Workshop on the future of Scientific Ocean Drilling with MSPs and *Chikyu* Phase 1

ONLINE-ONLY

17, 19, and 26 January 2023

CET 09:30 – 12:30
JST 17:30 – 20:30
GMT 08:30 – 11:30

WORKSHOP REPORT
final draft

June 4, 2023

Outline

Workshop Scope

In view of the post-2024 phase of scientific drilling, ECORD and Japan, through their offices ESSAC and JDESC, have agreed to encourage new scientific collaborations among the scientific communities of ECORD and Japan together with international partners with a two-phase scientific workshop with the scope to **enhance European and Japanese scientific collaboration for post-2024 scientific ocean drilling**. The workshops were intended to be inclusive to all SOD partners and to cover all scientific themes described in 2050 Science Framework.

On 14/06/2022 ESSAC and J-DESC were tasked by a Bilateral ECORD-JAPAN Working Group to identify a steering committee to implement the two-phase workshop.

The steering committee (see next section) agreed to proceed with phase-1 Online-only workshop to be held in January 2023 followed by a hybrid workshop tentatively schedule for the Fall 2023.

The aim of the **Phase-1 Workshop** is two-fold:

1) review the status of the planning of post-2024 Scientific Ocean Drilling and communicate the intention of the new ECORD-Japan program.
2) collect new ideas for the development of drilling proposals using the new MSP and *Chikyu*, based on identified knowledge gaps and novel scientific questions to be addressed in the next 5-10 years.

Aim 1 is realized through a series of invited talks illustrating the current status and future perspectives of SOD, the new MSP concepts and operational options, reviewing the 2050 Science Framework, and reviewing the existing drilling proposal at the Science Evaluation Panel (SEP). It is hoped that these presentations will help the planning and design of new drilling proposals during the break-out sessions and subsequently. Each presentation is followed by Questions & Answers through the chat line moderated by the Convener.

Aim 2 is realized through keynote talks introducing 4 themes identified for breakout sessions selected with inspiration from the 5 Flagship Initiatives of the 2050 Science Framework document and combining Climate Change and Ocean Health in one single theme:

- Climate Change and Ocean Health
- Deep Earth
- Geohazards
- Deep Life

followed by 2 days of thematic break-out sessions each convened by two Steering Committee members, in which Workshop participants could present ideas for implementing new scientific drilling initiatives for the development of new MSP and *Chikyu* drilling proposals based on identified knowledge gaps and novel scientific questions to be addressed in the next 5-10 years or maintain/improve existing drilling proposals. The presentations during the breakout sessions followed the submission, prior to the workshop, of short abstracts (see Annex 1). At the end of each breakout session, a summary of the achievements is given by the two co-conveners.

Phase-1 Workshop is therefore conceived as a brokerage event, where researchers from different communities could meet, share ideas, concepts and forms teams that will generate at least part of the scientific drilling proposals to be implemented with the MSP and *Chikyu* in post-2024 scientific ocean drilling.

The aim of **Phase-2 Workshop** is to invite researchers representing the most promising drilling ideas emerged during Phase-1 Workshop to begin the implementation of drilling proposals or workshop proposals to be submitted for funding using the available tools offered by ESSAC and J-DESC.

Steering Committee

Angelo Cammerlenghi (Co- Chair)	OGS, Italy
Masa Kinoshita (Co-Chair)	University of Tokyo, Japan
Giovanni Aloisi	IPGP, France
Thorsten Bauersachs	Kiel University, Germany
Rebecca Bell	Imperial College London, UK
Helen Coxall	Stockholm University, Sweden
Junichiro Kuroda	University of Tokyo, Japan
Azumi Kuroyanagi	Tohoku University, Japan
Kenji Matsuzaki	University of Tokyo, Japan
Tomo Morishita	Kanazawa University, Japan
Yuki Morono	JAMSTEC, Japan
Antony Morris	University of Plymouth, UK
Oliver Plümper	Utrecht University, Netherlands
Esther Schwarzenbach	University of Fribourg, Switzerland
Kohtaro Ujiie	University of Tsukuba, Japan
Sanny Saito	J-DESC, Japan (PMO representative)
Hanno Kinkel	ESSAC, Italy (PMO representative)

Workshop Agenda

Day-1. 2023/1/17		
09:30-09:40	Welcome and Scope of the Workshop	Masa Kinoshita, Vice-chair JDESC IODP Section, Earthquake Research Institute, University of Tokyo, Japan Angelo Camerlenghi, ESSAC Chair, OGS Italy
09:40–10:00	Current status and future perspectives of SOD, new MSP concepts	Gilbert Camoin, EMA Director, CEREGE-CNRS, France Nobu Eguchi, Director, Science Services Department Institute (MarE3), Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Japan
10:00–10:15	Summary of 2050 Science Framework download presentation	Roz Coggon, University of Southampton
10:15–10:30	Questions and Answers (moderated by the Co-Chairs)	
10:30–12:00	Keynote presentations Moderator: Sanny Saito J-DESC Japan Agency for Marine-Earth Science and Technology (JAMSTEC)	
	Keynote 1 – Climate Change and Ocean Health	Matt O'Regan, Department of Geological Sciences, Stockholm University
	Keynote 2 – Deep Earth	Katsuyoshi Michibayashi, Department of Earth and Planetary Sciences, Nagoya University
	Keynote 3 – Geohazards	Morelia Urlaub, Geomar, Kiel
	Keynote 4 – Deep Life	Yuki Morono, Japan Agency for Marine-Earth Science and Technology (JAMSTEC)
12:00–12:20	Overview of existing drilling proposals	Tim Reston, Co-chair of the IODP Science Evaluation Panel, School of Geography, Earth and Environmental Sciences, University of Birmingham

12:20-12:30	Summary and conclusions	Co-Chairs

Day-2. 2023/1/19		
09:30 – 09:35	Plenary: Introduction	Co-chairs
09:35–10:00	Plenary: Operational options for offshore drilling	Dave McInroy, ESO Science Manager, British Geological Survey, Edinburgh Nobu Eguchi, Director, Science Services Department Institute (MarE3), Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Japan
10:00–11:30	BREAK OUT SESSIONS	
	Climate Change and Ocean Health	Co-Coveners Helen Coxall, Stockholm University Junichiro Kuroda, The University of Tokyo
	Deep Earth	Co-Coveners Esther Schwarzenbach, University of Fribourg Tomo Morishita, Kanazawa University
	Geohazards	Co-Coveners Becky Bell, Imperial College London Kohtaro Ujiie, University of Tsukuba
	Deep Life	Co-Coveners Vanni Aloisi, Institut du Physique du Globe de Paris IPGP Yuki Morono, Japan Agency for Marine-Earth Science and Technology (JAMSTEC)
11:30–12:00	Plenary: Outcome from each Thematic Group	Co-conveners of each break out session
12:00-12:30	Plenary session: Synergy for the successful proposals/program	Co-chairs

Day-3. 2023/1/26		
09:30-10:00	Plenary: Introduction and practical goals	Co-chairs
10:00–11:30	BREAK OUT SESSIONS	
	Climate Change and Ocean Health	Co-Coveners Helen Coxall, Stockholm University Junichiro Kuroda, The University of Tokyo
	Deep Earth	Co-Coveners Esther Schwarzenbach, University of Fribourg Tomo Morishita, Kanazawa University
	Geohazards	Co-Coveners Becky Bell, Imperial College London Kohtaro Ujiie, University of Tsukuba
	Deep Life	Co-Coveners Vanni Aloisi, Institut du Physique du Globe de Paris IPGP Yuki Morono, Japan Agency for Marine-Earth Science and Technology (JAMSTEC)
11:30–12:00	Plenary: Outcome from each Thematic Group	Co-conveners of each break out session
12:00-12:30	Plenary: Summary and direction for Phase-2 WS	Co-Chairs

Participation

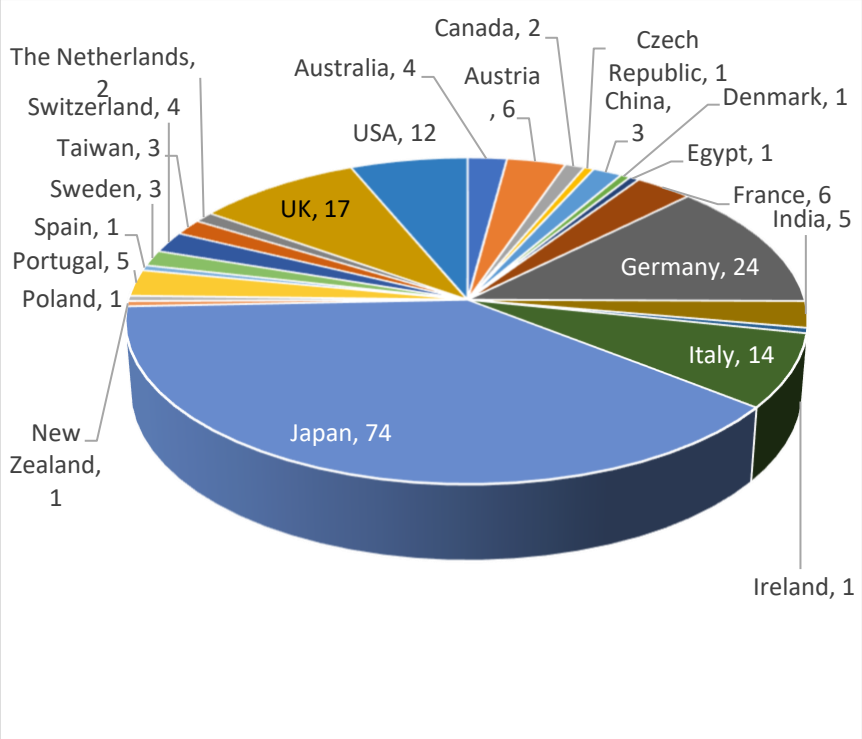
191 Registered participants

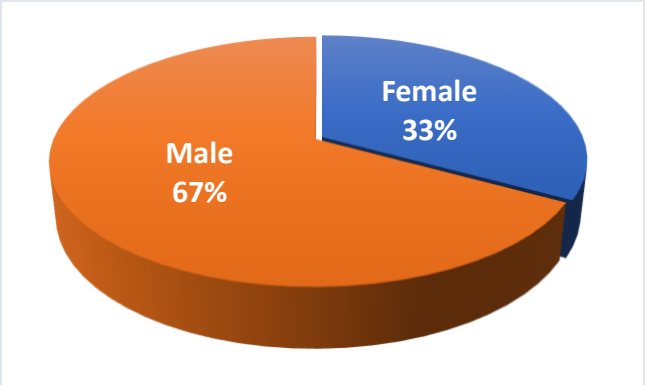
Of which:

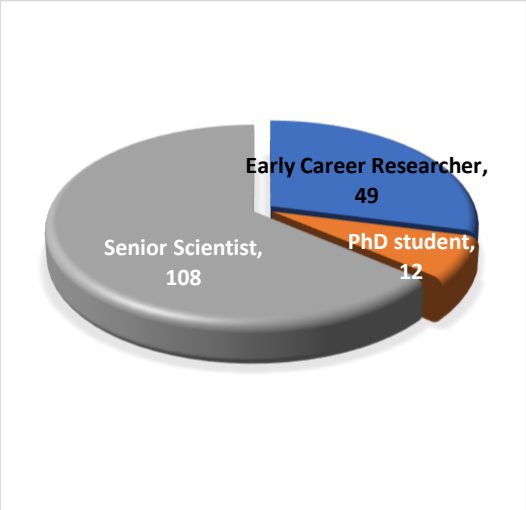
Career Stage	
12	PhD Students
49	Early Career Researchers
108	Senior Scientists
22	Not known

Gender	
63	Females
128	Males

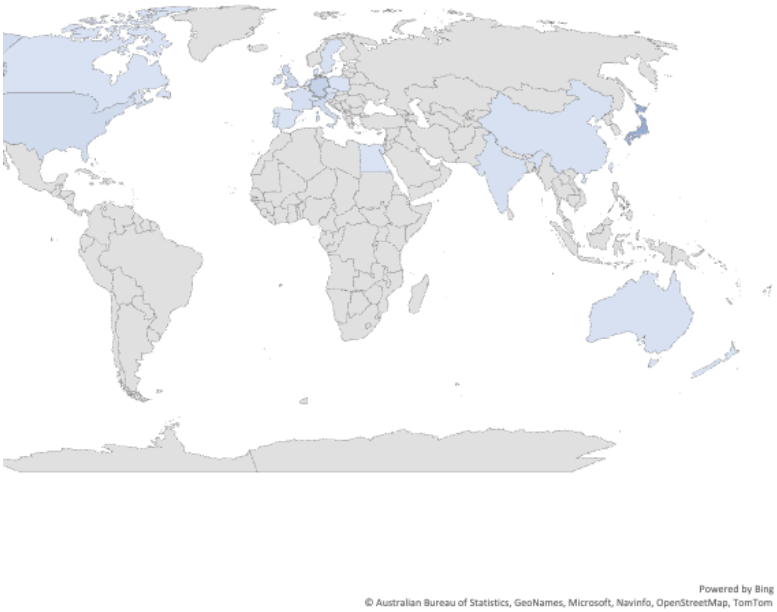
Geography	
86	ECORD
6	Austria
2	Canada
1	Denmark
6	France
24	Germany
1	Ireland
14	Italy
5	Portugal
1	Spain
3	Sweden
4	Switzerland
2	The Netherlands
17	UK
74	Japan
12	USA
6	Others non IODP members
5	ANZIC
5	India
3	China







+ 22 participants with unknown career stage



Online participants in each day

171	online participants on Day 1
143	online participants on Day 2
122	online participants on Day 3

Participation in thematic breakout sessions (average number)

~70	Climate Change and Ocean Health
~40	Geohazards
~30	Deep Earth
12	Deep Life

Fig. 1 – Group photo during Day-1

Outcomes and Outlook

ESSAC and JDESC are very pleased with the level of attendance. All invited speakers presented well-prepared talks in due time and contributed to the works by participating in the discussion and in the breakout sessions.

Discussions were always lively, even if only supported by the chat line. Certain important aspects of future scientific ocean drilling were solicited by the attendees and triggered short communications during the plenary sessions of Day three.

These were:

Orphan sites and unimplemented proposals

Larry Krissek, Chair of the *JOIDES Resolution* Facility Board, explained that 4 orphan sites presently reside at the JR Facility board. The proponents of the proposals from which these sites resulted will be asked for voluntary transfer to new program(s) for consideration for drilling.

Possible implementation of the 2050 Science Framework Flagship Initiatives,

Sanny Saito, J-DESC explained that the PMOs have discussed the matter agreeing that a pilot implementation of a Flagship Initiative should be started based on a program-wide Workshop. The agreed theme is Ground Truthing Future Climate Change. Implementation should begin as soon as the architecture of future program(s) will be finalized.

Emerging concept of Virtual Expeditions

Angelo Camerlenghi (member of the JRFB Working Group on Virtual Expeditions) and Minoru Ikehara (Center of Advanced Marine Core Research, Kochi University) reported briefly on the intentions of ECORD and Japan to include in post-2024 activities the possibility to support research focusing on the use of legacy cores and data with the purpose of increasing the access to the scientific ocean drilling infrastructure through their core repositories and data archives. Details are currently being discussed. ECORD and Japan are in line with the directions set by the JRFB Working Group, which includes participants of all present IODP Members.

Status of Chinese drilling platform

On behalf of Shouting Tuo (Director of the IODP-China Office) unable to attend the workshop, Nobu Eguchi has reported on the progress of building the new Chinese riser drilling vessel.

D.E.E.P. Regional Planning Workshop

Ron Hackney, Director of the Australian & New Zealand International Ocean Discovery Program (IODP) Consortium, announces the ANZIC's Australasian and Southern Ocean Regional Planning Workshop *Future Drilling to Explore Earth's Past* to support scientists in developing proposals for the next generation of scientific drilling.

The 1st aim of the Phase-1 Workshop has been fully accomplished, as nearly 200 scientists, mainly from the ECORD and Japan scientific communities, have received up-to-date information on the state of the art in the planning of post-2024 scientific drilling, provided that the uncertainty level is still high and that the situation is subject to change depending on the final decisions to be made by some of the IODP Members. Nevertheless, the message that ECORD and Japan have firm plans to build a joint program based on the combined use of Mission Specific Platforms and the *Chikyu*, with a novel flexible, ad-hoc planning which will imply a larger than before number of the scientific parties between onshore and offshore, has been successfully delivered.

The 2nd aim of the Phase-1 Workshop has also been accomplished as the 4 breakout sessions have been supported by the scientific community with novel ideas and discussion that identified gaps in current proposal focus that will generate new drilling proposal.

Climate Change and Ocean Health

As expected, theme **Climate Change and Ocean Health** received the largest number of expressions of interest. This is also because two of the 5 overarching themes identified in the 2050 Science Framework for Flagship Initiatives have been grouped in this theme. This interest expressed by the workshop participants reassures the agreement reached by the IODP PMOs that Climate Change should be the first Flagship Initiative to be implemented as a pilot initiative in the future.

Despite multiple existing proposals/pre-proposals and APL, the Session collected more than 12 novel initial ideas 5 of which derive from recent Magellan+ workshops. In addition, there are ~5 cases involving plans for potential re-design of previous proposals that were never scheduled.

The geographical focus of the presented ideas includes Arctic gateways (3); British Isles (1); Caribbean/Central America, Equatorial Atlantic (7): high southern latitudes (4); North Pacific (8), South Pacific (1): tropical/northern Indian Ocean: SW Indian Ocean (3), equatorial margins (2); Mediterranean (2).

Regarding Arctic drilling, although participants are aware of the technical/logistical difficulties of the challenging high-Arctic environment, the focus has been to reproduce success of ACEX. The identification of different types of stratigraphic targets, e.g. continental shelf sections in shallower water giving access to both younger and older strata, and accessible using a wider range of drilling technologies, is seen as something positive and a way forward for future high-Arctic perspectives.

Generally, in terms of global coverage, the geological age of the target sedimentary sections shown to be of interest to the community is diverse, including shallower strata (e.g. Quaternary) targets, as well as deeper times (e.g. Neogene, Paleogene, Cretaceous, and Jurassic). Giant Piston Coring is seen as an attractive and important tool that could be used more in the future, especially for addressing more easily accessible (shallow burial) Quaternary paleo-climate questions. Several groups could foresee projects involving this technology being developed in the next phase of deep-sea drilling planning, to bring novel or improve 'spatial' perspectives on ocean-earth systems, beyond a simple transect, e.g. shot-gun coring of the ACC, or sea ice domains where spatial variability is key.

The Session attracted some novel **specialist interest**, e.g. in relation to paleomagnetism, cold seeps, biogeochemistry, fluid exchange at land-ocean interfaces, which sparked some wider interest/ and follow up conversations we understand.

Interest has been expressed in the possibility to employ the riserless *Chikyu* drilling in deep waters of the N & SW Pacific and SW Indian Ocean. Proposal ideas requiring deep water riserless drilling in other oceans, including the Mediterranean Sea were also highlighted. More than 12 novel ideas specifically target MSP capabilities, involving intermediate water depth riserless drilling and long piston coring. A Land-to-Sea approach has been considered by three proposal ideas. The need for special tools to sample challenging sand-rich sections was also flagged.

Besides an array of new drilling proposal ideas, there was clear desire to adapt multiple existing proposals to MSP operations, including a selection residing at SEP and others that sit with the Facility boards, for which the Site Survey package is at an advanced stage or has been approved. A **dialogue between proponents & ECORD/Japanese operators will be useful for helping with identifying appropriate MSPs.**

A further point that came out of the Climate and Earth Health theme discussions, was that there is a view that a philosophical/paradigm shift is needed with respect to the extent to which different types of climate-focused proposals are scheduled. There is a perception that certain types of ideas or time

scales have been of greater priority than others, at some levels of the IODP steering, for example 'deep time' versus Quaternary. A case was made that drilling/coring access to Quaternary sediments is arguably logistically simpler (shallower burial), and achievable through national level activities, however, this ignores the package of benefits that comes with a project receiving large-scale international scientific and out-reach support from the IODP - the international exposure and community effort afforded by the IODP, staffed competitively through international selection channels, can propel the science in a way that smaller/national scale operations, cannot. Can the paradigm shift/evolve at the SEP level and higher?

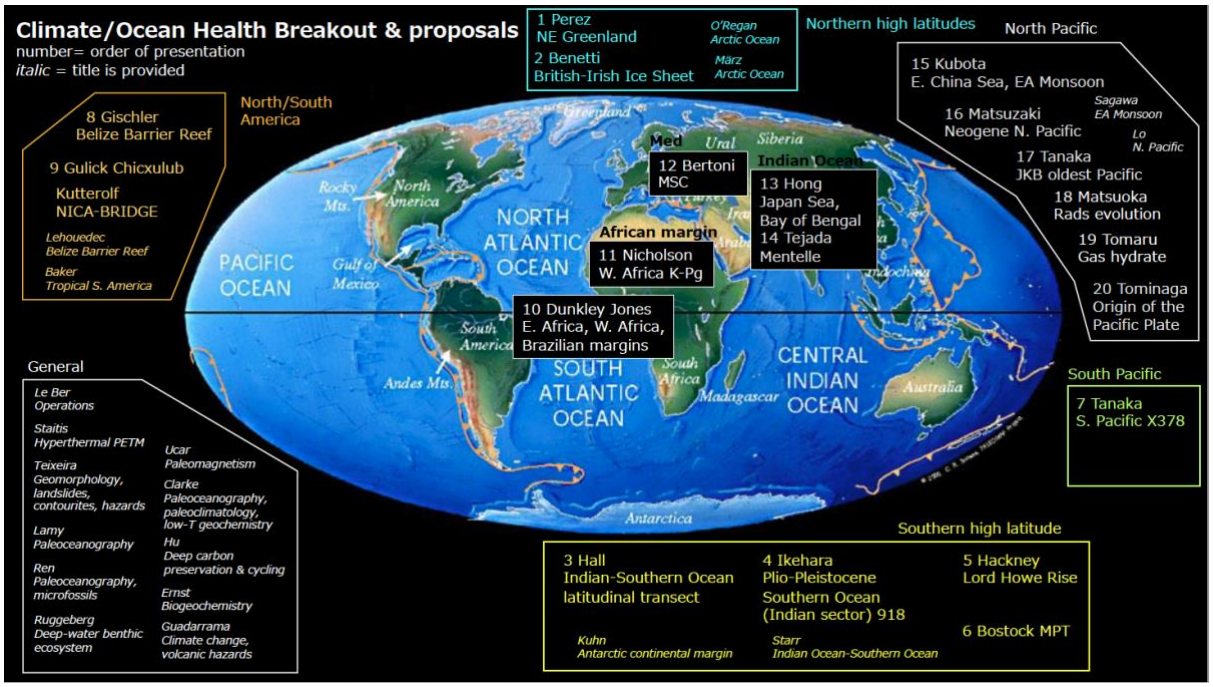


Fig. 2 - Summary of the geographic coverage of new and existing IODP proposals or fledgling proposal ideas January 2023.

Deep Earth

Direct sampling of oceanic plates from the deep ocean has played a vital role in understanding the Earth system. From the beginning of the ocean drilling project until now including SOD2050, the mantle drilling project, which penetrates the entire oceanic crust and the Mohorovičić seismic discontinuity and samples directly from the mantle, is one of the exploration targets of the earth science community. In April 2012, a Pacific mantle drilling project (M2M) was submitted to the IODP, and efforts by the hard rock community continue to make this plan a reality. If, in the near future, a continuous reference sample representative of the oceanic plate from the crust to the mantle is recovered and mantle observatory is developed to explore the Earth's deep interior, our understanding of the connection between the Earth's surface and mantle will expand dramatically and become a human asset and intellectual value that will last for future generations. At the beginning of the breakout session of the Deep Earth group, we confirmed the importance of aspirational goals as in the case of the mantle drilling project, even if they may not be completed within a 15-year timeframe. On the other hand, a main discussion point were the upcoming technological changes regarding the likely decreasing opportunities to drilling deeper into the ocean crust. The breakout session, thus, focused on what are the most attractive and "achievable" drilling targets for the Deep Earth community during the next 10-15 years. Fortunately, we received many abstracts for the session on Deep Earth (Fig. 3). The abstracts cover a wide range of scientific objectives including the Land to

Sea Program (a joint program with ICDP). In the meeting, we shared the scientific questions and target oceans, as well as drilling advantages and strategies described in the abstracts. We also identified knowledge gaps not covered in the abstracts and provided an open discussion on Deep Earth drilling.

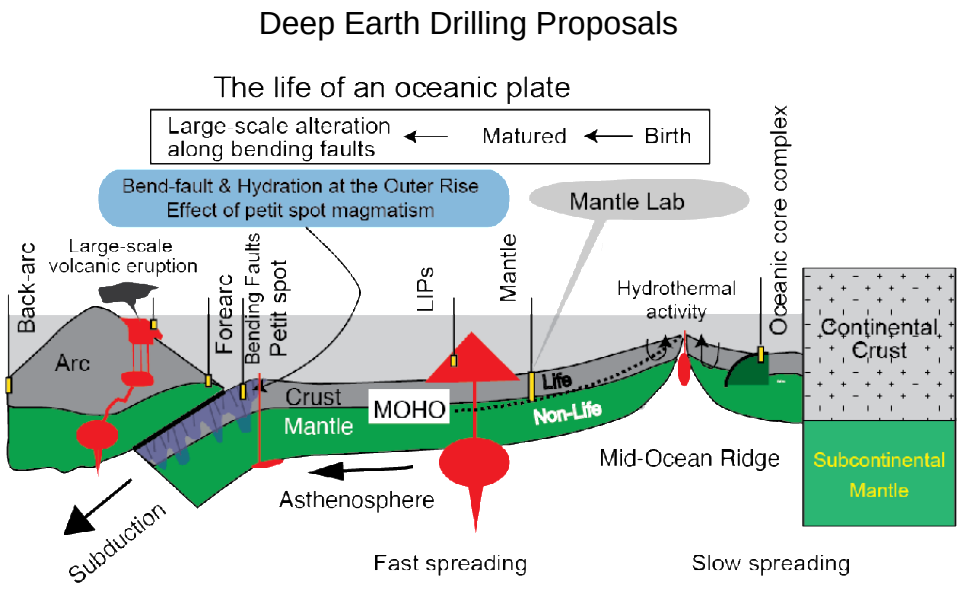


Fig. 3 – Graphic summary of abstracts presented in the Deep Earth breakout session.

The main topics from the abstracts in terms of tectonic setting are as follows: (1) the formation, evolution, and destruction of oceanic lithosphere, (2) back-arc spreading, (3) continental rifting and lower crust, (4) Large Igneous Provinces, and (5) subduction initiation. The formation and hydration reaction of oceanic plates along mid-ocean ridges has been a longstanding research focus in Earth Science. Hydration of aged oceanic plates including outer-rise regions is a scientific target of interest in relation to the water cycle, subducting plate earthquake, and as a microbial habitat. Recent seismic surveys of the "normal oceanic plate" have identified variations in the Moho reflection plan that may be related to hydration of the older oceanic plate. Petit-spot magmatism may be responsible for changes in the geophysical properties of the uppermost old oceanic plate, and an understanding of its relationship to plate-interface seismic activity at subduction zones is expected. Slow-spreading ridges represent a reasonable portion of the global mid-ocean ridges, and further study of slow-spreading ridges is required to understand their tectonic, magmatic and hydrothermal evolution. Since the back-arc basin is not a narrow ocean and maybe influenced by subduction dynamics, we need to compare how it resembles and differs from typical mid-ocean ridges. The Deep Earth community intends to further explore the interaction between the earth's surface and deep mantle during all phases of extensional tectonic activity, from the early stages of continental rifting, through the breakup and formation of rifted continental margins, to the initiation and evolution of seafloor spreading. On the other hand, the true size, volume, and rate of formation of Large Igneous Provinces are currently not well constrained, and therefore their origin and mantle source are a matter of extensive debate. Land to sea drilling of seafloor and onshore ophiolites provides a unique data set on the interaction between active fluid flow, hydrothermal alteration, and microbial activity on shore and offshore. Serpentinization (± carbonation) and serpentine diapirs in forearc environments provide clues to understanding ultramafic-hosted hydrothermal systems.

Further discussion points were also transform faults and the accumulation of arc crust, topics that were not covered by the abstracts. Transform faults are thought to play an important role in many aspects, including interaction with magma and hydrothermal fluids and their relationship to

subduction initiation. On the other hand, the basement of the volcanic arc is still poorly understood, particularly with regards to what is the volume and crustal evolution of the volcanic arc?

The habitability and the controlling factors for limits of life in the oceanic lithosphere are further main research topics that are not yet well understood and are a frontier within the deep biosphere community. In conjunction with the Deep life session, we exchanged the idea of "What place do we have to address microbiology in the origins and limits of life in the oceanic environment?" Here, a major question is also how we can distinguish between biogenic and abiogenic processes that are chemically often very similar.

Finally, further discussions are needed to come up with an attractive and feasible drilling project that includes multiple scientific objectives that can only be addressed by drilling the ocean floor. To achieve this objective, we have also identified the importance of developing new techniques for sample recovery from large water depths and deep penetration of hard rocks, in conjunction with the development of monitoring chemical and physical changes in boreholes. No matter what the challenging environment is, we need to continue to develop attractive scientific drilling projects and maintain and strengthen the Deep Earth Community.

Geohazards

Submarine landslide, earthquake, and volcanic hazards emerged as the main topics of discussion in the geohazards breakout session. Valuable suggestions were proposed during the session – all of them were motivated to mitigate devastating social damages from geohazards. We noted that important processes for some geohazards (particularly submarine landslides) may be location specific- therefore a change in the philosophy of science reviewing panels may be necessary. It may not be possible to examine global Geohazard processes from a single drilling site and location. Multiple drill sites in different parts of the world may be needed to fully tackle geohazard problems. This would require a 'paradigm shift' in the way we review drilling proposals (tackling site-specific problems is often seen as a weakness in proposals- whereas when it comes to geohazards, site-specific issues may be critical).

For submarine landslides, understanding the nature of the weak layer that promotes sliding is a key theme. The driving forces of sliding may be melting of gas hydrate and seismic vibration, whereas the sliding conditions may be preconditioned by the presence of intrinsic weak material and/or generation of overpressure – both of which remain untested. To resolve these questions, drilling strategies were discussed including multiple coring at multiple locations (e.g., deformed vs. undeformed section and coring near source and toe domains). Drilling to ~500 m would be necessary to cross sliding surfaces in most cases. Specific target areas discussed included NW Africa, Mentelle basin, and offshore Perth, Australia.

General key science questions for earthquake hazards are (1) do earthquake have precursors?; (2) is fault coupling/rupture barriers persistent?; (3) are earthquakes cyclic?; (4) how do slip rates vary over time?; (5) what controls stress accumulation/release?; and (6) how does mud volcanism relate/interact to and with the earthquake cycle? Observatories and monitoring at different depths are required with consideration of 3rd party funding to collect data from non-network observatories or connecting to existing networks. Paleoseismology is also useful to determine earthquake recurrence interval/rupture barrier persistence and can be facilitated by long piston-coring. The target areas discussed included Japan, Hikurangi, Hellenic Trench, Calabrian Arc, and Iberia- noting the importance to target both well-studied margins and those that remain enigmatic.

Specific key science questions were also discussed for earthquake hazards, which include (1) how does seamount subduction affect stress accumulation/seismic behavior?; (2) does petit-spot subduction cause rupture barrier?; (3) the relation between tsunamigenic slip and outer rise earthquakes; and (4) the link between backarc basin geothermal structure and seismic hazard potential. Drilling/monitoring

on leading edges and sideways of subducted seamount, core-log-seismic integration, and 2 km deep drilling with 100 m site shallow drilling are necessary to answer key questions. The target areas are Hyuga-nada, seaward of Japan Trench, and Okinawa Trough were discussed. Hyuga-nada would be a good target, because tectonic tremor and mud volcanism occur in association with the subduction of high relief. In contrast, seaward of Japan Trench would be a good place to assess how subduction of low relief affects rupture barriers.

Key scientific questions for volcanic hazards include (1) the relation between earthquakes and volcanic eruptions; (2) magmatic products and processes of caldera forming eruptions; and (3) recurrence history of eruptions. Both ~100 m subaerial and submarine drilling and observatories for monitoring are required. The target areas discussed were Kikai Caldera, Japan and Hellenic Arc/Calabrian Arc. The latter corresponds to sources of multi-hazards (volcanic, seismic, landslide, tsunami); a broader natural hazards approach would be beneficial in a densely populated coastal environment. The recent Tonga eruption would also be a relevant target for volcanic hazards.

Finally, the importance of climate-related geohazards (e.g. cyclones, floods) and the huge impact they pose to society was noted. However, as the Geohazards workshop participants almost entirely came from within the tectonics community we did not have the right expertise in the group to fully address the key questions on this topic. This would require future engagement with the Climate community.

Deep Life

During the Deep Life breakout session, presentations were given by workshop participants to explain ideas for deep biosphere drilling at different stages of maturation, form projects still at the embryo stage, to proposals accepted and ready for implementation. A number of proposals linked nicely with the geohazards (sedimentary fluid production via microbial clay transformation), resources (deep biosphere in gas hydrate settings) and climate themes (microbial CO_2 sink via submarine silicate alteration). Others tackled more fundamental problems of deep biosphere research, like microbial life in deep, old rocky formations, the limits of life in the deep, including the Chicxulub asteroid impact, and microbial life in the Mediterranean Salt Giant.

Over 20 years of IODP deep biosphere research have taught us that microbes persist or survive even in various extreme subseafloor environments. These environments are deep (~2.5 km below the seafloor), scarce in nutrients (ultra-oligotrophic South Pacific Gyre), old (~100 Ma sediment), and hot (~120 degrees Celsius). Despite these harsh and challenging conditions, microbes are living and exist as diverse as in ocean water and terrestrial soils. However, there are still open questions that remain. Firstly, we haven't identified the "extent (or end) of the biosphere." Secondly, while we have started to capture the species richness, we are still far from understanding the global significance of subseafloor communities. And thirdly, the sensitivity of ecosystems to environmental change is not yet known. Next to these fundamental research questions, we discussed the importance on more applied research, such as the reaction of the deep biosphere to the storage of energy - such as hydrogen, CO_2, hot water, compressed gas - in the subsurface.

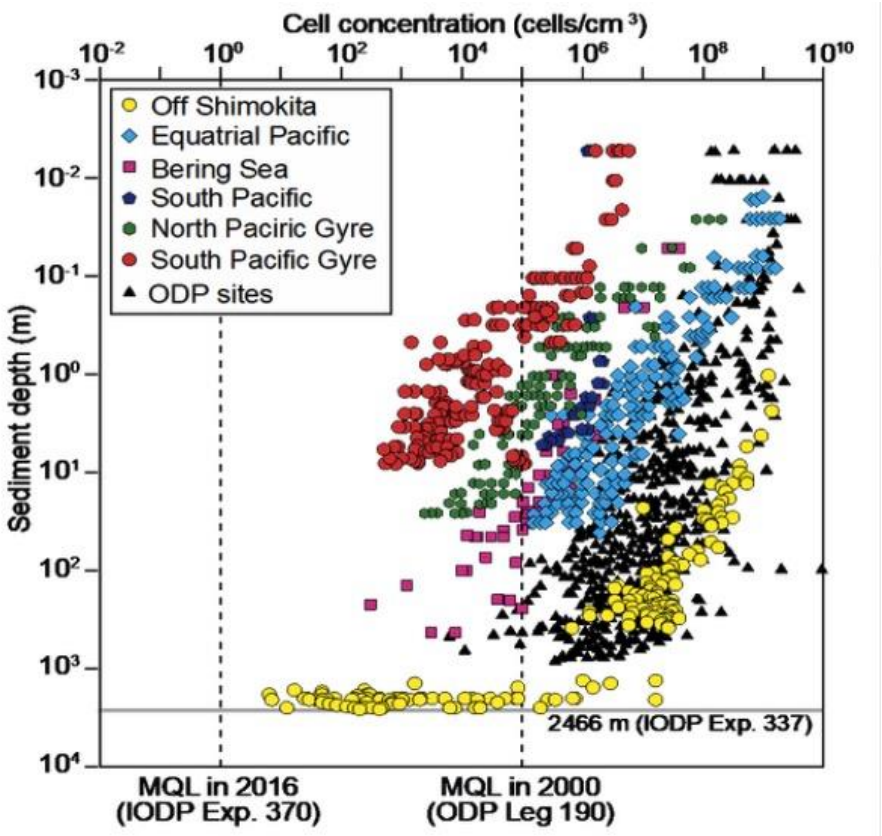


Fig. 4 - Abundance of subsurface microbes (in cells per cm^3) observed in ODP and IODP cores from the World Ocean. Microbial cells have been observed down to 2466 m below the seafloor. Modified from Kallmeyer et al. (2012) *PNAS* and Inagaki et al. (2015) *Science*. Understanding the significance of deep life for the functioning of the Earth System is one of the major challenges of future scientific ocean drilling.

To answer the remaining open questions and to explore new research areas, we need to acknowledge that the Deep Life is in transition. A potential way to address this are active experiments, on a human time scales, using an observatory to study the changes and transitions of life under chemically dynamic sub-surface conditions. One of the societally relevant areas of research involves microbe-driven energy generation, where we can utilize the power of microbes to generate energy. We then discussed the requirements to achieve our goals through the ECORD-Japan framework, such as ideal biogeochemical environments for drilling.

We also identified technological missing elements that need to be addressed in the future of scientific ocean drilling, such as developing standardized protocols for microbial-sampling, implementing contamination control/tracing measures, and improving core handling for preventing contamination exogeneous sources. We also highlighted the importance of heat flow measurement, temperature probing, and the differentiation of biotic and abiotic reactions, for the future frontiers to be explored in coming ECORD-Japan SOD Program.

And last but not least, we discussed about the importance of flexibility of sampling for SOD-Microbiology: while past SOD-microbiology efforts has been prioritizing Whole Round Core sampling, , developments of effective and efficient sampling techniques to share the materials for many purposes are necessary not only to widen the scope of expedition science

and to maximize scientific outcomes, but to bring the SOD-microbiology itself to higher level of success in future expeditions within the new ECORD-Japan SOD program.

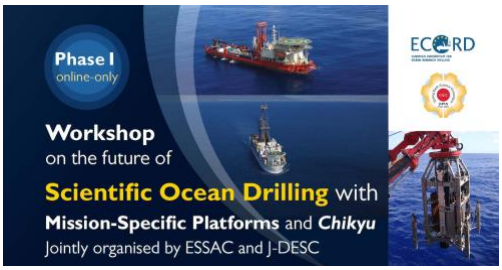
SUMMARY OF LEGACY OF DRILLING PROPOSALS FROM IODP-2

Legacy of IODP-2 proposals for future program(s)

- 94 active proposals currently in SEP
- 51 proposals and orphan sites at facility boards

NEW PROPOSALS ARE NEEDED SPECIFICALLY ADDRESSING THE FUTURE PROGRAM(S)

Instruments to facilitate the process:



Phase-2

ECORD
EUROPEAN CONSORTIUM FOR OCEAN RESEARCH DRILLING

MagellanPlus Workshop Series Programme

icdp
INTERNATIONAL CONTINENTAL SCIENTIFIC DRILLING PROGRAM

Drilling Earth Science Consortium
J-DESC
JAPAN
Since 2003

J-DESC Workshop

SPONTANOEOUS SUBMISSIONS

In addition:

Annexes

1- Abstracts (*either copied in or link to a combined edited file Hanno is working on*)
2- Link to invited speakers' presentations (via the Workshop Web page)
3- Participants list

Links:

https://www.ecord.org/workshop-on-the-future-of-scientific-ocean-drilling/