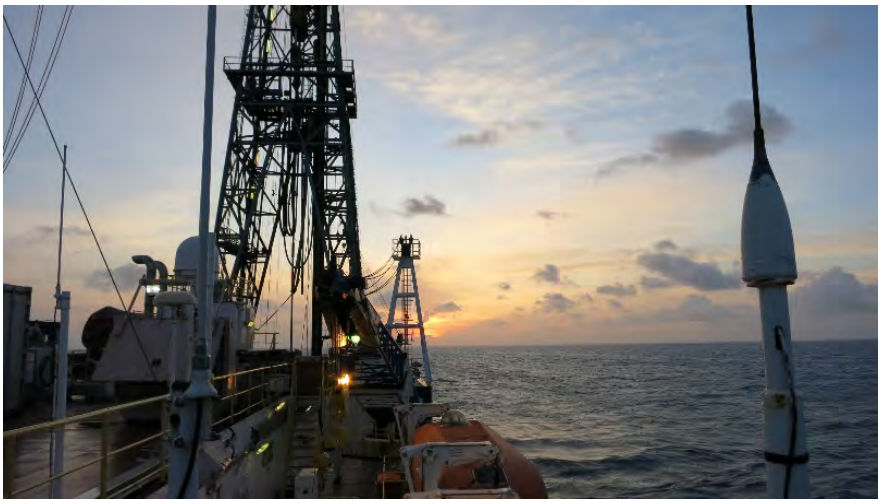


Good core recovery overall meant the principal objectives were achieved, with age constraints giving sedimentation rates that confirmed enormous input from the Nicobar fan. Whole round core samples have been sent around the world, and these will enable rock strength and frictional characteristics to be constrained. Stress profiles should allow the conditions at the deformation front to be modelled.

Even with its mechanical interruptions, the expedition has collected very valuable information that will contribute to the global understanding of the distinctive slip behaviour and long-term forearc structure of the Sumatran subduction zone. This information will be invaluable to our ever-increasing understanding of such earthquake-prone regions of the world.

The expedition achieved its primary objective, 'to sample the input sediment', albeit with an incomplete set of wireline logs. The delay caused by the brake's failure inhibited the success of the secondary objective (gathering *in situ* stress data) in so far as we ran out of time to run any image logs or deploy a packer for downhole measurements. However, the history of the Nicobar fan has been recorded.

The physical properties group proved a cohesive team, working well to provide all of the necessary petrophysical shipboard data and tests. This complimented the excellent preliminary characterisation, carried out by the sedimentology and geochemistry groups. Wireline logging struggled because of the instability of the drilled section, and it is clear that logging-while-drilling (LWD), a mainstay in the commercial world, really is a necessity in expeditions such as this one. Whilst expensive, LWD would provide insurance where bad hole conditions are predicted and good logging data are essential.

The physical properties group will come into its own after the expedition, and my post-cruise focus will be on the strength profile of the input sediment. Due to lack of shipboard stress data, strength data are planned to be combined with friction data from shipboard collaborators to define the strength and friction profile of the deformation front of the accretionary wedge.

Toby Colson (UWA) aboard the *JOIDES Resolution.*

Finally, arguably most importantly, the science team performed without fault. It was great to see new collaborations as well as friendships formed over the course of the two months. The crew of *JOIDES Resolution* was an asset with great food, service, technical assistance and friendly smiles and service at sea. The crew undoubtedly contributed, in their own way, as much to the science as the scientists and made this another positive step forward in our understanding of the earth.

Expedition 363: Western Pacific Warm Pool:

October to December 2016

(Katie Halder – Education officer, Canning College, Western Australia)

Katie Halder aboard *JOIDES Resolution*

After flying to Singapore I stayed overnight ready to join the *JOIDES Resolution.* I could hear the buzz of excited conversation as I descended to the hotel lobby to meet the scientists with whom I would be spending the next two months at sea. It was immediately clear from the greetings being exchanged and smiling faces that many of those gathered were old friends catching up, whilst others like me knew nobody. After a brief bus journey we rounded the corner to the dock. Necks craned to catch a first glimpse of our new home; it was easy to spot with its distinctive 66 m derrick, so I knew it instantly.

The *JOIDES Resolution* at a mighty 150 m long is one of the most capable drilling ships in the world, able to drill in both deep ocean water and to great depths below the ocean floor. It has been solely used for scientific research since its conversion from an oil exploration vessel in 1984. It can drill down through rocks and sediment on the ocean floor to remove long cores which are studied by scientists both during and after the voyage. Initial measurements and analysis of the cores is performed on board using the ship's laboratory equipment. The scientists work around the clock to maximise the equipment and time on the ship.

For our expedition we took sea floor cores around the Western Pacific Warm Pool. This is the largest patch of warm sea water in the world, and due to the high heat capacity of water it contains a great deal of stored energy. This influences important climate systems. These include the Asian monsoons, the Australian Monsoon and the El Nino cycle. The interaction between this large body of water and these weather systems is not well understood. Understanding the interplay between the extent of the Western Pacific Warm Pool and the climate in the past will help us to better predict future climate changes as the planet becomes warmer. Scientists are particularly keen to understand the last 10 million years of climate history, as during this time the Earth's land masses were similarly placed to where they are today so currents and climate systems are thought to be similar.

For the three days before leaving port the ship was a hive of activity. Goods were continually craned on and off the ship in preparation for the voyage. With a total of 124 people on board the preparations for the galley alone was staggering. The food included 10800 eggs, an astonishing 7000 kg of vegetables and 4000 kg of meat. The shelves and the corridors in the huge walk-in fridges were heaving under the weight of the food stacked to the ceilings.

The laboratories had to be restocked and prepared. The previous expedition's core samples needed to be removed from the ship's hold. Computer equipment was set up and made ready for the new personnel and the ship was refuelled, which was a 24 hour procedure in itself. The teams of personnel comprised engineers, the drill floor crew, the captain and his mates, the cooks and stewards working in the 'hotel stack', the laboratory technicians, the marine computer specialists and of course the scientists. All were briefed in preparation for the expedition.

My position on board was the 'education officer'. Like all on board I worked 12 hour shifts 7 days a week. My role was to engage the public with the research on board so that they gain a better understanding of the expedition's science and learn how scientific research is conducted more generally. This was done through the use of social media (by writing blogs and posting on facebook and twitter), and by engaging directly with schools, universities and other institutions through webinars and by making resources for teachers. The webinars were tailored to the needs and interests of the institution. With primary schools this mainly focused on what life was like on board with students' interested in our work routines and sleeping arrangements. For the secondary schools webinars included more about the scientific process and the concepts underpinning the work on board. Earth science has an increasingly large place in the science curriculum in Australian schools and it is a great opportunity for students to see the scientists researching this area in action. All the webinars included a short tour of the ship and a chance to engage with the scientists on board.

Life on board soon settled down into a routine. My midday to midnight shift allowed me to enjoy many sunset meals. We were lucky enough to glimpse the occasional pod of dolphins and had visits from different sea birds. After the end of the shift we would sometimes watch the stars when in transit between sites. In the nights on drill sites the deck is brightly light by the derrick's lights and stars looked somewhat dimmer under the electric glare. Tim Proctor, the camp boss, helped keep morale up by providing delicious birthday cakes to celebrate birthdays. He and his team also provided special meals to celebrate events. We had a sushi night where staff decorated the canteen and provided a feast of fishy treats.

Sushi buffet aboard the *JOIDES Resolution*

As the voyage reached its conclusion, with the hold filled with almost 7000 m of core, excitement rose with the prospect of seeing land once more. I was up at 5.00 am to see Guam appear in the early morning light. First a pilot came on board then tug boats moved us into place at the dock. Customs officers and passport control came to process our arrival in the United States. Finally we were cleared to leave the boat and to wait for the arrival of our bus to take us to our hotel.

Although my time as the education officer has finished there is always an education officer on the *JOIDES Resolution*. Schools can book free webinars with the *JOIDES Resolution* from the joidesresolution.org website. The education officer on board will try to meet the time requested by the school. I would certainly recommend that schools take advantage of this opportunity. It is an interesting and unusual experience for students to get a glimpse into research, work as a scientist and life on board a boat. Each expedition has different objectives so there are differences in the material presented but the overall opportunity to see science research in action remains common.

Expedition 366: Mariana Convergent Margin

December 2016 to February, 2017

(Emanuelle Frery, CSIRO Energy)

The mud volcanoes of the Mariana fore-arc are unique in the world. These huge edifices are the only known places in the ocean where blue mud is currently erupting and rocks are being pushed up to the seafloor directly from an active subduction zone—the Mariana Trench. Studying these seamounts is the key to unravelling what geological processes are happening at unreachable depths far beneath the seafloor, and to help uncover the story of the subducted oceanic plate (called the 'slab') after its disappearance below the upper plate where the mud volcanoes lie. This is the reason why I decided to spend two months at sea in the middle of the Pacific Ocean (along with the 30 other scientists that are part of Expedition 366) - to take part in the exciting adventure of a close glimpse into Earth's development and secrets.

The interface between the upper plate and the slab - called the mélange zone - is composed of a large range of rock types: from the sediments accumulated over millions of years above the subducting plate, to the ultramafic rocks, relics of the original plate formation at the mid-ocean ridge. The scientists on our expedition are focused on studying the evolution of the geological processes and physical conditions existing along the mélange zone and the mechanisms that allow some material to get pushed back up to the seafloor. The mélange zone is also the site of the huge ruptures and asspciated tsunami that have devastated Sumatra and Japanese margins over the past decade.

I remember my first glimpse of our research vessel, the *JOIDES Resolution*, two years ago when it was anchored in Fremantle harbour and I was lucky enough to climb aboard for a tour. This vessel has made history and contributed to major discoveries on paleoclimate, plate tectonics and more. Donning security shoes, helmets and protective glasses, we visited the huge drilling installations in the middle of the ship. The facilities were outstanding: from a helideck and massive drill rig, to spacious biological, chemical and geological laboratories with instruments usually never available in the field—on this ship it is possible to do very detailed and complex analyses. At that time, I did not know where to stand amidst this *well-oiled machine* crowded with technicians, scientists and crew members preparing the upcoming expedition.

Fast forward two years: I am now suddenly one of those scientists running up and down flights of stairs from the ship's conference room to labs to mess hall. I quickly fall into a routine: wake up at 9.30 am, go to gym, eat breakfast, cross-over meeting with my colleagues from the night shift, work a 12 hour shift (starting at noon), and at midnight go to bed. This was my routine for the eight weeks. I was part of it and, believe it or not, I enjoyed each moment of it.

I was working as a structural geologist in the core description laboratory, the place where all rocks brought up in cores are geologically described at both macroscopic and microscopic scales. These tasks require the complementary skills of hard-rock geologists, petrologists, meta-sediment specialists, and serpentinized ultramafic rock specialists. Given this full range of expertise, discussions around a rock clast or a mud section quickly become exciting and ideas immediately start to hatch. You are, on a daily basis, working side by side with Americans, Koreans, Chinese, German and Japanese colleagues. You are, on a daily basis, sharing your scientific baggage, learning from others, and developing common interests with diverse people.

My proposed plan for the expedition was to focus on the structures and petrophysical properties of the mud volcanoes, to try and better understand the architecture and the stress regime of the pathways used by the material to migrate from depth up to the seafloor. The Mariana mud volcanoes are presently interpreted as mounds that have been episodically formed over tens of million years by serpentinized material periodically erupting through a central conduit located above a network of normal faults rooted at depth on the mélange zone.

We gathered new data that better constrain the understanding of these huge features and challenge the current knowledge. For instance, temperature measurements taken at the summits and on the flanks of several volcanos clearly and systematically indicate an unexpected disequilibrium between both measured heat flows. In addition, we drilled down into pelagic sediments that accumulated prior to development of a mud volcano, providing a new estimate for when that mud volcano started to form. In collaboration with a petrophysicist and one of the co-chief scientists, I made a 3D kinetic model of the volcano's build-up, and was able to calibrate the new dataset with only certain durations and volumes of the episodic mudflows. At our daily scheduled science meetings, I could present our work to my on-board colleagues, which helped me testing the validity of my initial results and get new ideas for further analyses.

On the ship, lack of motivation is practically unheard of, and multiple collaborations can develop quickly. Sailing on our expedition we had talented scientists ranging from PhD students to scientific celebrities. For example, microbiologist Ken Takei is part of the team. We may not know him in the petrology world, but trust me — he is a highly renowned scientist in his field, the equivalent of a Gary Ablett, AFL speaking. Through his discoveries about the potential origins of life on earth as well as throughout our solar system, this guy is pushing the limit of how we define life—and he is pretty much a science super star in Japan. Being on this expedition is like being able to go backstage at a rock concert, and more than that, travel for two months with the band!

This expedition is special—it's the last before our co-chief Patricia Fryer's retirement. She has dedicated her long and successful career to exploring and understanding these mud volcanos, so it was an honour to sail with her. For many of the other scientists on-board, this is their very first expedition at sea, and the starting point of great upcoming adventures. The weeks flew by with the help of many celebrations: Christmas, New Year and Australia Day (Ok, we didn't actually celebrate Australia Day because nobody here had heard of it or of Australian Football. In the absence of beer and a decent barby I did not feel that it was the ideal place to share that Aussie event).

Discussing a serpentinised ultramafic clast: Emanuelle Frery (L) with Co-chief Pattie Fryer (R)

Anyway, being away from your mates and family during the holidays is not ideal, especially for the scientists with young kids. We all had a little apprehension but these celebratory moments unexpectedly turned out to be pure magic. People sang holiday songs in no less than 10 languages, we shared a yummy meal and we all felt warm inside. After the emotion followed instants of pure craziness. Have you ever had a dance party on a moving ship? It is definitely something to try, and you may even get addicted!

Over the eight weeks, we spotted only two boats far in the distance. We were isolated in the middle of the immense ocean. From time to time, the sea was dotted with white caps, there was some weather, but it did not last. When the first bird flew close to the ship we admired it. Someone said that they are migratory birds who are tired and spotted the boat from a long distance, and you feel sorry for them. There were more and more birds, and you climbed up to the top bridge to observe them, regal birds with blue beaks, flying a few meters above you. Then you realize that at sea as on shore, birds poop, and sometimes it lands on you - a relentless law of nature. You placidly look more and more towards the sea and realize that they are plenty of multi-coloured big fish surfing on the waves, and at that moment a water geyser erupts from the water. Whales are around the boat, inspecting it for hours until a magnificent sunset blankets the ocean.

Breaking science, new collaborations, strong friendships, open minds, new horizons; plenty of memories and images to feed my imagination. This IODP expedition is a once in a life-time journey, but it is also just the beginning of a wonderful human and scientific adventure.

IODP Expedition 370: Chikyu Nankai Margin sub-seafloor life

September to November, 2016

(Maija Raudsepp, The University of Queensland)

IODP Expedition 370, officially named *T-Limit of the Deep Biosphere off Muroto* aimed to determine the temperature limit of microbial life in the deep subseafloor. To achieve this objective, a single borehole was drilled to a depth of 1180 metres below sea floor (mbsf) by the *Chikyu* at Site C0023 in the Nankai Trough off Cape Muroto, Japan, at a water depth of 4776 m. This location was chosen as the *in-situ* temperature at the sediment-basement interface was predicted to be approximately 120°C. Thus, the cells numbers, the microbial communities and the influence of life on organic and inorganic geochemical profiles could be examined in a sedimentary column containing a temperature gradient from 30 to 120°C. To achieve these scientific objectives, time-sensitive microbiological samples were flown for analysis by helicopter from the *Chikyu* to super-clean facilities at the Kochi Core Centre in Japan, a first for an IODP expedition.

Work on the *Chikyu* was conducted between September 10 and November 11. This expedition was run under the expert guidance of co-chiefs Verena Heuer, Fumio Inagaki and Yuki Morono. My role on the expedition was as a shipboard microbiologist. The primary job of the shipboard microbiologists was to ensure quality control/quality assurance over all microbiological samples, to conduct chemical tracer analyses and to clean and process core sections for on-shore microbial analyses. This is particularly important as the core samples contained low microbial biomass. After core retrieval and imaging in an X-ray CT, time-sensitive samples were cut into sections and then the exterior of the cores was cleaned with sterile knives in an anaerobic chamber, which was fitted with a KOACH air filtration unit. During the expedition, the microbiology laboratory was a busy centre on the ship, cutting over 1000 whole round samples from 112 cores. These core samples have been set to laboratories globally for many different microbial analyses and experiments including cell counting, 16S rRNA gene sequencing, microscopy, determining the potential for microbial metabolic rates with radioactive tracers and microbial cultivation in bioreactors and batch experiments. Understanding the deep biosphere is very challenging, but this expedition has been a very successful scientific endeavour.

Maija Raudsepp meets the *DV Chikyu, dockside.*

For me, living and working on the *Chikyu* with a group of diverse international scientists has been an amazing experience. On many evenings I and the other day-shift researchers would visit the helideck to watch the sunset and to talk about science before enjoying a delicious dinner. Because of this expedition, I have gained many friends from around the world and started several exciting collaborations. Post-expedition, I have focused my research on enriching and culturing methanogens and iron reducing microorganisms from the sediment. I will also be using scanning and transmission electron microscopy to examine the interactions between these microorganisms and the minerals present.

Publications by Australian and New Zealand Ocean Drilling Participants

Australian and New Zealand scientists have proud track records in IODP and its predecessors, the Deep Sea Drilling Program (DSDP) and the Ocean Drilling Program (ODP). Neither Australia nor New Zealand was a member in the early days of ocean drilling, but many of our scientists participated. Australia eventually became a member of ODP from 1989 to 2003. During ODP (1988-2003) seventeen expeditions occurred in our region, many of them with lead proponents from Australia and New Zealand. Seven Australians were co-chief scientists on these expeditions, and the resulting literature is ground-breaking and very large. Australia and New Zealand joined IODP in 2008, and since then there have been seven expeditions in our region, with Australian co-chief scientists on two of them.

Membership strongly affects publication, with a time lag of some years. The number of publications from IODP expeditions since we joined is only a small proportion of what we expect in the longer term.

Ginny Lowe of IODP Publication Services has generated the figures in the two tables below for us, and we are very grateful to her and her colleagues for that help. She notes that the "Articles with authors representing Australia" and "Articles with authors representing New Zealand" columns include publications that were first-authored or had a contributing author from Australia or New Zealand, respectively. The total of these two columns will not necessarily match the number in the "Articles with authors representing Australia and/or New Zealand" column, which includes publications that were first-authored or had a contributing author from either Australia or New Zealand. Publications that included authors from both countries are only counted once in this total.

Table 5 shows that, at latest count, the number of all DSDP-ODP-IODP publications with Australian and/or New Zealand authors was 6934, 21% of all publications. ANZIC authors have been involved in at least 21.2% of ocean drilling publications since 2003. Note that it is likely that many relevant papers have not been identified by this automated system.

Table 6 indicates that ANZIC involvement in peer reviewed publications in the top three science journals was 13.8%, in the top twenty journals it was 10.2%, and in all journals it was 17.9%. Since 2003, the comparable figures were 17.2%, 8.9% and 19.5%.

The detailed figures below show that both Australia and New Zealand have outstanding publication records within IODP.

Expedition 370 -Microbiologists Maija Raudsepp (UQ) and Lorenzo Lagostina (ETH Zurich) cut out whole round core sections (photo credit: Yusuke Kubo)

Table 5: Scientific ocean drilling publications involving Australian and New Zealand scientists

Date of publication	Publications with authors representing Australia	Publications with authors representing New Zealand	Total publications with authors representing Australia and/or New Zealand	Total scientific ocean drilling publications	Percentage of publications with authors representing Australia and/or New Zealand
1968–1974	213	148	**302**	1,585	**19.1**
1975–1981	23	20	**43**	3,620	**1.2**
1982–1988	154	140	**251**	4,508	**5.6**
1989–1995	2,061	50	**2,110**	6,020	**35.0**
1996–2002	1,746	110	**1,855**	6,032	**30.8**
2003–2009	877	189	**1,051**	6,296	**16.7**
2010–2015	835	432	**1,255**	4,632	**27.1**
2016†	**47**	24	**67**	256	**26.2**
Total	**5,956**	**1,113**	**6,934**	**32,949**	**21.0**

Notes: This table was prepared in February 2017 by IODP Publication Services based on data in the Scientific Ocean Drilling Bibliographic Database, a subset of GeoRef hosted by the American Geosciences Institute (http://iodp.americangeosciences.org/vufind). The criteria for the country-specific queries were the date ranges listed and institutional affiliation containing the words "Australia" or "New Zealand." * = Totals include peer-reviewed articles in science journals; published conference proceedings and abstracts; books and chapters in books; theses; and DSDP, ODP, and IODP publications. † = Statistics for 2016 only reflect citations that were added to the database by February 2017 and do not represent a complete total of 2016 publications.

Table 6. Peer-reviewed scientific ocean drilling articles written by authors representing Australia or New Zealand and published in top-tier journals, compared to all peer-reviewed scientific ocean drilling articles.

Date of Publication	Scientific ocean drilling journal articles in top three science journals*			Scientific ocean drilling journal articles in top twelve Earth science journals†			All peer-reviewed scientific ocean drilling journal articles	
	Authors representing Australia	Authors representing New Zealand	All authors	Authors representing Australia	Authors representing New Zealand	All authors	Authors representing Australia and/or New Zealand	All authors
1968–1974	0	0	18	0	0	24	198	**1,457**
1975–1981	0	0	69	0	0	153	35	**2,512**
1982–1988	10	5	95	6	1	213	156	**2,702**
1989–1995	16	0	65	15	4	454	1,054	**3,581**
1996–2002	9	0	94	63	14	770	889	**3,329**
2003–2009	4	4	132	89	30	1,382	519	**3,309**
2010–2015	17	8	65	133	59	1,063	561	**2,274**
2016‡	0	2	6	3	3	79	49	**205**
Total	**56**	**19**	**544**	**309**	**111**	**4,138**	**3,461**	**19,369**

Notes: This table was prepared in February 2017 by IODP Publication Services based on data in the Scientific Ocean Drilling Bibliographic Database, a subset of GeoRef hosted by the American Geosciences Institute (http://iodp.americangeosciences.org/vufind). * = Top three science journals (based on Thompson/Reuters impact factor) = *Nature, Science,* and *Proceedings of the National Academy of Sciences of the U. S. A.* † = Top twenty Earth science journals (determined by impact factor of journals in ISI Web of Knowledge categories related to Earth science) = *Nature Geoscience; Earth-Science Reviews; Geology; Quaternary Science Reviews; Geological Society of America Bulletin; Earth and Planetary Science Letters; Geochimica et Cosmochimica Acta; Geophysical Research Letters; Journal of Petrology; Climate of the Past; Chemical Geology; Paleoceanography; Journal of Geophysical Research; Contributions to Mineralogy and Petrology; Geochemistry, Geophysics, Geosystems; Organic Geochemistry; Marine and Petroleum Geology; Tectonophysics, Physics of the Earth and Planetary Interiors;* and the *Journal of Quaternary Science.* Criteria for country-specific queries were the journal International Standard Serial Number (ISSN), the date ranges listed, and institutional affiliation containing the words "Australia" or "New Zealand." ‡ = Statistics for 2016 only reflect citations that were added to the database by February 2017 and do not represent a complete total of 2016 publications.

Workshops, Conferences and other Outreach activities

ANZIC Marine Geoscience Masterclass in Perth, February 2016

This course was funded by ANZIC and involved 20 high-achieving students drawn from all member universities, involving second year students from Australia and third year students from New Zealand. It was hosted by CSIRO, Curtin University and the University of Western Australia, and introduced students to the exciting world of marine geoscience, focussing on the themes of the new IODP Science Plan. One highlight was practical experience of marine geoscience using the small CSIRO research vessel *Linnaeus*, and another was the study of marine cores in a core library. The students have provided very favourable feedback. Many thanks go to Asrar Taludker and Andrew Ross (both CSIRO) for coordinating the Masterclass, and to all those who provided scientific input and support.

Science meets Parliament in Canberra in March

'Science meets Parliament' (SmP) is a two-day annual gathering of scientists with interested Federal politicians, arranged by *Science and Technology Australia*. A dinner is held in the Great Hall of the Australian parliamentary building, and there are interesting talks from politicians and from eminent scientists. This is an excellent opportunity to meet the 'Parliamentary Friends of Science', a body comprising about half of all the members – in itself an encouraging thing. All the 200 scientists attending are matched with individual politicians, and two or three scientists in related science areas meet a member in their own room to outline their science and its significance.

Stephen Gallagher (University of Melbourne) and Katharine Grant (Australian National University) represented ANZIC at this year's two-day function.

Katharine Grant reported that the specific aim of SmP is to help us better communicate our science to the media, policymakers and parliamentarians. The first day focused on professional development and began with an inspiring speech by Professor Brian Schmidt (Nobel Laureate and Vice-Chancellor of the ANU), who had previously attended SmP as a young post-doctoral student at ANU. The first session was a bit disappointing because it focussed heavily on politics and the media, rather than science and the media. The next session, on how to use science to shape public policy, was more enlightening. In the afternoon, previous delegates discussed how they had benefitted from attending SmP, and then we had an interactive session aimed at preparing us to meet parliamentarians the next day. The highlight of the day was the gala dinner at Parliament House attended by a number of parliamentarians including Christopher Pyne (Minister for Industry, Innovation and Science) and Bill Shorten (Leader of the Opposition).

The second day was based at Parliament House and each SmP delegate was assigned to an MP for a face-to-face meeting (along with 2-3 other delegates). I had a very pleasant meeting with Andrew Giles (Labour) from the House of Representatives, who was keen to hear about our particular areas of research as well as our views on how science in Australia could be improved and what needed to be addressed. The rest of the day included a lunch at the National Press Club, where Dr Alan Finkel (Chief Scientist for Australia) gave a televised speech; parliamentary Question Time; and panel discussions featuring (amongst others) Senator Kim Carr (Shadow Minister for Higher Education, Research, Innovation and Industry), Professor Aidan Byrne (CEO of the ARC), and Karen Andrews MP (Assistant. Minister for Science). Katharine enjoyed all of these and thought that overall SmP was a very worthwhile experience.

'Science meets Parliament' is an activity which brings all areas of science to the attention of many influential people, and it has strong support from the scientific and technological community.

Australian Earth Sciences Convention in Adelaide, in June 2016

The Australian Earth Sciences Convention was held in Adelaide from 26 to 30 June, with the IODP Sessions on 27 and 28 June. Five northern hemisphere scientists and 11 ANZIC scientists gave an excellent series of talks. The program enabled us to report to the geoscience community on the various IODP expeditions of the recent past and plans for the future. There was also an ANZIC Booth at AESC, run by Catherine Beasley. There was a considerable amount of outreach to those not previously aware of IODP, and both the talks and the booth generated real interest.

Local and International IODP Members at AESC

A small lunch was held at University House in Canberra on 30 June, taking advantage of the presence of Jamie Austin, Chairman of the IODP Forum. This brought together key members of the Canberra IODP community, other interested scientists, and representatives of ARC, the Chief Scientist's Office, and the Departments of Industry, Innovation & Science, and Prime Minister and Cabinet. A talk by Jamie Austin was followed by a very animated discussion about the value of IODP to Australia.

Geoscience Australia Open Day in Canberra, in August 2016

Held at the Geoscience Australia headquarters in Canberra, the Open Day is a highlight of local Australian Science Week activities. In 2016 GA welcomed over 6000 members of the public to hands-on activities, science displays, talks and fun for all ages.

ANZIC members including Neville Exon, Irina Borissova, Andrew Heap and Ron Hackney, shared the exciting work of IODP scientists around the world and with a special focus on our plans for a major collaboration with GA on the Lord Howe Rise.

Ron Hackney (Geoscience Australia) talks ocean drilling and meteorite impact with some of our young fans.

Input to Australian National Research Infrastructure Roadmap in late 2016

Three marine submissions involving IODP were provided to the very important National Research Infrastructure Roadmap, led by Alan Finkel the Australian Chief Scientist. Our submissions are available with all others at https://submissions.education.gov.au/Forms/National-Research-Infrastructure-Capability-Issues-Paper-Submissions.

1) *The IODP submission*, prepared by Richard Arculus, consisted of two documents. He argued that "Our membership of the IODP is a quantified example where high scientific and economic returns have been gained for a relatively low investment, together with the benefit of national exposure to international best practice, sustenance of southern hemisphere marine scientific leadership, exploration of our marine estate with impact for resource exploration, and training of the next generation of Earth scientists."

2) *The National Research Vessel Alliance submission* is well balanced and consists of three documents, with very positive coverage of IODP. It was led by Gavin Begg, the Research Chief of Aquatic Sciences at the South Australian Research and Development Institute, and Neville Exon was an author. To quote from it "The submission details the necessary infrastructure required to form a national alliance of a coordinated fleet of research vessels that cover Australia's extensive and valuable marine estate in order to fully realise the significant benefits from our blue economy. The submission focuses on large scale research vessels that have the capacity to operate distances to at least the continental shelf. The scale of these vessels enables the use of specialised and state-of-the-art equipment to sample deeper, offshore waters, as well as to accommodate the necessary teams of scientists to conduct the research. The submission covers the benefits, logistics and networks for operating a coordinated national research vessel fleet, including how best to support and use international infrastructure."

3) *The National Marine Science Committee submission*, on marine science as a whole, is a comprehensive document with favourable mention of IODP.

4**)** *Case Study for 2016 National Research Infrastructure Roadmap - International Ocean Discovery Program (IODP).* As a result of our submissions, the 2016 Roadmap, which will be provided to Government in February 2017, will include the following case study and a picture of the *JOIDES Resolution*:

The IODP is a large international collaborative research program that recovers cores drilled in the global seas and oceans to address diverse and fundamental scientific questions using information in the layers up to 4000 m below the sea floor. It examines how the Earth has worked in the past, how it works now, and how it may work in the future.

Benefits of Australia's membership of the IODP include international collaboration and scientific understanding in areas such as plate tectonics and other deep Earth processes, climate and ocean change, biodiversity, mineral and petroleum potential, and geological hazards like earthquakes, tsunamis and volcanic eruptions. Australian scientists are established players in scientific ocean drilling; they have and continue to be lead proponents of planned expeditions, and authors or co-authors of about 1000 peer-reviewed journal articles since 1968. From 2016 to 2018 our general region is a major IODP focus, with eight two-month expeditions being carried out at an operational cost of $US12-14 million per expedition.

Australian annual membership is 1% of IODP's annual budget but our scientific return is disproportionately high. The IODP has drilling assets worth US$1.1 billion and repositories holding more than 400 kilometres of cores. All information goes into the public domain and a moratorium on recovered core material and related data is less than two years. Australian annual membership has direct economic return from each visit of IODP research vessels to Australian ports averaging $US1 million and indirect economic returns through petroleum exploration using IODP drilling results on our continental margins.

Science meets Business in Melbourne in October

Science and Technology Australia's *Science meets Business 2016* focused on building science and business collaboration, including diagnosing problems, identifying solutions and providing tools to make change. The aim was to bring together business leaders and scientists to foster STEM/industry collaboration, to broker better mutual understanding between science and business, and to promote opportunities for innovation. There was by-invitation attendance by business and science leaders, with speakers from both sectors and from the Government and Opposition. Around 200 leaders from research, the private sector and government attended.

Oliver Nebel (Monash University) attended on behalf of ANZIC. He reported that the meeting was interesting, but that there was nothing really related to IODP. He talked to some people but more in generalities rather than issues related to ocean science.

After two years of our attendance at this meeting, it is clear that it is not a high priority for ANZIC.

Sarah Kachovich (University of Queensland) and Yehua Shan (Chinese Academy of Sciences) at the core sampling table.

Lord Howe Rise deep stratigraphic drilling planning meeting in Canberra in October

Geoscience Australia and JAMSTEC are undertaking collaborative research to better understand the geology of the central Lord Howe Rise. The Lord Howe Rise project commenced on 1 July 2015 and, if fully funded, will run for four years. There was a visit from a group including Yoshi Kawamura of JAMSTEC, a key driver of the project, and Lallan Gupta, Director of the Kochi Core Centre, on 26 and 27 October. During the visit a series of agreements covering different aspects of the project were signed by JAMSTEC and Geoscience Australia, so that an overarching agreement can readily be signed if adequate funding is agreed.

The workshop was an opportunity to:

- provide a project status update and overview to the project parties and a senior representative from the Embassy of Japan
- discuss and co-ordinate responses to the external reviews of the science proposal
- discuss the establishment of the Geoscience Australia Data Repository as a recognised IODP core-storage facility for the Lord Howe Rise Project.

Geoscience Australia staff participating in the visit included Andrew Heap, Ron Hackney, Scott Nichol, Andrew Owen, John Pugh and Kevin Turner. External participants included Kliti Grice (Curtin University), Neville Exon (ANZIC) and Yoshihide Miwa (Japan Embassy in Australia).

ANZIC Marine Geoscience Masterclass in New Zealand,

December 2016

A Marine Geoscience Masterclass for 20 outstanding second year students, was held in New Zealand from 1 to 11 December. It involved lectures and practical work, including fieldwork in the Wairarapa east of Wellington, and marine fieldwork on the Research Vessel *Polaris II* in Doubtful Sound. The feedback from those running the course was that these highly motivated students were a delight to work with. The feedback from the students was that it was a wonderful experience, with some saying it would change their academic choices, and some suggesting that it should be longer in future. New Zealand will be hosting the next two annual Masterclasses and the organisers are thinking about extending them somewhat.

All those involved in running the Masterclass, from GNS Science and Otago University, are congratulated on the success and thanked for their contributions.

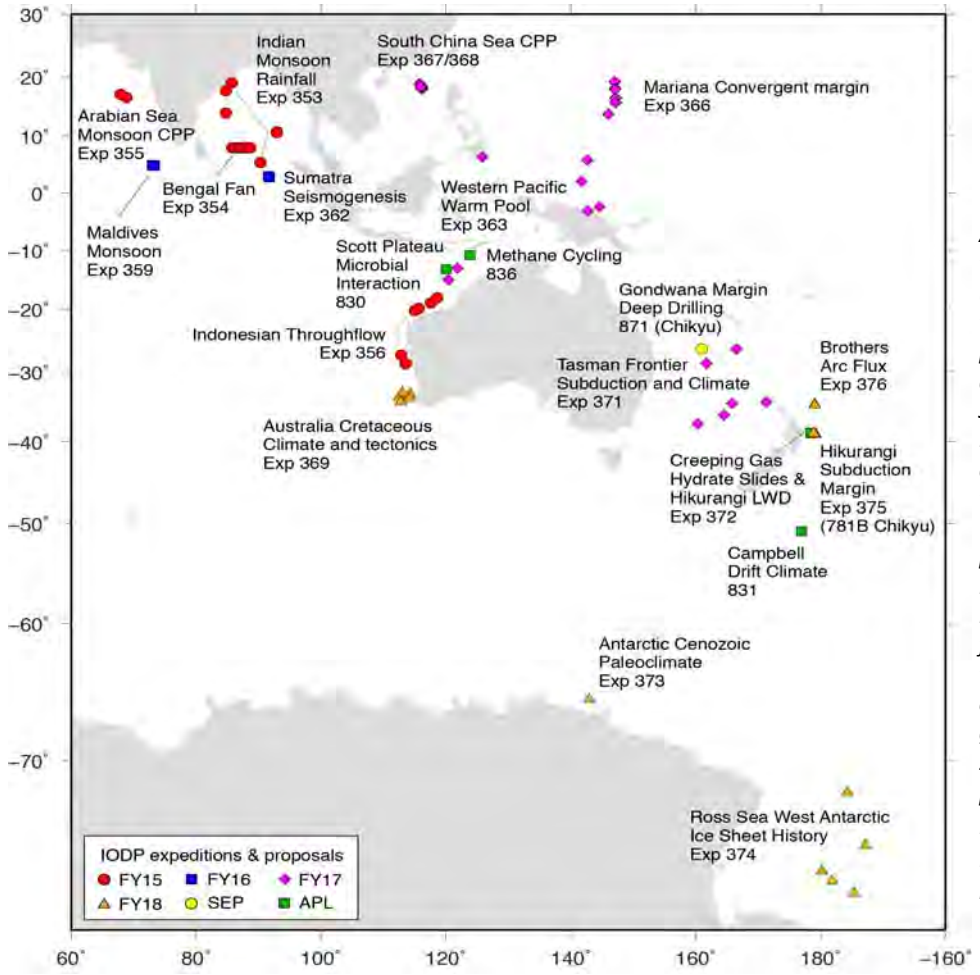
Australian and New Zealand IODP Consortium

The Future of IODP

The ten-year phase of ocean drilling from 2013 to 2023 was approved under the name *International Ocean Discovery Program*. Key funding decisions were made by the US National Science Foundation (NSF), the Japanese Ministry of Education, Culture, Sports, Science and Technology (MEXT), and the European Consortium for Ocean Research Drilling (ECORD) in late 2013, and they determine the future scope of IODP. The structure of this program is much looser than the previous one, with those who provide the vessels – the US, Japan and Europe – having ultimate control of their programs. Australian and New Zealand scientists have helped design proposals for research expeditions in the new IODP, with some of these expeditions already carried out.

ANZIC is funded to the end of 2020, and the situation with the vessel operators is variable. We all hope that funding will continue until 2023, in line with the IODP 2013-2023 Science Plan. The *JOIDES Resolution* has approved expeditions until early 2019, and funding to support those expeditions, always subject to review. The ECORD member countries will renew their membership in 2018 for the period 2019-2023. The Antarctic Cenozoic Climate Expedition 373 is one of the five alternative platform expeditions that are planned for 2017 -2021, with tentative scheduling for early 2020. The Japanese funding situation is unclear, but we very much hope that *Chikyu* will be drilling for IODP for years to come.

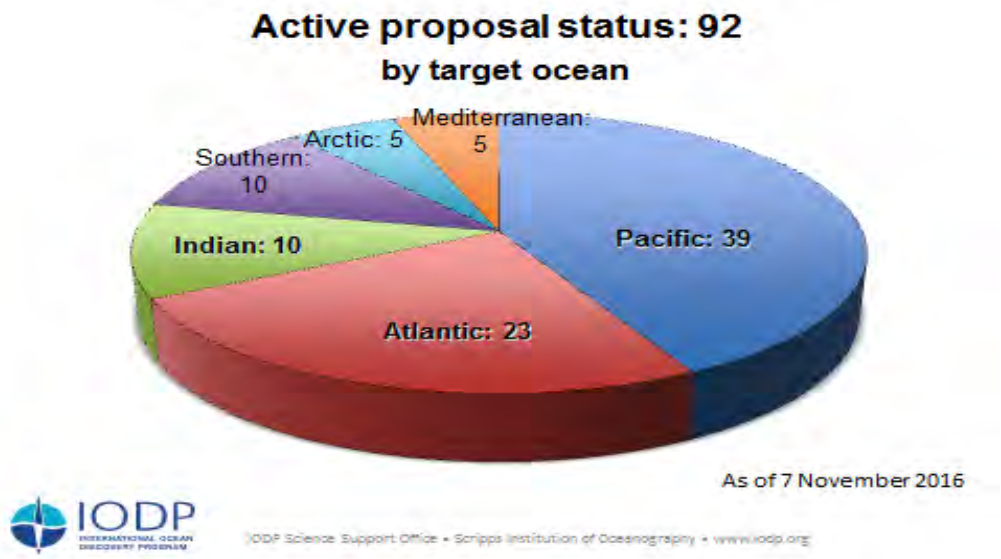
Map 3: Recently completed, approved and proposed IODP Expeditions for our region as of January 2016

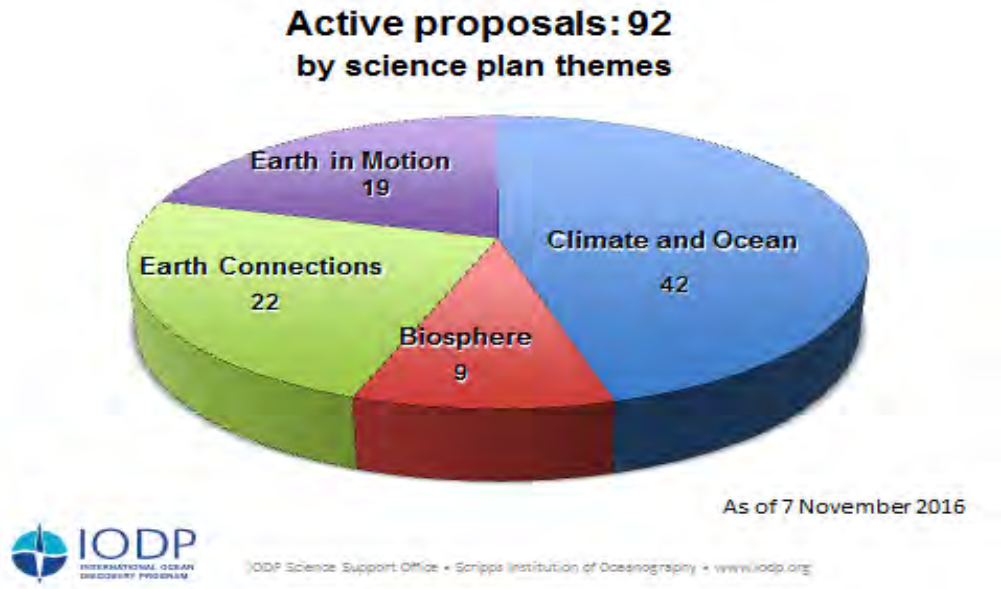


All these expeditions will or would use JOIDES Resolution except for proposals 781B, 813 and 871. A single JOIDES Resolution Expedition costs about $US8 million to mount. The map was kindly prepared by Katerina Petronotis of JRSO. Note that the US fiscal year is used in these diagrams: for example FY16 begins in October 2015. 'SEP' means a proposal with the IODP Science Evaluation Panel in February 2016.

Map 3 (p.35) was prepared after the decisions of the January 2016 Science Evaluation Panel meeting. Approved future *JOIDES Resolution* expeditions in our area were the Sumatra Seismogenic Zone Expedition 362 in August-September 2016, the Western Pacific Warm Pool Expedition 363 in October-November 2016, the SW Australia Cretaceous Climate Expedition 369 in October-November 2017, and the Hikurangi Subduction Margin Proposal 781A in 2018. The alternative platform Antarctic Cenozoic Paleoclimate Proposal 813, funded by ECORD, should be drilled in early 2019. The map also indicates that other regional expeditions are possible in 2018.

The diagrams below show that nearly 10% of active but not approved proposals (excluding planned expeditions) are led by ANZIC scientists, and that 60% of all active proposals are in the Indian and Pacific Oceans (data and diagrams provided by Holly Given at the IODP Science Support Office). These diagrams are another indication of ANZIC's value within IODP, and IODP's value to us.





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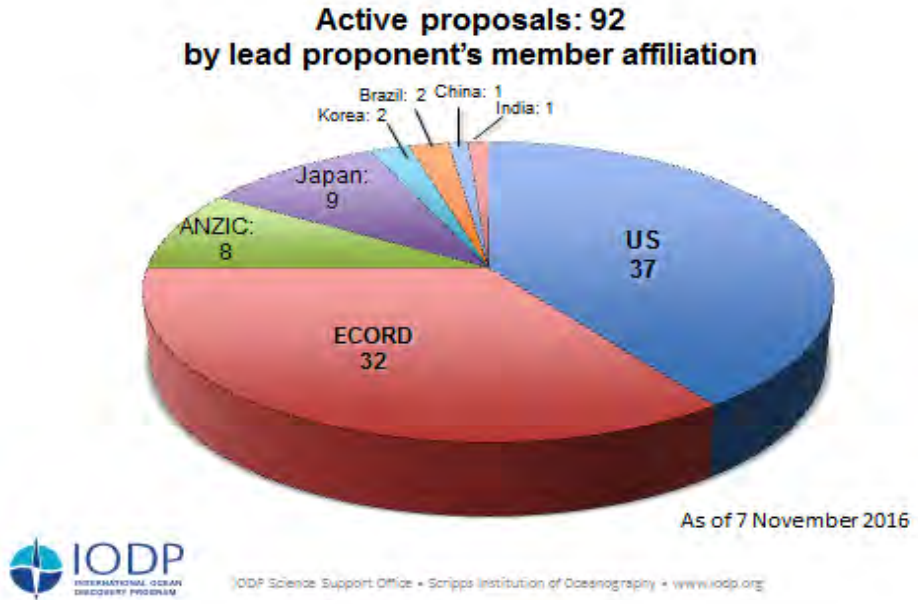

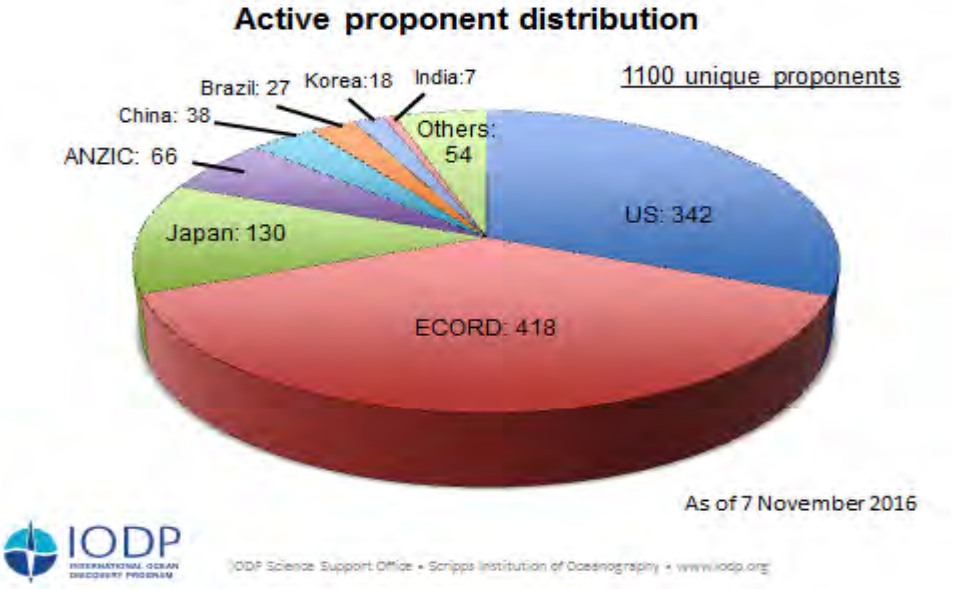

An Australasian IODP Regional Planning Workshop is to be held at Sydney University from 13 to 16 June 2017 (ANZIC web site). This will be a major regional workshop covering the Southwest Pacific Ocean, Southern Ocean and adjacent Antarctic margin, and the eastern Indian Ocean. This will be modelled on the earlier, highly successful, Indian Ocean and Southwest Pacific Ocean workshops. The workshop will cover all platform possibilities, but our main aim will be to start the process of writing good proposals to attract *JOIDES Resolution* back into our region around 2022. All international funding for participation in this workshop has been approved.

The IODP Science Plan

The IODP Science Plan ***Illuminating Earth's Past, Present, and Future*** was published in early 2013 (www.iodp.org/Science-Plan-for-2013-2023). The themes are:

Climate and Ocean Change: Reading the Past, Informing the Future

Ocean floor sediment cores provide records of past environmental and climatic conditions that are essential for understanding Earth system processes.

Biosphere Frontiers: Deep Life and Environmental Forcing of Evolution

Samples recovered by ocean drilling permit study of Earth's largest ecosystems, offering insight into the origins and limits of the deep biosphere, evolution of marine microfauna through times of environmental change, and human origins.

Earth Connections: Deep Processes and their Impact on Earth's Surface Environment

The dynamic processes that create and destroy ocean basins, shift the position of continents, and generate volcanoes and earthquakes extend from Earth's core to its atmosphere, and are fundamental for understanding global change within the context of planetary evolution.

Earth in Motion: Processes and Hazards on Human Time Scales

Many fundamental Earth system processes, including those underlying major geologic hazards, occur at "human" time scales of seconds to years, requiring new sampling, downhole measurement, monitoring, and active experimental approaches.

ANZIC Financial Situation

ANZIC's financial situation is sound, always depending on the actual cost of membership fees, which are denominated in $US. In this round of IODP, Australia (on behalf of ANZIC) pays annual Associate Membership payments for American (*JOIDES Resolution*) and European platforms of $US1.5 million, and agreed to pay another $US300,000 p.a. to Japan for Associate Membership and access to the *Chikyu*. In fact, with the *Chikyu* not very active in 2015 and 2016, we decided to transfer the $US600,000 for those two years to the *JOIDES Resolution* program, in exchange for additional shipboard positions for expeditions in our region in 2017 and 2018.

Australia's funding is guaranteed by the Australian Research Council and our scientific partners until the end of 2020.

New Zealand financial input depends entirely on their five ANZIC members, with GNS Science the major contributor, although other sources of income are being sought. It is predicted to continue at $US300,000 for the next few years.

ANZIC's income in 2016 was $A3.3 million: $A2 million from ARC/LIEF, $A875,000 from our Australian partners and $A415,000 from New Zealand. Our expenditure was on target for 2016, with a carry forward from the previous year of $A2 million.

For more information contact:

Professor Neville Exon, ANU, phone +61 2 6125 5131, email Neville.Exon@anu.edu.au.

Website http://www.iodp.org.au

Dr Chris Hollis, GNS Science, phone +64 4 570 4868, email C.Hollis@gns.cri.nz.

Website http://drill.gns.cri.nz

Expedition details:

http://www.iodp.org

http://iodp.org/expedition-map

Apply to sail:

http://www.iodp.org.au

http://drill.gns.cri.nz

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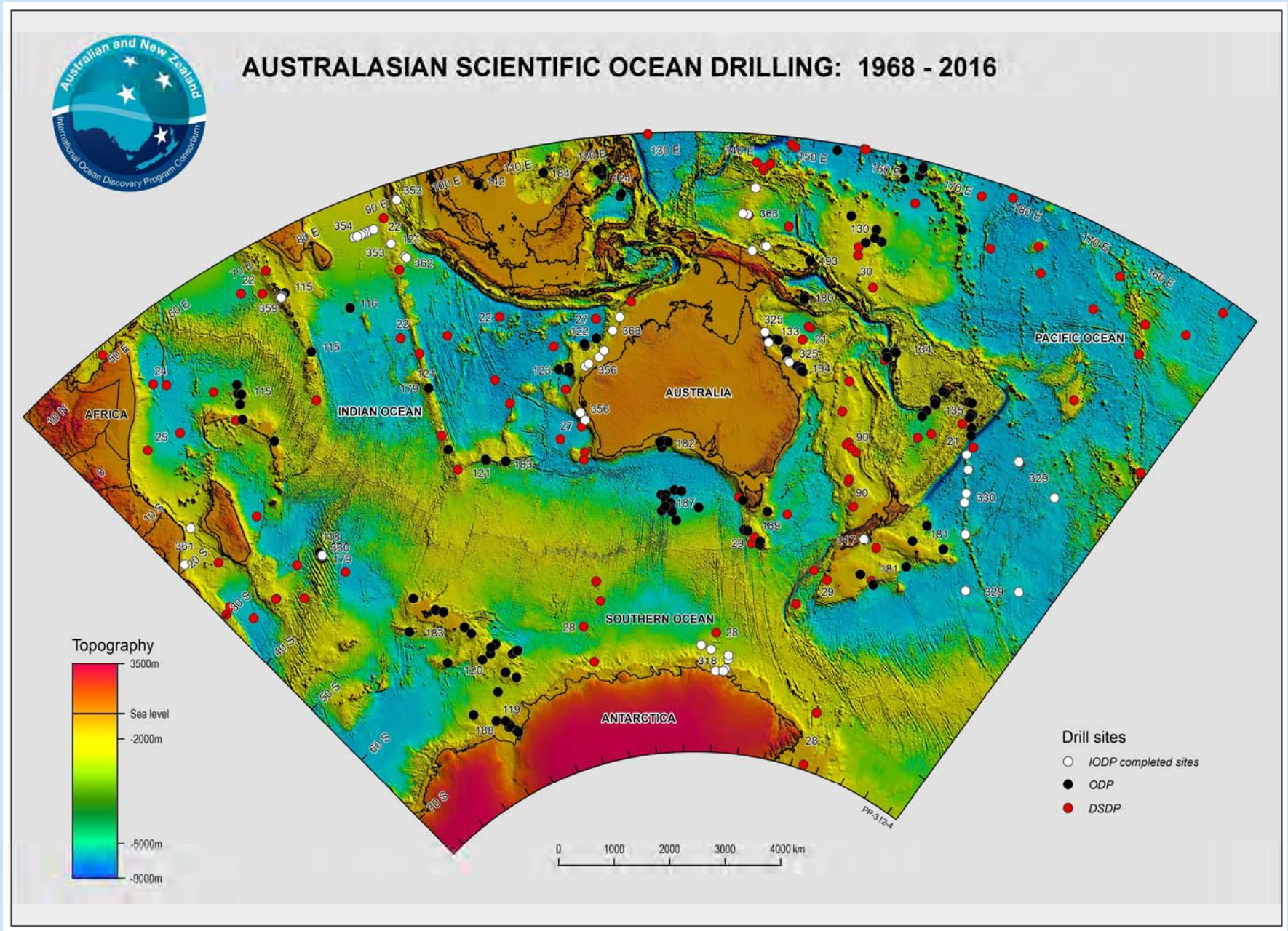
AUSTRALASIAN SCIENTIFIC OCEAN DRILLING: 1968 - 2016
Australian and New Zealand International Ocean Discovery Program Consortium
AFRICA
INDIAN OCEAN
AUSTRALIA
PACIFIC OCEAN
SOUTHERN OCEAN
ANTARCTICA
Topography
3500m
Sea level
-2000m
-5000m
-9000m
Drill sites
IODP completed sites
ODP
DSDP
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