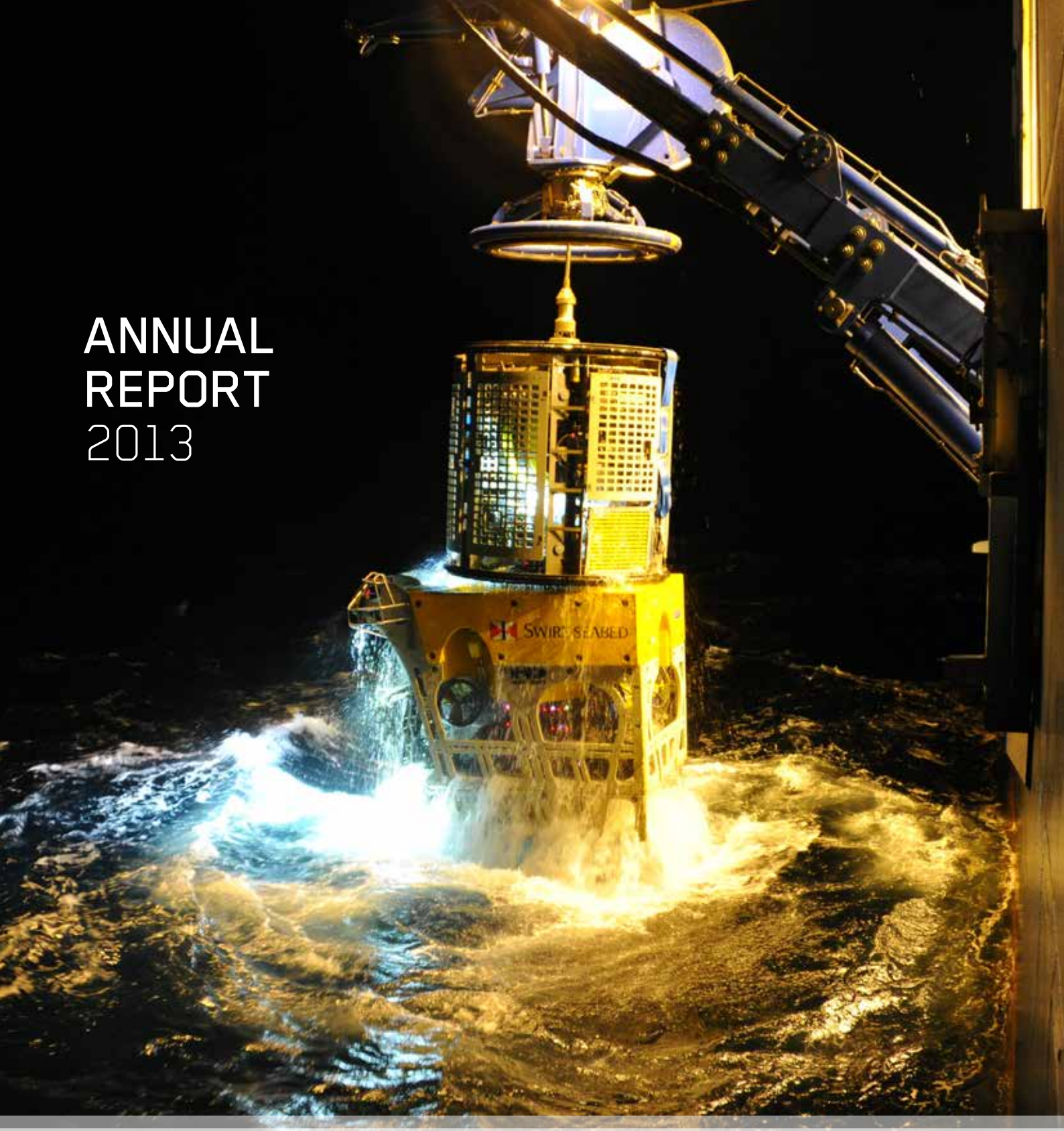


ANNUAL REPORT 2013

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

CENTRE FOR
GEOBIOLOGY

Table of Contents

Director's comment 3
Research highlights 4
- Norwegian robotics facility: ROV for deep sea research 5
- Sulfur biogeochemical cycling and surface environments on early Earth. 6
- Vent discoveries: Shallow volcanoes and new hydrothermal fields. 8
- Hess Deep revisited: How does the Earth's oceanic crust form? . . 10
- Learning more about Norway's unique arctic deep sea animal life . 12
- New research theme: Earth system evolution 14

Research themes 15
Organization 22
Workshops, seminars and short courses 24
Centre funded projects. 25
Research projects 26
Staff 28
Funding and expenses. 29
Selected publications 30
CGB Doctorate degrees awarded. 31

A new species of Ampharetidae (bristle worm) from the Loki Castle vent site

DIRECTOR'S COMMENT

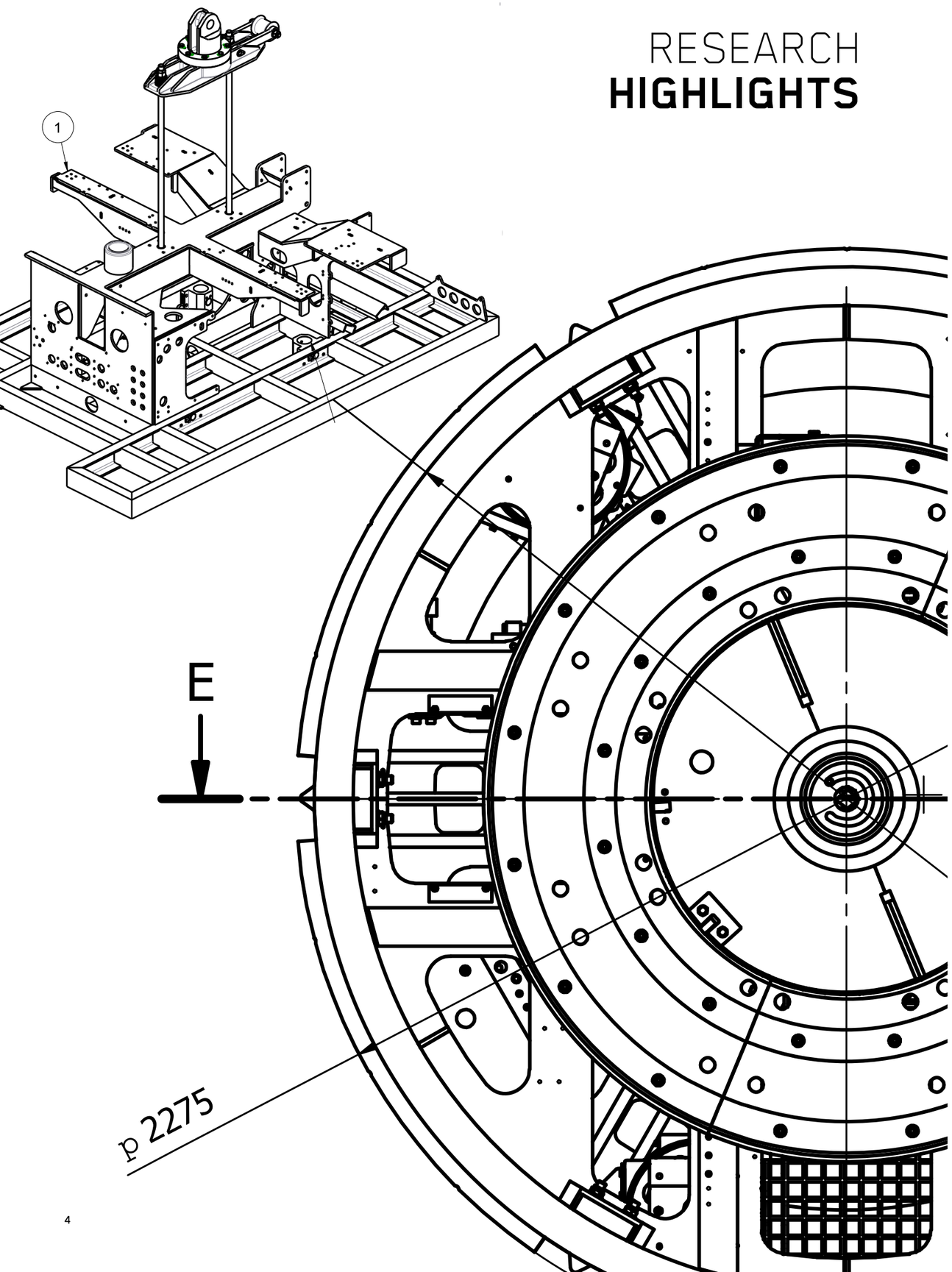
Young researchers are the backbone of the Centre for Geobiology (CGB). In 2013, their enthusiasm and drive continue to carry Centre research across traditional disciplinary boundaries. Some of their research results are highlighted in this report.

2013 was also a year with a strong field program. Two seagoing expeditions were organised by CGB, and Centre researchers also participated in an international cruise to the Mid-Atlantic Ridge. An expedition to the Arctic Mid-Ocean Ridge (AMOR) with R/V G.O. Sars resulted in the discovery of several hydrothermal vent sites. In collaboration with the Norwegian Petroleum Directorate, the East Jan Mayen Fracture Zone was also explored.

Several new projects were initiated in 2013. In collaboration with Institute of Marine Research, CGB will investigate effects of environmental stress on sponge grounds in a project funded by the Research Council of Norway (RCN). Environmental challenges relating to the industrialization of the deep sea is addressed in a new EU-project called MIDAS. Of great importance to the Centre, one of CGB's excellent young researchers received grants from the Bergen Research Foundation and RCN to establish a new research group focusing on "Earth system interactions and information transfer". This adds a new theme to CGB's research program.

Modern analytical facilities and research infrastructure is of fundamental importance for natural science research. 2013 started with Statoil investing 12 million kr. in new ICP-MS instruments for the Bergen Geoanalytical Facility – a complex of laboratories developed jointly by CGB and the Department of Earth Science. This investment enhances our capabilities in analytical geochemistry and geochronology. The year ended with the RCN announcing that CGB would receive 45 million kr. in funding to develop a national marine robotics facility. Marine robots have become essential tools for basic marine research, and are also necessary infrastructure for providing new knowledge about deep-sea resources. It has been a long-term goal for CGB to establish a national deep submergence facility. During a recent visit by the Minister of Education and Research, University of Bergen (UiB) announced that the momentum from this infrastructure grant will be used to establish a national Centre for Deep Sea Research. This will be a long-term legacy of CGB when the Centre of Excellence period ends in 2017.

Rolf-Birger Pedersen
Centre Director



RESEARCH
HIGHLIGHTS

NORWEGIAN MARINE ROBOTICS FACILITY
ROV FOR DEEP SEA RESEARCH

In November 2013 the Centre for Geobiology (CGB) was awarded 46 million Norwegian kroner from the Research Council of Norway to fund the development of a Remotely Operated Vehicle (ROV) for deep marine research.

The funding will be used to establish a national infrastructure, the Norwegian Marine Robotics Facility. UiB, via CGB, will partner with the Institute of Marine Research (IMR) and Christian Michelsen Research (CMR) to build this facility and to make marine robots available on Norway's fleet of ocean-going research vessels. A number of other Norwegian research institutions have also supported this initiative.

The new ROV will have the ability to dive to 6000 meters below sea level. Internationally, it will be one of a handful of research ROVs capable of operating at full abyssal depths. The ROV will operate in tandem with a tether management system (TMS) that will link the ROV to the mother ship through a many kilometers long steel wire that is capable of transporting 100 KW of power down to the TMS/ROV system, and relaying video and data signals back to the ROV operators and researchers on the ship. During descent and ascent to and from the seafloor the ROV is attached to the TMS. When the ROV is deployed to a particular depth of operation, it can be released, and can then "swim" freely to target areas while linked to the TMS through only a thin, neutrally buoyant umbilical. This provides the optimal conditions for scientific sampling, imaging, as well as for deployment, maintenance and recovery of seafloor instrumentation.

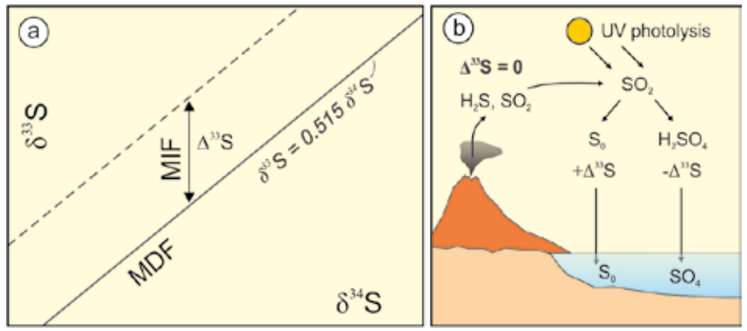
The ROV system will be tailored for use on the Norwegian fleet of ocean-going research vessels, but it will also be flexible enough to be used on the research vessels of other nations, or on ships of opportunity with sufficient space and dynamic positioning systems. On the R/V G.O. Sars the ROV will operate through the hangar. It will also be supported by a launch and recovery system that will make it possible to operate even in heavy seas and poor weather conditions. On the R/V Kronprins Haakon, Norway's first ice-classed research vessel, it will be operated through a moon-pool when in ice-covered waters.

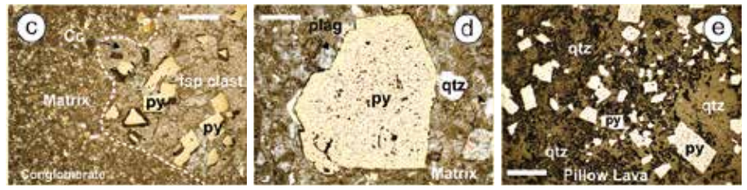
The new ROV will be an important tool for basic research spanning a range of disciplines, projects and programs. It will be fundamental for deep-sea biodiscovery and bioprospecting, and for clarifying the mineral potential in Norwegian deep-sea territories. It will also be used to explore and sample the continental shelf at frontier areas. It will be critical for establishing and operating ocean observatories designed to monitor the marine environment. Finally, the ROV system will open the deep-sea environment to the Norwegian public. High-resolution camera systems and sea-to-shore telelinks will transfer images to schools, science centers and media as unique marine environments are visited and discoveries are made.

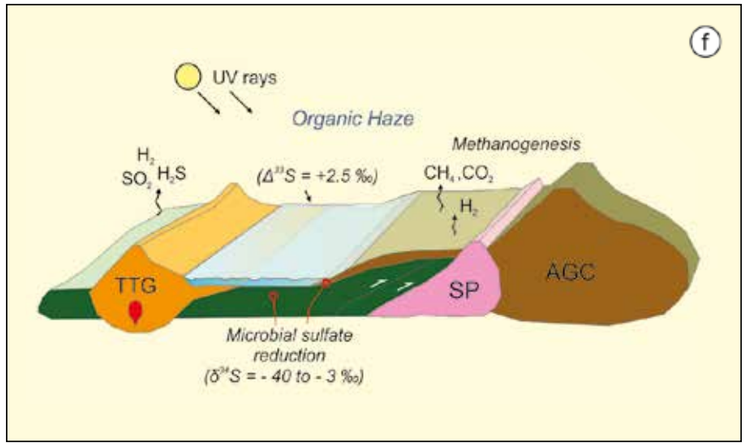
The Norwegian Marine Robotics Facility partners are now collaborating with Norwegian marine technology companies to design and build one of the world's most capable ROV-systems for deep-sea research. It is hoped that the first test dives will be conducted in early 2015. ■

ROV sampling 60 million years old sediments at 3000 meters water depth during a CGB/NPD cruise in September 2013.

SULFUR BIOGEOCHEMICAL **CYCLING** AND SURFACE ENVIRONMENTS ON EARLY EARTH







Researchers Eugene Grosch and Nicola Mcloughlin of the early Earth and Biosignatures group discover geochemical evidence for early sulphur-metabolizing microbes preserved in 3.33 to 3.45 billion-year-old sedimentary and volcanic rocks of the Barberton greenstone belt, South Africa. Feedbacks between the early geosphere and biosphere were explored including tectonic processes, hydrogen release into sediments and co-existing microbial communities on the early Archean Earth.

Embarking on a geological road trip back in time to when the juvenile Earth was developing into a habitable planet would be a fascinating experience. The closest an early Earth geobiologist can get to such an ancient world is to investigate remnants in the Archaean rock record. Some of the best preserved rocks come from the Barberton greenstone belt of South Africa and these were drilled during the Barberton Scientific Drilling Project. This drilling project recovered three cores with a total length of almost 1km, intercepting volcanic, hydrothermal, tectonic and shallow marine sedimentary settings. Multiple sulfur isotopes are a powerful tool to explore these early Archaean possibly habitable environments, before the Great Oxidation Event (GOE) on Earth c. 2.4 billion years ago. In a recent study (Grosch and McLoughlin, 2013, see page 30, no. 10), we conducted high-resolution in-situ multiple sulfur isotope (^{32}S, ^{33}S and ^{34}S) analysis of pyrite from these fresh drill cores to test current paradigms of Archaean environments and sulfur-based microbial metabolism.

Microbes are known to prefer the light isotope ^{32}S in their energy metabolisms. Thus, by calculating $\delta^{34}S$CDT values, which simply put is the ratio of heavy ^{34}S to the light ^{32}S isotope relative to a standard (CDT), it is possible to track evidence for isotopic fractionations due to microbial processes. Many researchers studying Archaean sulfur-bearing minerals have also observed so-called Sulfur Mass-Independent Fractionation anomalies (S-MIFs) or $\Delta^{33}S$ **(panel a)** which have only been found in rocks that are older than ca. 2.4 billion years old, prior to the Great Oxidation Event. This is argued to record evidence for the interaction of UV-rays with atmospheric sulfur dioxide by radiation that could only penetrate an oxygen-free Archaean atmosphere. In this model, UV-light breaks down the sulfur bearing molecules resulting in isotopic fractionation that is recorded in two ways **(see panel b)**: 1) by elemental sulfur aerosols (S^0) with positive MIF-anomalies (S^0, $+\Delta^{33}S$) that are preserved as sulfides in marine sediments; and 2) by sulfuric acid aerosols (SO_4) with negative MIF-anomalies (SO_4, $-\Delta^{33}S$) that become dissolved into seawater and are preserved as mineral salts in the rock record. We aim to test the idea that the size of Sulfur-MIFs found in the early rock record is related to the efficiency of UV-photolysis, which is influenced by the amount of organic haze or smog (CH_4/CO_2 ratio) in the reduced Archaean atmosphere, which may in turn depend on the activities of methanogenic microbes.

More broadly, our study investigated the range of geodynamic, biological and geochemical controls on the early sulfur cycle.

Our new sulfur isotope results together with geological field observations indicate that an early form of tectonic processes was the main control driving the Archaean sulfur cycle. We found that pyrites in ca. 3.432 billion year old shallow-marine sediments **(panels c and d)**, which overly oceanic pillow lavas **(panel e)**, record strong positive S-MIF signals ($+\Delta^{33}S$ = 1.4). This suggests exposure of these sediments to the oxygen free Archaean atmosphere by early tectonic-type processes. The new data also points to the existence of microbial sulfate reducing microbes which gain energy from using dissolved sulfate in seawater, thriving in the shallow sedimentary subsurface. No isotopic evidence could be found however, to support the use of elemental sulfur S^0 (wide $\delta^{34}S$, large $+\Delta^{33}S$) by microbes, challenging previous arguments for microbial elemental sulfur disproportionation being an important microbial energy-source on the early Earth. We also discovered the largest range and most negative $\delta^{34}S$ values so far recorded in an Archean rock from mineral veins also with significant S-MIF anomalies. These veins are interpreted to record evidence for shallow-level boiling zones with the pyrite forming as a result of boiling-induced oxidation of dissolved hydrogen sulfide gas releasing H_2 and CH_4 into the unconsolidated surface sediments and atmosphere. This newly formed hydrogen and methane may in turn have been used by methanogens that co-existed with sulfate reducing microbes in these early sediments. A sketch summarizing the early sulfur cycle and all of these processes is shown in panel f, as recorded in the Archean rocks of the Barberton greenstone belt. ■

Bathymetry generated using echosounder imaging of the northern Kolbeinsey Spreading Centre.

VENT DISCOVERIES:

SHALLOW VOLCANOES AND **NEW HYDROTHERMAL FIELDS**

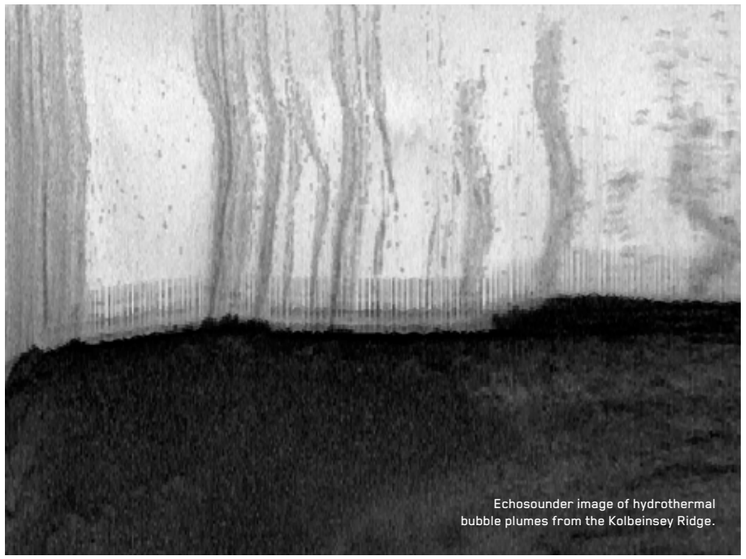
The 2013 summer cruise was extremely fruitful: at least five new venting areas were located and a large shallow volcanic area was explored. The goal of the Arctic marine expedition was to investigate the areas west and northeast of Jan Mayen Island. Here, in the middle of the Norwegian-Greenland Sea, the Arctic Mid-Ocean Ridge (AMOR) passes this volcanic island. Oceanic crust is formed along the AMOR by volcanic and tectonic activity at a rate of around two cm. per year.

R/V G.O. Sars carried the science team from Bergen to the first study area located around 100 km northeast of Jan Mayen. This area has known venting sites previously discovered by CGB, however the extent of the area had not been surveyed, meriting a full analysis.

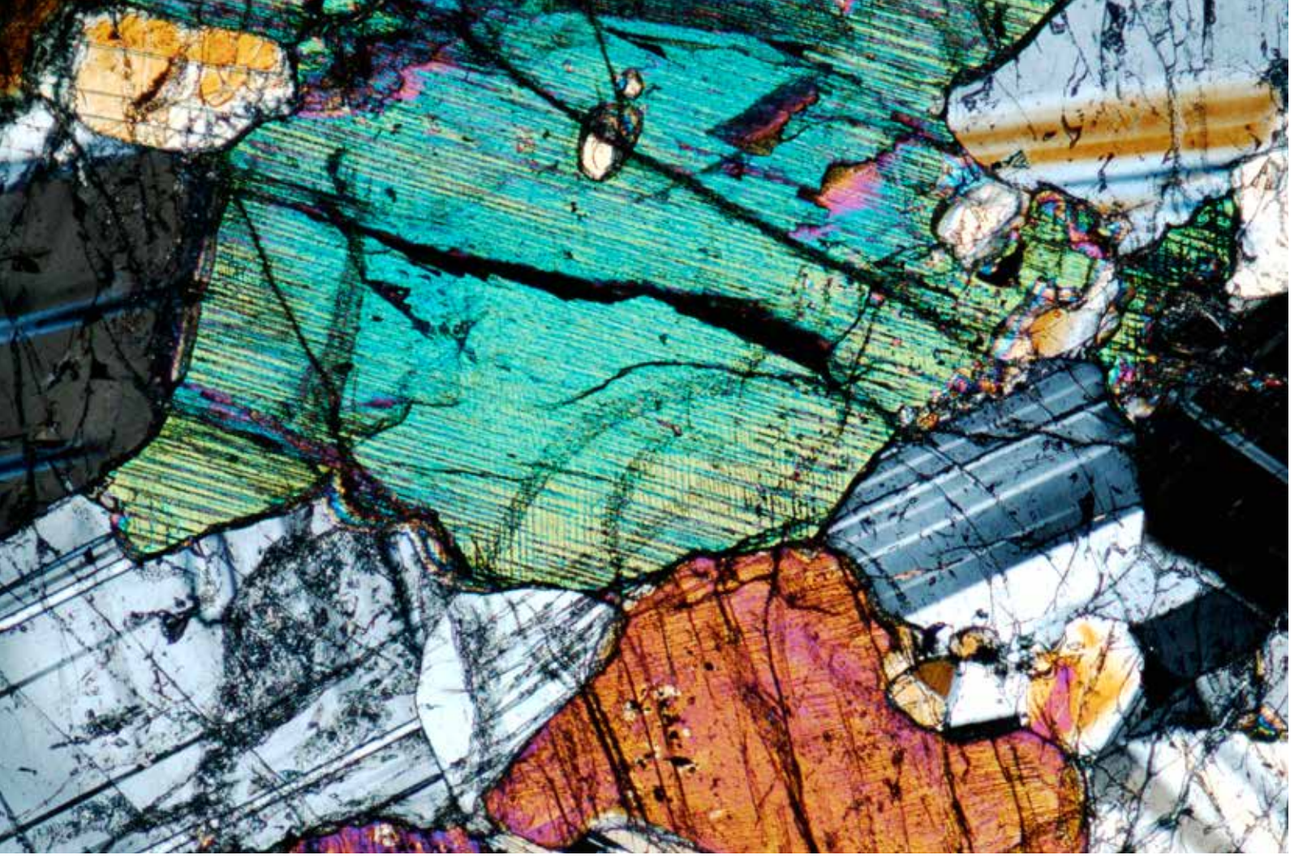
The team began their exploration by returning to known venting sites to test a new search tool. It is difficult and time consuming to detect a rising hydrothermal plume with chemical sensors and vent sites may be overlooked. In water shallower than 1000 m, CGB scientists now use novel water column acoustics to "see" gas bubbles produced from vent fields. After testing and tuning the technique at known vent sites, the survey team explored beyond the known extent of venting uncovering two new hydrothermal areas. Both are releasing volcanic gases to the water column, and based on previous sampling from the nearby Troll Wall vent field, we assume that the gases predominantly consist of CO_2. Deployment of CO_2 sensors in the area also documents that venting results in local acidification of the seawater. The Jan Mayen vent fields are truly a natural laboratory for studying the effect of acidification of Arctic marine environments, and deployment of semi-permanent observation platforms are now being planned.

Following the vent discoveries at the southern part of the Mohns Ridge, the science team shifted its attention to the unexplored part of the Kolbeinsey Ridge west of Jan Mayen. Except from at its southernmost termination, where the ridge meets the Icelandic shelf, no active hydrothermal vent fields have previously been located along the Kolbeinsey Ridge. Therefore an extensive survey was conducted, mapping the seafloor and observing the water column for possible shallow hydrothermal venting. The bathymetry revealed many large flat-topped volcanoes dotting the seafloor along the ridge – some almost breaking the sea surface. After days of survey, the water column imaging eventually detected a veritable forest of bubble plumes emitting from several of these volcanoes.

The expedition continued with a systematic search for vent sites northward along the AMOR. Three venting areas were located in deeper waters using chemical and physical sensors. CGB's exploration of the Arctic ridges have now resulted in the discovery of a number of venting areas, ranging in depth from one hundred to several thousand meters. Depth and geology control the fluid composition and the fluid flow, which again yields mineral deposits of differing size, mineralogy and economic potential. The water depth and the fluid composition also control the micro and macro fauna living at the vent fields. The 2013 discoveries will certainly result in new knowledge about the unique Arctic vent fauna first seen at the Loki's Castle field when it was discovered in 2008. Continued studies of the genes and proteins of the micro fauna from this range of hydrothermal habitats will also yield new knowledge about the functioning of hyperthermophiles and – possibly – deeper insight to the roots of life. In the meantime we are looking forward to deploying our new ROV and to for the first time see the beauty of these deep-sea natural treasures. ■



Echosounder image of hydrothermal bubble plumes from the Kolbeinsey Ridge.



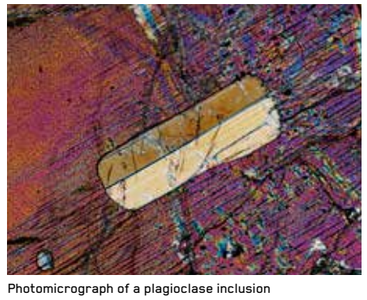
Photomicrograph from the first in-situ sampled significant interval of layered gabbroic rocks from a lower fast spread oceanic crust.

HESS DEEP – REVISITED

HOW DOES THE EARTH'S OCEANIC CRUST FORM?

A team of international researchers published in Nature after a 2 month expedition last year to drill into the ocean crust 4800m below the surface.

Romain Meyer, a researcher at the Centre for Geobiology, was a member of the team. The story began nearly 20 years ago when Centre leader Rolf Birger Pedersen was involved in a drilling mission to the Hess Deep in 1994. The international team of researchers involved in this drilling effort recognised the need for drilling deeper and in 2001 they collaborated to write a proposal that resulted in Integrated Ocean Drilling Program Expedition 345.



Photomicrograph of a plagioclase inclusion in a larger pyroxene.

The Expedition recovered the first ever continuous core section of mineralogically layered, gabbroic rocks crystallized in a magma-reservoir located nearly 4 km beneath the surface of the crust. The unique cores provide new information on the processes involved when the Earth's seafloor forms through volcanic processes at seafloor spreading ridges. Meyer is co-author of a Nature paper, "Primitive layered gabbros from fast-spreading lower oceanic crust". The paper presents results of the shipboard examinations of the unique drill cores.

While scientists have long been interested in learning more about the history and dynamics of the Earth's crust, the cost and challenges involved have been beyond the resources of any one institution or country. Scientific ocean drilling represents one of Earth sciences' longest and most successful international collaborations: formation of an international effort began with the earliest coring studies in the 1940's. Since the 1960's there have been several scientific drilling programmes. Norway has taken part in this program since the 1980's, and decided in 2013 to also join the next phase - named The International Ocean Discovery Program (IODP).

Harry Hammond Hess was one of the first to suggest that the seafloor forms by seafloor spreading, and he was also among the early pioneers of ocean drilling. In 1961 he wrote:

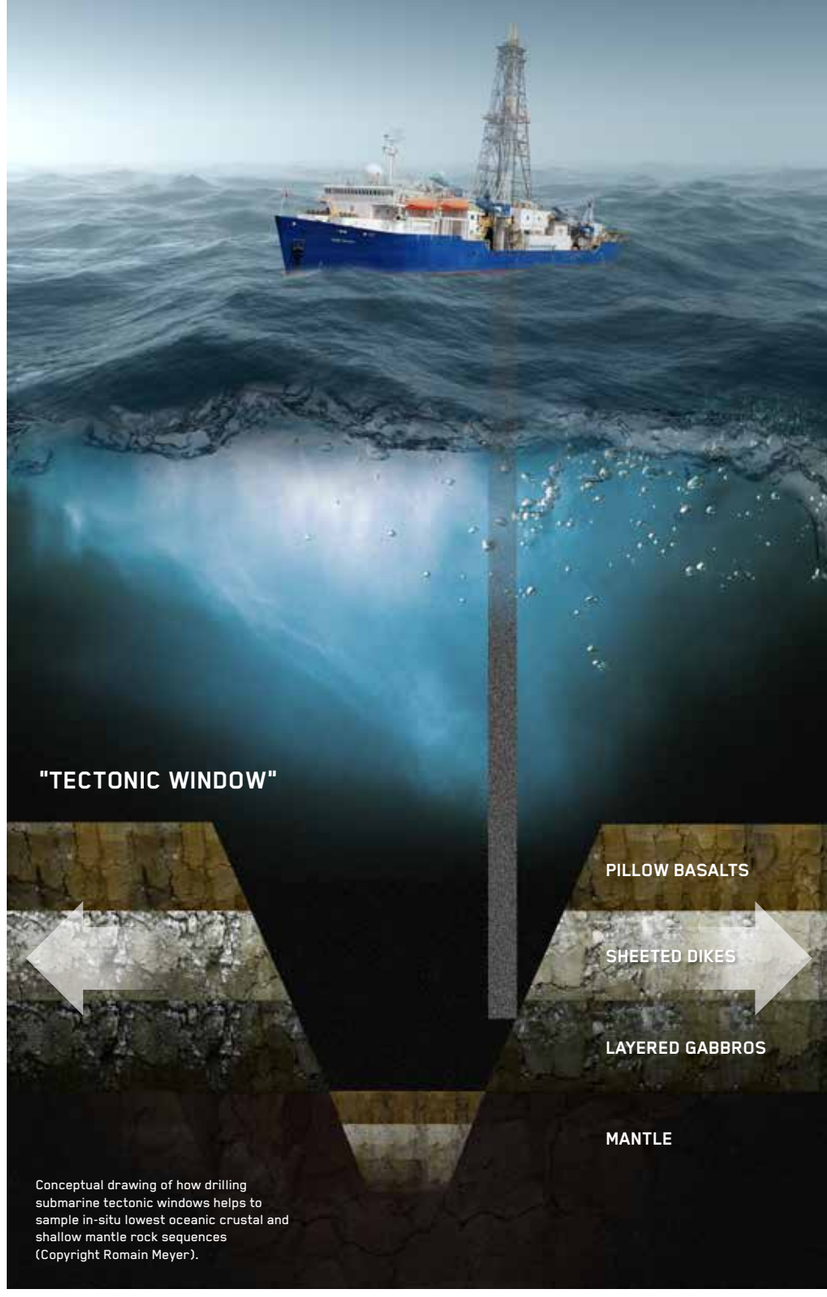
"The accretion of new ocean crust at mid-ocean ridge spreading centres is one of the fundamental processes of Earth evolution. Understanding the nature of the crust and mantle and the underlying geologic processes that form them is an ongoing fundamental justification for drilling in the ocean basins."

It is fitting that IODP Expedition 345 headed to the ocean floor feature named after him, Hess Deep, to test competing hypotheses of magmatic accretion and hydrothermal processes in the lower ocean crust.

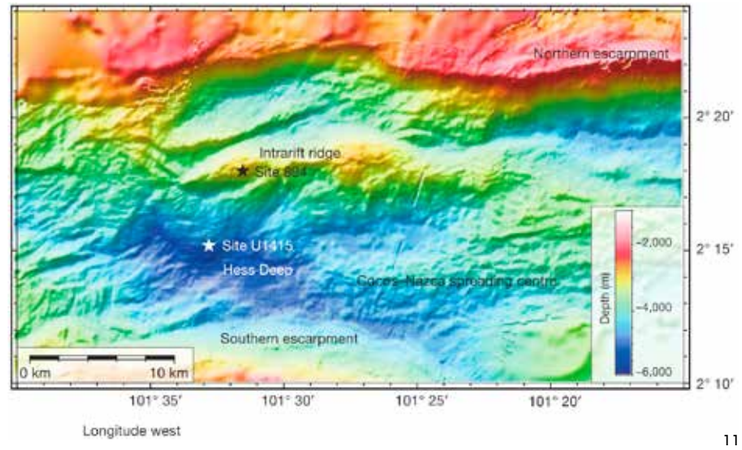
The Hess Deep rift valley is located in the fast-spreading East Pacific Rise, about 1000 km east of the Galapagos Islands. The site has long been identified as a "tectonic window", providing unique access to the lower crust as rifting in this area has exposed crustal rocks that were previously deeply buried. Several research cruises have sampled magmatic rocks by drilling, ROV, and submersible on the seafloor in this area. During Expedition 345, researchers aimed to complement these earlier findings with information about deeper rocks only accessible by drill cores.

Crust formation is a complex and dynamic process. On average, around 10 cm of new crust forms every year along the 12 000 km long spreading ridge called the East Pacific Rise. In 200 million years, a relatively short time in geologic perspective, the entire Pacific Ocean seafloor has formed in this way. To form the crust, billions of cubic metres of magma flow every year from the mantle into the lower crust. Here, 7-4 km below the seafloor, some magma crystallizes to form the lower crust. The remaining magma escapes to shallower levels of the crust, and a small fraction eventually erupts at the seafloor forming volcanoes. This is the most important crust-forming process on Earth, but it remains poorly understood because the lower crust had never been sampled until Expedition 345.

The drill cores reveal the minerals that crystallized from the magma. Their textures and compositions provide information about the lower crust. The layers in the cores record the history of melt transport from the mantle into the crust, and how it evolves as it cools and crystalizes, and interacts with older crust. These unique drill samples have already confirmed some long-standing predictions about the lower crust, however they have also refuted other hypotheses about how oceanic crust forms. In the *Nature* paper, the expedition researchers present their initial shipboard petrographic observations and geochemical analyses of the core rocks. These are combined with previous data obtained for shallow-level rocks, and result in the first robust composition estimate of the bulk chemical oceanic crust formed at a fast-spreading ridge. ■



Conceptual drawing of how drilling submarine tectonic windows helps to sample in-situ lowest oceanic crustal and shallow mantle rock sequences (Copyright Romain Meyer).



Map of the Hess Deep drill site from the Nature paper (see page 30, no. 8)

LEARNING MORE ABOUT **NORWAY'S UNIQUE ARCTIC DEEP SEA ANIMAL LIFE**

Scientists from the "Vent and Seep Biota" research theme have been continuing to assemble pieces of information to gain better understanding of the animals inhabiting the unique ecosystems living both in the reducing ecosystems around the vents and seeps that CGB has discovered, and beyond, in the poorly explored deep waters of the furthest reaches of Norway's economic zone.

Piece of a woodfall retrieved from almost 2800 m depth in the Norwegian Sea – heavily degraded by the wood-boring mollusks *Teredo* and *Xylophaga* and the amphipod *Exitomelita lignicola*.

Unique environment – a reducing environment

In chemosynthetic ("sun-independent") ecosystems, microbes act as the primary producers; their role is that of "plants" in photosynthetic ecosystems. The energy sources for the microbes in such habitats, now termed reducing habitats, are high concentrations of reduced chemical species, such as H_2S, H_2 and CH_4. Examples of reducing habitats include hydrothermal vents, seeps, and natural biological falls, such as whale carcasses and logs. Chemosynthesis involves microbial organisms working together in consortia to harness the chemical energy contained in the reduced compounds. This energy is used to produce biological building-blocks such as glucose, which can be used as an energy source by larger organisms.

Identifying the pieces – who is there?

One research track involves rigorous taxonomic work to identify the organisms collected. Determining if a sampled organism is a new species to science or a member of a previously identified species is demanding, pain-staking work. May 2013, the University Museum of Bergen hosted a workshop assembling taxonomic experts to study the polychaete (marine worm) fauna associated with Loki's Castle in more detail. The polychaetes also represent the group with the highest number of new taxa discovered and so far about a dozen new species of polychaetes are being formally described from the Loki Castle alone.

Putting the pieces together – what are they doing?

Another research track involves a more ecological, systems approach: once "who is there" has been determined, researchers need to determine "who is eating whom" and what the organisms are doing. At the base of the food chain are the primary producers. However, here in the deep sea the system is "sun-independent", and the primary producers are microbial organisms that can derive energy from chemical reactions; chemolithotrophes.

In 2013 CGB researchers produced some of the first results from a novel approach to determine "who is eating whom". As DNA analysis methodologies become increasingly accessible and standardised they can be applied to an increasing number of important questions. Here they were applied to analyses of stomach contents from an amphipod, a small crustacean that, due to its abundance in the sampling, is believed to be a major predator player in the food chain. It is challenging detective work. For example, the amphipod's own DNA must be removed from the results (but there may be some cannibalism), DNA fragments must be used that correspond to both partial digestion and sufficient length for analysis, and potential complications from secondary predation (i.e. that the prey items were predators themselves and contain DNA from their own prey in their guts!) must also be considered.

The results thus far suggest that the amphipod, *Themisto abyssorum*, is an omnivore rather than strictly a carnivore, and thus may occupy an important, re-cycling, "gate-keeper" position in the food chain of this ecosystem.

Pelagic vs benthic

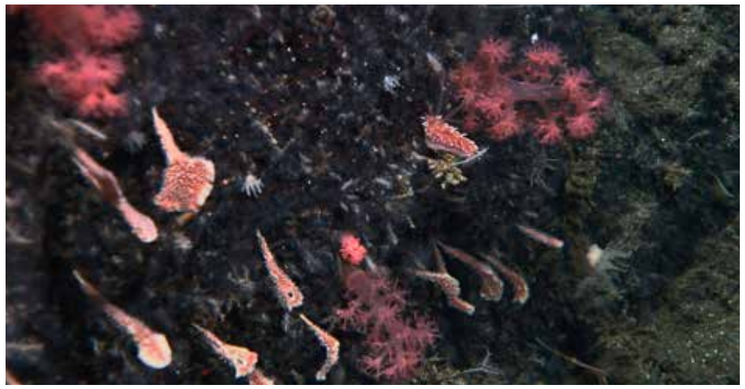
It is now well established that Norway's Arctic vents and seeps have a unique, specialised, endemic (native) benthic fauna. DNA analyses suggest that many of these organisms are more closely related to those found further north and in the north-east Pacific, than those found further south in the Atlantic. In 2013 some of the first results relating to the associated pelagic fauna were published. This is the fauna that is associated with the plume waters above the vents and seeps. The plume waters are enriched with reduced fluids compared to the surrounding water mass, resulting in increased primary production. The question for the researchers was would the fauna associated with the plume waters also be unique?

The first results of comparison studies of plume waters vs. surrounding waters is suggesting that, unlike the benthic findings, the pelagic communities are most affected by water mass characteristics, rather than the "sudden" and changing impacts of the input from reduced fluids.

Stepping stones

Reduced habitats are not continuous either in geography or time. Most reduced habitats have finite lifetimes as the supply of reduced chemicals becomes depleted. What happens to the members of a chemosynthetic community when their energy source "dries up"? What mechanisms have enabled similar organisms to be found in extremely widely dispersed locations in the deep sea? How did organisms from the north-east Pacific migrate across the Arctic to Norwegian arctic waters?

Researchers have been hypothesising that temporary habitats, such as wood falls and whale carcasses, in addition to vents and seeps, might serve as "stepping stones" and that these facilitate the spread of organisms across the deep sea floor. A shared group of keystone species directly or indirectly dependent on chemosynthetically derived energy has been identified. However, while the idea of "shared" species seems quite obvious, actually finding evidence for further speciation processes and diversification is more of a challenge. It is one thing to hypothesise about such a process; that CGB researchers actually found a natural wood fall on the seafloor of the North Atlantic was a stroke of extremely good fortune. Found 16 km from Loki's Castle, the log has been shown to be Siberian pine. In 2013, CGB researchers published the taxonomic identification of one of the organisms found living in the log, a new species of amphipod, belonging to a new genus of amphipod, called *Exitomelita*, and which is closely related to another new amphipod species identified on the chimneys of Loki's Castle: could this be an example of a stepping stone – taken one step further? ■



Carnivorous sponges (*Asbestopluma cupressiformis*) and soft corals (*Gersemia sp.*) from the Jan Mayen vent field.

Wood fall (a log of pine) found at 2800 m depth in the Norwegian Sea.

NEW RESEARCH THEME:

EARTH SYSTEM EVOLUTION

Bjarte Hannisdal, a post-doctoral researcher at CGB and the Department of Earth Science at UiB, was awarded the 4-year grant for his project entitled, "Earth System Interactions and Information Transfer" in 2013. The grant will enable him to establish a research team of 4 post-docs and PhD students who will study how the earth and life have affected one another through geological time, and to understand more about how the different components of Earth's systems interact.

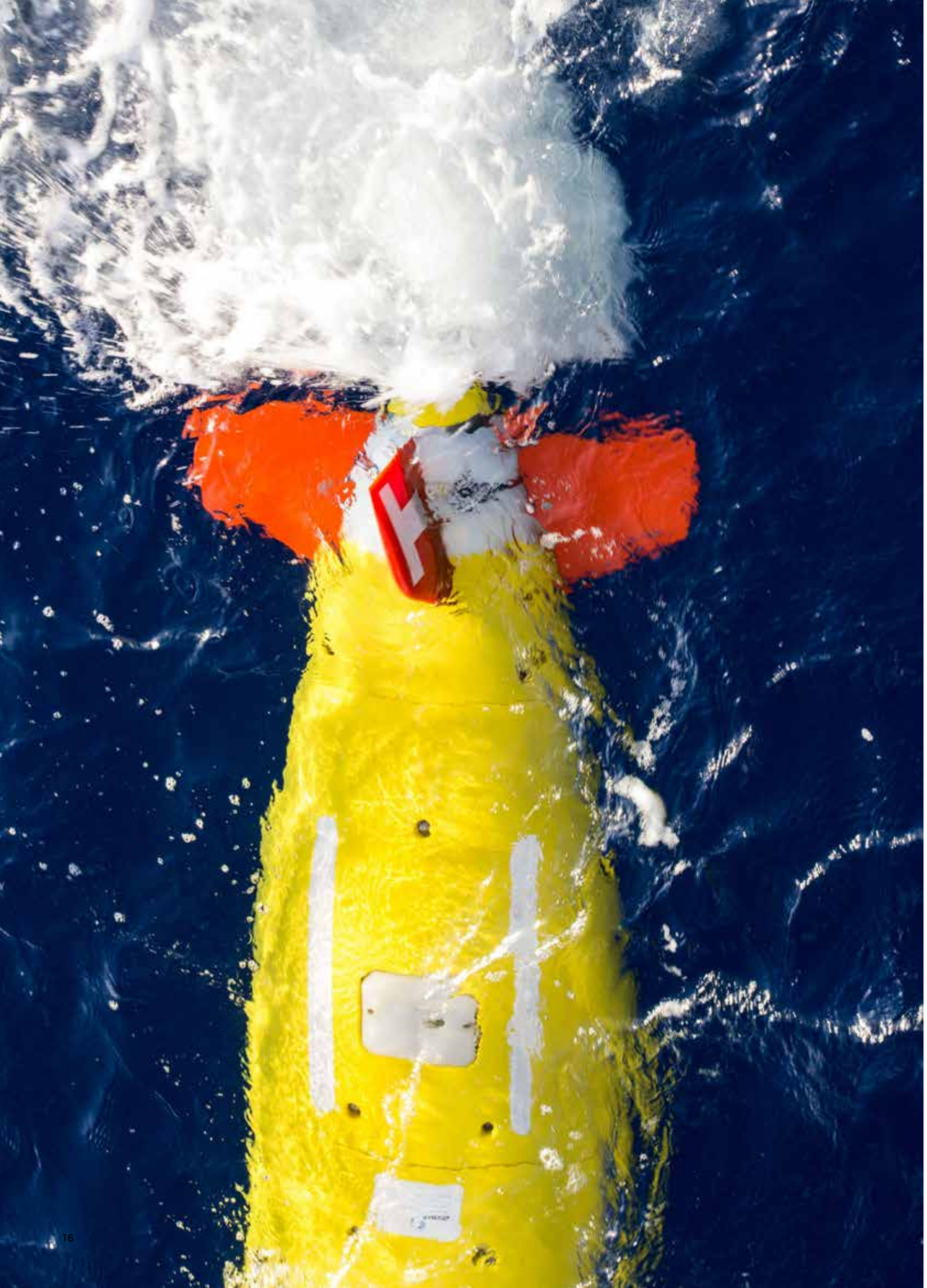
Climate tipping points, ocean acidification, sea level rise, biodiversity loss and mass extinctions; the scale and impact of future environmental projections are unprecedented in the history of human civilization. From a geological perspective, however, such dramatic upheavals have occurred repeatedly throughout Earth's history. Researchers therefore turn to the geological record for insights into causes, consequences, and time scales of global change in the past.

One major insight wrested from the rocks is that our planet has co-evolved with the life its hosts: environmental forces have shaped the evolution and function of diverse life forms, and this evolving biota has shaped the chemical and physical characteristics of the Earth. Studying such Earth system interactions in the deep past requires a broad, interdisciplinary approach that combines data and methods across scales, which will form a new research theme at CGB: Earth System Evolution.

With newly awarded grants from the Bergen Research Foundation and the Research Council of Norway, an Earth Systems Evolution team will be assembled to develop and test innovative statistical tools for detecting complex system interactions from sparse data. These methods will be applied to geological records of evolving Earth system components on time scales ranging from the present up to several billion years. Statistical relationships will be confronted with numerical models, to further test causal hypotheses.

The goal of the new research theme is to generate new fundamental insights into the evolving interactions between tectonics, climate changes, carbon cycling, ocean chemistry, sediment deposition, and marine ecosystems. The results of this research may thus have wide implications for our understanding of the history of our planet and the evolution of the biosphere. ■

Hydrothermal minerals from the Mid-Atlantic Ridge



GEODYNAMICS OF THE DEEP SEAFLOOR

This theme involves deep-sea exploration and searching for new extreme environments. It provides the foundation for the Centre's geobiological research by providing knowledge about the geological and geochemical context of the Centre's focus sites. In addition, researchers working in this theme have several independent research objectives relating to hydrothermal systems, seabed fluid flow and the geodynamics of spreading ridges.

Architecture and formation of oceanic lithosphere

Researchers from CGB are studying the structure and composition of the oceanic lithosphere. At slow spreading rates, melt supply decreases and plate separation is partly accommodated by tectonic processes, which result in an asymmetric spreading and an uplift of deep-seated materials from the lower crust and upper mantle. Magmatic and tectonic processes thus interact to produce a compositionally heterogeneous lithosphere along slow spreading ridges, such as the Mohns and Knipovich ridges in the Norwegian Greenland Sea. In recent years, it has been shown that oceanic detachment faults play a major role in plate separation and construction of the oceanic lithosphere; they are also a favorable environment for the development of hydrothermal systems. In November 2013, the CGB was actively participating in the French-funded ODEMAR (Oceanic DEtachment along the Mid-Atlantic Ridge) cruise along 13°20-30'N oceanic detachments. This cruise is a part of a long-term international effort to study oceanic detachment faults and will be complemented with a seismic experiment taking place in the same area in 2015 (UK-funded) to study the structure of the lithosphere and the distribution of seismic activity associated with detachment faulting. The outcomes of this international project will greatly contribute to understanding the seafloor spreading mechanisms along the strongly asymmetric Mohns Ridge.

The formation mechanisms of new oceanic lithosphere and its evolution are presently the most dominant processes in the chemical differentiation of our planet. The IODP Expedition 345 cored the first significant intervals of primitive modally layered gabbroic rocks from just above the mantle – crust transition. The spectacular layering is presently studied within a high resolution spatial and analytical transect across the best-developed and preserved layered lithology. The unexpected abundant orthopyroxene found within these primitive gabbroic rocks, deviates from standard MORB crystallization models. The early stability of this phase is being chemically studied at CGB with experiments performed in Hannover. A new continuous sampling technique provided CGB with a more representative sample to study average modal and geochemical compositions and so cast light on seawater circulation within this lower crustal segment.

Researchers working in the geodynamic theme are also investigating the earth mantle, deep below the seafloor surface. In 2013, new isotope geochemistry data have been measured on samples collected during the SUBMAR program (1999-2004). These new data are showing the existence of different ancient mantle domains along the North Atlantic ridges system. This dataset will be completed with new samples collected during the 2013 G.O. Sars summer cruise along northern Kolbeinsey Ridge, and is expected to bring some new insights on the nature of Jan Mayen hotspot volcanism.

Hydrothermal systems and seafloor mineral deposits

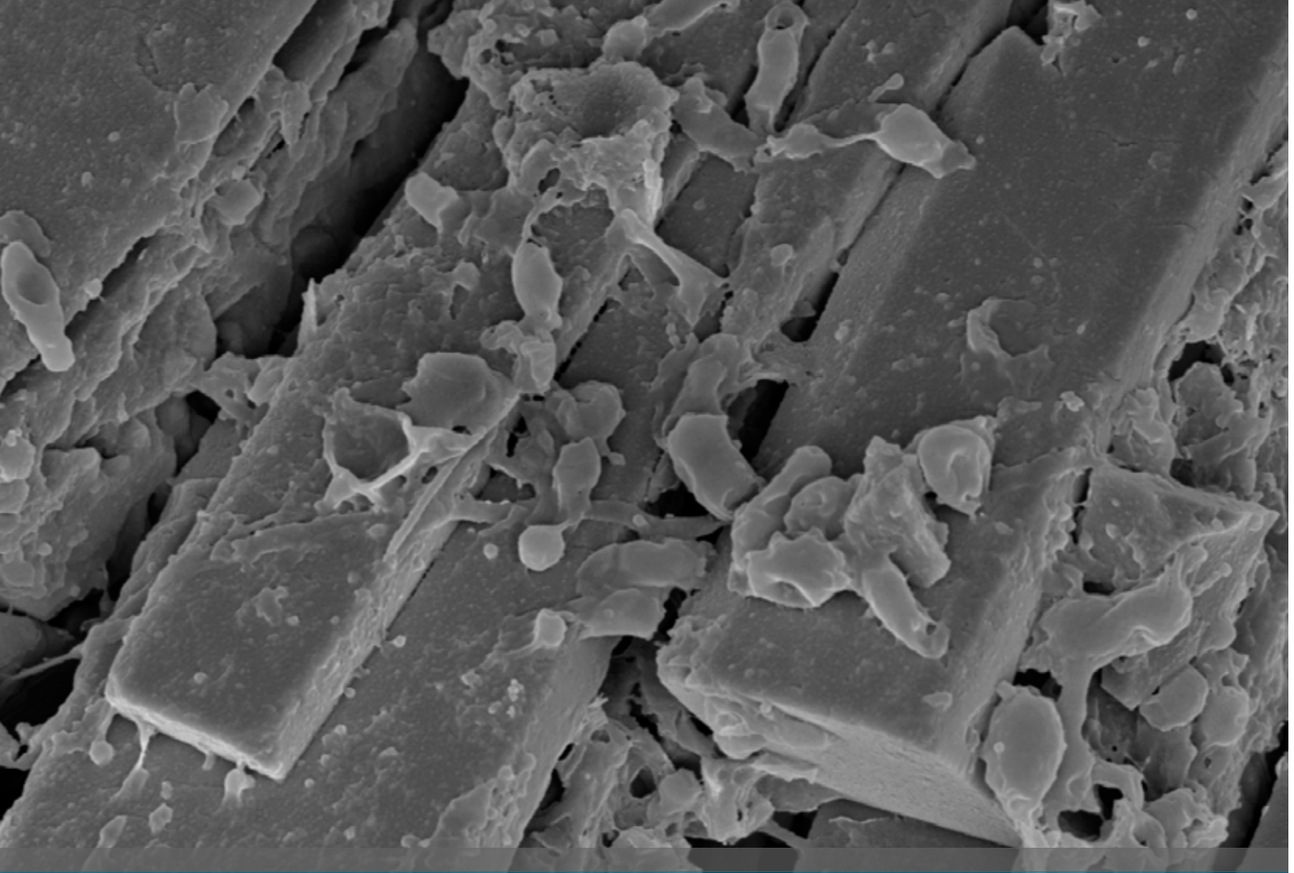
Increasing global demand for the supply of raw materials has recently raised awareness for the metal resource potential of seafloor hydrothermal systems (e.g. Cu, Zn, Pb). Global knowledge of these systems distribution is, however, still in its infancy as no more than 200 high-temperature hydrothermal systems capable of forming massive sulfide deposits are known. Slow to ultra-slow spreading settings such as the Arctic Mid-Ocean Ridge represent promising areas in the quest for seafloor hydrothermal systems capable of forming sulfide accumulations with high enough grades and/or tonnage to be considered ore mineral deposits. It is therefore important to assess quantitatively the potential for undiscovered massive sulfide resources occurring in the Arctic Sea. The scientific community is responsible to generate information that will be used by government and industry when they put forward a legal framework for exploring and exploiting those delicate systems. Knowledge is the best approach to protect and develop a sustainable plan of action for the next decade.

The CGB team has been focusing its research on known hydrothermal systems of the Arctic Mid-Ocean Ridge, namely the Jan Mayen vent fields and Loki's Castle whereas other systems are now in prospect of further exploration in the upcoming cruises. Although they have some geochemical differences, both systems are characterized by a Zn+CufflPb(fflAu) coupled with barite-rich mineralization in the vent chimneys, and Cu+Zn (ffl Se) sulfide mineralization in the hydrothermal mounds. These are typical features of basalt-hosted type hydrothermal sulfide mineralization with moderate zone refining processes. Further understanding of these systems will increase the possibility for finding new potential exploration targets that ultimately may lead to discovery of new hydrothermal systems.

One of the main research objectives of the CGB scientific cruise on the R/V G.O. Sars in June/July 2013 was not only to revisit the Centres unique natural laboratory, the CO_2-rich Jan Mayen vent fields at 71°N, but also to give some constraints on the occurrence of hydrothermal venting along the ultraslow spreading Arctic Mid-Ocean Ridge (AMOR) system. To do so, the water column above parts of the mid-ocean ridge system was systematically investigated for anomalies of chemical parameters. By using a CTD equipped with state-of-the-art sensors for Eh, CO_2 and CH_4 as well as onboard gas chromatography for H_2 and CH_4, hydrothermal anomalies were found in the water column above the Mohns Ridge. These point to at least three more vent systems along this section of the AMOR. The geochemical studies of volatiles released to the water column by hydrothermal venting enhance our understanding of the formation and speciation of C-O-H-S fluids as nutrients for biological activity as well as help to identify potentially interesting sites for massive sulphide deposits.

In 2013 CGB also successfully used a novel exploration technique to locate shallow hydrothermal vents using the water column multibeam system of the G.O. Sars. This system was deployed at the Jan Mayen spreading center to locate two additional hydrothermal vents to the east of the Troll Wall field. Following the success at Jan Mayen, water column detection was also used at the Northern Kolbeinsey Ridge to successfully locate the first hydrothermal systems ever found at this site. This survey technique combines large-scale multibeam mapping of seafloor morphology with rapid vent identification, making it an ideal technique in all shallow-water regions for locating active venting sites.

The 2013 cruise also collected extensive acoustic surveys of hydrothermal bubble plumes using fisheries acoustic systems. Prior to the 2014 field season these data will be processed to constrain the flux of gas from these hydrothermal systems, a measurement essential for understanding the impact of these volcanic systems on the ocean and atmosphere. These measurements will be further refined with the deployment of an acoustic lander at Jan Mayen in the summer of 2014. ■



Microbes on minerals from a hydrothermal chimney.

WATER-ROCK-MICROBE INTERACTIONS & THE DEEP BIOSPHERE

Researchers within the theme on water-rock-microbe interactions and the deep biosphere have continued to build on results from previous years. We have now been able to verify correlations between the abundance of uncultured microbial groups and specific geochemical parameters in the deep-sea sediments of the Knipovich Ridge rift valley north of Loki's Castle vent field. We are currently using this information in an attempt to culture and characterize these hitherto undescribed organisms.

We collected new sediment cores in summer 2013 from the flank of the Mohns Ridge. These cores come from locations that have not been studied previously. We are now working to describe the microbial communities from these cores as well as trying to understand the geochemical processes on-going at these locations. These new results when combined with our previous results from the rift valley sediments will provide us with a broader understanding of the ecosystem within the seafloor in the Arctic.

Although the annual CGB cruises are of great importance to our research, participation in IODP cruises is also an important activity. Deep-sea sediments drilled during the IODP 336 expedition to North Pond, at the western flank of the Mid-Atlantic Ridge, were the focus of research in 2013. The aim of this work was to elucidate the significance of the nitrogen cycle within the deep biosphere. Our preliminary results have shown that microbial-mediated redox reactions involving nitrogen compounds are prominent throughout the entire sediment column in the cores from North Pond. These results suggest that the nitrogen cycle in this type of marine setting is much more pronounced than previously thought and seems more important than other major geochemical cycles, e.g. the sulfur cycle.

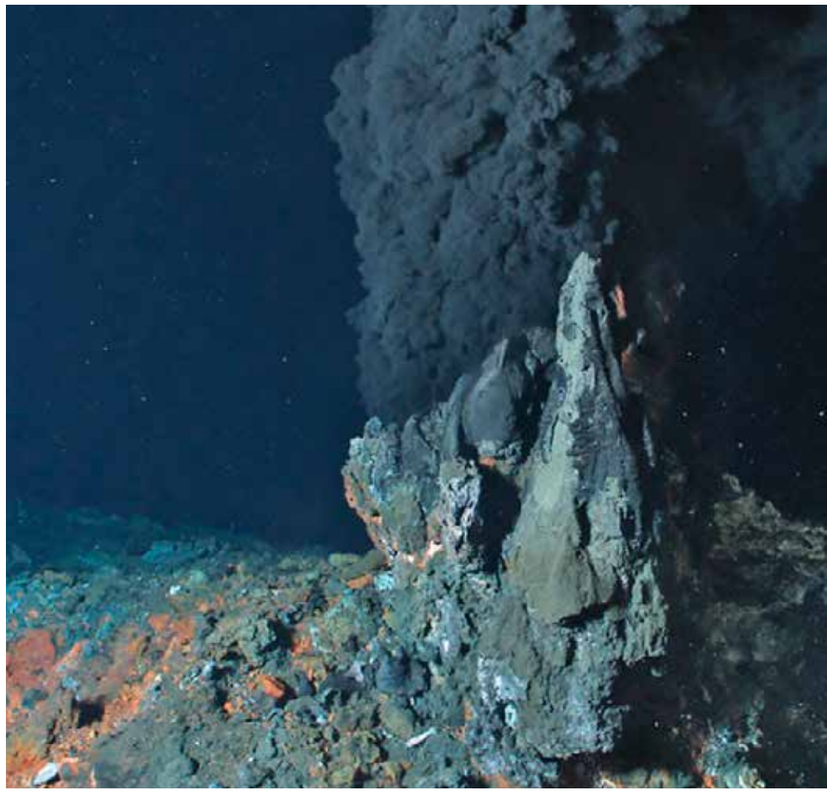
Researchers from this theme have also been investigating mine tailings in some Norwegian fjords. The results have revealed elevated levels of heavy metals in the pore fluids of these mine tailing deposits compared to background levels in sediments some distance away. Despite similar low contents of organic matter, the deposits show highly variable redox conditions from no to nearly complete sulphate depletion combined with high methane content. The different redox conditions likely reflect differences in the composition and the chemical treatment of the tailings prior to deposition. Further analyses are needed to evaluate how these factors influence the mobility of the heavy metals in the deposits.

Theme researchers worked closely with researchers from the other themes to study the formation of low-temperature hydrothermal iron-deposits at the Jan Mayen vent fields. We hope to use these deposits as modern models for ancient iron formations.

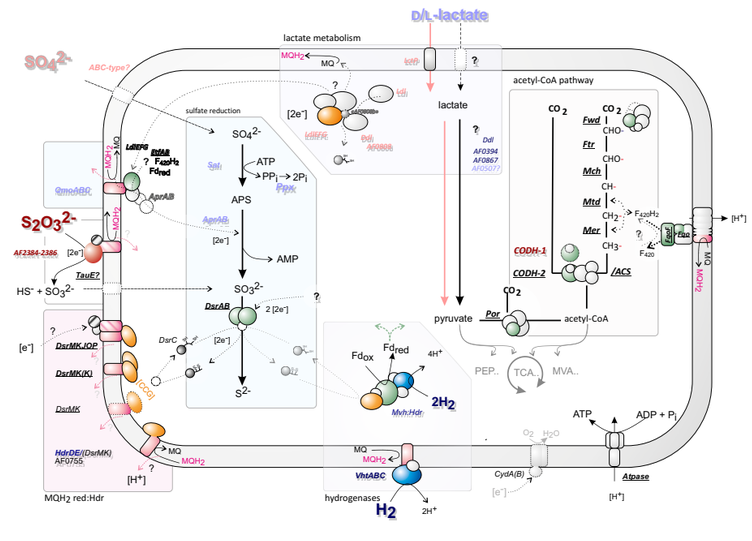
Theme researchers have also been involved in a study of input and dispersion of hydrothermal volatiles, heavy metals and rare earth elements in deep-sea plumes from the Arctic vent fields. Preliminary results indicate that the hydrothermal components are quickly transported for significant distances by strong currents, providing nutrients for organisms in the Norwegian-Greenland Sea. ■

LIFE IN EXTREME ENVIRONMENTS AND ROOTS OF LIFE

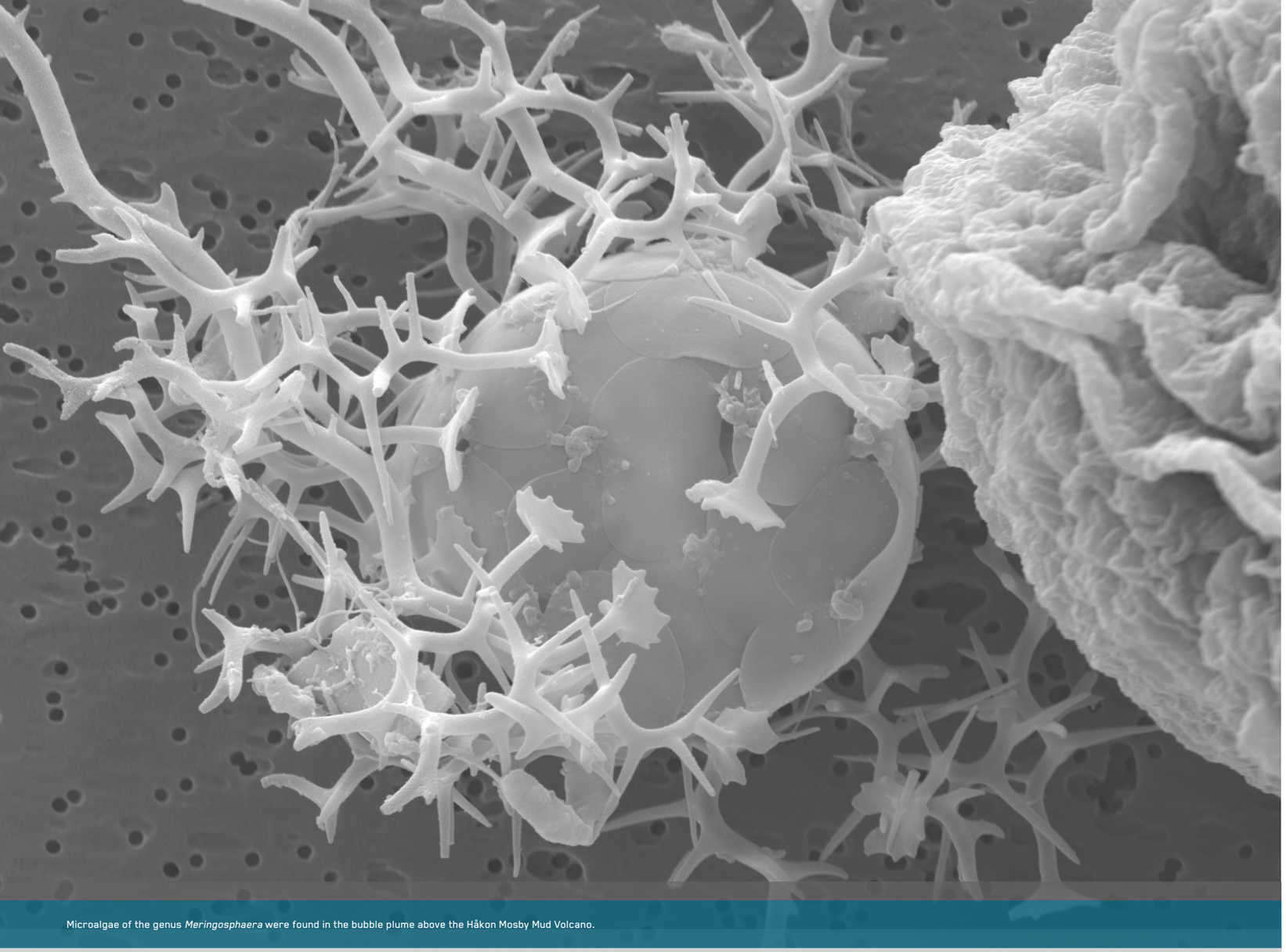
Hydrothermal vent ecosystems are driven by the chemical energy available when reduced fluids mix with seawater. The redox gradients developing in this process create the basis for chemosynthetic food-webs and hot spots for biological activity are formed. Although the oceans on early Earth were anoxic, it is likely that the total redox range of modern hydrothermal vent fields in today's oxygenated oceans include those present in Early Earth systems. Hydrothermal vent ecosystems thus provide unique windows into microbial metabolisms that operated in deep time and insights into the roots of life. Despite exposure to extremes in pressure, temperature, salinity and fluxes in nutrient availability, a richness of microbial life is found at hydrothermal vents indicating that life thrives under seemingly harsh environmental conditions. In this theme we focus on understanding how microbial diversity is affected by formation of different energy landscapes through variations in fluid compositions in hydrothermal vents; if closely related ecotypes respond differently to variations in environmental conditions; and if viruses influence the dynamics of the microbial communities. A major focus is also on unraveling new and detailed knowledge of the biochemistry and metabolic properties of hydrothermal vent microorganisms by whole-genome transcriptome analyses of model organisms by genomics and metagenomics and through cultivation of novel microorganisms. This year at the Centre we have advanced our understanding of the functioning of microbial communities in diffuse hydrothermal venting sediments. An integrated "metaomics" approach yielded insights into the functioning of the major microbial taxa in this community and indicated that the dominant genera Sulfurimoans and Sulfurovum were the most important primary producers in the sediments utilizing the high concentration of hydrogen sulphide present in the venting fluids. We have revealed that the use of in situ growth chambers results in microbial communities dominated by yet uncultivated microbial lineages from which we have reconstructed several nearly-complete genomes using metagenomics. We thus have obtained data that may impact our understanding of the diversity of metabolic pathways operating in deep time and provide clues to biochemical adaptations to extreme environmental conditions. The genetic reservoir created will also form the basis for discovery of enzymes of biotechnological relevance and create a solid foundation for the national biotechnological pipeline that the research theme is part of through the NorZymeD-project. This project focuses on developing a biotechnological pipeline that will enable Norwegian industry to use the genetic reservoir from AMOR directly. Finally, we are advancing our understanding of the microbial processes of bio-corrosion by isolation and whole-genome sequencing of the main species involved. ■



A "black smoker" hydrothermal vent field discovered on the Mid-Atlantic Ridge during the 2013 ODEMAR cruise.



Central energy and carbon metabolism of a hydrothermal dwelling microorganism (*Archaeoglobus fulgidus*).



Microalgae of the genus *Meringosphaera* were found in the bubble plume above the Håkon Mosby Mud Volcano.

VENT AND SEEP BIOTA

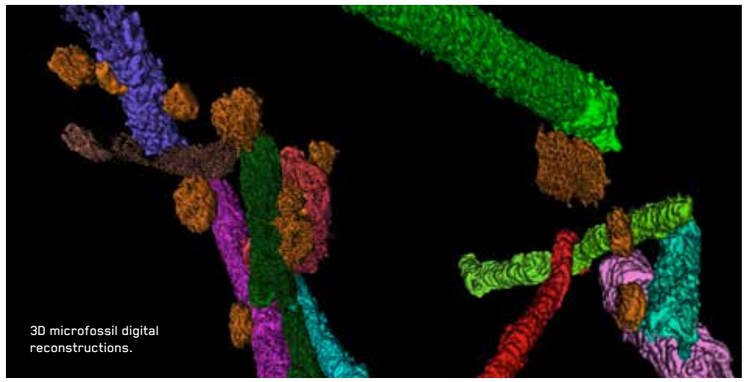
This theme involves the exploration of the deep-water fauna in the Arctic and the NE Atlantic oceans with special emphasis on hydrothermal vents and seamounts along the Arctic Mid-Ocean Ridge. Among the main objectives in the ongoing work is to investigate local adaptations and speciation processes, as well as address potential ecological and evolutionary connectivity between different chemosynthetic habitats in the area including hydrothermal vents, cold seeps and sunken wood. We have shown that chemosynthetic habitats in the Norwegian and Greenland seas host an endemic and highly specialized fauna. More than 90% of the specialized fauna represents new and undescribed species, and extra effort has therefore been concentrated on describing them. There are obvious similarities between the fauna found at hot vents along the AMOR, the fauna of cold seeps along the Norwegian margin, and from wood-falls in the abyssal Norwegian Sea. A shared group of keystone species directly or indirectly dependent on chemosynthetically derived energy has been identified. At a first glance the snails *Rissoa griegi* and *Skenea profunda* as well as the amphipod *Exitomelita sigynae* seem to dominate the fauna completely. When having a closer look, however, polychaetes are highly abundant and highly diverse. The polychaetes also represent the group with the highest number of new taxa discovered and so far about a dozen new species of polychaetes are being formally described from Loki's Castle alone. Molecular tools are now being used to provide more information about the evolutionary history of this special fauna, and to explore the possible connections between the Atlantic and Pacific reduced habitat faunas through time. Our explorations have revealed large mineral resources on these deep-sea ridge systems and there is a growing interest in utilisation of these resources. The consequences of deep-sea mining are not well known and we are aiming to understand the ecosystem resilience, function and potential environmental recovery after mineral extraction in vent systems. The novelty and high degree of endemism of the vent fauna in the Norwegian and Greenland Seas call for more in-depth studies and use of the precautionary approach in future management of these unique deep-sea habitats. ■

EARLY EARTH AND BIOSIGNATURES

Twenty thirteen was an exciting year for the Early Earth and Biosignatures theme with progress on wide ranging topics. These research activities spanned almost the entire geological timescale, from Archean 3.45 billion-year-old rocks to modern geobiological field sites.

Our research also spanned many different spatial scales, from field and drill core investigations of geological relationships, to micro and nanoscale studies of geochemical signatures. Our approach of combining information from multiple spatial and temporal scales is essential to our goals of identifying traces of life or so-called biosignatures in deep time, and to reconstructing ancient Earth processes.

Efforts to develop nanoscale methods for analysing ancient biosignatures were very successful in 2013. In recent seafloor rocks, focused ion beam technology at the Norwegian nanolab is being used to investigate alteration processes that may be microbially mediated. In deep time, a study by Wacey et al. 2013, (see page 30, no. 25) combined 3-dimensional reconstruction methods with nanoscale sulfur isotope analysis by nanoSIMS to investigate a 1.9 billion-year-old fossilized microbial community. This found unprecedented evidence of heterotrophic microbes consuming the organic remains of other microorganisms, which was reconstructed in unprecedented three-dimensional detail (image inset) by nanometer scale serial slicing and imaging of the fossilized microbes.

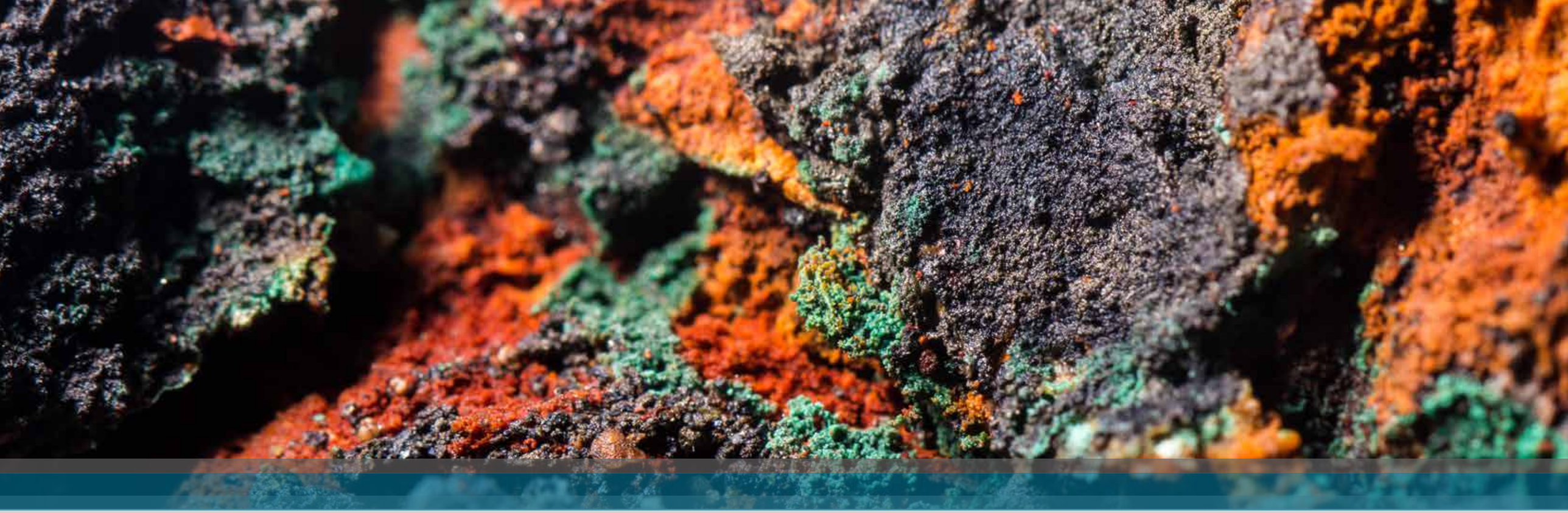


3D microfossil digital reconstructions.

Work on early Archean Earth environments and processes continued apace in 2013. A key publication presented sulfur isotope data from the Barberton Scientific Drilling Project, greatly expanding the global dataset on Archean sulfur isotope values (Grosch and McLoughlin, 2013, see page 30, no. 10). In a feature article in this report it is explained how this data was used to generate new insights into the biological, geological and chemical processes that cycled sulfur on the early Earth. In particular, the types of sulfur based microbial metabolisms that were and weren't present, and also the impact of emerging tectonic processes on the sulfur cycle.

Studies of recent oceanic lavas were published in a photographic atlas in 2013 reporting microscopic alteration textures in subseafloor rocks, intended as a guide to the interdisciplinary research effort to identify markers of microbial activity in the deep subseafloor (Fisk and McLoughlin, 2013, see page 30, no. 6). This year the research theme was joined by a new PhD student who will investigate biosignatures of iron-oxidizing bacteria in the Norwegian-Greenland Sea. These microorganisms are very sensitive to the local concentrations of oxygen and the knowledge gained from these modern ecosystems will be used to investigate the rise of atmospheric oxygen in deep time. This major transition in earth history known as the Great Oxidation Event that commenced c. 2.4 billion years ago was the subject of a PhD thesis by Qu Yuangao (see page 31) completed in 2013. This focused on the Shunga event that records vast deposition of organic matter and accumulation of oil in the rock record. Carbon isotope analysis and ultrastructural investigation of the organic matter were combined to study this radical perturbation in the ancient carbon cycle.

In conclusion, 2013 was a diverse and busy year for our theme. Dissemination of our research results also took place at several conferences with presentations and convener activities at all of the following meetings: the European Geophysical Union, the Nordic Astrobiology Conference, and Goldschmidt (Geochemistry) conference. The coming years promise to be equally exciting and rewarding for the Early Earth and Biosignatures theme. ■



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 Departments of Biology and Earth Sciences.

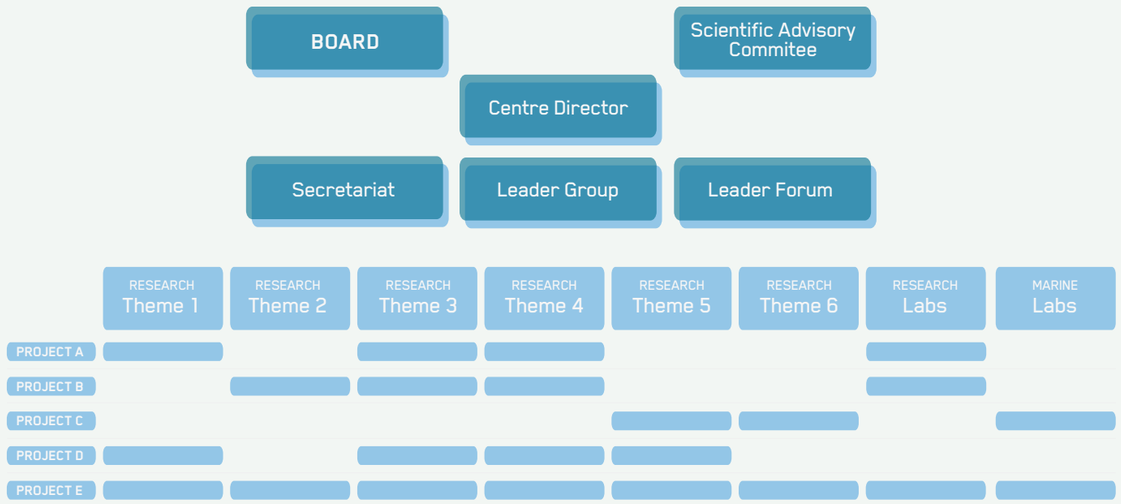
Although initially organised around research themes, the Centre has since adopted a matrix model approach that facilitates and promotes the inter- and multi-disciplinarity necessary to attain the Centre's research goals. In this model the Centre activities – the rows in the matrix - are organised as projects. The columns of the matrix are the crosscutting themes of the Centre research plan. 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

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

THE GOVERNING BOARD

Dag Rune Olsen, (leader), Dean of the Faculty of Mathematics and Natural Sciences
Gunn Mangerud, Head of the Department of Earth Sciences
Anders Goksøyr, Head of the Department of Biology
Svenn-Åge Dahl, Director of the Department of Research Management at UiB
Ole Tumyr, employee representative from the Department of Earth Sciences
Runar Stokke, employee representative from the Department of Biology



WORKSHOPS, SEMINARS AND **SHORT COURSES**

Researchers at the Centre for Geobiology (CGB) took advantage of numerous opportunities to present their research results to both academic and general audiences in 2013. Unexpected cutting-edge results continue to attract public attention to CGB activities.

In terms of press coverage, the most exciting results of 2013 were the findings of the research cruises conducted in 2013. The discoveries have accumulated a great amount of attention, including articles in local and international newspapers, online media and televised reports, demonstrating the magnitude of Norwegian and worldwide interest in deep sea exploration.

CGB researchers represented both the Centre and the University of Bergen at a number of public functions throughout the year. Highlights include the Christie Conference, which is an annual event organised by UiB as a meeting platform for academia and the community. The 2013 theme was for the event was special research centres at UiB including the Norwegian Research Council's Centres of Excellence. Norway's annual Research Week was themed "Oceans" in 2013, to which CGB researchers strongly contributed. Other public areas where CGB researchers participated include Geology Day, Bergen International Film Festival, and two special open houses; one for Geology teachers, and one for high-school students.

CGB researchers are also in-demand in advisory roles for a number of fields including astrobiology, bio-economy, bio-prospecting, deep-sea mining, and CO_2 storage. Two CGB students participated in a communication programme sharing cutting-edge research findings with high-school students called: "Let's talk about climate: engaging tomorrow's stewards today". Additionally, CGB professors returned to Reykjavik, Iceland in summer 2013 to lead a geobiology course aimed at teaching students practical methods in microbiology, geochemistry, and molecular biology amongst the countless hotsprings found there.

In addition to public relations, Centre researchers also lead and hosted the following meetings for academic and industrial researchers:

Goldschmidt 2013 Session

CGB scientists co-convened the session "Alteration Processes and Geobiochemical Interactions at Mid-Ocean Ridges" presented at the Goldschmidt 2013 conference in Florence, Italy from August 25-30. The well-attended session provided a platform for contributions from the multi-disciplinary research community investigating the complex interplay between abiogenic and biogenic processes linked to alteration and hydrothermal circulation at ultraslow to fast spreading mid-ocean ridges.

ECO2 2nd Annual Meeting

CGB hosted the second annual meeting of the European ECO2 (Sub-seabed CO_2 Storage: Impact on Marine Ecosystems) meeting in Bergen May 13 – 16 with about 100 attendees. The main achievement of the meeting was to share and compare the comprehensive data sets obtained through numerous scientific expeditions by different project partners and to develop a common understanding of various aspects on sub-seabed CO_2 storage and its environmental impacts. ■

CENTRE FUNDED PROJECTS

The CGB research plan is carried out through a number of external projects and Centre funded projects under the different research themes. In 2013 the CGB Leader Group also decided to continue the Seed Project initiative whereby Centre researchers engaging short term research initiatives could apply for funding for 1-1 1/2 year. The following seed projects where funded by CGB in 2013:

- Archean Geodynamics & Environments for Life (Eugene G. Grosch)
- Multiple sulfur isotope analysis of microbially-mediated mineral sulfides at the micron scale (David Wacey, Nicola McLoughlin and William Hocking)
- Fluid – rock interaction during alteration of mantle lithosphere – an example of the Leka ophiolite complex (Jiri Konopasek, Rolf Birger Pedersen and Jan Kosler)
- Developing laser-ablation ICP-MS methods for use in U/Th dating of geological and archaeological samples (Jan Kosler and Elizabeth Farmer)
- Is methane oxidation in extreme geothermal environments metal independent (Nils-Kåre Birkeland)
- Analysis of 16S rRNA and mcrA genes in cryotubert tundra soil (Vigdis Torsvik)

RESEARCH
PROJECTS 2013

PROJECTS FUNDED BY THE RESEARCH COUNCIL OF NORWAY

DURATION	TITLE	LEADER*/PARTNER**
2009 – 2017	Subsurface CO_2 storage – Critical Elements and Superior Strategy (FME SUCCESS)	Rolf Birger Pedersen**, Ingunn H Thorseth**
2010 – 2013	Long-term Carbon Storage in Cryoturbated Arctic Soils (CryoCARB)	Christa Scleper*, Tim Urich**,Vigdis Torsvik**
2010 – 2013	Hotspot Rift Interaction & Geochemistry of the North Atlantic Mantle: the Aegir Ridge 'Hole' in the Iceland Hotspot	Rolf Birger Pedersen**
2011 – 2013	Improved submarine tailing placements (STPs) in Norwegian fjords (ImpTail)	Ingunn H Thorseth**
2011 – 2014	Mining of Norwegian biogoldmine (BioGoldMine)	Ida Helene Steen*
2011 – 2014	Biological methane oxidation by methanotrophic verrucomicrobia under hot and acidic conditions	Nils Kåre Birkeland*
2012 – 2017	Enzyme development for Norwegian biomass – mining Norwegian biodiversity for seizing Norwegian opportunities in the bio-based economy (NorZymeD)	Ida Helene Steen**
2013 – 2016	Vulnerable habitats and species in petroleum resource management: impact of sediment exposure on sponge grounds (SedExSponge)	Hans Tore Rapp** Friederike Hoffmann**

INTERNATIONAL PROJECTS FUNDED THROUGH THE EUROPEAN SCIENCE FOUNDATION (ESF)/ERA-NET

DURATION	TITLE	COORDINATOR*/ PRINCIPAL INVESTIGATOR**/ COLLABORATOR***	PROGRAMME
2008 – 2013	Ultra-slow spreading and hydrogen-based biosphere: A site survey proposal for zero-age drilling of the Knipovich Ridge (H2DEEP)	Rolf Birger Pedersen* (Main Coordinator)	ESF/ EuroMARC (EUROCORES)/NFR FREPRO
2010 – 2013	Long-term Carbon Storage in Cryoturbated Arctic Soils Individual project 5: High-resolution Microbial Community Structure (CryoCARB)	Christa Schleper* Vigdis Torsvik*** Tim Urich***	ESF/ PolarCLIMATE/ NFR
2010 – 2013	Microbial and viral ecology of hot spring environments with emphasis on 454 pyrosequencing and microbial and viral interactions (MicVirEcolHotSprings)	Lise Øvreås, Ruth-Anne Sandaa	EU/Marie Curie International Outgoing Fellowships for Career Development
2011 – 2014	Sub-seabed CO_2 Storage: Impact on Marine Ecosystems (ECO2)	Rolf Birger Pedersen**	EU
2014 – 2016	Managing impacts of deep-sea resource exploitation (MIDAS)	Rolf Birger Pedersen **	EU

PROJECTS FUNDED BY OTHER SOURCES (PUBLIC AND PRIVATE)

DURATION	TITLE	LEADER*/ PARTNER**	PROGRAMME/ FUNDING SOURCE
2010 – 2015	Earth System Modelling	Jan Kosler**, Bjarte Hannisdal**, Jiri Slama**	Statoil
2012 – 2013	OD Jan Mayen Ryggen III	Rolf Birger Pedersen*	Oljedirektoratet
2011 – 2013	Deep-water sponges of the Greenland-Iceland-Norwegian Seas	Hans Tore Rapp*	Det Norske Videnskapsakademi
2011 – 2014	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	Preparing for sub-sea storage of CO_2: Baseline gathering and monitoring for the North Sea (CO_2 – Base)	Rolf Birger Pedersen**	CLIMIT/GASSNOVA
2013 – 2015	Taxonomy and distribution of sponges (Porifera) in Norwegian waters II	Hans Tore Rapp*	NTNU/Artsdatabanken

PROJECTS FUNDED FROM 2014 (ANNOUNCED IN 2013)

DURATION	TITLE	LEADER*/ PARTNER**	PROGRAMME/ FUNDING SOURCE
2014 – 2015	Norwegian Marine Robotics Facility Remotely Operated Vehicle for Deep Marine Research (NORMAR)	Rolf Birger Pedersen*	INFRASTRUKTUR/ NFR
2014 – 2015	Purchase of ICP-MS	Jan Kosler*, Rolf Birger Pedersen**, Ingunn H. Thorseth**	Statoil
2014 - 2016	Earth System Interactions and Information Transfer	Bjarte Hannisdal*	FRINATEK/NFR
2014 - 2017	Earth System Interactions and Information Transfer	Bjarte Hannisdal*	Bergen Forskningsstiftelse

STAFF

SCIENTISTS

Birkeland, Nils Kåre
Dahle, Håkon
Furnes, Harald
Gittel, Antje
Hannisdal, Bjarte
Hoffmann, Friederike
Kosler, Jan
Marques, Filipa
McLoughlin, Nicola
Mørkved, Pål Tore
Pedersen, Rolf Birger
Rapp, Hans Tore
Reigstad, Laila Johanne
Roerdink, Desiree
Schleper, Christa
Slama, Jiri
Steen, Ida Helene
Stokke, Runar
Swetman, Andrew
Thorseth, Ingunn H.
Torsvik, Vigdis
Øvreås, Lise

POST-DOCS

Baumberger, Tamara
Grosch, Eugene
Hamelin, Cedric
Jørgensen, Steffen L.
Meyer, Romain
Yuangao, Qu
Roalkvam, Irene
Rooks, Christine
Wacey, David
Økland, Ingeborg
Xavier, Joana

PHDS

Alvizu, Adriana
Cruz, Ines
Denny, Alden
Eilertsen, Mari Heggernes
Flesland, Kristin
Gjerløw, Eirik
Hestetun, Jon Thomassen
Hocking, William
Johannessen, Karen
Landschulze, Karin
Le Moine Bauer, Sven
Olsen, Bernt Rydland
Pedersen, Leif Erik
Savchuk, Oles
Schouw, Anders
Van der Roost, Jan
Wissuwa, Juliane
Zhao, Rui

TECHNICIANS

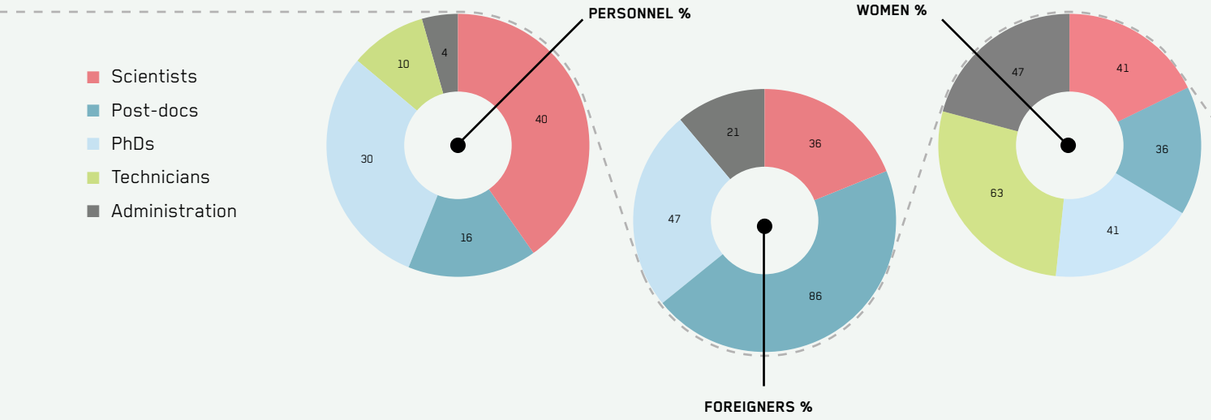
Almelid, Hildegunn
Daae, Frida Lise
Dundas, Siv Hjorth
Tøpper, Birthe
Ronen, Yuval
Steinsbu, Bjørn Olav
Tumyr, Ole

ADMINISTRATION

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

PERSONNEL SUMMARY

CATEGORY	PERSON-YEARS	FOREIGNERS (% PERSON-YEAR)	WOMEN (% PERSON-YEAR)
Scientists	17.3	36	41
Post-docs	6.8	86	36
PhDs	12.9	47	41
Technicians	4.0	0	63
Administration	1.9	21	47
Total/Average	**42.9**	**38**	**46**



FUNDING AND EXPENSES

FUNDING

	(1000 NOK)
University of Bergen	24280
Research Council of Norway	8220
Grand Total	**32500**

OTHER PROJECT FUNDING

	(1000 NOK)
International projects	505
Other Research Council projects	6087
Other Public Funding	8700
Private Funding	3900
Total	**19192**

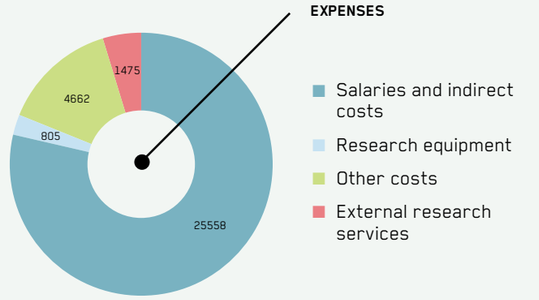
NEW PROJECTS STARTING 2014

(announded in 2013)

	(1000 NOK)
Norwegian Marine Robotics Facility Remotely Operated Vehicle for Deep Marine Research (NFR)	45 700
Purchase of ICP-MS (Statoil)	12 000
Earth System Interactions and Information Transfer (BFS)	4 092
Earth System Interactions and Information Transfer (NFR)	6 313
Total	**68 105**

EXPENSES

	(1000 NOK)
Salaries and indirect costs	25558
Research Equipment	805
Other cost	4662
External research services	1475
Grand Total	**32500**



SELECTED **PUBLICATIONS** 2013

In 2013 CGB researchers have produced more than 52 scientific publications and over 95 scientific presentations. Below is a list of some selected publications.

1. **Cárdenas, Paco A.; Rapp, Hans Tore.** Disrupted spiculogenesis in deep-water Geodiidae (Porifera, Demospongiae) growing in shallow waters. Invertebrate biology. 2013; Volume 132.(3) p. 173–194
2. **Daae, Frida Lise; Økland, Ingeborg Elisabet; Dahle, Håkon; Jørgensen, Steffen Leth; Thorseth, Ingunn Hindenes; Pedersen, Rolf B.**. Microbial life associated with low-temperature alteration of ultramafic rocks in the Leka ophiolite complex. Geobiology 2013; Volume 11.(4) p. 318–339
3. **Dahle, Håkon; Roalkvam, Irene; Pedersen, Rolf B.; Thorseth, Ingunn Hindenes; Steen, Ida Helene.** The versatile in situ gene expression of an Epsilonproteobacteria-dominated biofilm from a hydrothermal chimney. Environmental Microbiology Reports 2013; Volume 5.(2) p. 282–290
4. **Drost, Kerstin; Wirth, Richard; Košler, Jan; Jørgensen, Hege Fonneland; Ntaflos, Theodoros.** Chemical and structural relations of epitaxial xenotime and zircon substratum in sedimentary and hydrothermal environments: a TEM study. Contributions to Mineralogy and Petrology 2013; Volume 165.(4) p. 737–756
5. **Eme, Laura; Reigstad, Laila Johanne; Spang, Anja; Lanzén, Anders; Weinmaier, Thomas; Rattei, Thomas; Schleper, Christa Maria; Brochier-Armanet, Céline.** Metagenomics of Kamchatkan hot spring filaments reveal two new major (hyper) thermophilic lineages related to Thaumarchaeota. Research in Microbiology 2013; Volume 164.(5) p. 425–438
6. **Fisk, Martin; McLoughlin, Nicola.** Atlas of alteration textures in volcanic glass from the ocean basins. Geosphere 2013; Volume 9.(2) p. 317–341
7. **Furnes, Harald; de Wit, Maarten; Robins, Brian.** A review of new interpretations of the tectonostratigraphy, geochemistry and evolution of the Onverwacht Suite, Barberton Greenstone Belt, South Africa. Gondwana Research 2013; Volume 23.(2) p. 403–428
8. **Gillis K.M.; Snow, J.E.; Klaus, A.; Abe, Natsue; Adrião, Á; Akizawa, N; Ceuleneer, G; Cheadle, M.J.; Faak, K.; Falloon, T.J.; Friedman, S. A.; Godard, M.; Guerin, Gilles; Harigane, Y.; Horst, A. J.; Hoshide, T.; Ildefonse, B.; Jean, M.M.; John, B.E.; Koepke, J.; Machi S.; Maeda, J.; Marks, N.E.; McCaig, A.M.; Meyer, R.; et al.** Primitive layered gabbros from fast-spreading lower oceanic crust. Nature 2013. Volume 505. p. 204- 207
9. **Gittel, Antje; Barta, Jiri; Kohoutova, Iva; Mikutta, Robert; Owens, Sarah; Gilbert, Jack; Schnecker, Joerg; Wild, Birgit; Hannisdal, Bjarte; Maerz, Joeran; Lashchinskiy, Nikolay; Capek, Petr; Santruckova, Hana; Gentsch, Norman; Shibistova, Olga; Guggenberger, Georg; Richter, Andreas; Torsvik, Vigdis Lid; Schleper, Christa Maria; Urich, Tim.** Distinct microbial communities associated with buried soils in the Siberian tundra. The ISME Journal 2013, Volume 8. p. 841–853
10. **Grosch, Eugene Gerald; McLoughlin, Nicola.** Paleoarchean sulfur cycle and biogeochemical surface conditions on the early Earth, Barberton, South Africa. Earth and Planetary Science Letters 2013; Volume 377. p.142–154
11. **Hamelin, Cédric; Bezos, Antoine; Dosso, Laure; Escartin, Javier; Cannat, Mathilde; Mevel, Catherine.** Atypically depleted upper mantle component revealed by Hf isotopes at Lucky Strike segment. Chemical Geology 2013; Volume 341. p.128–139
12. **Hestetun, Jon Thomassen; Fourt, Maïa; 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 2013 p. 1–32
13. **Jørgensen, Steffen Leth, Thorseth, Ingunn Hindenes, Pedersen, Rolf B., Baumberger, Tamara, Schleper, Christa Maria.** Quantitative and phylogenetic study of the Deep Sea Archaeal Group in sediments of the Arctic mid-ocean spreading ridge. Frontiers in Microbiology 2013; Volume 4, p. 299
14. **Konopasek, Jiri; Košler, Jan; Slama, Jiri; Janousek, Vojtech.** Timing and sources of pre-collisional Neoproterozoic sedimentation along the SW margin of the Congo Craton (Kaoko Belt, NW Namibia). Gondwana Research 2013 http://dx.doi.org/10.1016/j.gr.2013.06.021
15. **Košler, Jan; Slama, Jiri; Belousova, Elena; Corfu, Fernando; Gehrels, George; Gerdes, Axel; Horstwood, Matt; Sircombe, Keith N.; Sylvester, Paul; Tiepolo, Massimo; Whitehouse, Martin J.; Woodhead, Jon D.**. U-Pb detrital zircon analysis – results of inter-laboratory comparison. Geostandards and Geoanalytical Research 2013; Volume 37.(3) p. 243-259
16. **Lanzén, Anders; Simachew, Addis; Gessesse, Amare; Chmolowska, Dominika; Jonassen, Inge; Øvreås, Lise.** Surprising Prokaryotic and Eukaryotic Diversity, Community Structure and Biogeography of Ethiopian Soda Lakes. PLoS ONE 2013; Volume 8.(8)
17. **Makhalanyane, Thulani P.; Valverde, Angel; Birkeland, Nils-Kåre; Cary, Stephen C.; Tuffin, I. Maria; Cowan, Don A.**. Evidence for successional development in Antarctic hypolithic bacterial communities. The ISME Journal 2013; Volume 7.(11) p. 2080–2090
18. **Olsen, Bernt Rydland; Troedsson, Christofer; Hadziavdic, Kenan; Pedersen, Rolf B.; Rapp, Hans Tore.** A molecular gut content study of Themisto abyssorum (Amphipoda) from Arctic hydrothermal vent and cold seep systems. Molecular Ecology
19. **Rapp, Hans Tore.** A monograph of the calcareous sponges (Porifera, Calcarea) of Greenland. Journal of the Marine Biological Association of the United Kingdom
20. **Rapp, Hans Tore; Göcke, Christian; Tendal, Ole Secher; Janussen, Dorte.** Two new species of calcareous sponges (Porifera: Calcarea) from the deep Antarctic Eckström Shelf and a revised list of species found in Antarctic waters. Zootaxa 2013; Volume 3692.(1) p.149–159
21. **Schouw, Anders; Sinada, Faisal; Birkeland, Nils-Kåre.** Thermoanaerobacter spp. recovered from hot produced water from the Thar Jath oil-field in South Sudan. African Journal of Microbiology Research 2013; Volume 7.(46) p. 5219–5226
22. **Stokke, Runar; Hocking, William Peter; Steinsbu, Bjørn Olav; Steen, Ida Helene.** Complete genome sequence of the thermophilic and facultatively chemolithoautotrophic sulfate reducer Archaeoglobus sulfaticallidus PM70-1T. GenomeA 2013
23. **Sweetman, Andrew Kvassnes; Levin, Lisa; Rapp, Hans Tore; Schander, Christoffer.** Faunal trophic structure at hydrothermal vents on the southern Mohn's Ridge, Arctic Ocean. Marine Ecology Progress Series 2013; Volume 473. s.115–131
24. **Urich, Tim; Lanzén, Anders; Stokke, Runar; Pedersen, Rolf B.; Bayer, Christoph; Thorseth, Ingunn Hindenes; Schleper, Christa Maria;Steen, Ida Helene; Øvreås, Lise.** Microbial community structure and functioning in marine sediments associated with diffuse hydrothermal venting assessed by integrated metaomics. Environmental Microbiology 2013
25. **Wacey, David; McLoughlin, Nicola; Kilburn, Matt R.; Saunders, Martin; Cliff, John B.; Kong, Charlie; Barley, Mark E.; Brasier, Martin D.** Nanoscale analysis of pyritized microfossils reveals differential heterotrophic consumption in the similar to 1.9-Ga Gunflint chert. Proceedings of the National Academy of Science of the United States of America 2013; Volume 110.(20) p. 8020–8024

CGB **DOCTORATE DEGREES AWARDED**

In 2013 four PhD fellows from CGB defended their thesis for the Degree of Philosophy Doctor (PhD) at the Faculty of Mathematics and Natural Sciences. In total, 11 PhDs have been defended by CGB graduate students in the period 2007–2013:

2009

TAJUL ISLAM

Discovery of novel methanotrophs from extreme environments.

20 MARCH 2009

2010

PACO CÁRDENAS

Phylogeny, Taxonomy and Evolution of the Astrophorida (Porifera:Demospongiae).

4 JUNE 2010

SIV KRISTIN PRESTEGARD

Marine Bioprospecting; Identification, physiology and proteomics of benthic diatoms with cytotoxic properties from the intertidal zone of Norwegian coastal waters.

18 JUNE 2010

2011

MIA BENGTSSON

Bacterial biofilms on the kelp Laminaria hyperborea.

23 MARCH 2011

2012

IRENE ROALKVAM

Diversity, stratification and in situ metabolism of anaerobic methanotrophic archaea in Nyegga cold seeps.

8 JUNE 2012

KIRSTEN MÖLLER

Transition metal isotope fractionation in marine hydrothermal deposits of the Mohns Ridge, North Atlantic Ocean.

24 AUGUST 2012

BJØRN OLAV STEINSBU

Characterization of Microorganisms from Marine Hydrothermal Systems.

29 AUGUST 2012

2013

STEFFEN JØRGENSEN

Linking Microbial Community Structures and Geochemistry in Deep-Sea Sediments & pursuing the link between identity and function.

18 JANUARY 2013

INGEBORG ØKLAND

Low temperature geochemical reactions and microbial life in ultramafic rock.

8 FEBRUARY 2013

ANDERS LANZÉN

Analysis of sequencing data in environmental genomics - Exploring the diversity of the microbial biosphere.

12 APRIL 2013

YUANGAO QU

Isotopic and structural characteristics of organic matter in the Paleoproterozoic Zaonega Formation, Karelia, Russia.

18 JUNE 2013

PHOTO CREDITS

Thank you to the generous and talented photographers who have allowed us to use their photos in the 2013 Annual Report and in other outreach materials. The photos in this annual report may not be copied or reproduced in any form without permission of the photographer.

Alden Denny
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David Wacey
Eugene Grosch
Hans Tore Rapp
Ingunn Thorseth
Jon Anders Kongsrud
Marte Torkildsen
Rolf Birger Pedersen
Romain Meyer

Centre for Geobiology
Postboks 7803
NO-5020 BERGEN
Norway

Established by the Research Council of Norway

Norwegian Centre of Excellence

UNIVERSITAS BERGENSIS