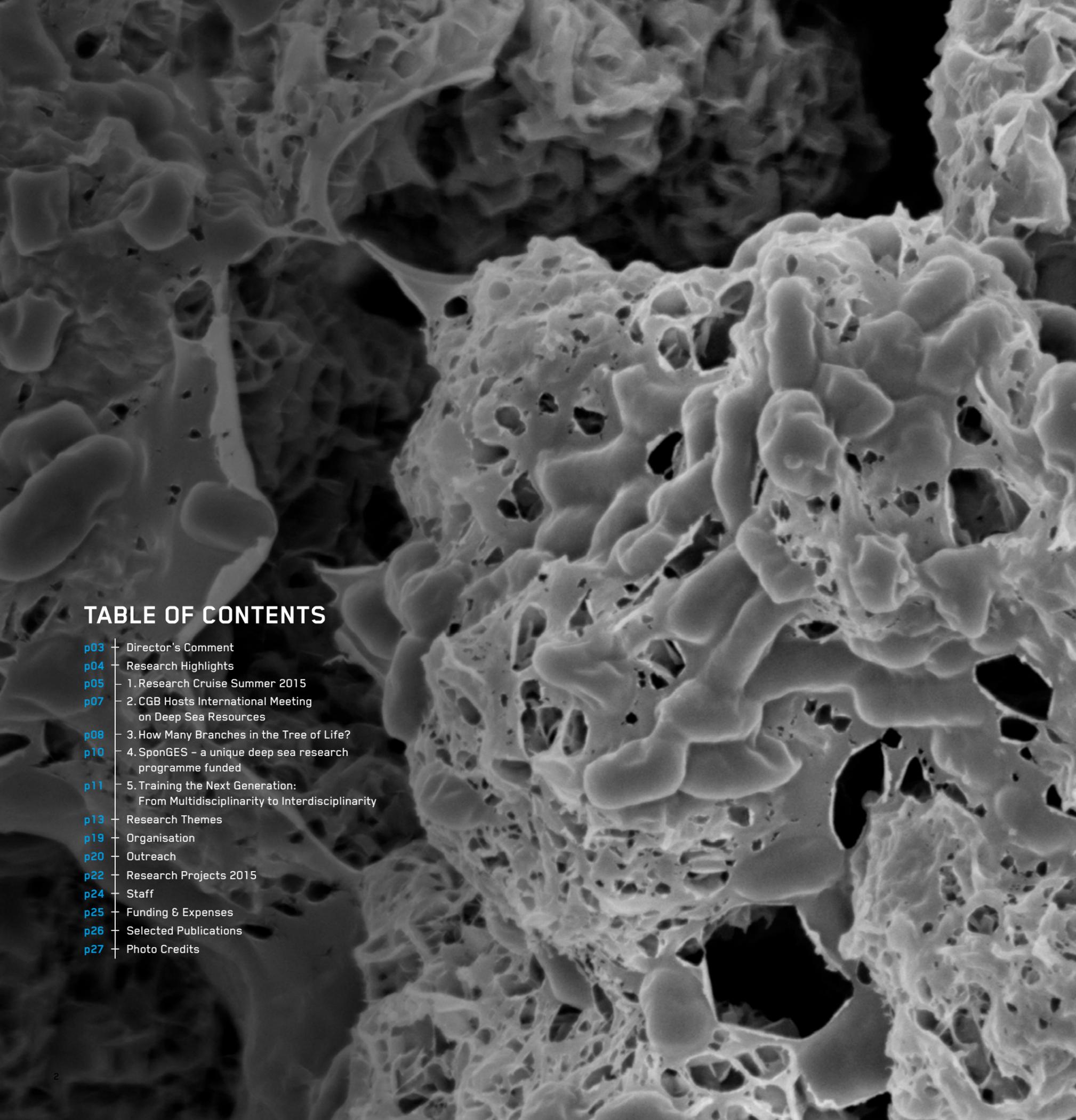




ANNUAL  
REPORT  
2015

DEEP SEAFLOOR • DEEP BIOSPHERE • DEEP TIME & ROOTS OF LIFE

CENTRE FOR  
**GEOBIOLOGY**



## TABLE OF CONTENTS

- p03 | Director's Comment
- p04 | Research Highlights
- p05 | 1. Research Cruise Summer 2015
- p07 | 2. CGB Hosts International Meeting on Deep Sea Resources
- p08 | 3. How Many Branches in the Tree of Life?
- p10 | 4. SponGES - a unique deep sea research programme funded
- p11 | 5. Training the Next Generation: From Multidisciplinarity to Interdisciplinarity
- p13 | Research Themes
- p19 | Organisation
- p20 | Outreach
- p22 | Research Projects 2015
- p24 | Staff
- p25 | Funding & Expenses
- p26 | Selected Publications
- p27 | Photo Credits

## DIRECTOR'S COMMENT

As the 10-year period draws to a close, the Centre for Geobiology (CGB) has achieved one of its major goals: setting the new discipline of Geobiology and the Deep Sea in general firmly on the University of Bergen's agenda. The university's new strategy document for 2016-2022 is entitled, "Ocean, Life, Society", and opens with the following statement about the university's activities in these areas: "There is a common thread from the skeletons in the Whale Hall at the Natural History Museum in Bergen, through Fridjof Nansen's ground breaking studies of the nerve cells of hagfish, to today's ongoing outstanding **geobiological deep sea research**". Geobiology is now firmly anchored in Master and PhD programmes at UiB, and work to establish courses within the Bachelor curriculum is underway.

An unpredicted development at CGB has been the many applied directions that have resulted from the Centre's focus on basic deep sea, geobiological research. In 2015, CGB researchers have been invited speakers and advisors in a number of applied arenas, including bio-prospecting and mining genetic resources, as well as deep-sea mineral resources and mining waste issues. CGB also hosted an international, interdisciplinary workshop focusing on the exploitation of seafloor massive sulphide deposits, where more than 70 experts from 14 countries participated.

Centre researchers were also involved as participants and leaders in large new projects at the national and international level. Examples include 3 from the EU Horizon 2020 programme,

the projects SponGES, Virus-X and InMare.

As CGB researchers continue to study the unique organisms discovered along the Arctic Mid-Ocean Ridge system, they identified a new lineage of microorganism that was shown to represent the closest known prokaryotic relative to the complex cells of the eukaryotes. This work, which was published in *Nature* in 2015, may force us to re-analyse our basic thinking about the origins of life, and to re-define the currently accepted tree of life!

Finally, the highlight of the year was the launching of Norway's first research-dedicated Remotely Operated Vehicle (ROV), the *Ægir 6000*. Capable of diving to 6000m, the new ROV can be used with a number of suites of modular sensors and collecting equipment. The *Ægir 6000* was used together with the Autonomous Underwater Vehicle (AUV), *Hugin*, on the research cruise summer 2015 enabling the cruise team to be much more effective at localising hydrothermal vent fields – and a new vent field was indeed discovered in record time! ■



Ingunn Thorseth  
Centre Director



# RESEARCH HIGHLIGHTS

## RESEARCH CRUISE SUMMER 2015

The highlight of this year's field activity was the launching and testing of Norway's new, marine research-dedicated, remotely operated vehicle (ROV), christened the Ægir 6000 after a mythical Norwegian figure associated with the sea.

Norway is well positioned to be a world leader in marine research. It has a long history as a marine nation as well as easy access to different kinds of marine environments, including deep, open ocean. The Research Council of Norway has supported the establishment of a nationally-based, world-class, modern infrastructure for deep sea research: the Norwegian Marine Robotics Facility (NORMAR), which is jointly run by the University of Bergen (UiB), the Institute of Marine Research (IMR) and the Christian Michelsen Institute (CMI).

### “Eyes” and “hands” on the seafloor

The building, launching and testing of the Ægir moves the Facility from the drawing-board to action stations; in this case, the seafloor. Capable of diving to 6000m, the new ROV has an up-to-date suite of different sampling modules and cameras that will enable it to be virtual extensions of both the “eyes” and “hands” of CGB researchers, as well as other Norwegian and international researchers, on the deep seafloor. The results from this summer's cruise will further Centre research activity in a number of areas including: the degradation (“weathering”) of marine mine tailings; bioprospecting for new enzymes; increasing our understanding of venting processes; and learning more about the unusual animals that live in these extreme and inaccessible environments. While testing the Ægir, CGB researchers found their 6th new hydrothermal vent field!



The AUV Hugin being recovered, summer 2015.

Read more about this summer's cruise on the CGB web site [Research / In the Field / Summer Cruise 2015](#)

### Testing the Ægir

In addition to discovering a new vent, the Ægir successfully undertook sampling activities and recovered incubators previously left in situ at different sites on the deep seafloor. While the Ægir's dedicated Tether Management System (TMS) was not fully

operational for this summer's activity, it was possible to rent another TMS system. The TMS system extends the ROV's capabilities. It is a cage-like containment system for transporting the ROV during deployment. It stores and deploys the tethering cable enabling the ROV itself to be decoupled from the motion of the surface vessel as well as allowing it to operate at a larger radius from the mother ship. The TMS also has sample storage facilities so that the ROV can make several collection efforts, thus making each dive potentially much more effective.

### In situ mine tailing experiments

CGB researchers are conducting a series of *in situ* experiments that will provide information about the effects of depositing mine tailings on the seafloor – specifically, how this material will “weather” on the seafloor.

Three different types of experiments are on-going at both Loki's Castle Vent Field and the Jan Mayen Vent Fields: deployment of incubators, taking of push cores and deliberately making scars in the sulphide chimneys on the seafloor. Two incubators were set out at each field in 2014. They were filled with ground, gem-grade pyrite (FeS<sub>2</sub>), which is the

### CGB HYDROTHERMAL VENT FINDS:

VENT NAME	YEAR DISCOVERED
Jan Mayen Vent Field: Soria Moria	2005
Jan Mayen Vent Field: Trollveggen	2005
Loki's Castle	2008
Jan Mayen Vent Field: Perle & Bruse	2014
7-sisters	2014
New vent	2015

The new ROV “Ægir 6000” being launched together with a Tether Management System (TMS), summer 2015.



The G.O.Sars' RIB in action, summer 2015.

most common of all sulphide minerals. Ægir recovered one of these this summer; the other will remain on the seafloor to “incubate” further.

### Enzyme hunting

Enzymes are bio-catalysts. They are specific, reusable, efficient, effective, and generate little waste. Bioprospecting is the process of exploring nature for potential new, naturally occurring enzymes to help make many industrial processes more efficient. Unexplored and inaccessible communities such as those CGB has discovered around the arctic deep sea hydrothermal vents provide unique opportunities for such enzyme searches.

During this summer's cruise, CGB researchers collected one of the team's incubators from a hydrothermal vent (Perle & Bruse), near Jan Mayen. The incubators had been filled with krill shells, wood pulp and wheat grains – complex organic carbon sources. After recovery, the communities that had grown in the incubator were subjected to metagenomic studies aimed at enzyme mining. In this case the CGB researchers were looking for enzymes that are capable of breaking down complex organic compounds.

### Gently sampling bio-diversity

The ROV's “dig and scoop” drawer can be used for seafloor sampling of bottom dwelling organisms capable of tolerating rough

handling. This summer CGB researchers tested an important new sampling instrument: a new suction pump module with a set of rotating chambers. The suction pump sampling tool is used to relatively gently extract samples from the seafloor. On previous research cruises the ROV has been outfitted with a suction pump sampler that was only capable of conducting one sampling operation per dive. The new module's rotating chambers will make it possible to undertake several different sampling



CGB researchers Desiree Roerdink (L) and Steffen Leth Jørgensen (R).

operations in different locations on each ROV dive because the chambers are completely separated from one another, thereby isolating each sample.

In addition to the suction pump samples, the video uptake on the Ægir 6000 provided excellent film material of deep sea organisms in situ, something that is of increasing importance when studying and identifying organisms living in such inaccessible and inhospitable environments. ■

# CGB HOSTS INTERNATIONAL MEETING ON DEEP SEA RESOURCES

Over 70 international experts, from 14 different countries, representing a cross-section of different lines of intervention, including geology, environment, biology and policy, gathered May 2015, at a workshop hosted by the Centre for Geobiology (CGB).



Filipa Marques

The workshop was entitled, “From Seafloor Hydrothermal Systems to the Sustainable Exploitation of Massive Sulfide Deposits: Myths and Realities of the Deep Sea”. It was led by Associate Professor, Filipa Marques.

An international workshop provides researchers and students with an opportunity to exchange ideas and results. It can stimulate network building, the formation of new partnerships and collaborations and initiate new research directions. This potential was enhanced by the extremely multidisciplinary nature of the workshop participants.

### Setting the Groundwork for Science-Driven Policy Making

Advances in technology are making one of

the last frontiers on Earth more accessible: the deep sea. With knowledge and reflection, we have a chance to optimise our exploration and exploitation.

- What biological and mineral resources exist in the deep sea?
- What potential importance do these resources have for supporting continued human development on Earth?

Deep sea mining is a case in point. Specialised mining companies have already been engaging in preliminary studies and some, for example, Nautilus, are set to begin production within a few years.

- Are we ready?
- Are the regulatory, environmental, legal and more structures in place?

Marques gathered researchers from different institutes and disciplines, together with

policy makers from different organisations, to seriously debate the future of ocean-mining.

Should we engage in deep sea mining?

- Can we justify the potential environmental damage and risks?
- Do we need to access these resources to sustain our current and future development?

### Disseminating knowledge to society

In keeping with UiB's mission and goals, this Deep Sea workshop was an excellent opportunity for researchers to both impart and reflect on the most recent research scientific results. It began with a series of 4 open lectures sessions that shared the discussion and information with the wider university community and any interested members of the public. The workshop provided opportunities for dialogue and the exchange of ideas between researchers and policy-makers and stakeholders. It also fulfils CGB's mandate to generate and share new fundamental interdisciplinary knowledge that significantly impacts such a new international research frontier. ■



Top: Cindy Van Dover (L) and Steve Scott (R). Bottom: Lawrence Cathles (L) and Robert Embley (R).

Ingunn H. Thorseth (L) and Kristina Gjerde (R).

# HOW MANY BRANCHES IN THE TREE OF LIFE?



Gravity corer being launched.

Most of us generally think about the multitudes of creatures occupying the many, outermost, smallest branches of the tree of life. However, some researchers are pre-occupied with what is really a question of how many trunks there are in the tree of life: where and when did the first branching occur? How many original branches were there? Prokaryotes? Eukaryotes? Archaea?

It is very seldom that a researcher is part of an epiphany result that sheds light on such fundamental questions. Nevertheless, CGB post-doc, Steffen Leth Jørgensen's research turned out to yield exactly such a groundbreaking result, and the work was published in *Nature* in 2015.

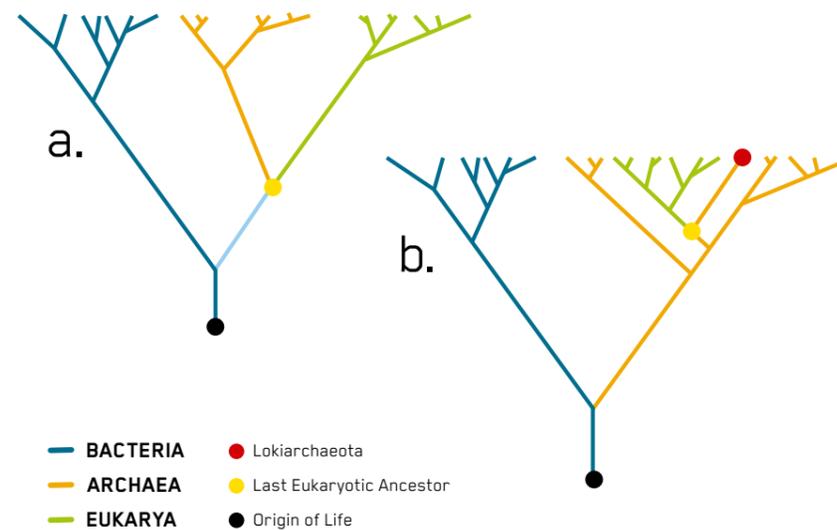
## Characterising Life on the Frontiers

Who lives there? What are they doing? How do they thrive? CGB researchers have been working systematically to try to identify, isolate and characterize the organisms they are finding during their deep sea explorations.

A major focus of the Centre's deep sea activity has been the fascinating phenomenon of hydrothermal venting. A number of different kinds of vents have been discovered, revealing in turn, different geological processes on-going at mid-ocean ridges, and the slow- / ultra-slow-spreading Arctic mid-ocean ridge in particular. Analyses of the samples collected, including sediment cores and sea-floor structures such as chimneys, are not only revealing detailed geological and geochemical information, but the samples are teaming with microbial life.

## Being CSI Investigators

CGB researchers have worked hard to establish metagenomics pipelines capable of undertaking the complex analyses needed to resolve the microbial field data being collected. Although they have had some success with isolating and culturing a few individual microbes, the vast majority of microbes are, as yet, uncultured. The researchers are essentially Crime Scene Investigators as they



a. Representation of the classical 3 domain tree of life introduced by Carl Woese in the late 80ies. It consist of the monophyletic groups; Bacteria, Archaea and Eukarya.  
b. Representation of the newly proposed 2 domain tree of life in which only Bacteria and Archaea are monophyletic and where Eukarya is located within the archaeal domain with Lokiarchaeota representing the closest sister group to Eukarya.

use advances in technology to unravel the mysteries of who is there and what they are doing.

Jørgensen explains what happened in this particular study. During a research cruise summer 2008 – the cruise where CGB discovered their first Black Smoker, Loki's Castle – Jørgensen was collecting sediment cores from the areas around the vent, but some distance away, to establish reference, base-line information about the microbial communities in the sediments near and away from the vents. CGB researchers undertook comprehensive molecular and geochemical studies of the core sediments. Typically, different sediment horizons in the core have different microbial communities based on differences in the core's geochemical composition.

## On the Track of an Uncultured Mystery

One horizon, in particular, attracted Jørgensen's interest as it was highly enriched in a specific uncultured archaeal group - the Deep Sea Archaeal Group (DSAG). Archaea have often been found as being a significant component of the microbial communities in marine sediments, and the DSAG is one of the most predominant archaeal groups found to be present. However, despite their high abundance, no members of this group have yet been characterised and thus nothing about their metabolism is known.

The group was particularly interesting to Jørgensen because previous phylogenetic work with this group, i.e. work with its evolutionary history and relationships to other groups, had shown that the DSAG are

found near the base of the tree of life (actually at the base of the so-called TACK-phyllum). The decision was made to undertake a full-scale metagenomics' study of the sample's genetic material with CGB's collaborators in Uppsala, Sweden.

The initial results showed that the DSAG genome was full of eukaryotic signature genes! This was so unexpected that the team undertook further analyses to ensure that there had been no possible contamination. Jørgensen explains that the team found it even more fascinating that these genes were not just random genes, but the exact type of genes one would expect to find in the ancestor to the complex eukaryotic cells. This work makes an important contribution to the ongoing debate about the nature and timing of events leading to the development of the Eukaryotic Domain (eukaryogenesis).

## Lokiarchaeota

The team have proposed the name *Lokiarchaeota* for this group of Archaea, previously named DSAG/Marine Benthic Group B. The name references the sampling location, Loki's Castle. Loki is the name of an ancient Norse shaping-shifting deity, described as being a "staggeringly complex, confusing and ambivalent figure who has been the catalyst of countless unresolved scholarly controversies. It is a fitting name for a group of organisms that are now playing a central role in an ongoing debate about the base of the tree of life, as it was for the vent system itself, which was maddeningly elusive before it was finally discovered.

According to Jørgensen, the story about the *Lokiarchaeota* does not end here; there is much more genomic information about this group awaiting further interpretation.

Read more from CGB's web site / News archive / May 2015.

The current consensus is that eukaryotes evolved from prokaryotes. However, the two prokaryotic domains, Bacteria and Archaea, are relatively simple in terms of their cytological complexity, while eukaryotic cells are typified by a high degree of cellular compartmentalization. From an evolutionary point of view, it is hard to reconcile that the cellular complexity in eukaryotes evolved from the simpler systems.

Does the tree of life begin with 3 main lineages, the 3 domains Bacteria, Archaea and Eukaryotes? Or are the Archaea and Eukaryotes, in fact, sister lineages?

Evidence for a common ancestry between archaea and eukaryotes was further substantiated when the first archaeal genomes were sequenced, revealing that many of the genes involved in the cellular core of the genetic information processing genes of Archaea were shared with, or similar to those of Eukaryotes. It appears that eukaryotic genomes include genes of both archaeal and bacterial origin as well as genes that are specific to Eukaryotes. The presence of many bacterial genes in Eukaryote genomes can be explained by the endosymbiosis processes that gave rise to organelles such as mitochondria and chloroplasts. However, the identity and nature of the host cell, LECA, from which the core components of the eukaryotic nuclear lineage descended, is unclear. Recent studies focusing on phylogenetic analyses of universal protein datasets have provided robust support for the idea that Eukaryotes emerged from the archaeal 'TACK superphylum'. This current work supports this theory. ■

## LAST COMMON EUKARYOTIC ANCESTOR

Who was the Last Common Eukaryotic Ancestor (LECA), ultimately the ancestor from which we humans evolved? This is a profound question, not only in an academic context but for our understanding and perception of who we are, ourselves.



## SPONGES – A UNIQUE DEEP SEA RESEARCH PROGRAMME FUNDED

Researchers from UiB and CGB will coordinate a research project focusing on the exploration of the deep sea sponge grounds in the north Atlantic. The project named “SponGES – Deep sea Sponge Grounds Ecosystems of the North Atlantic: an integrated approach towards their preservation and sustainable exploitation” is supported for four years with a 10 million Euro grant from Horizon 2020, the EU’s research and innovation programme. All together 18 universities and institutions are involved as partners.

Deep sea sponge-dominated communities (grounds, aggregations and gardens) form a variety of vulnerable marine ecosystems widespread throughout the North Atlantic in areas such as shelves, slopes, seamounts, mid-ocean ridges, canyons and fjords, where they often “come in conflict” with fishing and other human activities. Their biodiversity, ecological importance and biotechnological potential are assumed to be similar to or even

higher than other deep sea ecosystems such as cold-water coral reefs or vents/seeps systems. However, in contrast to these, sponge grounds have so far received relatively little scientific or conservation attention.

The overall objective of SponGES is therefore **to develop an integrated ecosystem-based concept for the preservation and sustainable exploitation of vulnerable deep sea sponge ecosystems of the North Atlantic**. By establishing an international and interdisciplinary consortium of researchers from institutions, environmental non-governmental and intergovernmental organizations, SponGES will specifically aim at:

- 1 Strengthening the knowledge-base on North Atlantic sponge ground ecosystems by investigating their distribution, diversity, biogeography, function and dynamics

- 2 Improving innovation and industrial application by unlocking the biotechnological potential of these ecosystems
- 3 Improving the capacity to model, understand and predict threats and impacts and future anthropogenic and climate-driven changes to these ecosystems
- 4 Advancing the science-policy interface and developing tools for improved resource management and good governance of these ecosystems from regional to international levels across the North Atlantic ■



## Training the Next Generation: FROM MULTIDISCIPLINARITY TO INTERDISCIPLINARITY

One of CGB’s key goals has been to train a new generation of truly interdisciplinary researchers: genuine geobiologists.

The idea was to take students from various multidisciplinary backgrounds and to train them to cross disciplines so that they would become a new generation of interdisciplinary geobiology researchers, with a common language, background and approaches.

Here we feature five CGB researchers who have completed a PhD during the time they have been associated with the Centre. Originally a mixture of biologists and geo-

logists, all five now consider themselves to be geobiologists. Each spoke of an academic journey that had been challenging, fascinating, positive and enriching. There were some common elements to their experiences of becoming interdisciplinary: a willingness to learn new “languages” and new “ways of thinking”; the importance of being co-located – how physically sitting close together facilitated formal and informal exchanges and

collaborations; becoming “interdisciplinary” takes extra time and effort so there is a need to know that one is part of a venture with a long-term perspective; that it is grounded at UiB and will continue after the CGB project period

Read more on CGB’s web site [Education / Training the Next Generation](#)

### BUILDING INTERNATIONAL NETWORKS

**NAME:** Tamara Baumberger  
**PHD TITLE:** Volatiles in Marine Hydrothermal Systems  
**PHD DATE OF COMPLETION:** 2011



Tamara Baumberger

Swiss National, Tamara Baumberger, actually completed her PhD at ETH Zurich Switzerland. During this time, however, she had a number of exchange periods at CGB, including participating in the annual summer cruises. Following the completion of her PhD, Baumberger came to CGB full time as a post-doc researcher.

#### Fostering international collaborations

Baumberger is a concrete example of CGB’s engagement in international network building. This is especially important in a field as

technically demanding and costly as deep sea exploration. International collaborations make it possible to share and pool costly resources such as specialised equipment and laboratories, ship time etc. in addition to exchanging personnel, knowledge and approaches.

#### Exchanging expertise

Baumberger herself has shared CGB expertise when she has participated in international cruises elsewhere in the world, including NOAA research cruises. She will continue CGB’s network building as she takes up a NOAA post-doc position in Newport, Oregon, USA. However, she will continue to be involved in Centre activity, including being involved in the supervision of a CGB PhD student.

### NEW IDEAS FLOURISH IN INTERDISCIPLINARITY

**NAME:** Steffen Leth Jørgensen  
**PHD TITLE:** Linking Microbial Community Structures and Geochemistry in Deep-Sea Sediments & pursuing the link between identity and function  
**PHD DATE OF COMPLETION:** January 2013

Danish National, Steffen Leth Jørgensen, came to CGB as a Master student. He is now a post-doc and his research addresses fundamental questions in one of the most frontier areas in Biology; the sub-surface biosphere (read more about some recent results that were published in *Nature* on pages 8–9).



Steffen Leth Jørgensen

Jørgensen says that one achieves a much deeper understanding of a research problem and the research itself can be placed in a much broader context at the cross-over between disciplines. According to Jørgensen, mastering the “jargon” is critical to truly becoming an interdisciplinary scientist – and this is best accomplished by being exposed to the different disciplinary languages on a daily basis; by having researchers from different disciplines co-locate.

#### No question too big!

From student to researcher, Jørgensen feels that being at an international, interdisciplinary centre such as CGB has provided him with the analytical tools and the freedom to grow. It has enabled him to establish himself as an international researcher who is contributing to helping to elucidate key questions in the deep biosphere.



Bernt Rydland Olsen



Irene Roalkvam



Ingeborg Elisabet Økland

## INTERDISCIPLINARITY PROVIDES GREATER CONTEXT

**NAME:** Bernt Rydland Olsen

**PHD TITLE:** Developing Molecular Tools to study Trophic Interactions in zooplankton and their implementation in a vent system

**PHD DATE OF COMPLETION:** June 2014

Bernt Rydland Olsen began becoming an interdisciplinary researcher while still at the Department of Biology! He needed to build an interdisciplinary “tool box” of approaches to help him gain overall understanding of whole eco-systems. At CGB he is working to include geological and geochemical approaches to provide context for his work, something that further enriches his understanding of an eco-system. Olsen believes that such close interdisciplinary collaboration is necessary for the systemic environmental research questions of today, and critical for addressing the global issues we face in the future.

### Generating Global Understanding

Practically speaking, interdisciplinarity at CGB has facilitated infrastructure collaborations between research groups. This has given participants from any one group access to field opportunities and research results that would not have been possible otherwise. As a result, the unexplored deep sea environments that CGB has discovered are being studied from many different disciplinary perspectives and the results are being interpreted and presented in an integrated interdisciplinary way that provides more complete, global understanding of these new and unique environments.

## INTERDISCIPLINARITY PROVIDES UNIQUE DEPTH

**NAME:** Irene Roalkvam

**PHD TITLE:** Diversity, stratification and in situ metabolism of anaerobic methanotrophic archaea in Nyegga cold seeps

**PHD DATE OF COMPLETION:** June 2012

Irene Roalkvam speaks of how different disciplines involve not only different “languages” but also different approaches and ways of thinking, particularly with respect to time and space. Coming from a microbiology background, she notes that, compared to microbiologists, geologists have more of a tendency to think globally and over periods of thousands of years.

### Papers have greater depth

Roalkvam underlines the importance of having different kinds of data from the same sample material. It helps to build a stronger understanding of the environments being explored by CGB.

She says that she feels that she can write better, more in-depth papers when geological and geochemical data is also included in the analysis. She also values opportunities for interdisciplinary discussions during the research and write-up processes that exist at CGB.

Roalkvam’s research has also been a part of a new, exciting direction at CGB: building bridges between pure and applied research. In particular, her work has been providing some insights into some of the issues involved in bio-corrosion.

### Having time to grow

2015 has been a particularly productive year for Roalkvam, which underlines the importance being able to participate in research over time periods that are long enough for

establishing the work properly; building and maintaining the infrastructure; establishing networks, partnerships and collaborations; undertaking field and lab work as well as conducting the analyses. CGB has had a 10-year project period, and the hope is that the work will continue under the umbrella of a new deep sea centre.

## BUILDING BRIDGES

**NAME:** Ingeborg Elisabet Økland

**PHD TITLE:** Low temperature geochemical reactions and microbial life in ultramafic rock

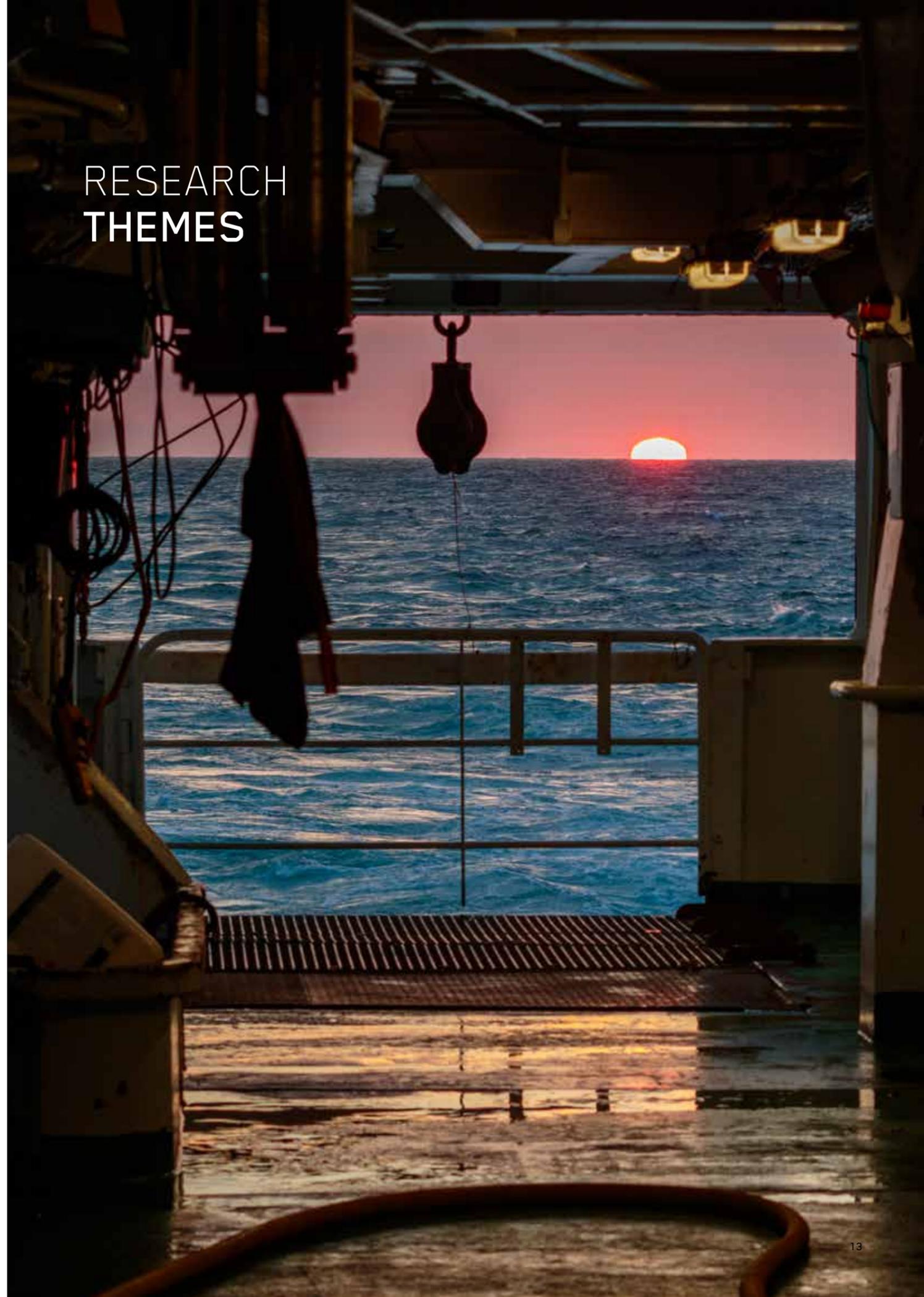
**PHD DATE OF COMPLETION:** February 2013

Ingeborg Elisabeth Økland understands that knowledge of one discipline alone is not enough to understand the “bigger picture”. Her own path to interdisciplinarity has moved from geology to geochemistry to geomicrobiology! She says that the next generation will go one step further; for them, working interdisciplinarily will simply be a “way of thinking”.

### From basic to applied

Økland’s research has involved extensive fieldwork both on land and at sea. In particular, she has used the unique geology of the Norwegian Island, Leka, as a model to help bridge understanding of such landscapes with the more inaccessible deep sea counterparts. Her basic research activity has been to better understand the reactions occurring between rocks, water and microorganisms. This work is now also helping to bridge another important knowledge gap that exists between basic and applied research. She is part of a CGB advisory initiative to carry out risk assessment analyses to determine the potential impacts of storing mine tailings in the sea. ■

# RESEARCH THEMES



# GEODYNAMICS OF THE DEEP SEAFLOOR

Ancient on-land volcanogenic massive sulfide deposits (VMS) are a major source of base-metals such as copper, zinc, lead, silver and gold. Their modern analogues, the seafloor hydrothermal systems, are actively precipitating metal-rich sulfides that may eventually lead to the formation of seafloor massive sulfide (SMS) accumulations of potential economic interest.

Following the successful discoveries of the previous cruises in the Arctic Mid-Ocean Ridge (AMOR), CGB continues its research on the nature and genesis of seafloor hydrothermal systems and their sulfide accumulations. The findings have proven that the ridge hosts a wide range of types of hydrothermal systems, some with unique characteristics that may not have a direct known equivalent elsewhere on the planet.

One PhD thesis was completed and submitted in 2015 under the title "Mineralogy and Geochemistry of contrasting hydrothermal systems on the Arctic Mid-Ocean Ridge (AMOR): The Jan Mayen and Loki's Castle vent fields". This research is a significant contribution to the inventory of AMOR system providing data that allow us to understand the base-metal distribution in these two distinct systems of the AMOR. Newly sampled sulfide-sulfate rich rocks from the "Perle og Bruse" site near Jan Mayen Vent Field are being subjected to similar research methods.

The Seven Sisters volcanic suite, a N-S alignment of small flat-topped volcanic edifices on the Northern Kolbeinsey ridge, hosts a shallow (~130 m depth), relatively high temperature (~200°C) hydrothermal system. In 2015, rocks from the Seven Sisters were subjected to metallogenetic and geochemical studies. Results indicate that the mineralization style at Seven Sisters displays hybrid characteristics between magmatic-dominated epithermal deposits and seafloor hydrothermal systems. Many authors have

pointed out the possibility that transitional hybrid VMS deposits with epithermal-style metal enrichment may occur in shallower waters and some examples have been found in arc and back-arc settings. But to the best of our knowledge, Seven Sisters would be the first basalt-hosted modern hybrid system within a slow spreading MOR setting.

Our main objectives have been successfully achieved as we have continued to explore the AMOR, with new findings being discovered every year. The evident diversity of hydrothermal systems explored so far, can only signify that the full comprehension of

these systems is in its infancy, and that any attempt to prematurely portray a generalized model of seafloor hydrothermal system occurrence on the AMOR is imprudent. The team's purpose is therefore to continue exploration and research and to better understand the complexity, diversity and distribution of these ore-forming systems by using a holistic approach that encompasses the study of both active and inactive/fading portions of the seafloor hydrothermal systems, hosted in different rock types, and in deep and shallow segments of the arctic ridge. ■



Photomicrograph in transmitted light microscopy depicting translucent networks of cryptocrystalline silica spherules surrounding opaque, fine-grained, Cu-Fe and Zn sulfides. Sample from the Seven Sisters Hydrothermal System, Northern Kolbeinsey Ridge.

# WATER-ROCK-MICROBE INTERACTIONS & THE DEEP BIOSPHERE

This year has been extraordinarily exciting because of the discovery of *Lokiarchaeota* (see special feature on pages 8-9).

Another highlight was the funding of the Icelandic Surtsey drilling campaign SUSTAIN by the International Continental Scientific Drilling Program (ICDP), with an anticipated start late summer 2016. Here CGB will be involved both in the initial sampling and in the post-drilling *in situ* observatory. This drilling project will be the first to obtain "zero age" basalt from a marine environment; collecting material that will enable us to elucidate the biogeochemical interactions in this young rock.

In 2015, we continued to build our commitment to international drilling operations by participating in the International Ocean Discovery Program (IODP) expedition 357 to the Atlantis massif. The aim of this expedition was to explore the extent and activity of the subsurface biosphere in young ultramafic and mafic seafloor. Our analyses of the samples collected will include specific focus on the nitrogen cycle.

In addition to these international activities, we continue to have special attention on the subsurface geomicrobial processes and element cycling in the Norwegian-Greenland

Sea. We anticipate that the implementation of this year's cruise data will enable us to produce some valuable insights on the deep marine nitrogen cycle.

As partner of the EU project MIDAS (Managing Impacts of Deep Sea resource exploitation), we continued our investigation of weathering processes on seafloor massive sulphides (SMS) through the use of *in-situ* experiments at the arctic vent fields. The preliminary results from the material that was collected during this summer cruise show a positive correlation between the abundance of microorganisms on the mineral surfaces and the degree of weathering. This suggests that geomicrobiological processes play an important role in the degradation of the sulphide minerals in SMS deposits and this potentially releases heavy metals. This indicates that assessment of the potential environmental impact of mineral dissolution related to deep-sea mining activities should include biogeochemical processes in addition to abiotic geochemical leaching, which is often the only factor taken into account in simulation experiments of such impacts. ■

Sulphide mineral grains after one year of seafloor weathering.



# LIFE IN EXTREME ENVIRONMENTS & ROOTS OF LIFE

Deep-sea hydrothermal systems host ecosystems that are driven by the energy that is available from chemical disequilibria.

These chemical disequilibria form when reduced hydrothermal fluids mix with seawater. Due to the presence of many complex sub-seafloor processes, the chemical composition of the venting fluids varies within and between hydrothermal systems. The resulting spatially and temporally shifting energy landscapes make deep-sea hydrothermal vent ecosystems excellent natural laboratories for studying the association between chemical energy availability and microbial community structure.

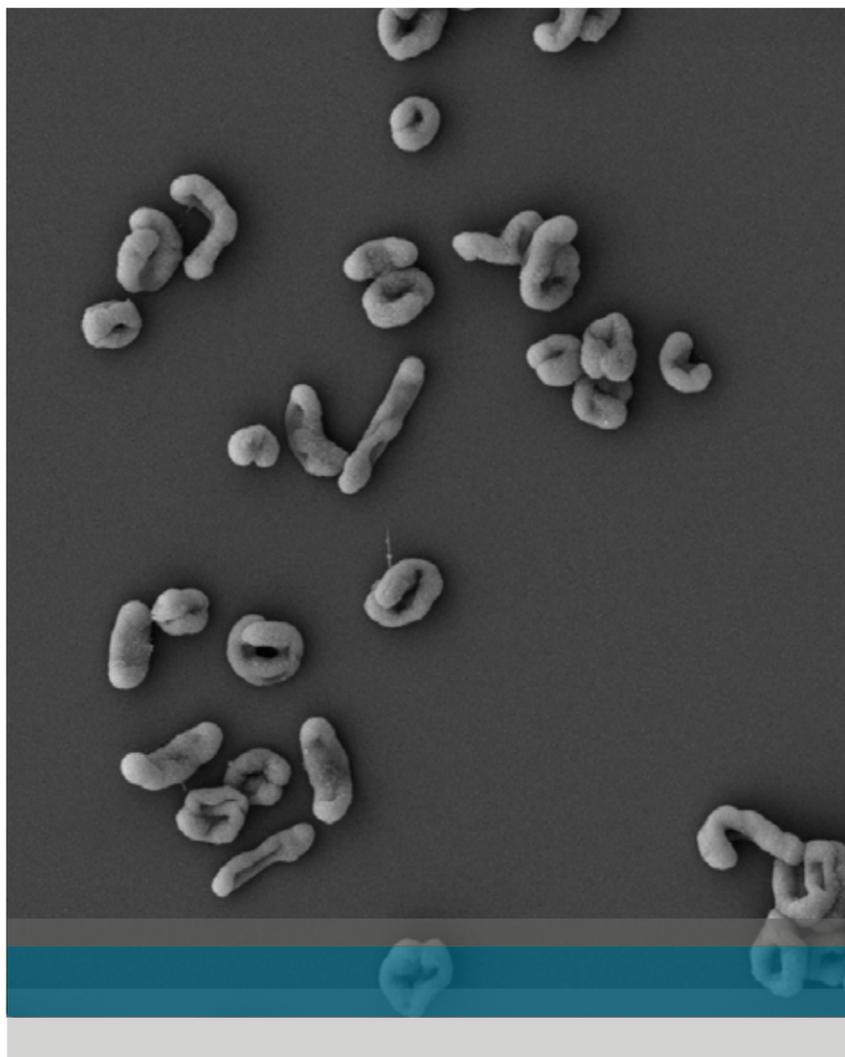
In our research activity thus far, we have been investigating the microbial responses to shifting energy landscapes on and around black smokers in the different vent fields CGB has discovered along the AMOR. As yet knowledge is lacking about the extent to which the results from these investigations can be used to infer the actual energy landscapes and distributions of functional groups of organisms in wider areas characterized by diffuse or ultra-diffuse low-temperature flow. However, recent investigations, involving

geochemical analyses, transcriptomics and r6S rRNA profiling, have given us detailed insights on the complex, but apparently tight coupling, between geobiological processes in diffuse flow areas. Specifically, in a study of the Loki's Castle VF published this year, we reported that the metabolic groups of organisms in low-temperature venting barite chimneys are largely consistent with energy availability. Moreover, we found that while  $H_2$  served as an electron donor in the high-temperature venting area, it was absent in the low-temperature fluids. Consistent with this observation, hydrogenase, the key enzyme for consumption of  $H_2$ , was differentially expressed between the two sites. This result demonstrates how sub-seafloor processes, in this case a presumed anaerobic  $H_2$  consumption, has a direct effect on the activity of microbial communities on the seafloor.

In addition to being influenced by the energy landscapes, the physical structuring of the resident microbial communities seems to be affected by variations in the extent of venting. For example, a heat resistant biopolymer was crucial for the attachment of filamentous *Epsilonproteobacteria* of the genus *Sulfurovum* to the chimney wall of the black smokers in the high temperature venting area, while cotton-like microbial mats were found growing on top of the low-temperature barite chimneys. In these microbial mats, single cells of *Epsilonproteobacteria* of the genus *Sulfurimonas* were attached and interconnected by thin threads of an extracellular polymeric substance.

These findings illustrate how different genera of *Epsilonproteobacteria* can colonize different vent fluid mixing zones differently, even within the same vent field. Altogether our results illustrate the importance of systematic comparative studies of spatially closely connected niches in order to fully understand the geomicrobiology of hydrothermal microbial ecosystems. ■

One of the new isolates CGB has characterised: *Hypnocyclicus thermatrophus* pictured here in its more dormant state, "sleeping" in a ring. ■



# VENT AND SEEP BIOTA

This theme involves the exploration of the deep-water fauna in the Arctic and the NE Atlantic oceans with special emphasis on hydrothermal vents and seamounts along the AMOR.



Among the main objectives in the ongoing work is to investigate local adaptations and speciation processes, as well as to address potential ecological and evolutionary connectivity between different chemosynthetic habitats in the area, including hydrothermal vents, cold seeps and sunken wood. We have previously shown that chemosynthetic habitats in the Norwegian and Greenland seas host an endemic and highly specialized fauna, particularly at the deep parts of the Knipovich Ridge and Loki's Castle.

Last year field work was devoted testing a prototype of the new bio-suction sampler designed for use with the ROV Aegir 6000. Already in the first test dive, the new sampler proved that it will make a valuable contribution to biological sampling, as it allows us to study vent sites in more detail due to its five-chamber revolving system; this means 5 times as many sampling opportunities per

dive – a significant increase in sampling efficacy. This will have a significant impact on our deep-sea biology research in our Norwegian waters.

We have previously shown that there are obvious similarities between the fauna found at hot vents along AMOR, at cold seeps along the Norwegian margin, and from wood-falls in the abyssal Norwegian Sea. While the Jan Mayen Vent Fields has been extensively sampled, less effort has been put into sites further north along AMOR. To enable us to finalize our fauna inventory, re-sampling of the Loki's Castle Vent Field was therefore the main aim for the 2015 ROV test-cruise.

Successful sampling of Loki's Castle in combination with the discovery of the new vent field, has enabled us to take a major step forward in our work. The new vent field provides another study area in the deeper part of AMOR and serves as a valuable link between

the more shallow Jan Mayen Vent Fields to the west and the deeper Loki's Castle Vent Field to the east, and will aid in improving our understanding of the genetic and historical connectivity of key species. The discovery of another vent field in the area adds to the growing interest in potential mineral (and bio-) resources to be found along the ridge. However, the consequences of deep-sea mining on both the benthic and pelagic communities are not well known. Therefore we are focusing on building a thorough understanding of the ecosystem functioning, as well as its resilience and potential for recovery after mineral extraction in these vent systems. The novelty and high degree of endemism of the vent fauna in the Norwegian- and Greenland Seas call for more in depth, base-line studies and suggest the use of a precautionary approach in future management of these unique deep-sea habitats. ■

# EARTH SYSTEM EVOLUTION



With the first new team members, David Diego (postdoc) and Kristian Agasøster Haaga (PhD), arriving in the spring of 2015, this theme is now actively exploring new methods for detecting complex interactions from geological data, gaining new fundamental insights into Earth system interactions across time scales.

As an example, novel answers have been found to a long-standing question: did climate changes play a causal role in the macroevolution of planktonic foraminifera, a microfossil group of profound importance to the Earth sciences, over the last 65 million years? In an innovative study that fundamentally challenges the current approach to documenting the history of life, three conceptually very different analyses provide dynamical evidence for the causal role of climate changes in the global proliferation of foraminifera. This work was done over the past year in collaboration with colleagues at the University of Oslo, was presented at the 2015 Annual Meeting of the Geological Society of America, and a preprint is available at: <http://biorxiv.org/content/early/2016/03/15/043729>.

The international collaboration with researchers at Bristol and Leeds continues, with a new analysis of the intricate relationship between global fossil and sedimentary rock records, currently in preparation for *Biology Letters*. Ongoing work on Quaternary climate system interactions was presented at the 2015 International Union of Quaternary Research meeting in Japan. This work involves researchers at the Bjerknes Centre for Climate Research, and will be strengthened in the following years with a dedicated researcher to be hired in 2016 funded by the Bergen Research Foundation (PI Hannisdal). Finally, this theme will become more closely integrated with other core activities at CGB through a new PhD project starting in 2016 aimed at analysing the

The fossil whale *Dorudon atrox* from the Wadi-Al-Hitan, the "Valley of the Whales", a UNESCO World Heritage Site in Egypt. It lived around 40 million years ago, during a time when the Earth was descending from its usual, warm "greenhouse" state into a cool, "icehouse", culminating in the recent glaciations during which humans evolved. The Earth System Evolution theme aims at elucidating the linkages between long-term climatic and biological evolution during this dramatic period of Earth's history.

coupling between geochemical energy landscapes and microbial ecosystems in deep-marine sediments and hydrothermal systems. ■

# ORGANISATION



The Centre for Geobiology (CGB) is part of the Faculty of Mathematics and Natural Sciences at the University of Bergen (UiB) and is hosted by the Department of Biology and the Department of Earth Science.

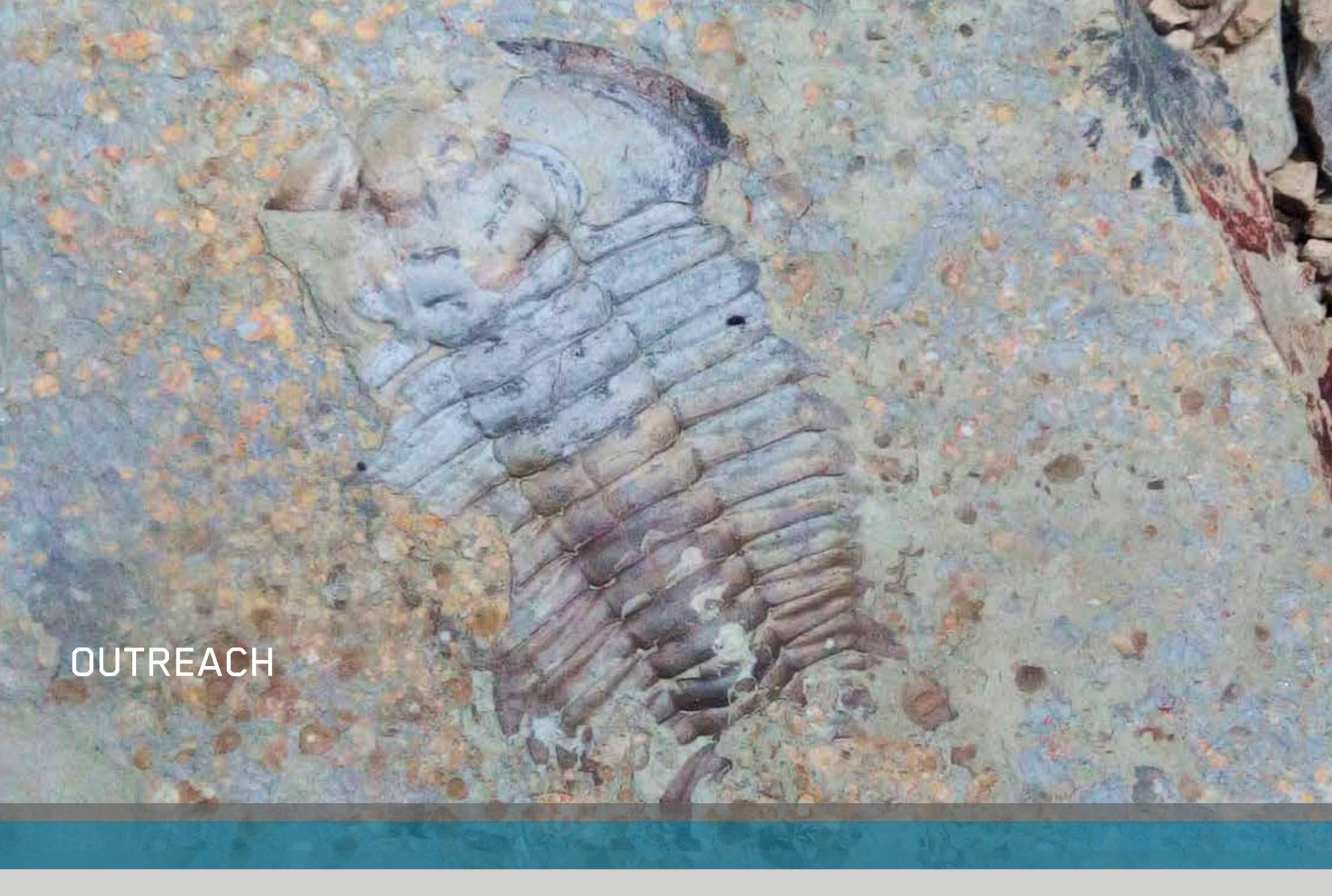
Although initially organised around research themes, the Centre since has adopted a matrix model approach that facilitates and promotes the inter- and multi-disciplinarity necessary to attain the Centre's research goals. In this model the thematic leaders (leader group) are responsible for developing the research themes by initiating new and overseeing existing projects. It allows young, early-stage researchers to acquire leadership training as individual project leaders (leader forum).

## SCIENTIFIC ADVISORY COMMITTEE

- Chris German Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, USA
- Cindy Van Dover Duke University Marine Laboratory, Beaufort, North Carolina, USA
- John Parkes School of Earth & Ocean Sciences, Cardiff University, UK
- Frances Westall Le Centre de Biophysique Moleculaire, CNRS, Orléans, France

## THE GOVERNING BOARD

- Helge K. Dahle (chairman) Dean of The Faculty of Mathematics and Natural Sciences, UiB
- Gunn Mangerud Head of Department of Earth Science
- Anders Goksøyr Head of Department of Biology
- Heidi Espedal Acting Director of the Department of Research Management
- Bjarte Hannisdal Employee representative Department of Earth Science
- Runar Stokke Employee representative Department of Biology



## OUTREACH

### **CGB International Workshop on Deep Sea Resources**

The deep sea is one of Earth's final frontiers. Optimal and sustainable exploitation is only possible through collaborative efforts by research and industry. CGB is contributing to this effort. May 2015, over 70 participants from 14 different countries gathered in Bergen to consider "From Seafloor Hydrothermal Systems to the Sustainable Exploitation of Massive Sulfide Deposits: Myths and Realities of the Deep Sea". The workshop was led by CGB Associate Professor Filipa Marques.

The 3-day event began with a series of 4 open lectures that provided important background information including the history of deep sea exploration since the exciting discovery of the first hydrothermal vents in the 1970s. From basic science – both

geology and biology – through the current status of global policies and the need for informed legislation, to the need for a more informed public, the workshop provided extensive opportunities for global experts to cross disciplinary boundaries, share experiences and latest research results.

### **CGB at Norway's National Science Week ("Forskningsdagene")**

One of the critical tasks of institutions of higher learning and research is to communicate their results to the general public; to engage with the general public. The Research Council of Norway has developed an important vehicle for this activity, held every year: National Science Week.

Led by Runar Stokke, CGB researchers interacted with students and public during

Bergen's National Science Week. They presented their work on enzyme hunting. The goal is to find new enzymes that will help industry to provide better and more efficient products that are also less wasteful and less polluting, and which will promote the bio-economy of the future. For example, the enzymes they are purifying can be used to convert waste from activities such as aquaculture, forestry and other industries to food, feed, bio-fuel, bio-gas, plastics, medicines, chemicals and other valuable goods.

During National Science Week, CGB researchers also presented their recent work successfully isolating, characterising and sequencing 5 new isolates. The hope is that these newly identified microorganisms will contain unique enzymes. Microorganisms

that live in hostile environments have evolved interesting enzymes to enable them to cope with the stresses of their environment. Microorganisms isolated from relatively unexplored, inaccessible, extreme environments such as those found in CGB's newly discovered deep-sea hydrothermal vent fields along the Arctic Mid-Ocean Ridge, may well harbour enzymes that have never been observed before. Such enzymes might be of interest for industrial processes occurring under relatively extreme conditions.

### **CGB researcher receives EMBO Workshop poster award**

Irene Roalkvam's poster presented the biocorrosion potential of a nitrate reducing *Arcobacter* species. It detailed the metabolic and genomic characteristics of the microbe,

which was isolated from injection water, and showed how the *Arcobacter* strain could play a role in biocorrosion. Conference participants presented work in both basic studies and industrial applications of microbiology related to sulphur metabolism. Roalkvam commented that discussions with fellow participants working in biocorrosion had been fruitful and were a highlight of the workshop.

### **CGB Researchers in Advisory Roles**

Deep sea resources, both biological and geological, are attracting increasing interest as advances in technology are making them more accessible. Scientists around the world are expressing concern that the exploitation of this relatively unexplored frontier takes place in a responsible and sustainable way. Solid scientific data, such as that being generated at CGB, is needed to serve as a foundation for establishing management and monitoring guidelines. A number of CGB researchers have been asked to contribute expertise at various international meetings held in 2015. This is an important part of UiB and CGB's mandate – to disseminate knowledge beyond the academic community.

Here are some examples:

Filipa Marques represented CGB/UiB at Cleantech Summit 2015, a global technology summit in Finland. Marques was invited to present information on issues relating to deep sea resource exploitation. She and Rolf Birger Pedersen represented CGB/UiB at an official meeting in Portugal, hosted by the Norwegian Embassy, where the management of marine resources was on the agenda. Marques underlines the importance of building bridges between institutions and countries. Norway and Portugal have enjoyed a long history of marine collaboration, from research vessels to fisheries, and now to deep sea resources.

Industry leaders in the Sogn and Fjordane Region of Norway hosted a seminar aimed at stimulating long-term growth in the region. Academic and industrial leaders were invited to give presentations. Ingeborg Økland represented CGB/UiB. Her presentation dealt with some of the applied spin-off potentials resulting from CGB's deep sea research.

Irene Roalkvam presented her work on biocorrosion in a couple of workshops; EMBO in Denmark (where her poster won a prize) and the ISMOS 5 conference in Stavanger. She felt that being able to exchange ideas between academic and more applied researchers was a valuable experience.

### **CGB Participates in Political and Policy Arenas**

Marques represented CGB and deep sea research at the recent opening of UiB's new office in Brussels. The office will enable UiB, and the other two office partners, NTNU and SINTEFF, to be more involved in EU research funding and decision-making activities. The Deep Sea is one of UiB's strategic interest areas.

Rolf Birger Pedersen and Eoghan Reeves represented CGB / UiB at the annual Transatlantic Science Week (TSW) in Boston, to promote enhanced cooperation between Canadian, American, and Norwegian stakeholders in research, innovation, and higher education. This year's theme was "Blue Futures". The TSW is an arena where different stakeholders can meet with the purpose of developing long-term collaborations or partnerships.

September 2015, the Norwegian government announced a marine master plan to gather the major marine research environments in a cluster in Bergen, along with partners from the marine industries, to create a collaboration that would have international impact. UiB's new strategy document for 2016-2022 is entitled, "Ocean, Life, Society", and its first paragraph underlines its commitment to geobiological deep sea research. CGB and the continuation of its work in a new Deep Sea Research Centre will help UiB play an active role in such a cluster. ■

# RESEARCH PROJECTS 2015

## PROJECTS FUNDED BY THE RESEARCH COUNCIL OF NORWAY

DURATION	TITLE	LEADER*/PI**/CO-PI***
2009-2017	Subsurface CO <sub>2</sub> storage - Critical Elements and Superior Strategy (FME SUCCESS)	Rolf Birger Pedersen**, Ingunn H. Thorseth*** FMEINFRA
2010-2015	Develop acoustics for monitoring of leakage from sub bottom CO <sub>2</sub> disposals (AKUGASS)	Rolf Birger Pedersen* RFFVEST
2011-2016	Mining of Norwegian biogoldmine (BioGoldMine)	Ida Helene Steen* BIOTEK2021
2011-2015	Biological methane oxidation by methanotrophic verrucomicrobia under hot and acidic conditions	Nils-Kåre Birkeland* FRIMEDBIO
2012-2017	Enzyme development for Norwegian biomass - mining Norwegian biodiversity for seizing Norwegian opportunities in the bio-based economy (NorZymeD)	Ida Helene Steen** BIOTEK2021
2013-2016	Vulnerable habitats and species in petroleum resource management: impact of sediment exposure on sponge grounds (SedExSponge)	Hans Tore Rapp** Friederike Hoffmann** HAVKYST
2013-2015	Microorganisms in the arctic: major drivers of biogeochemical cycles and climate change	Lise Øvreås* POLARPROG
2013-2015	Novel thermostable enzymes for industrial biotechnology (THERMOGENE)	Nils-Kåre Birkeland* BIOTEK2021
2014-2016	Norwegian Marine Robotics Facility - Remotely Operated Vehicle for Deep Marine Research (NORMAR)	Rolf Birger Pedersen* FORINFRA
2014-2017	Earth System Interactions and Information Transfer (ESIIF)	Bjarte Hannisdal* FRINATEK

## INTERNATIONAL PROJECTS FUNDED THROUGH THE EUROPEAN COMMISSION (EU)

DURATION	TITLE	COORDINATOR*/ PI**/ CO-PI***	PROGRAMME
2011-2015	Sub-seabed CO <sub>2</sub> Storage: Impact on Marine Ecosystems (ECO2)	Rolf Birger Pedersen** Ingunn H. Thorseth***	FP7
2014-2017	Managing Impacts of Deep-sea resource exploitation (MIDAS)	Rolf Birger Pedersen** Ingunn H. Thorseth***	FP7
2015-2018	Industrial Applications of Marine Enzymes (INMARE)	Ida Helene Steen **	H2020

## PROJECTS FUNDED BY OTHER SOURCES (PUBLIC AND PRIVATE)

DURATION	TITLE	LEADER*/PARTNER**
2011-2015	Deep-water sponges of the Greenland-Iceland-Norwegian Seas	Hans Tore Rapp* Det Norske Videnskapsakademi
2011-2016	The Emergence of Life on Earth 3+ billion years ago	Nicola McLoughlin* UiB/Bergen Forskningsstiftelse
2012-2015	Better handling of microbial induced corrosion during operation	Ida Helene Steen* VISTA
2012-2016	Taxonomy and distribution of sponges (Porifera) in Norwegian waters	Hans Tore Rapp* NTNU/Artsdatabanken
2012-2016	Preparing for sub-sea storage of CO <sub>2</sub> : Baseline gathering and monitoring for the North Sea (CO <sub>2</sub> - Base)	Rolf Birger Pedersen** CLIMIT/GASSNOVA
2014-2017	Earth System Interactions and Information Transfer (ESIIF)	Bjarte Hannisdal* UiB/Bergen Forskningsstiftelse
2015-2016	Extremophilic Archaea in Bulgarian geothermal environments (BG09)	Nils-Kåre Birkeland** EEA Scholarships Fund

# STAFF

## SCIENTISTS

Bach, Wolfgang  
Birkeland, Nils Kåre  
Dahle, Håkon  
Grosch, Eugene  
Hamelin, Cedric  
Hannisdal, Bjarte  
Hoffmann, Friederike  
Marques, Filipa  
McLoughlin, Nicola  
Pedersen, Rolf Birger  
Rapp, Hans Tore  
Reeves, Eoghan  
Reigstad, Laila Johanne  
Slama, Jiri  
Steen, Ida Helene  
Stokke, Runar  
Thorseth, Ingunn H.  
Øvreås, Lise

## POST-DOCS

Baumberger, Tamara  
Castro, David Diego  
Jørgensen, Steffen L.  
Meyer, Romain  
Olsen, Bernt Rydland  
Qu, Yuangao  
Roalkvam, Irene  
Roerdink, Desiree  
Rooks, Christine  
Xavier, Joana  
Økland, Ingeborg Elisabet

## PHDS

Alvizu, Adriana  
Arsin, Hasan  
Denny, Alden  
Eilertsen, Mari H.  
Flesland, Kristin  
Haaga, Kristian Agasøster  
Hestetun, Jon Thomassen  
Johannessen, Karen  
Landschulze, Karin  
Le Moine Bauer, Sven  
Pedersen, Leif Erik  
Savchuk, Oles  
Schaen, Adam  
Schouw, Anders  
Stensland, Anne  
Van der Roost, Jan  
Wissuwa, Juliane  
Zhao, Rui

## TECHNICIANS

Almelid, Hildegunn  
Daae, Frida Lise  
Dundas, Siv Hjorth  
Fedøy, Anita-Elin  
Roumejon, Stephan G.  
Ronen, Yuval  
Steinsbu, Bjørn Olav  
Torkildsen, Marthe  
Tøpper, Birthe  
Tumyr, Ole  
Vågenes, Stig

## ADMINISTRATION

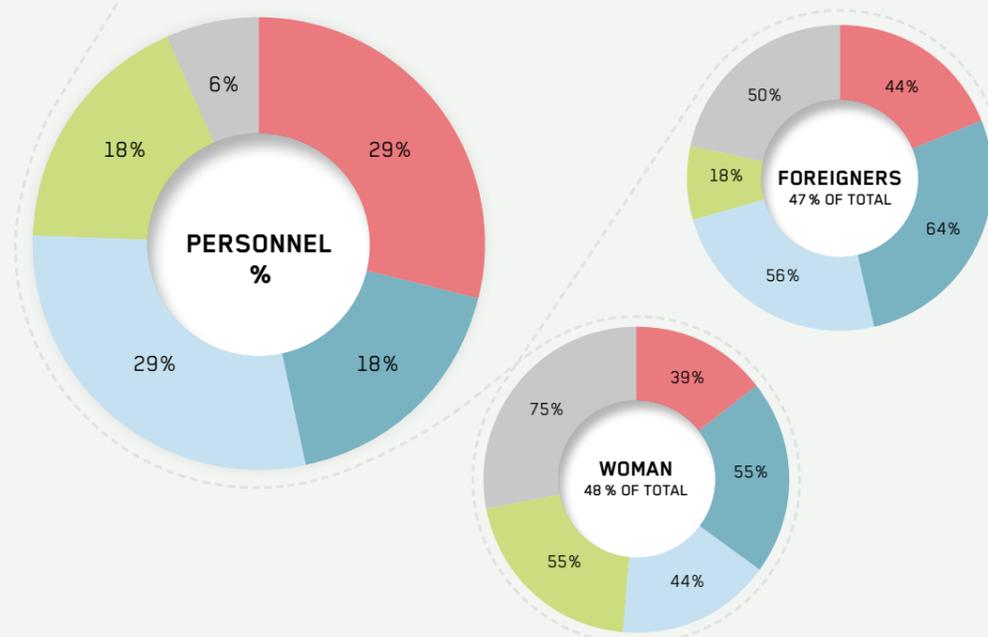
Bartle, Elinor  
Hesthammer, Steinar  
Lappegård, Heidi  
Olesin, Emily

## PERSONNEL SUMMARY

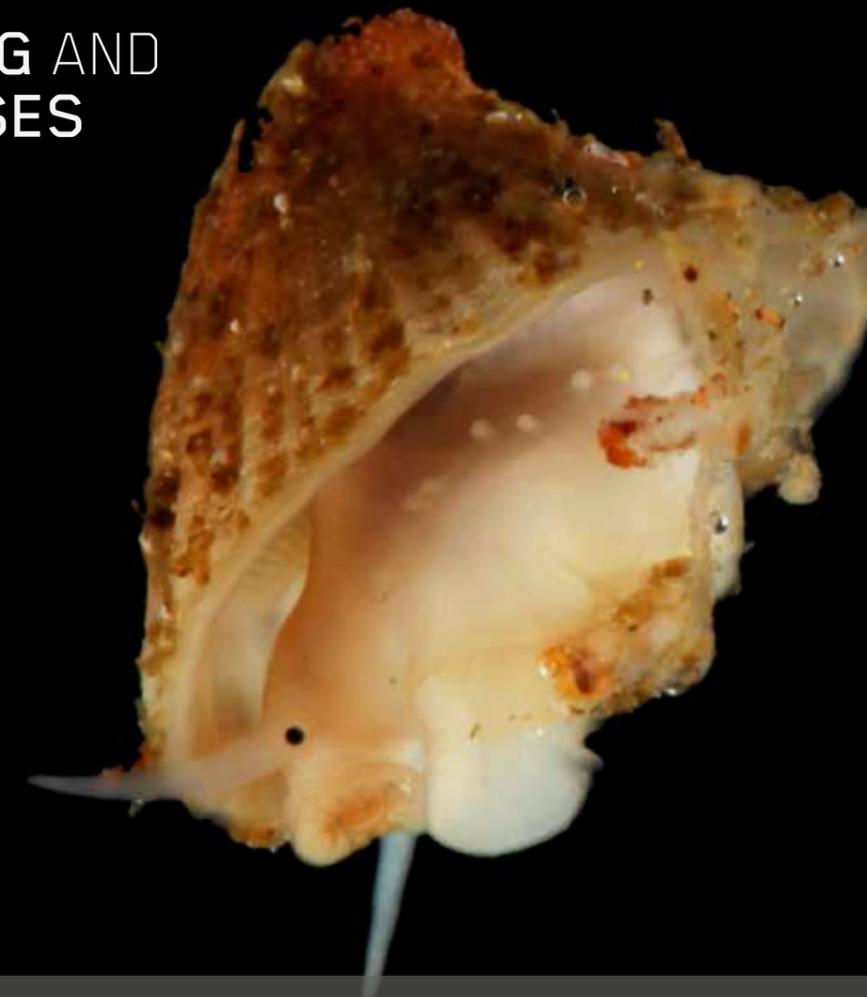
CATEGORY	PERSON-YEARS	FOREIGNERS (%)	WOMEN (%)
Scientists	11.3	44	39
Post-docs	9.8	64	55
PhDs	15.1	56	44
Technicians	4.6	18	55
Administration	1.9	50	75
<b>Total</b>	<b>42.6</b>		

# PERSONNEL

- Scientists
- Post-docs
- PhDs
- Technicians
- Administration



# FUNDING AND EXPENSES



## FUNDING

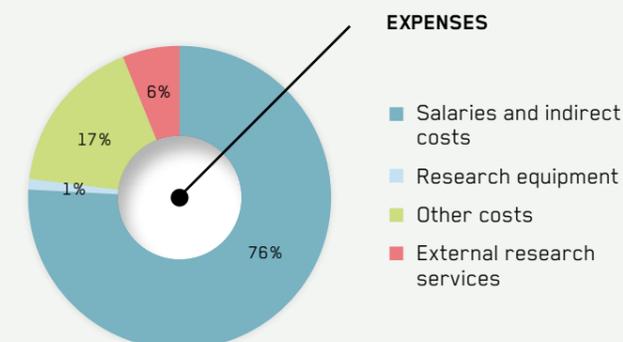
	(1000 NOK)
University of Bergen	22 299
Research Council of Norway	9 220
<b>Grand Total</b>	<b>31 519</b>

## OTHER PROJECT FUNDING

	(1000 NOK)
International projects	984
Other Research Council projects	30 405
Other Public Funding	710
Private Funding	1 191
<b>Total</b>	<b>33 290</b>

## EXPENSES

	(1000 NOK)
Salaries and indirect costs	23 932
Research Equipment	371
Other cost	5 296
External research services	1 920
<b>Grand Total</b>	<b>31 519</b>



# SELECTED PUBLICATIONS 2015

In 2015 CGB researchers have produced more than 49 scientific publications and over 61 scientific presentations. Below is a list of some selected publications.

1. **Bjerga, Anders; Konopasek, Jiri; Pedersen, Rolf B.** Talc-carbonate alteration of ultramafic rocks within the Leka Ophiolite Complex, Central Norway. *Lithos* 2015; Volume 227. p.21–36
2. **Cárdenas, Paco A.; Rapp, Hans Tore.** Demosponges from the Northern Mid-Atlantic Ridge shed more light on the diversity and biogeography of North Atlantic deep-sea sponges. *Journal of the Marine Biological Association of the United Kingdom* 2015; Volume 95.(7) p.1475–1516
3. **Dahle, Håkon; Økland, Ingeborg Elisabet; Thorseth, Ingunn Hindenes; Pedersen, Rolf B.; Steen, Ida Helene.** Energy landscapes shape microbial communities in hydrothermal systems on the Arctic Mid-Ocean Ridge. *The ISME Journal* 2015; Volume 9.(7) p.1593–1606
4. **D'Hondt, Steven; Inagaki, Fumio; Zarkian, Carlos; Abrams, Lewis J.; Dubois, Nathalie; Engelhardt, Tim; Evans, Helen; Ferdelman, Timothy; Gribsholt, Britta; Harris, Robert N.; Hoppie, Bryce W.; Hyun, Jung-Ho; Kallmeyer, Jens; Kim, Jinwook; Lynch, Jill E.; McKinley, Claire C.; Mitsunobu, Satoshi; Morono, Yuki; Murray, Richard W.; Pockalny, Robert; Sauvage, Justine; Shimono, Takaya; Shiraishi, Fumito; Smith, David C.; Smith-Duque, Christopher E.; Spivack, Arthur J.; Steinsbu, Bjørn Olav; Suzuki, Yohey; Szpak, Michal; Toffin, Laurent; Uramoto, Goichiro; Yamaguchi, Yasuhiko T.; Zhang, Guo-liang; Zhang, Xiao-Hua; Ziebis, Wiebke.** Presence of oxygen and aerobic communities from sea floor to basement in deep-sea sediments. *Nature Geoscience* 2015; Volume 8.(4) p.299–304
5. **Gjerløw, Eirik; Höskuldsson, Ármann; Pedersen, Rolf B.** The 1732 Surtseyan eruption of Eggöya, Jan Mayen, North Atlantic: deposits, distribution, chemistry and chronology. *Bulletin of Volcanology* 2015; Volume 77:14.(2)
6. **Grosch, Eugene Gerald; Hazen, Robert M.** Microbes, Mineral Evolution, and the Rise of Microcontinents – Origin and Coevolution of Life with Early Earth. *Astrobiology* 2015; Volume 15.(10) p.922–939
7. **Hestetun, Jon Thomassen; Fourt, Maia; Vacelet, Jean; Boury-Esnault, Nicole; Rapp, Hans Tore.** Cladorhizidae (Porifera, Demospongiae, Poecilosclerida) of the deep Atlantic collected during Ifremer cruises, with a biogeographic overview of the Atlantic species. *Journal of the Marine Biological Association of the United Kingdom* 2015; Volume 95.(7) p.1311–1342
8. **Hocking, William Peter; Roalkvam, Irene; Magnussen, Carina; Stokke, Runar; Steen, Ida Helene.** Assessment of the carbon monoxide metabolism of the hyperthermophilic sulfate-reducing archaeon *Archaeoglobus fulgidus* VC-12 by comparative transcriptome analyses. *Archaea* 2015; Volume 2015:235384.
9. **Montinaro, Alice; Strauss, Harald; Mason, Paul; Roerdink, Desiree; Munker, Carsten; Schwarz-Schampera, Ulrich; Arndt, Nicholas T; Farquhar, James; Beukes, Nicolas J; Gutzmer, Jens; Peters, Marc.** Paleoproterozoic sulfur cycling: Multiple sulfur isotope constraints from the Barberton Greenstone Belt, South Africa. *Precambrian Research* 2015; Volume 267. p.311–322
10. **Nesbo, Camilla Lothe; Swithers, Kirsten S.; Dahle, Håkon; Haverkamp, Thomas Hendricus Augustus; Birkeland, Nils-Kåre; Sokolova, Tatiana; Kublanov, Ilya; Zhaxybayeva, Olga.** Evidence for extensive gene flow and Thermotoga subpopulations in subsurface and marine environments. *The ISME Journal* 2015; Volume 9.(7) p.1532–1542
11. **Olsen, Bernt Rydland; Troedsson, Christofer; Hadziavdic, Kenan; Pedersen, Rolf B.; Rapp, Hans Tore.** The influence of vent systems on pelagic eukaryotic micro-organism composition in the Nordic Seas. *Polar Biology* 2015; Volume 38.(4) p.547–558
12. **Pedersen, Leif-Erik Rydland; McLoughlin, Nicola; Vullum, Per Erik; Thorseth, Ingunn Hindenes.** Abiotic and candidate biotic micro-alteration textures in subseafloor basaltic glass: A high-resolution in-situ textural and geochemical investigation. *Chemical Geology* 2015; Volume 410. p.124–137
13. **Qu, Yuangao; Engdahl, Anders; Shixing, Zhu; Vajda, Vivi; McLoughlin, Nicola.** Ultrastructural Heterogeneity of Carbonaceous Material in Ancient Cherts: Investigating Biosignature Origin and Preservation. *Astrobiology* 2015; Volume 15.(10) p.825–842
14. **Rapp, Hans Tore.** A monograph of the calcareous sponges (Porifera, Calcarea) of Greenland. *Journal of the Marine Biological Association of the United Kingdom* 2015; Volume 95.(7) p.1395–1459
15. **Roalkvam, Irene; Bredy, Florian; Baumberger, Tamara; Pedersen, Rolf B.; Steen, Ida Helene.** *Hypnocyclicus thermotrophus* gen. nov. sp. nov. isolated from a microbial mat situated in a hydrothermal vent field. *International Journal of Systematic and Evolutionary Microbiology* 2015; Volume 65. p.4521–4525
16. **Roalkvam, Irene; Drønen, Karine; Stokke, Runar; Daae, Frida Lise; Dahle, Håkon; Steen, Ida Helene.** Physiological and genomic characterization of *Arcobacter anaerophilus* IR-1 reveals new metabolic features in Epsilonproteobacteria. *Frontiers in Microbiology* 2015; Volume 6.
17. **Roerdink, Desiree; van den Boorn, Sander H.J.M.; Geilert, Sonja; Vroon, Pieter Z.; van Bergen, Manfred J.** Experimental constraints on kinetic and equilibrium silicon isotope fractionation during the formation of non-biogenic chert deposits. *Chemical Geology* 2015; Volume 402. p.40–51
18. **Slama, Jiri; Pedersen, Rolf B.** Zircon provenance of SW caledonian phyllites reveals a distant timanian sediment source. *Journal of the Geological Society* 2015; Volume 172.(4) p.465–478
19. **Smieja-Król, Beata; Janeczek, Janusz; Bauerek, Arkadiusz; Thorseth, Ingunn Hindenes.** The role of authigenic sulfides in immobilization of potentially toxic metals in the Bagno Bory wetland, southern Poland. *Environmental science and pollution research international* 2015; Volume 22.(20) p.15495–15505
20. **Spang, Anja; Saw, Jimmy H.; Jørgensen, Steffen Leth; Zaremba-Niedzwiedzka, Katarzyna; Martin, Joran; Lind, Anders E.; van Eijk, Roel; Schleper, Christa Maria; Guy, Lionel; Ettema, Thijs J.G.** Complex archaea that bridge the gap between prokaryotes and eukaryotes. *Nature* 2015; Volume 521.(7551) p.173–179
21. **Staudigel, Hubert; Furnes, Harald; DeWit, Maarten.** Paleoproterozoic trace fossils in altered volcanic glass. *Proceedings of the National Academy of Sciences of the United States of America* 2015; Volume 112.(22) p.6892–6897
22. **Stokke, Runar; Dahle, Håkon; Roalkvam, Irene; Wissuwa, Juliane; Daae, Frida Lise; Tooming-Klunderud, Ave; Thorseth, Ingunn Hindenes; Pedersen, Rolf B.; Steen, Ida Helene.** Functional interactions among filamentous Epsilonproteobacteria and Bacteroidetes in a deep-sea hydrothermal vent biofilm. *Environmental Microbiology* 2015; Volume 17.(10) p.4063–4077
23. **Türke, Andreas; Nakamura, Kentaro; Bach, Wolfgang.** Palagonitization of basalt glass in the flanks of mid-ocean ridges: implications for the bioenergetics of oceanic intracrustal ecosystems. *Astrobiology* 2015; Volume 15.(10) p.793–803
24. **Wanless, Virginia Dorsey; Shaw, Alison M.; Behn, Mark D.; Soule, Samuel Adam; Escartin, Javier; Hamelin, Cedric.** Magmatic plumbing at Lucky Strike volcano based on olivine-hosted melt inclusion compositions. *Geochemistry Geophysics Geosystems* 2015; Volume 16.(1) p.126–174
25. **Xavier, Joana R.; Cárdenas, Paco A.; Cristobo, Javier; van Soest, Rob; Rapp, Hans Tore.** Systematics and biodiversity of deep-sea sponges of the Atlanto-Mediterranean region. *Journal of the Marine Biological Association of the United Kingdom* 2015; Volume 95.(7) p.1285–1286

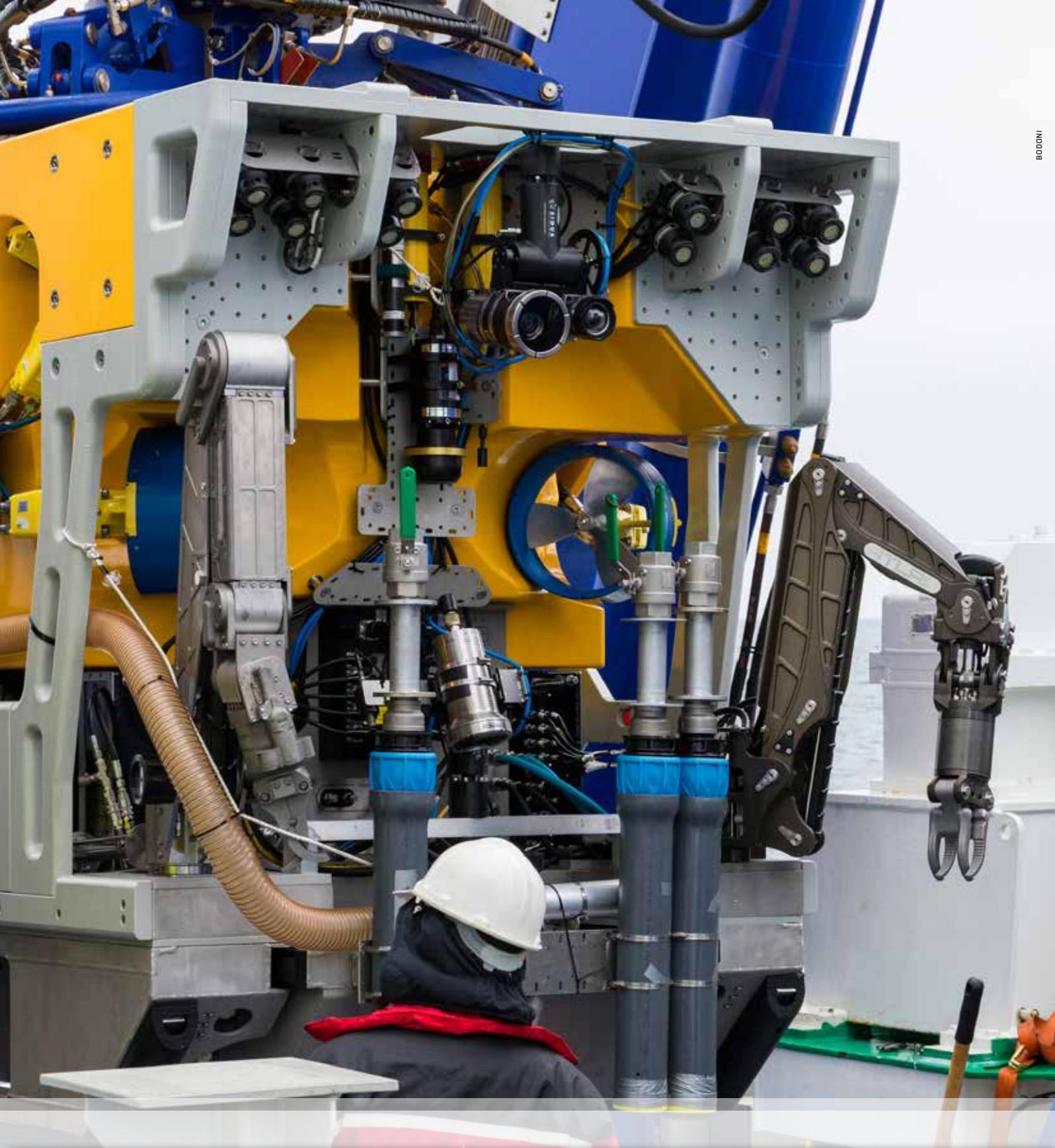


## PHOTO CREDITS

Thank you to the generous and talented photographers and researchers who have allowed us to use their photos and illustrations in the 2015 Annual Report and in our other outreach materials. The photos in this report may not be copied or reproduced in any form without the permission of the photographer.

Frida Lise Daae  
Anita-Elin Fedøy  
Cedric Hamelin  
Ana Filipa Marques  
Bernt Rydland Olsen  
Rolf Birger Pedersen

Shanan E. Peters (UW Madison)  
Yuangao Qu  
Hans Tore Rapp  
Irene Roalkvam  
Ingunn H. Thorseth  
Ingeborg Elisabet Økland



Centre for Geobiology  
Postboks 7803  
NO-5020 BERGEN  
Norway

Established by  
the Research Council  
of Norway

 Norwegian  
Centre of  
Excellence

