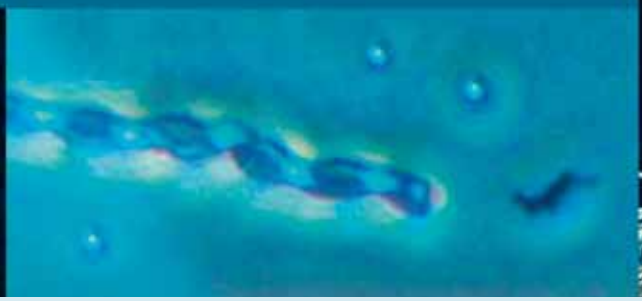
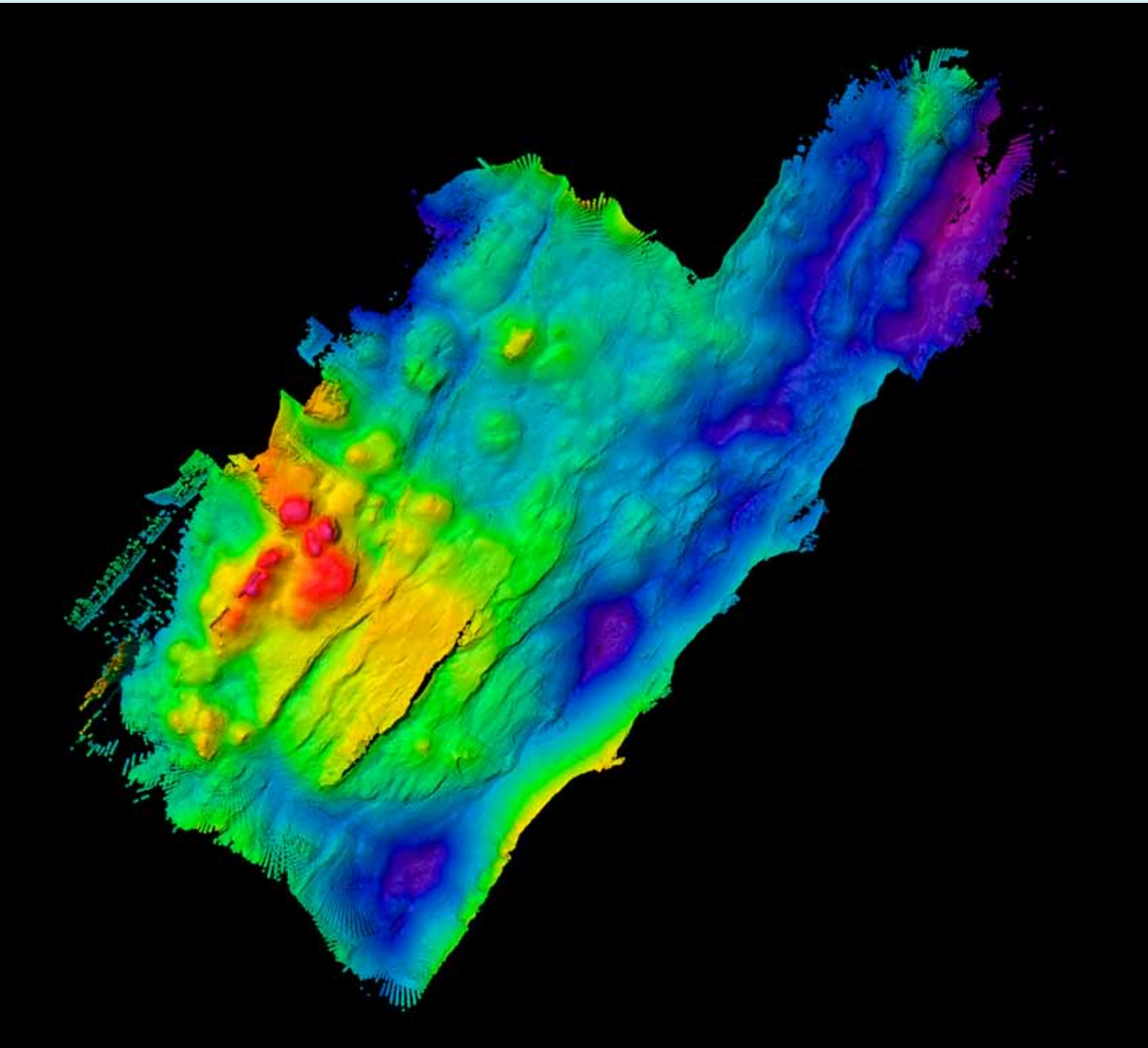
Centre for Geobiology

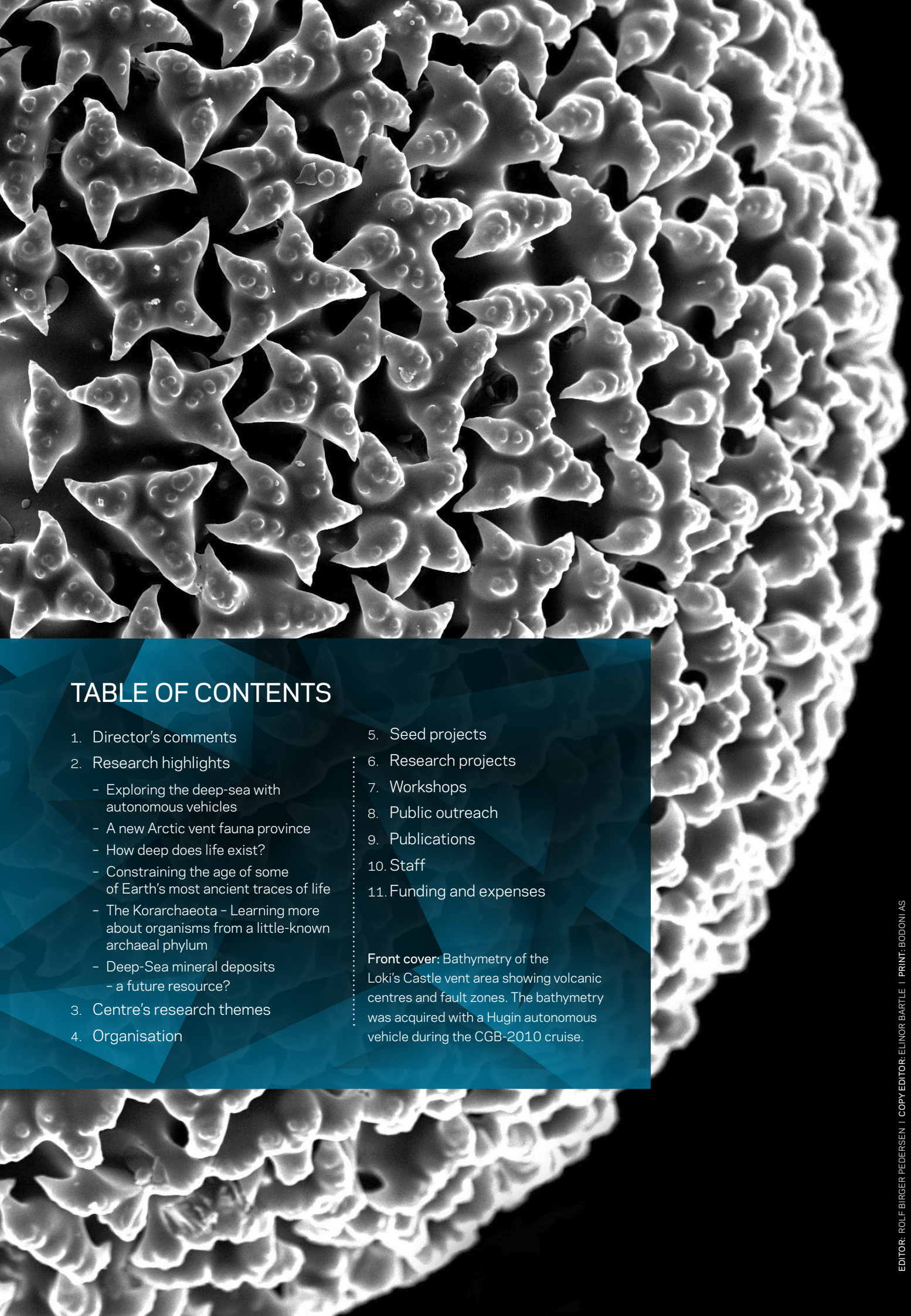
Norwegian Centre of Excellence



# Annual Report 2010

Deep Seafloor • Deep Biosphere • Deep Time & Roots of Life





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**Front cover:** Bathymetry of the Loki's Castle vent area showing volcanic centres and fault zones. The bathymetry was acquired with a Hugin autonomous vehicle during the CGB-2010 cruise.


**EDITOR:** ROLF BIRGER PEDERSEN | **COPY EDITOR:** ELINOR BARTLE | **PRINT:** BODONI AS

DIRECTOR'S COMMENTS

# 2010 – a year of reflection and evaluation

On December 1st 2010, CGB submitted its mid-term evaluation report to the Research Council of Norway (NFR). The report is a landmark set by NFR three and a half years into the Centre of Excellence period. Its purpose is to evaluate if CGB has been successful, and if funding should therefore be continued for the second five-year period. The expectations for Centres of Excellence are set high – and researchers, staff and students at CGB have been working hard to match them.

Individual expert panels have now evaluated each of the eight Centres that started in 2007, and an international evaluation committee will soon submit the final evaluation report. At the time of writing this annual report, the expert panel's evaluation has been received. Its evaluation of CGB's achievements during the initial 3.5 years is indeed very positive – and we hope that the final conclusion will be likewise.

Although demanding, the mid-term evaluation process has been useful. It has given CGB personnel time to reflect on what has been achieved so far, assessing current status and planning for the future.

Accomplishments include the building up of specialised analytical facilities; establishment of UiB among the marine research communities capable of deep-sea research; development of unique natural laboratories – and new discoveries. In addition CGB researchers have developed high-level research competencies in specific methodologies, led and participated in workshops and meetings, and have established and expanded international and national networks and partnerships. Although strongly focused on basic science, CGB has also used its expertise to contribute to research on important societal challenges such as $CO_2$ storage. CGB's publication and presentation record is becoming increasingly focused with, in 2010, over 90 papers published and over 100 presentations made.

Establishing a multidisciplinary centre in-between a pair of strong host departments is not without challenges. The evaluation process has also provided an opportunity to use the experience acquired to assess if organisation model chosen has been successful. With some adjustments, we believe that it can provide sufficient Centre independence while at the same time integrating it with the host departments.

CGB's original research plan has shown itself as visionary and achievable. As we wait and hope for a thumbs-up for a second 5-year period, we plan new exciting expeditions to the deep-sea and back into deep-time; searching for the roots of life.

*Rolf-Birger Pedersen*
DIRECTOR

RESEARCH HIGHLIGHTS

# Exploring the deep-sea with autonomous vehicles

Initially designed for use under warfare conditions – autonomous underwater vehicles (AUV) are now exploring the deep-sea for science!

Summer 2010, during a CGB-led international expedition, a five meter long torpedo-shaped AUV was launched from the *RV G.O. Sars* into the middle of the Norwegian/Greenland Sea. Once in the sea, the battery-driven propeller started rotating and the AUV disappeared below the surface. Following a pre-determined programme it started a silent and lonely voyage to 3000 metres deep where it explored the seafloor around the deep-sea volcanoes located there, looking for hot vents and new ecosystems. Twenty hours later the AUV returned to the surface – and researchers and crew heaved a sigh of relief that the 30-million-kr piece of equipment was once again safely on-board! Once on deck, the data collected in the deep could be unloaded. It revealed detailed maps and pictures of the seafloor as well as masses of information collected from the many different kinds of sensors. Among other things, the data showed where hot hydrothermal water was discharging from the seafloor.

The AUV, *"Hugin",* was developed by the Norwegian Defence Research Establishment (FFI) and produced by Kongsberg Maritime - a world leader in AUV technology. Together with the Institute of Marine Research they established a consortium to manage the *Hugin* AUV's operation. In 2010 CGB undertook to modify the *RV G.O.Sars* so that she was capable of being a platform to launch the AUV. CGB has continued to invest in this AUV, and recently UiB became the fourth member of the "*Hugin*-consortium".

The AUV is a multi-dimensional instrument platform that can be programmed to engage in diverse measurement routines autonomously. For example, it is equipped

with a range of advanced navigational and acoustic systems. In addition, it has unique water column, seafloor, and sub-seafloor imaging capabilities. Its range of chemical, physical and optical sensors make it ideal for detecting chemical and particle anomalies in the water column. The use of AUVs has the additional benefit of optimising research and sampling time aboard research vessels as it can operate autonomously while researchers engage in other tasks.

The operation of this AUV from the *G.O.Sars* platform opens new research possibilities for CGB (and other Norwegian research institutions). In particular it will enhance research activities relating to locating new seabed fluid-flow systems and their associated chemosynthetic ecosystems. Use of the AUV will also be important for the more applied aspects of CGB's research activity relating to the monitoring of subsurface $CO_2$ storage sites.

*Kongsberg Maritime.*

CGB's efforts to use modern robotics for deep-sea research is now paying off. The new capability of combined use of AUV and ROV from the *G.O.Sars* is bringing UiB to the forefront in deep-marine research.

# A new Arctic vent fauna province

When the macrofauna found around hydrothermal vents was first observed in the late 1970s, researchers quickly recognised that it was composed of communities of organisms that were unprecedented and very specialized. The amazing organisms differed markedly from that found in the area surrounding the vents.

*A Melitid amphipode sampled at Loki's Castle. This is one of several new species discovered at this Arctic Mid-Ocean Ridge vent field.*

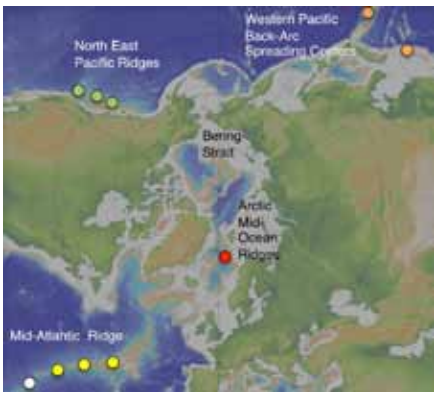
Most of the hydrothermal vents discovered thus far are found along spreading zones of mid-ocean ridges. While organisms found around the vents are related to each other as well as to organisms found in other chemically-fuelled ecosystems, such as cold seeps, whale- and wood falls, the fauna of different sites may vary greatly. For example, the fauna found at Pacific vent sites is quite distinct from that found at Atlantic sites. At Pacific vent sites large tubeworms thrive in the hot sulphur-rich water as a result of symbiosis with microorganisms that live by utilizing $CO_2$ $H_2S$. In the Atlantic Ocean clouds of shrimp swarm around black smoker vent fields - again depending on symbioses with bacteria to live in the otherwise poisonous environments.

Recently the discovery of a vent field on the East Indian Ridge revealed a vent community with a mixed Atlantic and Pacific provenance. This discovery provided support for the idea of an along-ridge migration process for vent organisms. The organisms could use active vent sites as a kind of set of stepping-stones. The stepping-stone idea and differences between different vents / chemosynthetic ecosystems offer great possibilities for studying gene flow between communities.

The nature of vent fauna in the Norwegian Sea and the Arctic Ocean has been a missing piece in the deep-sea-vent-ecology-puzzle. Along the mid-Atlantic Ridge Iceland forms an impassable physical barrier for northward along-ridge migration of benthic organisms. As the Arctic Ocean itself is relatively isolated from the rest of the world's oceans and has a high proportion of native / unique organisms in its deep waters, researchers were curious as to what the vent fauna of any vents found north of Iceland would be like.

The CGB discovery of the Loki's Castle vent field in 2008 revealed a vent fauna that is indeed different from that found further south in the Atlantic. However, they were astonished to find that some of the species found at Loki's Castle were actually more closely related to species known from vent sites in the northern Pacific than to those in the Atlantic. It thus seems most likely that the migration occurred across the Arctic from the Pacific!

CGB researchers have a unique research situation. The hydrothermal vents along the Arctic Mid-Ocean Ridge (AMOR) are relatively close geographically to another kind of chemosynthetic ecosystem; the cold seeps found on the continental margins. This makes the Arctic Ocean and the Norwegian Sea ideal for stepping-stone genomic studies.




*Map showing the location of the Loki's Castle vent field at the Arctic Mid-Ocean Ridge as well as vent fauna provinces in the Atlantic and the Pacific.*

The novelty of the Arctic vent fauna is such that CGB researchers, together with their network of national and international collaborators, have been able to propose that the AMOR is a new zoogeographical province for vent fauna. This result was published in *Nature Communications* in 2010.

# How deep does life exist?

How deep can life exist in the Earth's crust? How does it live there? What is it living on? These are some of the questions addressed by the Integrated Ocean Drilling Program (IODP). IODP is an international research program that explores the history, structure and the deep biosphere of the earth as recorded in seafloor sediments and rocks. Building on earlier similar international drilling projects, the results of this ocean basin exploration have revolutionized our view of Earth history and global processes.

CGB researchers and students are participating in this international effort. In 2010 a PhD student from CGB was on board the scientific drilling vessel *JOIDES Resolution* for IODP Expedition 329. The expedition's aim related to one of IODP's fundamental objectives – learning more about the subseafloor biosphere. During this expedition, the *JOIDES Resolution* extracted drill cores that went, not only through the seafloor sediments, but also into the first 100m or so of the underlying crust.

In October 2010, IODP Expedition 329 set out from Tahiti for a two-months expedition to the heart of the South Pacific Gyre (SPG); an area known for its low productivity. The SPG is Earth's largest system of ocean currents and it has many characteristics that make it a good choice for exploring the nature of subseafloor sedimentary communities and habitats as its center is farther from continents than the center of any other gyre. The SPG contains a continuous sweep of oceanic crust with thin (1-100 m) sedimentary cover spanning thousands of km and the seafloor under it is more than 100 million years old. In addition, its surface waters are the clearest in the world. Thus the sediments of this region have some of the lowest organic burial rates on Earth.

The SPG is therefore ideal for testing hypotheses concerning the factors that limit hydrothermal circulation and chemical habitability in aging oceanic crust. One particularly intersting hypothesis to be tested was if the deep microbial biosphere in this region is nourished to a significant extent by hydrogen produced abiotically at depth.

The 2010 expedition to the South Pacific Gyre is one of a series aimed at exploring the deep biosphere on Earth. In 2000, CGB researchers lead an IODP expedition to the Indian Ocean where DNA was extracted for the first time from the upper layer of the oceanic crust. Now, ten years later, CGB collaborators at Oregon State University have published a paper about the first investigation to find life in the deepest layer of the ocean crust – over 1km below the seafloor. This kind of research is unique because the technical demands of deep ocean drilling are so great. Their results suggest that the deep ocean crust hosts a microbial community – the Deep Biosphere - that is capable of degrading hydrocarbons as well as fixing carbon and nitrogen. The Deep Biosphere also has the potential to employ a diversity of non-oxygen electron acceptors as energy sources. What is particularly interesting about this deep microbial community is that it may be utilizing carbon sources that are produced independently of the surface biosphere.

CGB's Centre Leader was interviewed by *New Scientist* and underlined the importance of this new evidence for a deep biosphere. He pointed out that the reactions that produce hydrogen, methane and heavier hydrocarbons inside the crust could also be happening deeper down in the mantle – meaning life could be thriving even deeper!

# Constraining the age of some of Earth's most ancient traces of life

*Sampling of 3.4 billion year old pillow lavas in the Barberton Greenstone Belt.*

CGB researchers were the first to identify microbes "eating" volcanic glass from the rims of sea floor pillow lavas. It is hypothesised that the microbes involved in this process are part of the microbial community that constitutes the subseafloor biosphere.

When new pillow lava erupts onto the seafloor it cools quickly when it contacts the almost freezing water of the deep sea. The microbes colonise fractures in the newly formed glassy basalt outer rims of the pillows. Researchers speculate that perhaps there they can obtain chemical nutrients from the newly formed rock. In turn, they leave behind in the glass tunnels that may be annulated, twisted, spiral-shaped or branched.

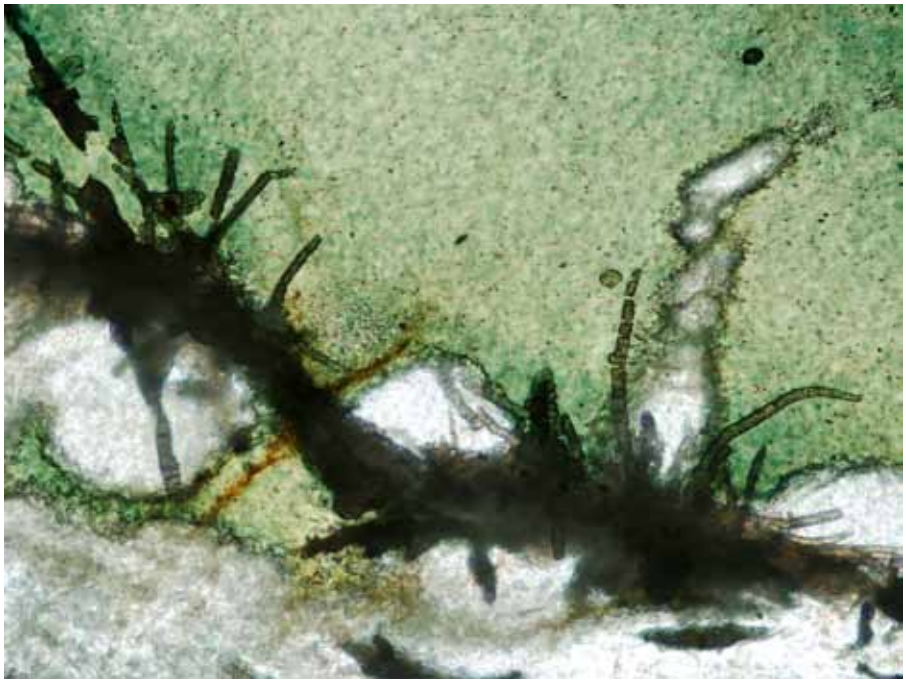
CGB researchers have recognised similar patterns – trace fossils or biosignatures – in ancient rock records. Pillow lavas that erupted onto the seafloor 3.47-3.45 billion years ago (Ga) are found in Barberton Greenstone Belt in South Africa. These are not only some of the most ancient rocks still present on Earth today, but this particular area has undergone relatively little metamorphism - geological change - in the 3 billion years since they were first formed, making them some of the best preserved examples of ancient rock.

There are no living organisms today in the tunnel traces in the ancient rock material.

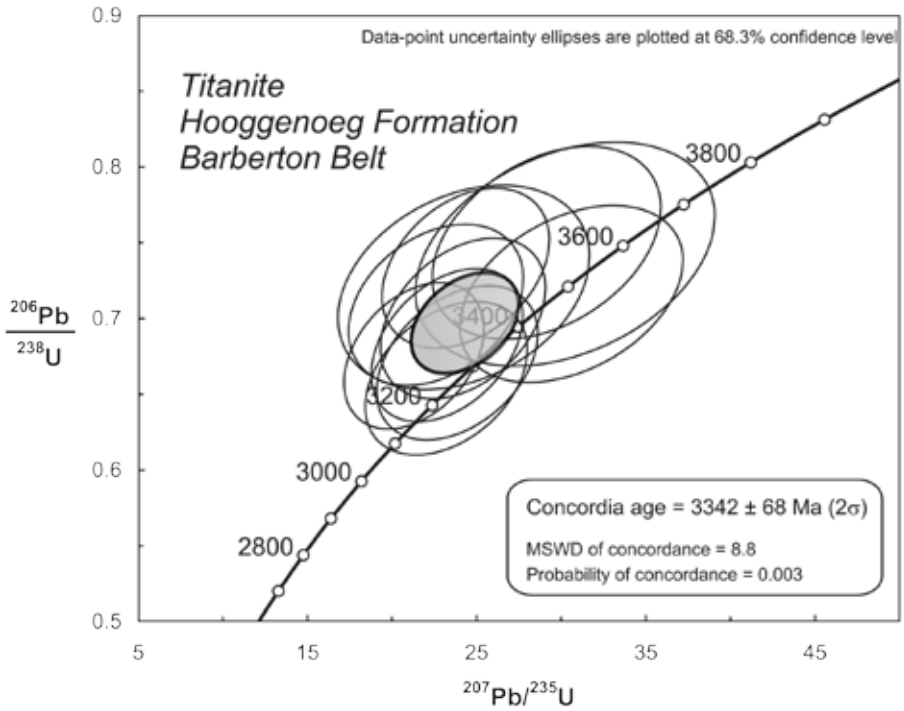
It is believed that after building the tunnels the microorganisms died out. Their organic material then decayed and left the empty tunnels behind. Over time rocks undergo metamorphic changes caused by increased pressures and temperatures. For these particular rocks, the hollow tunnels were filled with mineral material. This process is a bit like pouring plaster-of-paris into a footprint; it makes an identical cast of the shape. Titanite ($CaTiSiO_5$) is a common mineral involved in such processes. The mineral also includes some uranium (U) which decays to lead (Pb) with a half-life of several billion years.

CGB researchers have developed a microanalysis technique that measures the U/Pb ratio in the titanite precisely. They have used this technique to obtain a radiometric age for these biosignatures. Their results are important for establishing the antiquity of life on earth; they enable scientists to obtain an absolute date for the mineralisation of the biosignatures. This date can be compared to the age of the host rock. The constraints of the two dates demonstrate that the biosignatures are indeed ancient and were not formed by some much younger microorganisms that attacked the rocks at some time later during the past 3 billion years. Specifically the results of their studies showed that the age of the infilling titanite was 3.342 ±0.068 Ga. Thus the bio-alteration of the pillow lava must have occurred before this time but after the Barberton Greenstone Belt pillow lavas erupted onto the seafloor 3.47-3.45 Ga.

This work underlines the usefulness and importance of the U/Pb dating technique for determining the age of traces of life in ancient rocks. It provides further evidence that life in the subseafloor biosphere was already established on Earth by 3.342 Ga and provides more insight into the question of how life first evolved on our planet.



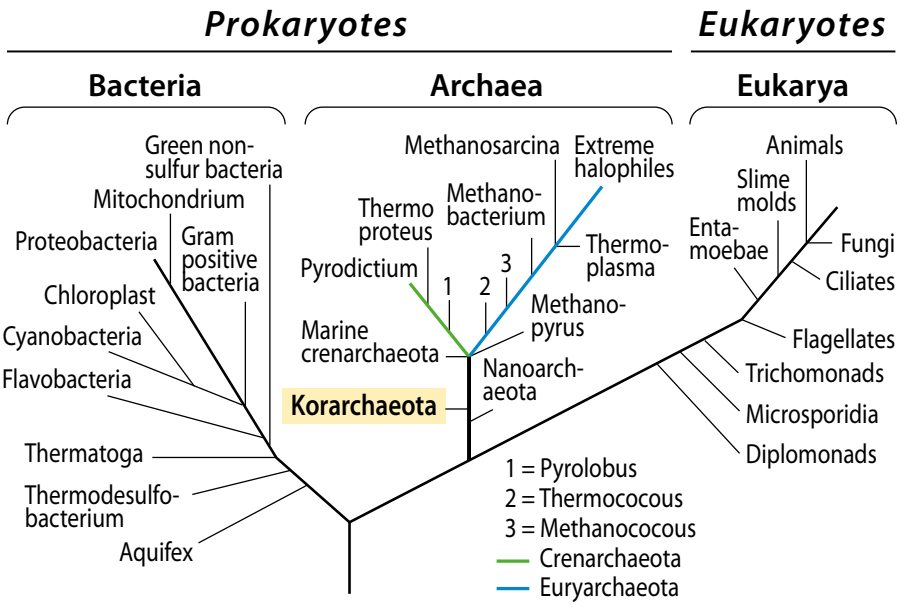
*Tubular microstructures in 3.4 billion year old lavas that are interpreted to have formed by microbial activity.*




*Graph is a U-Pb concordia diagram showing the age of the microbial trace fossils. From a paper by Fliegel et al (2010).*

# Learning more about organisms from a little-known archaeal phylum – the Korarchaeota

Identifying and characterising archaeal organisms are important activities because so little is known about this domain. The Archaea were proposed as the third domain of life in Carl Woese's "three Domains of Life" model in 1977. Although sharing characteristics with Bacteria, the Archaea possess genes and several metabolic pathways that are more closely related to those of Eukaryotes, especially in terms of the enzymes involved in the transcription and translation. Archaea were first identified in extreme environments, although today they are believed to be ubiquitous wherever microbes are found. There are today four phyla of Archaea: the Crenarchaeota, Euryarchaeota, Thaumarchaeota and Korarchaeota.




Organsims in the Korarchaeota phylum are very little characterised and are, in the tree of life, reckoned to be an ancient, deep-branching phylum of the Archaea. Only a single Korarchaeota genome is known and the genome analyses revealed a number of both Crenarchaeota- and Euryarchaeota-like features. One hint from the genome analysis is that Korarchaeota cannot exist independently – it is a scavenger and must exist in consortia with other microbes. Indications from this and previous studies show that a partner microbe they may coexist with is the bacteria *Aquificales*. It has been suggested that the *Aquificales* consume the $H_2$ produced by the Korarchaeota during their metabolism, so that an excess does not build up in the environment and inhibit growth.

Thus far the Korarchaeota have been found in extreme habitats such as terrestrial hot springs, shallow marine hydrothermal vents, hydrothermal wells, deep-sea hydrothermal vent fluids / sediments / chimneys and on the sea-floor of abyssal hills. CGB researchers undertook a specific study of the diversity, distribution and abundance of Korarchaeota in unexplored terrestrial hot spring locations on two continents. Were there differences in populations between locations and/or continents? And what about differences between marine and terrestrial populations?

Previous work had characterised Korarchaeota from a limited number of marine locations as well as from a few hot springs in Yellowstone National Park. The CGB team project involved 19 different terrestrial hot springs located on two continents: Iceland and Kamchatka in Russia. The Korarchaeota-specific primers used for the identification detected them in 12 of the 19 investigated hot springs.

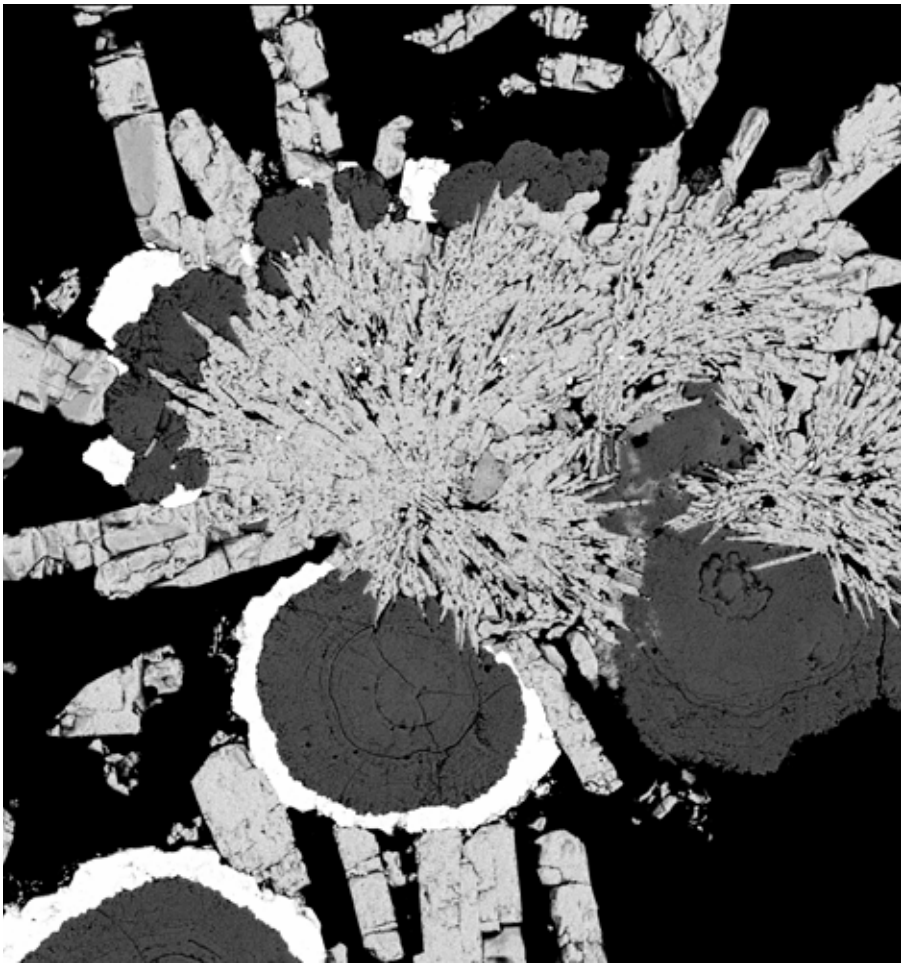
Looking at the 16S rDNA sequences, there was a clear difference between the terrestrial populations obtained in this study and the Korarchaeota previously detected in marine environments. In addition, while the similarity in the terrestrial 16S rDNA sequences was high – over 90% among the Korarchaeota representatives from these different springs – there were strong indications of a terrestrial biogeographical distribution pattern separating the Korarchaeota of Kamchatka from those from Iceland, and these again separated from those detected previously in springs of Yellowstone National Park.

The CGB results add important information to the understanding of the Korarchaeota organisms and the habitats they thrive in, in addition to providing some interesting insights into the workings of microbial communities. For example, is obligate consortia existence a characteristic feature of the most deeply branching, ancient organisms? Such information brings us one step closer to learning more about our last ancient common ancestor and the roots of life.

# Deep-Sea mineral deposits – a future resource?

As with petroleum today, copper mining was once important source of revenue for Norway. At the turn of the 19th century sulfide mining took place at many different sites in Norway; from Karmøy in the south to Sulitjelma in the north. The copper-rich ore was extracted through km-deep shafts. Communities with up to thousands of inhabitants developed around these mineral resources. Nobody at that time knew that these copper-rich ores in the Norwegian mountains had actually been formed almost 500 million years ago around black-smoker vent fields deep in an ancient ocean. The phenomenon of hydrothermal vents on the sea floor was first discovered in 1977. These hot vents not only hosted unique life forms – but they also demonstrated how mineral deposits currently form and have been forming on the seafloor for billions of years.

As a result of technology developments in the offshore oil and gas industry, it is no longer necessary to wait millions of years for sea floor to be transformed to land mass, and today it may be possible to directly mine newly discovered deep-sea mineral deposits. In addition, the costs of such deep-sea mining efforts may soon become profitable as a result of increasing metal prices. Newly established seafloor-mining companies are already beginning to explore the deep sea exclusive economic zones of Western Pacific states for mineral resources.



The CGB discoveries of vent fields along the Arctic Mid-Ocean Ridge have shown that deep-sea mineral deposits are present within the Norwegian exclusive economic zone. It is too early to determine the potential of these resources, but in a paper on the hydrothermal activity along the Arctic Mid-Ocean Ridge that was published in 2010, CGB researchers reported that unusually large mineral deposits have formed around the Loki's Castle vent field. The large mineral deposit at this site was attributed to the very slow seafloor spreading rates in the region.

In a recent views article in *Nature*, Cindy Lee Van Dover – a member of the CGB Scientific Advisory Committee – asked for tighter regulations on deep-sea mining. She argued that extracting minerals from sea-floor vents should not be allowed to go ahead without a coherent conservation framework. The deep-sea scientific community is divided on the deep-sea mining issue and some argue that even the tightest regulations would not provide sufficient protection and that the deep-sea should remain as one of the last environments on Earth not being exploited by mankind.

Mining always has environmental costs. Mining on land may have brought growth and prosperity to Norway hundred years ago, but it has also left mine tailing pollution problems that remain an environmental challenge today. CGB, in collaboration with NIVA, has received project funding to investigate the environmental consequences of these left-over mine tailings in Norwegian fjords – providing yet another example of how the analytical procedures developed in basic research projects can be applied to societally and industrially relevant issues.

*Lead, silver, zinc, antimony, and barium minerals from the Soria Moria vent field.*

# Research themes

The research at Centre for Geobiology is focused on five themes. Below is an update on the research carried out under these themes in 2010.

**GEODYNAMICS OF THE DEEP SEAFLOOR**

This theme involves deep-sea exploration and the search for new extreme environments. It therefore provides a foundation for the Centre's geobiological research. In addition it has several independent research objectives relating to hydrothermal systems, seabed fluid flow and the geodynamics of spreading ridges.

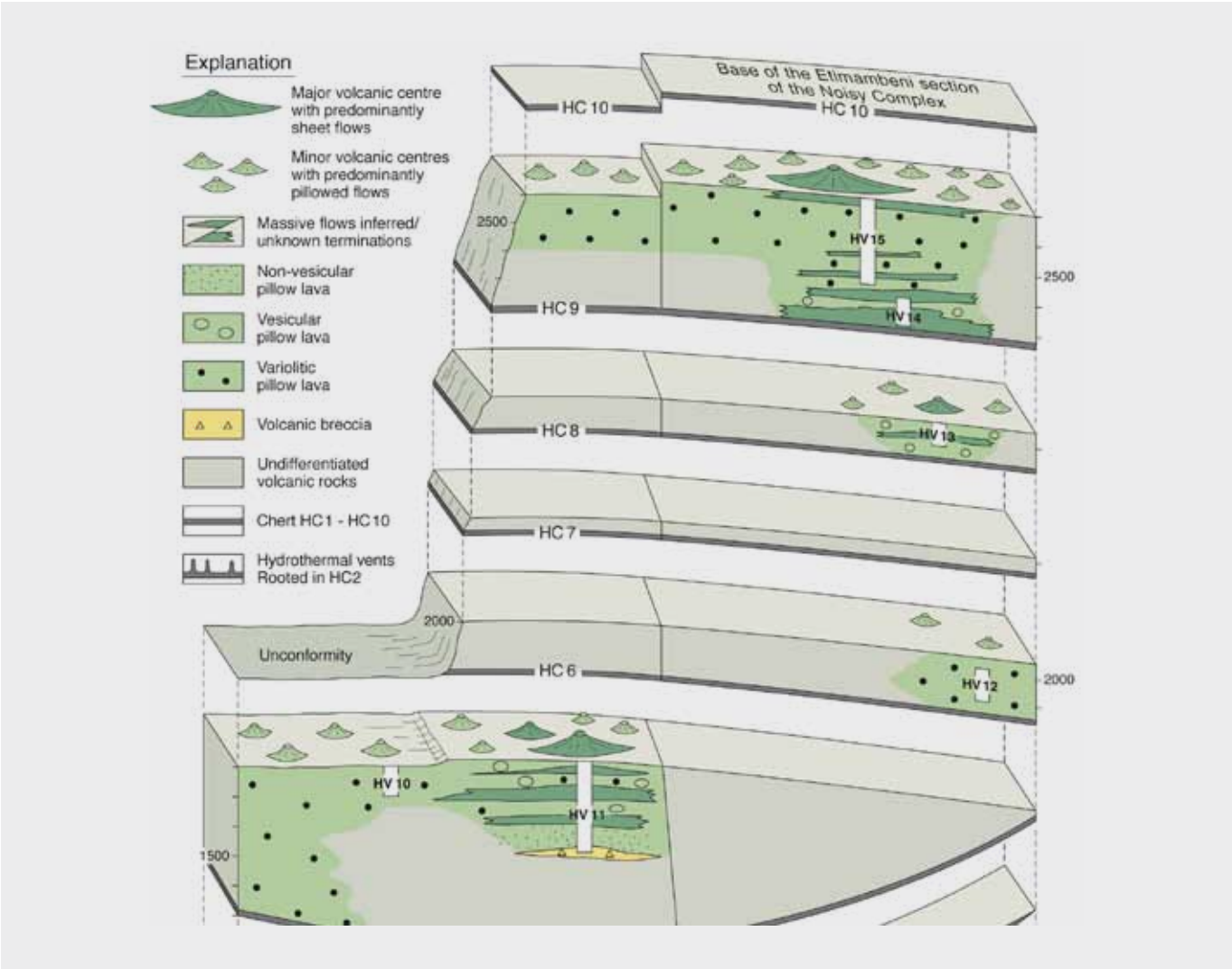
In 2010 research was focused on the Loki's Castle vent field. An AUV was used to map the vent field and the volcanic area around it in great detail (see "Exploring the deep-sea with autonomous vehicles"). The field hosts one of the largest metal-sulphide deposits yet located in the deep sea. This discovery shows hydrothermal venting along the Arctic Mid-Ocean Ridge (AMOR) is more abundant than previously believed and that, as a result, mineral deposits of significant size may be present within the Norwegian Exclusive Economic Zone (EEZ). This and other findings have been important for giving the international research community new understanding about the diversity and extent of venting along the most slowly spreading parts of the global spreading ridge system.

The research activities in this area increased this year as a result of a new collaborative international project focusing on ridge-plume interaction and the evolution of the Icelandic hot-spot.

**ROCK-WATER-MICROBE INTERACTIONS & THE DEEP BIOSPHERE**

In this theme researchers have considered various aspects of rock-water-microbe interactions and have delved into the deep biosphere. They have undertaken culturing experiments and microbial diversity analyses to study microbial activity during the formation of low-temperature hydrothermal iron and barite. They have combined this with architectural, microtextural and geochemical analyses as well as with iron and sulphur isotope studies. The results have provided information about suitable biosignatures for detecting traces of life biosignatures, in modern and ancient hydrothermal deposits, including jasper, banded iron formations, and stromatolites.

Through laboratory experiments and geochemical modelling researchers have



studied the formation of inorganic energy sources for subsurface microbial life. They have also studied subsurface microbial communities utilizing hydrogen in both drill cores and in situ experiments in peridotites within an ophiolite complex.

Studies of microbial colonization and alteration of young seafloor basalt indicate that: 1) the number of cells found in basalt is significantly higher than that found in deep seawater, 2) fossilization of the microbial cells results in the accumulation of organic carbon, and 3) microbial growth and biomineralisation are major controls on the porosity and texture of the altered basalt and thus likely to impact the chemical exchange between basalt and seawater in general.

In their work focusing on the hydrothermal subseafloor basaltic environment, they have isolated and characterised a novel thermophilic and lithoautotrophic archaeon. This increases our understanding of the deep endolithic biosphere in the basaltic ocean crust.

**LIFE IN EXTREME ENVIRONMENTS AND ROOTS OF LIFE**

The holistic "eco-systems biology" approach that researchers in this theme have developed, involving metatranscriptomic and metaproteogenomic tools, gives them a previously unachievable insight into the diversity, structure-function relationships and adaptive features of microorganisms living in the extreme environments of CGB's natural laboratories, such as hydrothermal vent and cold seep ecosystems. This approach also allows them to identify the expression of key enzymes for redox reactions and metabolic pathways in these environments as well as being able to assign functions to specific taxonomic groups.

Researchers in this theme have used this approach to study samples from a number of "extreme" environments. Aspects of this approach have provided information about the abundance, diversity and biogeography of members of the deeply branching archaean kingdom Korarchaeota, isolated from hot springs on Iceland and in Kamchatka, Russia. It has enabled them to generate the first insights into the microbial assemblages dominating CGB's natural laboratories, identifying subsurface ecosystems enriched in potentially deeply branching microbial lineages. They have learned that the ecosystem in thermophilic springs on Svalbard, a site considered to be a terrestrial analogue of the Martian subsurface habitat, is driven by chemolithoautotrophic sulphur-oxidizers. They have also discovered that the microbial mats found around Loki's Castle vents are dominated by a low number of microbial species including sulphur-oxidizers, methane-oxidizers, methanogens as well as thermophilic fermentative or sulphate-reducing bacteria.

**VENT AND SEEP BIOTA**

This theme involves the exploration of fauna associated with reduced habitats in the deep sea in the Arctic and NE Atlantic. There has been great international interest about what an Arctic vent fauna would be like. It has been shown this year that for the Jan Mayen vent fields the fauna is mainly composed of shallow- and bathyal species from the surrounding waters with only a few examples of species adapted to reduced habitats. These fields are located at the southern edge of the Arctic, and are in relatively shallow waters.

However, the results show that the fauna around Loki's Castle, the Arctic deep-water black smoker vent field that CGB discovered in 2008, is strikingly different. Here is a locally derived and vent-adapted fauna which is unique in species and species composition when compared to other known vent sites.

Loki's Castle's vent fauna also shares obvious similarities to the fauna of cold seeps along the Norwegian margin and wood-falls in the abyssal Norwegian Sea, and there are also very clear indications that there has been a migration of vent fauna into the Arctic Ocean from the Pacific Ocean rather than from the known vent sites further south in the Atlantic Ocean. In addition, all major fauna elements (including polychaetes, gastropods, amphipods and fish) seem to be specially adapted to the extreme conditions in this environment and most of them harbour symbiotic microorganisms. As a result the CGB scientists have been able to propose that the AMOR is a new zoogeographical province for vent fauna.

**EARLY EARTH AND BIOSIGNATURES:**

This theme involves research on some of the oldest rock sequences on Earth. A major focus is the interaction of microorganisms with submarine glassy lavas that was basically unknown 20 years ago. It was first described and modelled by CGB scientists. Current studies of traces of colonization by microorganisms in ancient greenstone belt pillow lavas show that many exhibit textural traces or biosignatures. Moreover, researchers in this theme have been able to confirm the antiquity and endogenicity of these traces by developing a radiometric dating technique that shows these traces are indeed Archean in age. They are now developing new textural, morphological and geochemical evidence to further test their biogenicity of the traces.

The archiving of the 3.4 km long Far-DEEP core is an on-going activity for CGB researchers. The core intersects rocks that span 2.5-2.0 Ga. This is the interval of time when the Earth's atmosphere became oxygenated. Current studies are investigating causes and effects of the oxygenation event by analysing heavy stable isotope composition (Fe, Cu, Cr isotopes), as well as by studying the massive accumulation of organic material found in the core using Raman spectroscopy and stable isotope analyses.

# Organisation


| | RESEARCH THEME 1 | RESEARCH THEME 2 | RESEARCH THEME 3 | RESEARCH THEME 4 | RESEARCH THEME 5 | RESEARCH LABS | MARINE LABS |
|---|---|---|---|---|---|---|---|
| PROJECT A | X | | X | X | | X | |
| PROJECT B | | X | X | X | | X | |
| PROJECT C | | | | | X | | X |
| PROJECT D | X | | X | X | X | | |
| PROJECT E | X | X | X | X | X | X | |

# Centre Projects

The Centre Project initiative continued successfully in 2010. The following projects were continued from 2009:

- Diversity and functioning of archaea in marine methane enriched sediments
- Adaptations of *Archaeoglobus* species to environmental changes
- Biomineralisation and biosignatures: iron hydroxides, carbonates and barite deposits
- Water-mineral/rock reactions and hydrogen formation
- Whalefalls – phase 2
- Phylogeography of Vent, Seep and Fall Fauna
- Macrofauna on hydrothermal vents and cold seeps in the northernmost Atlantic ocean II
- The Macrofauna of the Schulz massive, North Atlantic (73° N) – phase II
- CGB Barberton Scientific Drilling Programme
- Search for a new novel vent field at the Knipovich Ridge

**THE FOLLOWING PROJECTS WERE NEW IN 2010:**

- In-situ analytical techniques in Geobiology
- Stable isotope fractionation of Sr by marine organisms
- Is methane oxidation an ancient metabolic trait?
- Diversity and quantification of key functional genes involved in biogeochemical cycles
- Microbial communities associated with hydrothermal systems at the Arctic Mid-Ocean Ridge
- Ecophysiology of extreme microbial communities

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.

The Centre is organised in a matrix model 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 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.

**SCIENTIFIC ADVISORY COMMITTEE**

| | |
|---|---|
| Antje Boetius | Max-Planck-Institut für Marine Mikrobiologie, Bremen Germany |
| 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 |

**THE GOVERNING BOARD**

| | |
|---|---|
| Geir Anton Johansen | (leader)( Previous Vice Dean 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 |

# Research Projects

## PROJECTS FUNDED BY THE RESEARCH COUNCIL OF NORWAY

| DURATION | TITLE | LEADER*/PARTNER** |
|---|---|---|
| 2006 – 2010 | Funcional Metagenomics to Study Prokaryotes from Arctic/Sub-arctic Springs of Hydrothermal Origin | Christa Schleper* |
| 2007 – 2010 | Hidden reservoirs of Biological diversity – geobiology of unexplored endolithic communities associated with lichens | Torbjørg Bjelland* |
| 2007 – 2010 | "SylfoSYS" Silicon cell model for the central carbohydrate metabolism of the archaeon *Sulfolobus solfataricus* under temperature variation. | Christa Schleper* |
| 2007 – 2010 | Metagenomics and gene discovery in Antarctic terrestrial habitats. | Nils-Kåre Birkeland* |
| 2009 – 2010 | "NOON" Pre-project for Cable-based Ocean Observatory | Rolf Birger Pedersen** |
| 2009 – 2012 | "FarDeep" The Emergence of an Aerobic World – Drilling Early Earth Project | Victor Melezhik* |
| 2009 – 2017 | "SUCCESS" Subsurfac $CO_2$ storage – Critical Elements and Superior Strategy | Rolf Birger Pedersen**/ Ingunn H Thorseth** |
| 2010 – 2013 | Hotspot Rift Interaction & Geochemistry of the North Atlantic Mantle: the Aegir Ridge 'Hole' in the Iceland Hotspot | Rolf Birger Pedersen** |
| 2010 – 2011 | Leiv Eriksson sabbatical / travel | Christoffer Schander* |

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

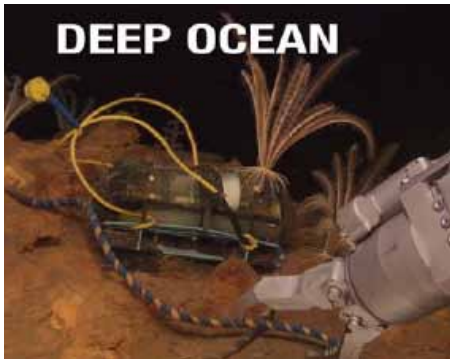
| DURATION | TITLE | COORDINATOR*/ PRINCIPAL INVESTIGATOR**/COLLABORATOR*** | PROGRAMME |
|---|---|---|---|
| 2007 – 2010 | "SylfoSYS" Silicon cell model for the central carbohydrate metabolism of thearchaeon Sulfolobus solfataricus under temperature variation. International consortium of 10 groups.<br>**WP1:** Fermentation/Perturbation Christa Schleper***<br>**WP2:** Biochemistry Nils Kåre Birkeland***<br>**WP3:** Transcriptomics /Metabolomics/ Proteomics/Comp. Genomics Christa Schleper*** | Christa Schleper* (Main Coordinator) | Era-Net/SysMO |
| 2008 – 2011 | "H2DEEP" Ultra-slow spreading and hydrogen-based biosphere: A site survey proposal for zero-age drilling of the Knipovich Ridge.<br>**Project 1:** The Magmatic, Tectonic and Hydrothermal Architecture of the Southern Knipovich Ridge: Geophysical Survey and Geological/ Geomicrobiological sampling. Rolf Birger Pedersen **/ Rolf Mjelde **/ Ingunn H. Thorseth **<br>**Project 2:** Core complex formation and evolution: Geodynamic synthesis, Knipovich Ridge Javier Escartin **/ Rolf Birger Pedersen **<br>**Project 3:** Linking Hydrothermal Alteration, Serpentinization, and Fluid Fluxes to Biological Niches at the Knipovich Ridge Gretchen Früh-Green **/ Ingunn Thorseth **<br>**Project 4:** Sulfide Petrology, Ore Genesis and the Deep Biosphere at Knipovich Ridge Fernando Barriga **/Rolf Birger Pedersen ***/ Ingunn Thorseth***<br>**Project 5:** Geomicrobiology: microbial communities and processes associated with basement alteration at the ultraslow spreading Knipovich Ridge Ingunn H, Thorseth **/ Rolf Birger Pedersen | Rolf Birger Pedersen* (Main Coordinator) | ESF/ EuroMARC (EUROCORES)/NFR |

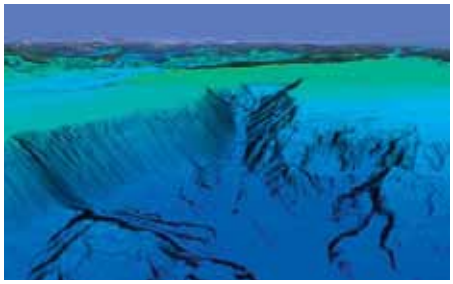
| | | | |
|---|---|---|---|
| 2010 - 2012 | "CryoCARB" Long-term Carbon Storage in Cryoturbated Arctic Soils<br>Individual project 5: High-resolution Microbial Community Structure<br>Christa Schleper**/ Vigdis Torsvik***/ Tim Urich*** | Christa Schleper* | ESF/ PolarCLIMATE/NFR |
| 2010 - 2013 | "MicVirEcolHotSprings" Microbial and viral ecology of hot spring environments with emphasis on 454 pyrosequencing and microbial and viral interactions | Lise Øvreås, Ruth-Anne Sandaa | EU/Marine Curie/ International Outgoing Fellowships for Career Development |

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

| DURATION | TITLE | LEADER*/PARTNER** |
|---|---|---|
| 2007 - 2011 | Biotechnology and microbial diversity of Ethiopian soda lakes | Lise Øvreås* SIU |
| 2009 - 2011 | Preparing for sub-sea storage of $CO_2$ | Rolf Birger Pedersen** Gassnova |
| 2009 - 2012 | Direct dating of diagenic processes by in-situ analysis of U-Th-Pb isotopes in authigenic phosphate minerals by laser ablation ICP-MS | Jan Kosler* Statoil |
| 2009 - 2012 | Metagenomics and metaproteomics of deep arctic hydrothermal systems | Ida Helene Steen* VISTA |
| 2009 - 2012 | Subsurface metagenomics, functional microbial diversity analysis and gene discovery in deep and hot petroleum reservoirs | Nils Kåre Birkeland* VISTA |
| 2010 - 2015 | Earth System Modelling | Jan Kosler**, Bjarte Hannisdal**, Jiri Slama** Statoil |
| 2010 - 2012 | De Novo sequencing of iron oxidising bacteria through reconstruction of microbial genomes from iron hydroxide deposits at the Arctic deep seafloor | Lise Øvreås*, Meltzer Høyskolefond |
| 2009 - 2010 | Workshop on identification of vent, seep and seamount fauna | Christoffer Schander* Videnskapsakademiet |
| 2010 - 2011 | The Emergence of Life on Earth 3+ billion years ago | Nicola McLoughlin, UiB-Friforsk |
| 2010 | Researcher support (Daniel Fliegel) | Harald Furnes, University of Alberta |
| 2008 - 2010 | SONGRAM Sponge Risk Assessment and Monitoring | Hans Tore Rapp* NDP/ StatoilHydro |
| 2009 - 2010 | Deep water sponges in the GIN Seas - workshop and project | Hans Tore Rapp* Videnskapsakademiet |

# Workshops and short courses


The past year has been an active one for CGB researchers in terms of conference activity. They have been involved in over 100 scientific conference proceedings and have, in addition, been invited or even keynote speakers over 30 times.

In spring 2010 Ida Helene Steen was on the organising committee for the Norwegian Geological Union's "Arctic Conference Days: the Deep Ocean". In addition to chairing two sessions, CGB researchers were involved in 15 presentations or posters at the conference. CGB also had a strong presence at this year's annual American Geophysical Union meeting in December 2010 where they gave nearly 20 presentations or posters and the Centre Leader was responsible for organising a session entitled: Deep-sea Hydrothermal Systems – New knowledge for new discoveries and new technology.

In addition, CGB researchers have organised a number of workshops and short courses at the Centre or at the University of Bergen (UiB) including:

- participation in a workshop at GEO on quantifying gas accumulations and hydrates and assessing their response on sediments and biota
- a short course on Raman-spectroscopy
- a workshop on macrofauna associated with Arctic hydrothermal vents and seamounts
- a short course in extracting ecological signal from noise providing an overview of tools for the analysis of high throughput sequencing data from microbial communities
- a short course in Phylogeny/ARB Training software tools (used in the classification and phylogenetic analysis of sequence data)

# Public Outreach

From the start CGB researchers have been committed to public-oriented dissemination activities. This effort has continued in 2010 with nearly a dozen popular science articles published and over 20 media appearances (newspaper, radio or TV).

The most visible public outreach activity of 2010 was the release of the Discovery Channel's episode featuring the *G.O.Sars* and Centre researchers. A link to the one-hour feature can be found online:

Discovery Channel's web site: Discovery Channel Mighty Ships Series G.O. Sars

http://www.discoverychannel.ca/Showpage.aspx?sid=13057

Download: Discovery Channel Mighty Ships GO Sars HDTV XviD-TERRA

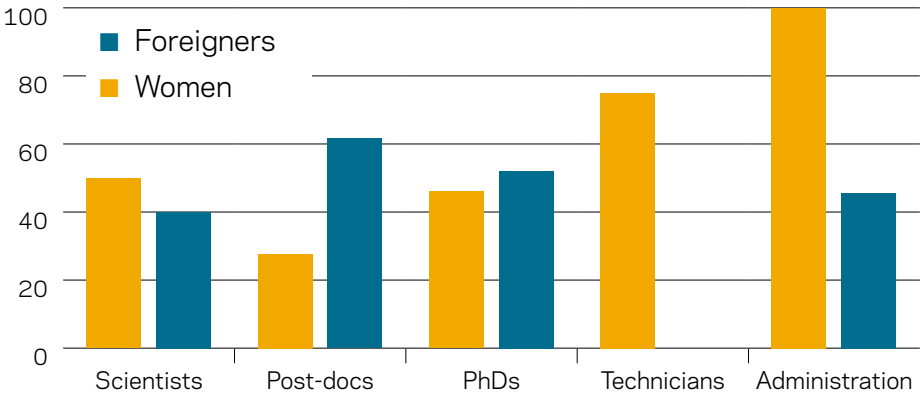
http://www.torrentdownloads.net/torrent/1652449150/Discovery+Channel+Mighty+Ships+GO+Sars+HDTV+XviD-TERRA+-+%7B+%7D

# Staff

PERSONNEL IN %

- 27% Scientists
- 24% Post-docs
- 30% PhDs
- 14% Technicians
- 4% Administration

## % PERSON-YEAR




## PERSONNEL SUMMARY

| CATEGORY | PERSON-YEARS | FOREIGNERS (%PERSON-YEAR) | WOMEN (%PERSON-YEAR) |
|---|---|---|---|
| Scientists | 9.8 | 40 | 47 |
| Post-docs | 8.8 | 61 | 30 |
| PhDs | 10.8 | 52 | 46 |
| Technicians | 5.2 | 0 | 75 |
| Administration | 1.5 | 47 | 100 |
| Total | 36.1 | 43 | 49 |

## Scientists

Birkeland, Nils Kåre
Bjelland, Torbjørg
Furnes, Harald
Hannisdal, Bjarte
Hovland, Martin
Kelly, Debbie
Kosler, Jan
McLoughlin, Nicola
Melezhik, Victor
Pedersen, Rolf Birger
Rapp, Hans Tore
Reigstad, Laila
Schander, Christoffer
Schleper, Christa
Schoenberg, Ronny
Steen, Ida Helene
Thorseth, Ingunn H.
Torsvik, Vigdis
Urich, Tim
van Zuilen, Mark
Øvreås, Lise

## Post-docs

Bjelland, Torbjørg
Dahle, Håkon
Drost, Kerstin
Eickmann, Benjamin
Garcia-Moyano, Antonio
Hannisdal, Bjarte
Huang, Shanshan
Keen, T. Jeffrey
Slama, Jiri
Stokke, Runar

# Funding and expenses

CGB FUNDING (1000 NOK)

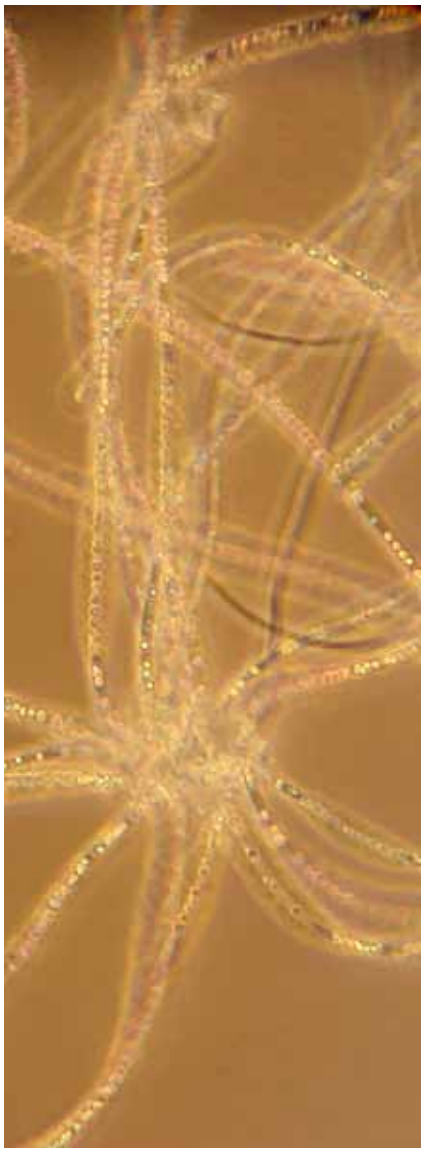
- Research Council of Norway - 10812
- University of Bergen - 18650

CGB EXPENSES (1000 NOK)

- Salaries and indirect costs
- Research equipment
- External research services
- Other costs

## FUNDING AND EXPENSES

| **FUNDING** (1000 NOK) | | **EXPENSES** (1000 NOK) | |
|---|---|---|---|
| Research Council of Norway | 10812 | Salaries and indirect costs | 19195 |
| University of Bergen | 18650 | Research equipment | 4035 |
| Total funding | 29462 | External research services | 1121 |
| | | Other costs | 3660 |
| | | Total expenses | 28011 |



## PhDs

Bengtson, Mia
Cárdenas, Paco
Flesland, Kristin
Grosch, Eugene
Hansen, Heidi
Hocking, William
Jørgensen, Steffen Leth
Landschulze, Karin
Lanzén, Anders
Möller, Kirsten
Olsen, Bernt Rydland
Roalkvam, Irene
Steinsbu, Bjørn Olav
Yuangao, Qu
Økland, Ingeborg

## Technical staff

Almelid, Hildegunn
Daae, Frida Lise
Gjerlöw, Eirik
Fossdal, Renata
Hoem, Solveig
Hjort Dundas, Siv
Norheim, Marianne
Ronen, Yuval
Tumyr, Ole

## Administration

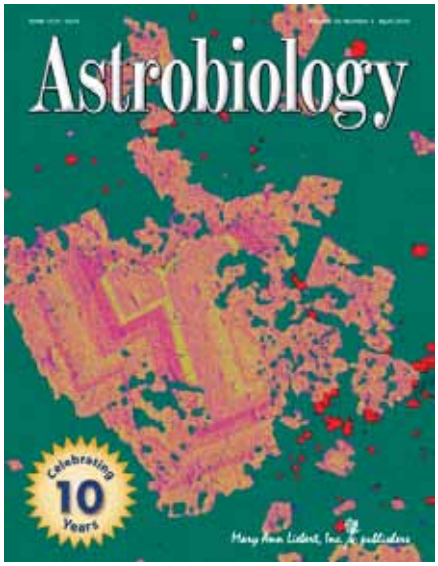
Bartle, Elinor
Fjellbirkeland, Anne

# Selected Publications

In 2010 CGB researchers and students published 93 papers in peer-reviewed journals and 104 conference proceedings. A full list of publications can be found on the CGB website: www.uib.no/geobio/en.

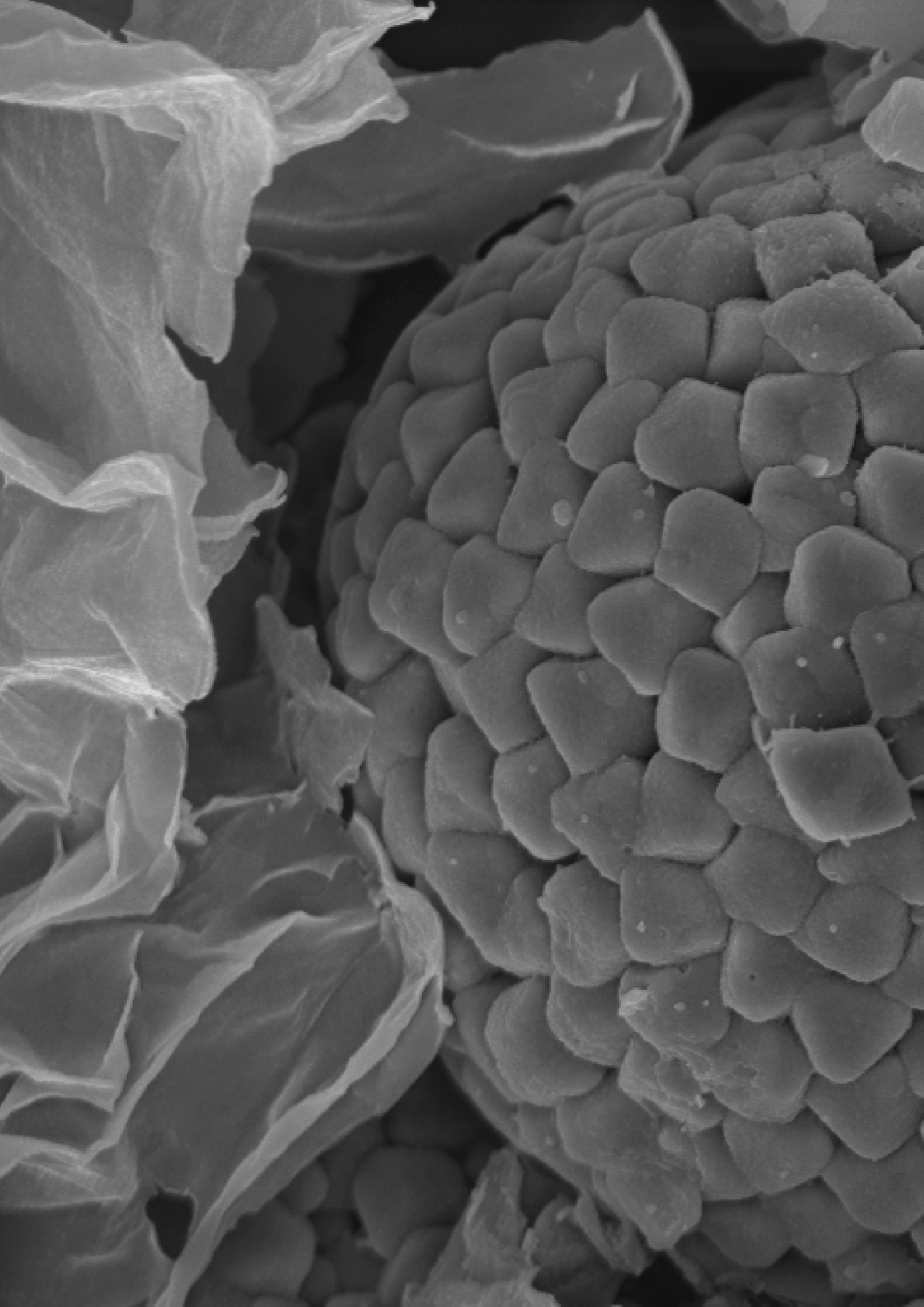
Below is a list of some selected publications:

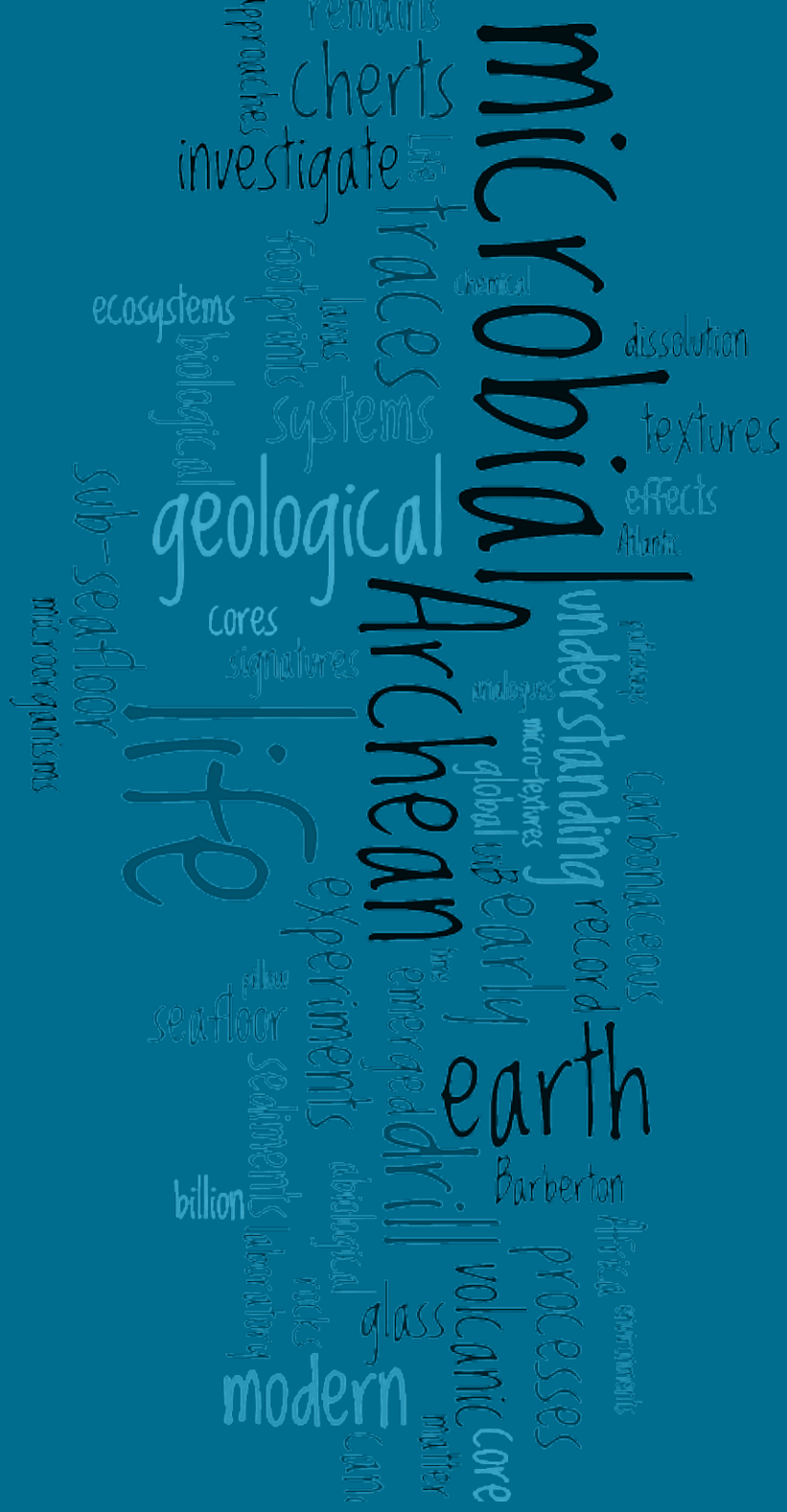

1. **Bjelland T**, Grube M, **Hoem S, Jørgensen SL, Daae FL, Thorseth IH, Øvreås L** (2010). Microbial metacommunities in the lichen-rock habitat. Environ. Microbiol. Reports doi:10.1111/j.1758-2229.2010.00206.x.
2. **Fliegel D, Kosler J, McLoughlin N**, Simonetti A, de Wit MJ, Wirth R, **Furnes H** (2010). In situ dating of earth's oldest trace fossil at 3.34 Ga. Earth and Planetary Science Letters: 299: 290-298
3. **Hannisdal B**, Peters SE (2010). On the Relationship between Macrostratigraphy and Geological Processes: Quantitative Information Capture and Sampling Robustness. Journal of Geology 118:111-130.
4. **Hovland M**, Heggland R, De Vries MH, Tjelta TI (2010). Unit-pockmarks and their potential significance for predicting fluid flow. Marine and Petroleum Geology 27:1190-1199.
5. **Huang S**, Lopez-Capel E, Manning DAC, Rickard D (2010). The composition of nanoparticulate nickel sulfide. Chemical Geology, 277, 207-213.
6. **Kandilarov A,** Landa H, Mjelde R, **Pedersen RB**, Okino K, Murai Y (2010). Crustal structure of the ultra-slow spreading Knipovich Ridge, North Atlantic, along a presumed magmatic portion of oceanic crustal formation. Marine Geophysical Research. Volume 31, Issue 3 (2010), Page 173. DOI 10.1007/s11001-010-9095-8.
7. Lepland A, **van Zuilen MA**, and Philippot P. 2010. Fluid deposited graphite and its geobiological implications in early Archean Gneiss from Akilia, Greenland. Geobiology in press (published online 12/11/10).
8. **McLoughlin N**, Staudigel H, **Furnes H, Eickmann B**, Ivarsson M (2010). Mechanisms of microtunneling in rock substrates: distinguishing endolithic biosignatures from abiotic microtunnels. Geobiology 8:245-255.
9. **Melezhik VA**, Fallick AE (2010). On the Lomagundi-Jatuli carbon isotopic event: The evidence from the Kalix Greenstone Belt, Sweden. Precambrian Research 179:165-190.
10. **Pedersen RB, Rapp HT, Thorseth IH,** Lilley M, Barriga F**, Baumberger T,** Bernasconi-Green G**, Flesland K,** Fonseca R**, Jørgensen SL.** (2010). Discovery of a black smoker vent field and a novel vent fauna at the Arctic Mid-Ocean Ridge. Nature Comm. 1:126 doi: 10.1038/ncomms1124.
11. **Pedersen RB, Thorseth IH,** Nygård TE, Lilley MD & **Kelley DS.** 2010. Hydrothermal activity at the Arctic mid-ocean ridges, in Diversity of Hydrothermal Systems on Slow Spreading Ocean Ridges, Geophys. Monogr. Ser., vol. 188, edited by P. A. Rona et al., pp. 67--89, AGU, Washington, D. C.
12. **Reigstad LJ, Jorgensen SL, Schleper C** (2010). Diversity and abundance of Korarchaeota in terrestrial hot springs of Iceland and Kamchatka. ISME Journal 4:346-356.
13. **Schander C, Rapp HT**, Halanych K, Kongsrud JA, Sneli J-A (2010). A case of co-occurrence between a *Sclerolinum pogonophoran* (Siboglinidae, Annelida) and *Xylophaga* (Bivalvia) from a Northeast Atlantic wood-fall. Marine Biodiversity Records. doi:10.1017/S1755267210000394.



14. **Schander C, Rapp HT**, Kongsrud JA, Bakken T, Berge J, Cochrane S, Oug E, Byrkjedal I, Todt C, Cedhagen T, Fosshagen A, Gebruk A, Larsen K, Levin L, Obst M, Pleijel F, Stohr S, Waren A, Mikkelsen NT, Hadler-Jacobsen S, Keuning R, Petersen KH, **Thorseth IH, Pedersen RB** (2010). The fauna of hydrothermal vents on the Mohn Ridge (North Atlantic). Marine Biology Research 6:155-171.
15. **Schleper C** (2010). Ammonia oxidation: different niches for bacteria and archaea? ISME Journal 4:1092-1094.
16. **Steinsbu BO, Thorseth IH,** Nakagawa S, Inagaki F, Lever MA, Engelen B, **Øvreås L, Pedersen RB**. 2010. *Archaeoglobus sulfaticallidus* sp. nov., a novel thermophilic and facultatively lithoautotrophic sulfate-reducer isolated from black rust exposed to hot ridge flank crustal fluids. International Journal of Systematic and Evolutionary Microbiology, 60, 2745–2752.
17. Wacey D, **McLoughlin N,** Whitehouse MJ, Kilburn MR (2010). Two co-existing sulfur metabolisms in a ca 3,400 Ma sandstone. Geology 38, 1115-1118.



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