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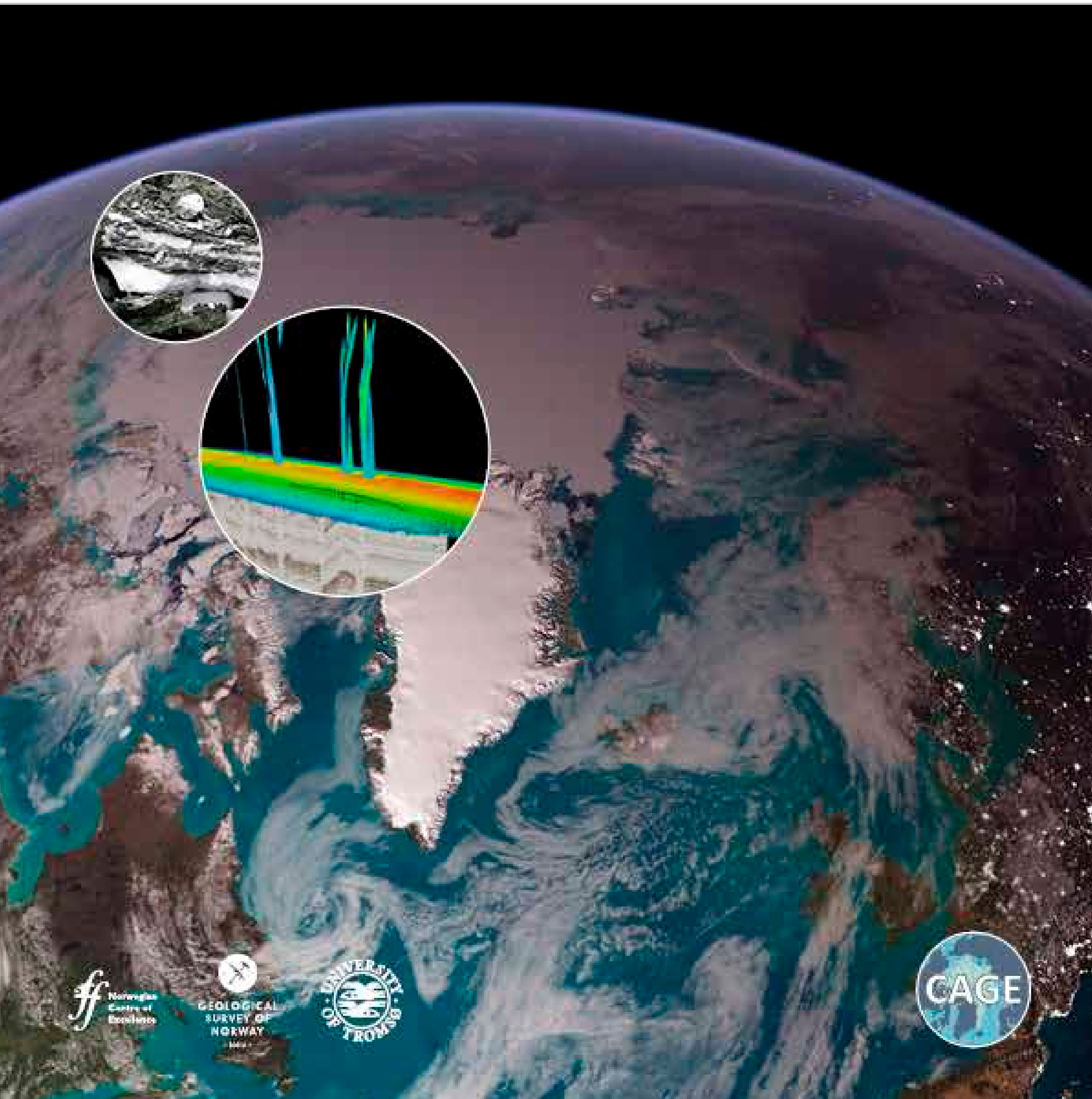
UiT
THE ARCTIC
UNIVERSITY
OF NORWAY

CAGE – Centre for Arctic Gas Hydrate, Environment and Climate

Annual report 2014



Professor Jürgen Mienert on board UiT's research vessel Helmer Hanssen. Photo: Torger Grytå

A word from the director

CAGE studies sub-seabed methane hydrates and related greenhouse gas release processes in Arctic environments. Enormous amounts of methane hydrate, an ice-like substance, exist in the ocean floor at high pressure and low temperature. Ocean warming makes it potentially vulnerable to melting. We know that methane released in this way acted as a powerful greenhouse gas accelerating climate warming in the geological past. *We aim to examine what it could mean to our future.*

Our internationally recognized work was awarded Norwegian Centre of Excellence in 2013, giving us significant funding from the Norwegian Research Council for 10 years. This allows us to build a long-term strategy within Arctic marine science.

Our field stretches over vast geographic distances in the Arctic: from the Kara Sea in the East, via the Barents Sea, to the Norwegian sector of the Arctic Ocean. CAGE teams focusing on the biogeochemistry and benthic biology of methane seeps choose from several dynamic systems to document sources and sinks of methane, including future impact on the environment.

CAGE reached a full operational phase, and made major investments in lab and ocean observatory infrastructure, where one high-tech system is already under development by Kongsberg Maritime.

Scientific highlights

Our campaigns on the *R/V Helmer Hanssen* were very successful in 2014. We have among seafloor and ocean research activities effectively coordinated shipboard surveys and aircraft campaigns.

We have made new discoveries on almost every expedition.

Observations on various scales make it possible for us to do a systematic study of methane sources and sinks from the sub-seafloor to the surface of the ocean as well as through time. A 4-D understanding of the link between gas hydrate, fluid flow, and environmental change is one of our primary missions. Key achievements over the last year are the inclusion of biogeochemical modeling and microbiological studies.

Current scientific results show a large diversity in the flux of methane that reaches the ocean surface. CAGE is obtaining geophysical measurements from beneath the seafloor to quantify the amount of methane hydrate. Oceanographic and geochemical measurements from within ocean water masses help us to quantify the amount of methane released from hydrate and distributed in the ocean. We are studying how active methane release sites, at the vast regions of shallow Arctic shelves, affect the atmosphere.

Training and cooperation

We have reached a high value of training at sea for our PhD students. We are leading a research school, Arctic Marine Geology and Geophysics, which is a part of The Norwegian Research School in Climate Dynamics.

International collaboration is of great importance for CAGE. We have initiated projects in 2014 with many other distinguished national marine research establishments, and international marine institutions such as the Woods Hole Oceanographic Institution, USA. Other collaborations allowed for cooperation with several EU funded projects adding to our expertise. Such as Marine Gas Hydrates: An indigenous resource of natural gas (GEOMAR).

Recruitment

We have already grown beyond the initial plan of 40 positions including international collaborations. All of the offices have been established and we have recruited a significant part of laboratory engineers, scientific staff, and PhD students.

Combining the growing number of field observations into groundbreaking advances of Earth and Environmental Sciences, and developing hypotheses-driven integrated research plans is a priority for the CAGE leadership and our young research team.

The enthusiasm and dedication of our staff makes us confident that our ideas will influence the approach to climate challenges in the Arctic Ocean in the future.

Professor Jürgen Mienert
Centre Director

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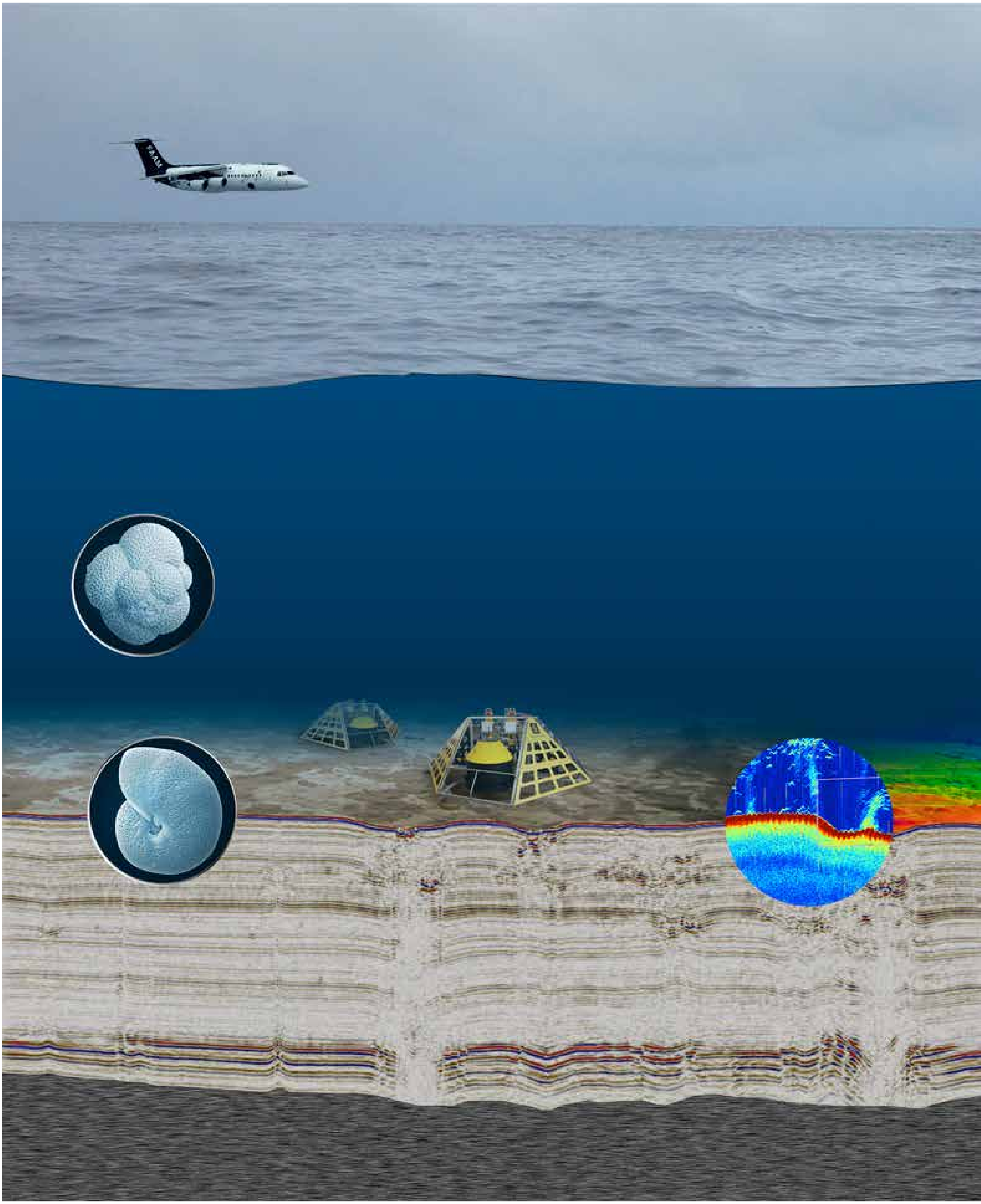
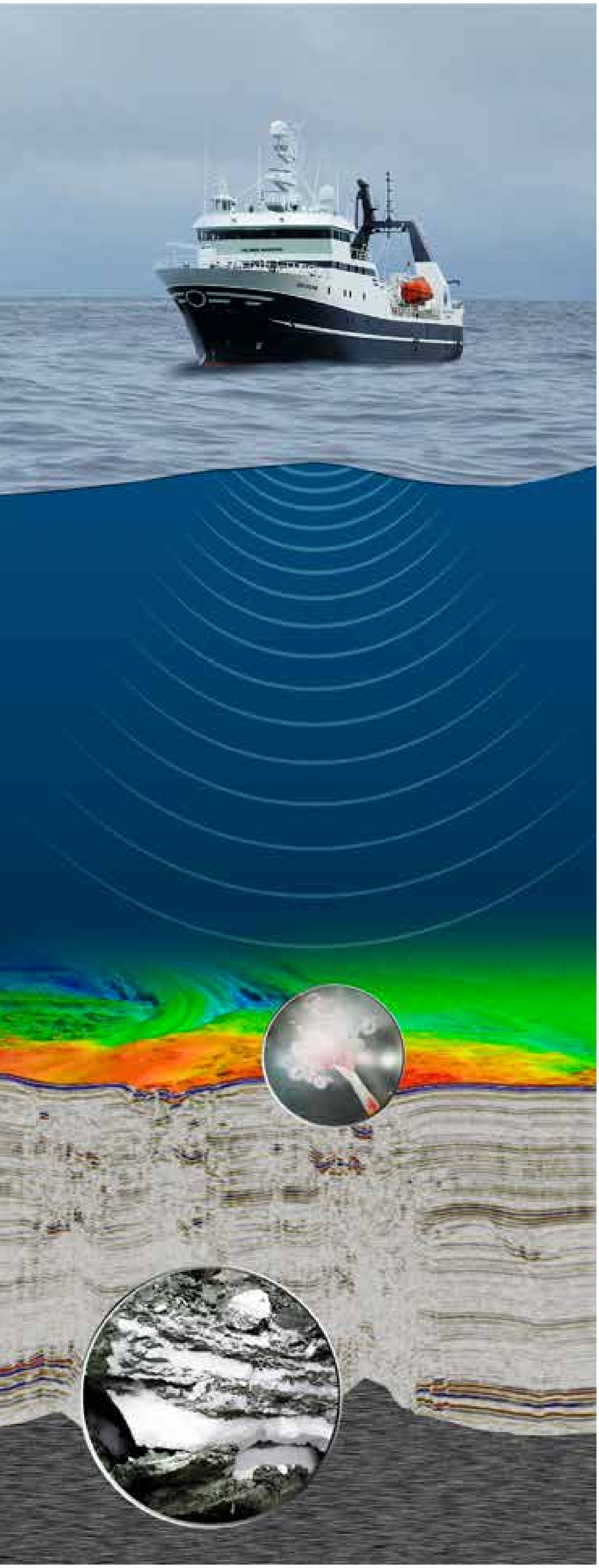




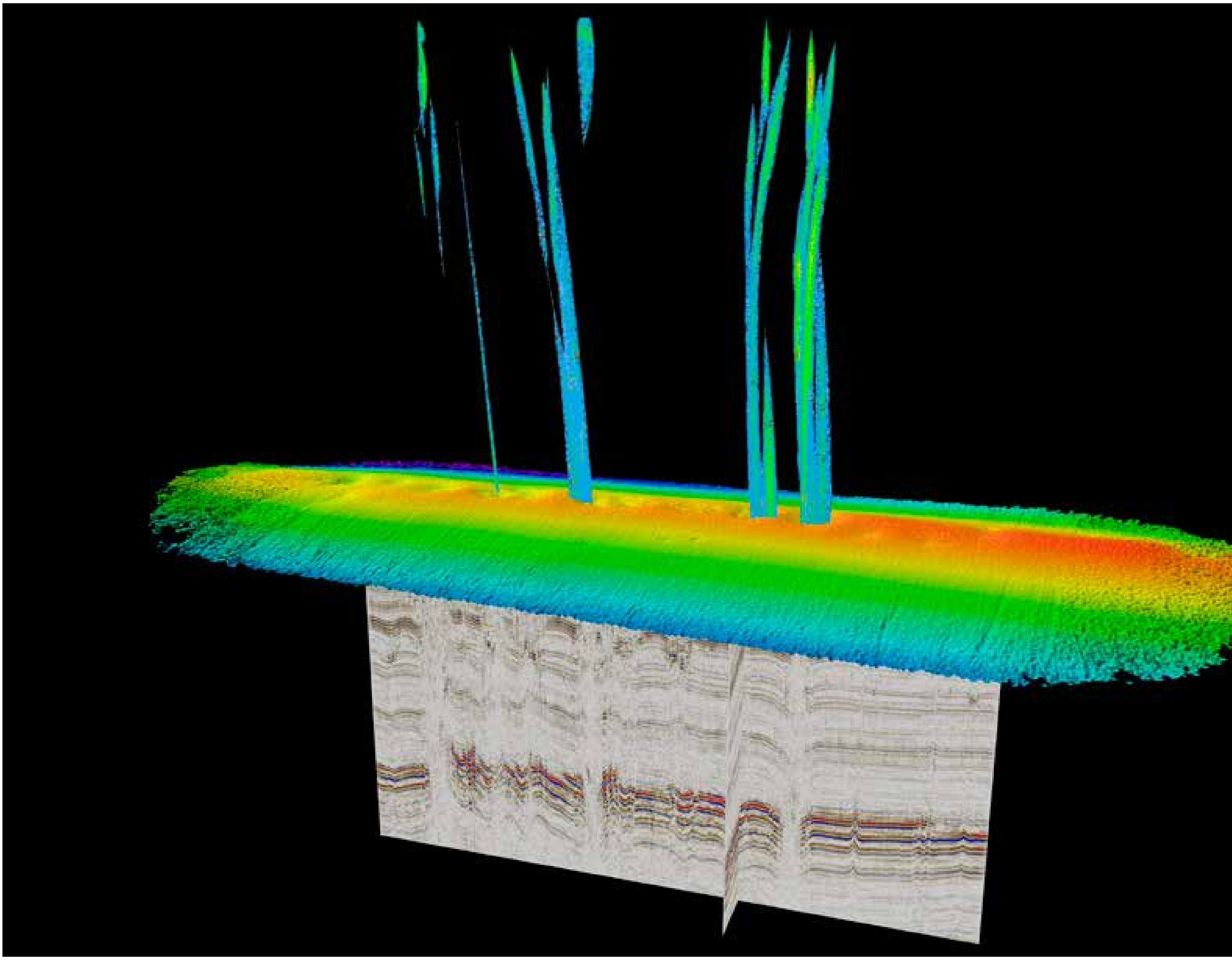
Atmosphere

Water column

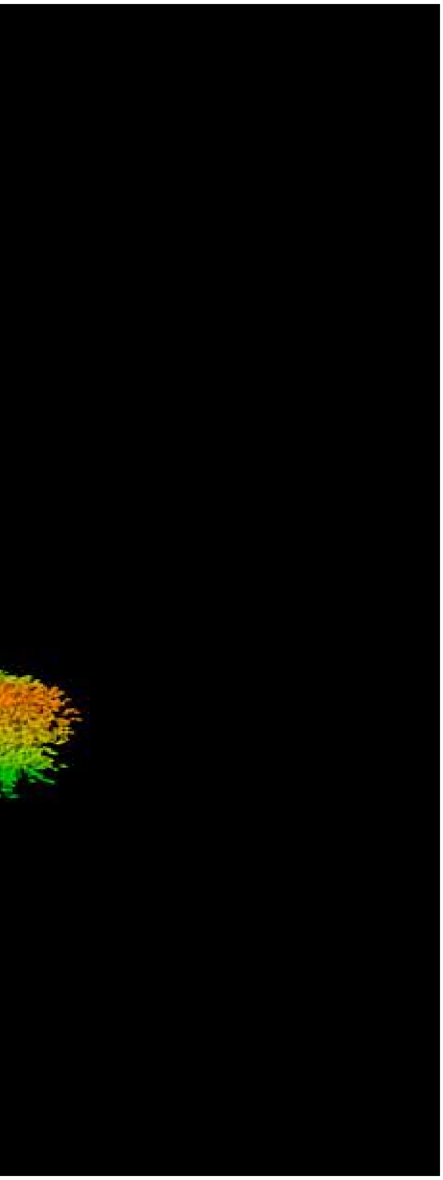
Seabed

Sub seabed

Gas Hydrate



Today methane gas flares, rise up from the Arctic Ocean floor on the Vestnesa Ridge in the Fram Strait. They reach up to 800 meters in the water column, the same hight as the largest man made structure in the world, Burj Khalifa in Dubai. Vestnesa is one of the main research areas for CAGE and datasets such as these are key to addressing the research questions of the Work Package 1. Illustration: A.Portnov/CAGE



WORK PACKAGE 1:

Sub Seabed Reservoirs

This work package focuses on two key questions: (1) how much carbon is stored in methane hydrate and free gas reservoirs in the Arctic, and how susceptible it is to climate change, and (2) at what rates, by which means, and under which circumstances is methane expelled from sub seabed reservoirs? Both of these questions link with other work packages on quantification of methane emissions, ecosystem impacts, coupling of ice sheet and gas-hydrate models and potential climate feedbacks.

Team Leader: Stefan Bünz

Stefan has ten years of broad research experience in marine geology and geophysics. A great part of his research is aimed to better understand gas hydrate systems, their distribution and their origin. Stefan holds a PhD degree in marine geology and geophysics from UiT The Arctic University of Norway. He has been an associate professor at the Department of Geology at UiT since 2007. ■

Shyam Chand
Researcher

Andreia Plaza Faverola
Researcher

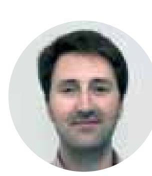
Sunil Vadakkepuliyambatta
Postdoctoral researcher

Pavel Serov
Guest PhD candidate

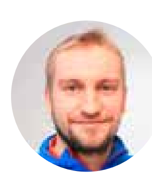
Peter Franek
Postdoctoral researcher

Sandra Hurter
PhD candidate

Giacomo Osti
PhD candidate



Alexandros Tasianas
PhD candidate



Alexey Portnov
PhD candidate

Sunny Singhroha
PhD candidate

Kate Waghorn
PhD candidate

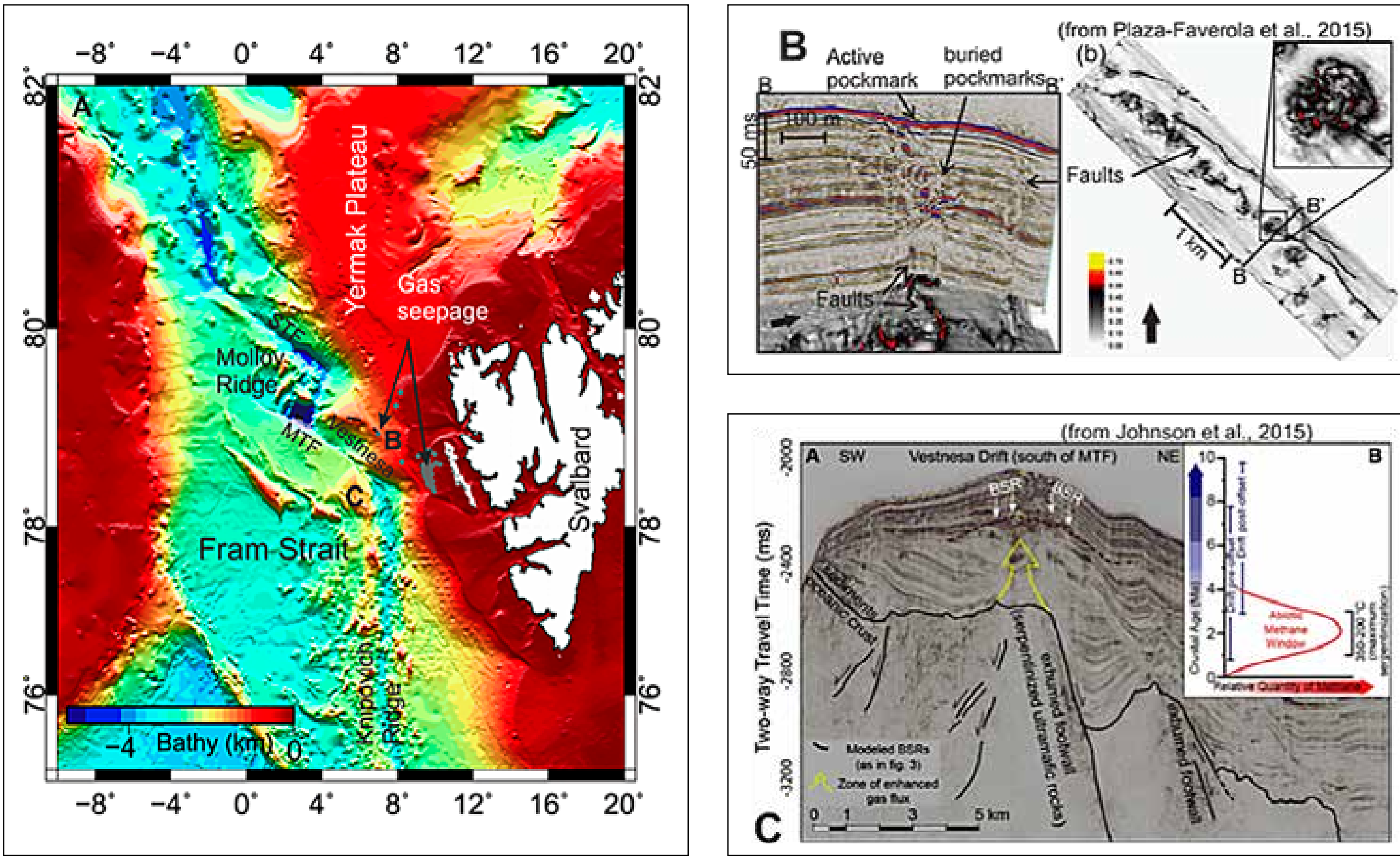


Figure 1: (A) bathymetry map showing location of Vestnesa Ridge in the context of surrounding tectonics. Flare sites are indicated as grey dots; (B) Shows a seismic section from our 3D P-Cable data set imaging a gas chimney in the active part of Vestnesa Ridge. The inset (b) shows the link between gas chimneys and sea-seabed faults; (C) Shows a seismic section where fluid migration from serpentinized material is expected through a major fault underlying the gas hydrate system at the southern part) of Vestnesa Ridge.

Scientific highlights

We employ state-of-the-art technology in sub-seabed imaging using broadband high-resolution data. Our development of 4D time-lapse studies of subsurface gas migration improves models for fluid flow in subsurface sediments.

Our target areas are the western Svalbard continental margin, the Barents Sea and the Kara Sea, while doing reconnaissance of hydrate occurrence and its stability in adjacent basins.

New findings on Vestnesa Ridge, Svalbard

Several CAGE cruises in 2014 were dedicated to the collection of acoustic data and geological samples from the area of Vestnesa ridge, offshore West-Svalbard.The ridge, at 1000 meter water depth, hosts a 100 km long gas hydrate system. This gas hydrate system is formed by thermogenic, abiogenic and microbial methane, a largely unexplored combination for gas hydrate formation. This makes it suitable for integrated study through a close cooperation between the different work packages in CAGE. Seafloor pockmarks and underlying gas chimneys are documented all along Vestnesa ridge. However, active seepage has been documented exclusively at the easternmost part of the ridge. We used high resolution 3D P-Cable seismic from the active and the inactive parts of Vestnesa Ridge to image the structures underlying these features. Our data show that the part of the ridge where gas seepage is observed at present consists of a highly faulted and fractured area. We present a model of seepage evolution along Vestnesa Ridge in time and space and suggest that tectonic stress has been one important mechanism influencing seepage of methane offshore west-Svalbard. (Published in 2015)

Discovery of a new gas hydrate system

Additional seismic data acquired in 2014 documents a new gas hydrate system at the flanks of the active Knipovich oceanic spreading ridge. This system may be sustained by abiotic gas. Microbial and thermogenic gas generation from the degradation of organic carbon in ocean sediments is well known to form gas hydrates. However, there is a third type of gas, abiogenic gas (not related to decomposition of organic matter), that represents an additional source of gas for hydrates, that remains largely uninvestigated.

At the western flank of Knipovich Ridge a gas hydrate province exists in > 2000 m water depth. In this slow-spreading ridge, the generation of abiogenic methane is likely to have occurred during the high temperature serpentinization of ultramafic rocks.

Analysis of Gas Hydrate Stability Zone dynamics in the Norwegian Arctic

The Barents Sea is a major part of the North Atlantic where warm Atlantic water mixes with the cold Arctic waters. Abundant shallow gas accumulations, fluid flow features, and gas hydrates occur in the SW Barents Sea because of hydrocarbon leakage from deep reservoirs. Recent ocean warming has increased the bottom water temperature in the SW Barents Sea by at least one degree Celsius. We model the gas hydrate stability field in the SW Barents Sea over the last 50 years. The hydrate stability zone thickness is highly sensitive to the gas composition and the geothermal gradient, and show very high local variability. Ocean warming primarily affects hydrate stability most likely only in the upper few tens of meters of sediments. *Our results show that increasing global ocean temperatures could cause destabilization of hydrates located within 100 meters of the seafloor in approximately 200 years.*

Modelling the evolution of climate-sensitive Arctic subsea permafrost in regions of extensive gas expulsion at the West Yamal shelf

There is a significant expulsion of methane from shallow Russian shelf areas. This methane release may increase and be released into the atmosphere melting rates because of intense degradation of relict subsea permafrost. Modelling of the permafrost at the West Yamal shelf helped us describe its evolution from the Late Pleistocene to Holocene. Results suggest a highly-dynamic permafrost system that directly responds to even minor variations of lower and upper boundary conditions. The heat flux from below and/or bottom water temperature changes from above, have a significant impact on permafrost. We present several scenarios of permafrost evolution. The model adapts well to corresponding field data, providing crucial information about the modern permafrost conditions in a warming Arctic.

Microseismicity of fluid-leakage structures

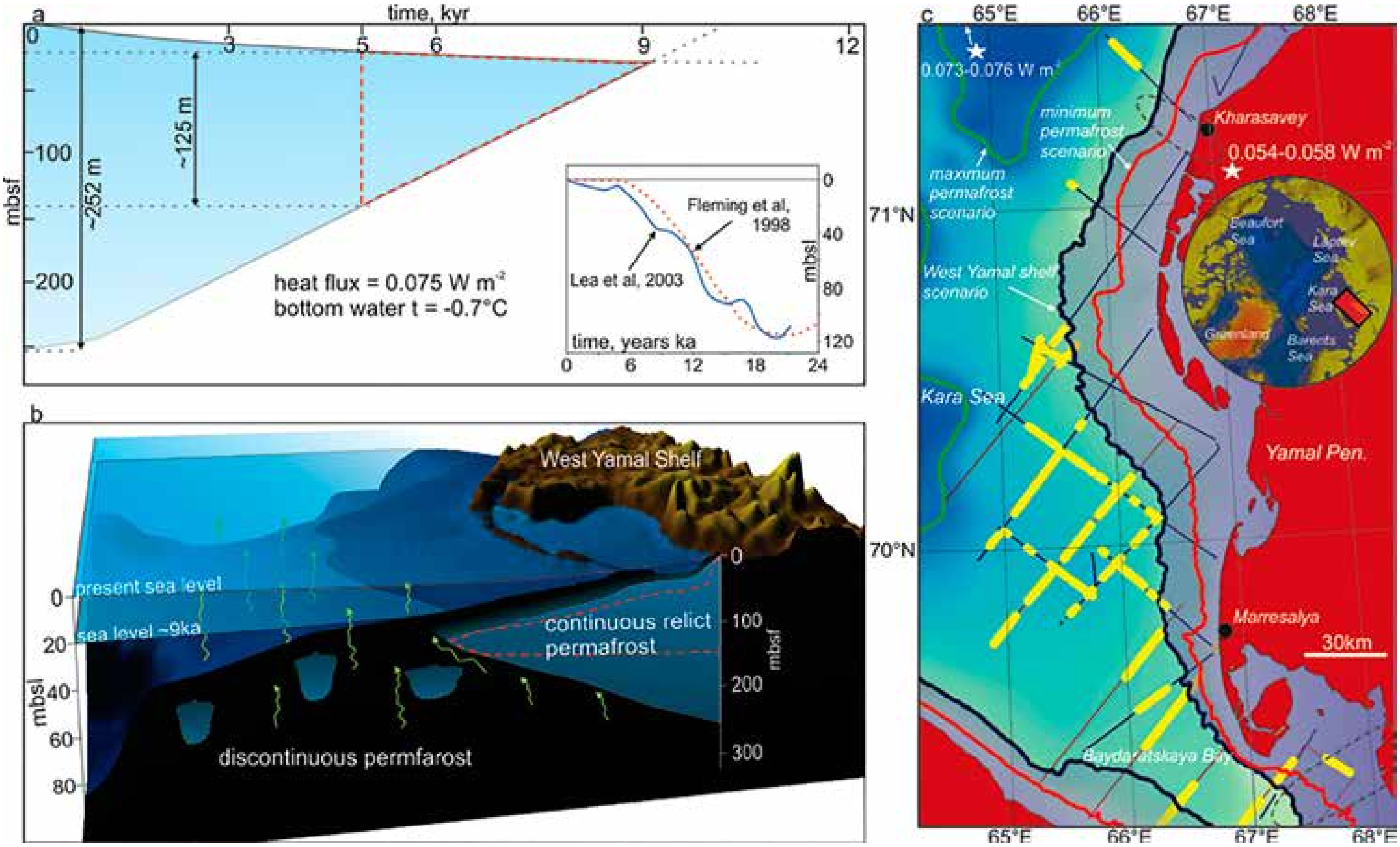
Analysis of long-term, 2-years seismic records from the Håkon Mosby mud volcano, situated on the continental slope of SW Barents Sea, documents several types of seismic signals: earthquakes, harmonic tremors and short duration events. We connected records of earthquakes with earthquakes that were localized and analyzed by seismological centers (International Seismic Centre, European–Mediterranean Seismological Centre, and NORSAR). Observed harmonic tremors occur in swarms that can last up to several hours. Periodicity of the occurrence of tremor swarms is about 6 hours based on statistical analysis. We suggest that the main mechanism behind these tremors is the fluid flow circulation in the conduit and/or pseudo-mud chamber. Also, the tremors may be resonant vibrations of gas bubbles that behave as coupled oscillators during the release of fluids and gases from the mud volcano.

Infrastructures

- One of the key technologies in CAGE is the high-resolution P-Cable 3D seismic system, a national infrastructure developed and located at the UiT. Together with mini-GI gun sources, it delivers high-resolution broadband seismic data providing unprecedented detail of subsurface structure and stratigraphy.
- CAGE has successfully applied to use the seafloor drill rig MeBo from University of Bremen on a cruise with RV Maria Merian. The campaign has been delayed but is now scheduled for summer 2016. CAGE plans to drill three locations on the Vestnesa Ridge in cooperation with MARUM, Bremen and GEOMAR, Kiel (Germany)

Recruitment

- Kate Waghorn started her PhD in October studying abiotic gas hydrate systems and fluid flow processes at mid-ocean ridges.
- Sunny Singhroha started his PhD in December developing seismic detection technologies for hydrates and quantification of hydrocarbon trapped in hydrate- and gas-bearing sediments on the Vestnesa and Svyatogor Ridges. ■



Conceptual model of the West Yamal shelf, showing the continuous permafrost governing the documented gas expulsions. Map illustrating the extensive gas flare front in the water column (yellow lines) observed in 2010 and 2012. Maximum and minimum scenarios of continuous permafrost distribution, revealed from modelling results are marked with green and red lines respectively. Figure: CAGE.

Methane is leaking from offshore permafrost

The magnificent images of craters on Yamal Peninsula, caused by collapsing permafrost, have become world famous. But did you know that this permafrost extends to the ocean floor? And it is thawing.

Text: Maja Sojtaric
[Previously published on cage.uit.no, alphagalileo.com. eurekalert.com.]

Yamal Peninsula – the end of the world in Siberia – has recently become world famous. A spectacular sinkhole appeared as out of nowhere in the permafrost of the area, sparking the speculations of significant release of greenhouse gas methane into the atmosphere.

What is less known is that there is a lot of methane released from the seabed offshore the West Yamal Peninsula. Gas is released in an area of at least 7500 km^2, with gas flares extending up to 25 metres in the water column. And even more methane gas is contained by a impermeable cap of now degrading permafrost on the ocean floor.

"The thawing of permafrost on the ocean floor is an ongoing process, likely to be exaggerated by the global warming of the world's oceans." says PhD Alexei Portnov at Centre for Arctic Gas Hydrate, Climate and Environment (CAGE).

Portnov and his colleagues have in 2014 published two papers about permafrost offshore West Yamal, in the Kara Sea. Papers look into the extent of permafrost on the ocean floor and how it is connected to the significant release of the greenhouse gas methane.

Permanently frozen ground

Permafrost, as the word implies, is permanently frozen ground. For something to stay permanently frozen, the temperature must of course stay bellow 0 degrees Celsius.

"Terrestrial Arctic is always frozen, it is on average extremely cold in Siberia which maintains permafrost down to 800 meters ground depth. But the ocean is another matter. Bottom water temperature is usually above zero. Theoretically, therefore, we could never have permafrost under the sea," says Portnov "However, 20 000 years ago we had a last glacial maximum during which the sea level dropped to minus 120 meters. That means that this area was land, it was Siberia. And Siberia was frozen. The permafrost on the ocean floor today was established in this period."

Last glacial maximum was the period in the history of the planet when ice sheets covered much of the Northern hemisphere. These ice sheets profoundly impacted Earth's climate, causing drought, desertification, and a dramatic drop in sea levels. The area of the Yamal Peninsula was not covered in ice, but it was exposed to extremely cold conditions.

When the ice age ended some 12 000 years ago, and the climate warmed up, the ocean sea levels increased. Permafrost was submerged in ocean water, and started it's slow thawing. The reason it has not thawed completely so far is that bottom water temperatures are low, some – 0,5 degrees. That could very well change.

A fragile seal that is leaking

It was previously proposed that the permafrost in the Kara Sea and other Arctic areas extends to water depths up to 100 metres, creating a seal that gas cannot bypass. Portnov and collegues have found that the West Yamal shelf is leaking, profoundly, at depths much shallower than that.

Significant amount of gas is leaking at depths between 20 and 50 metres. This suggests that a previously continuous permafrost seal is much smaller than proposed. Close to the shore the permafrost seal is 250 metres thick, but tapers off towards 20 metres water depth. And it is fragile.

"The permafrost is thawing from two sides. The interior of the Earth is warm and is warming the permafrost from the bottom up. It is called geothermal flux and it is happening all the time, regardless of human influence." says Portnov.

Evolution and degradation

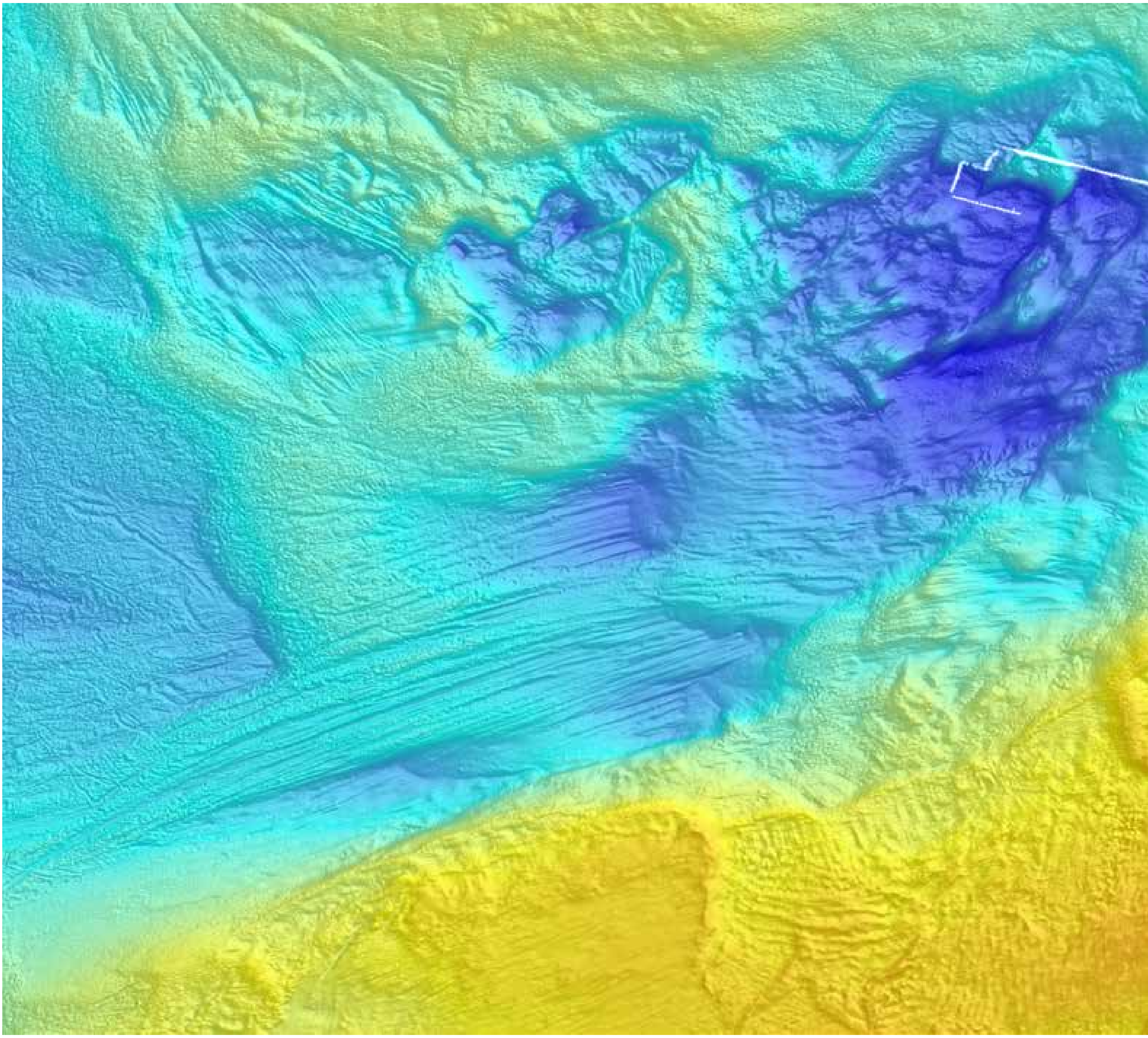
Portnov used mathematical models to map the evolution of the permafrost, and thus calculate its degradation since the end of the last ice age.The evolution of permafrost gives indication to what may happen to it in the future. If the bottom ocean temperature is – 0,5 degrees celsius the permafrost would likely take 9000 years to thaw. But if this temperature increases, the process would go much faster, because the thawing than also happens from the top down.

"If the temperature of the oceans increases by two degrees as suggested by some reports, it will accelerate the thawing to the extreme. A warming climate could lead to an explosive gas release from the shallow areas."

Permafrost seals the free methane gas in the sediments. But it also stabilises gas hydrates, ice-like structures that usually need high pressure to form.

"Gas hydrates normally form in water depths under 300 metres, because they depend on high pressure. But under permafrost the gas hydrate may stay stable even where the pressure is not high enough, because of the constantly low temperatures."

Gas hydrates contain huge amount of methane gas, and it is destabilisation of these that is believed to have caused the craters on the Yamal Penninsula. ■



The seafloor of Håkjerringdjupet, offshore Troms northern Norway, records the activity of past ice sheets. This bathymetry dataset images beautifully streamlined landforms formed by the deformation of sediment beneath fast-flowing ice streams which drained ice from the mainland in the east, to the shelf edge in the west. Illustration: MAREANO/NGU Text: Monica Winsborrow.

WORK PACKAGE 2:

Sub-seabed

The role of ice ages for fluid flow and methane hydrate. The primary scientific focus of this work package relates to the interactions between fluid flow, methane hydrate, and ice sheets. This is addressed through the following research questions:

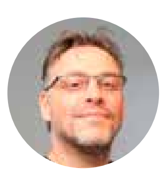
1. How did ice sheets/paleo-environments vary through the ice ages?
2. How do gas hydrate, fluid flow and deeper hydrocarbon systems interact with glacial processes?
3. How did gas hydrate stability fields change through the ice ages?

In addition we contribute to lithological, chronological and environmental frameworks for glacial sediments in chosen CAGE study areas.

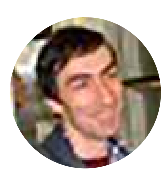
Team Leader: Professor Karin Andreassen

Professor Karin Andreassen is a professor in marine geology and geophysics at UiT The Arctic University of Norway. She holds a PhD degree in applied geophysics from UiT. Her main research areas are the Cenozoic developments of the Barents Sea. She focuses on glacial geomorphology, sediments and processes, shallow gas and fluid flow.

Andreassen has also been a visiting professor at the University of Cambridge, the University of Montpellier, and the University of Barcelona. ■



Alun Hubbard
Professor



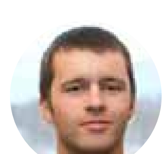
Leonid Polyak
Adjunct professor

Henry Patton
Postdoctoral researcher

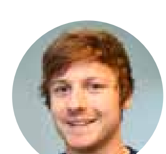
Monica Winsborrow
Researcher

Emilia Daria Piasecka
PhD candidate

Mariana da Silveira Ramos Esteves
PhD candidate

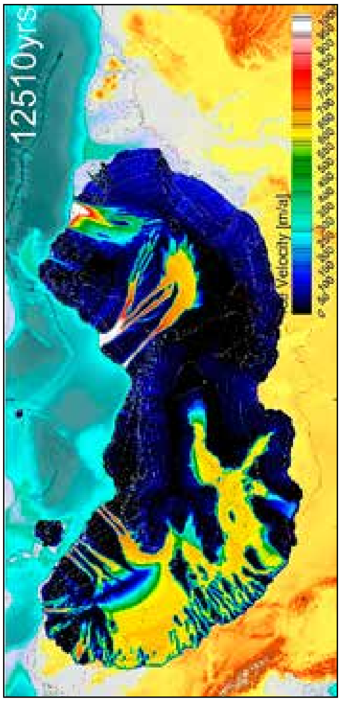


Eythor Gudlaugsson
PhD candidate

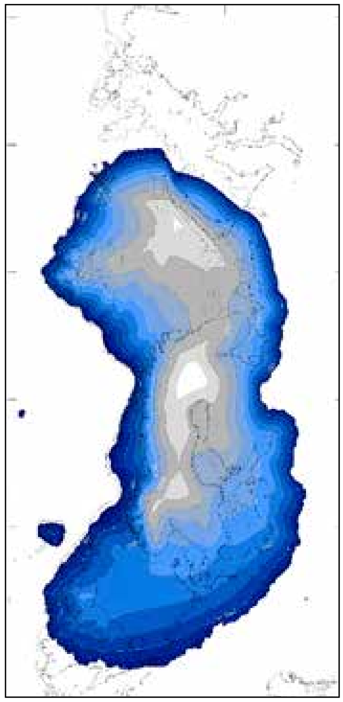


Calvin Shackleton
PhD candidate

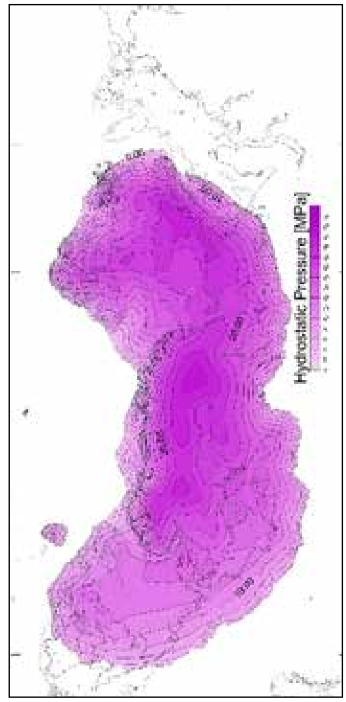
Nikolitsa Alexandropoulou
PhD candidate



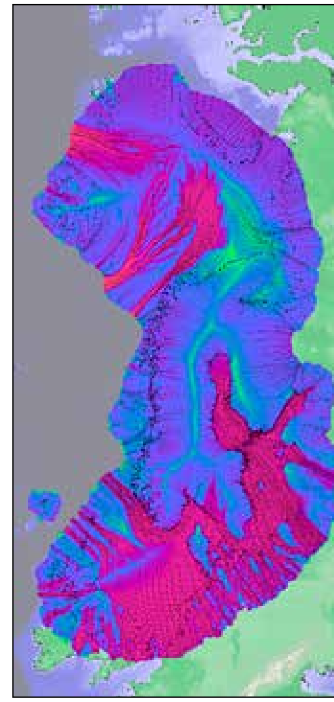
Ice velocity



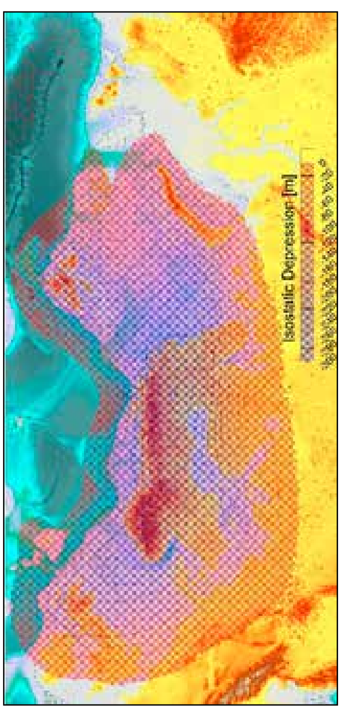
Ice thickness



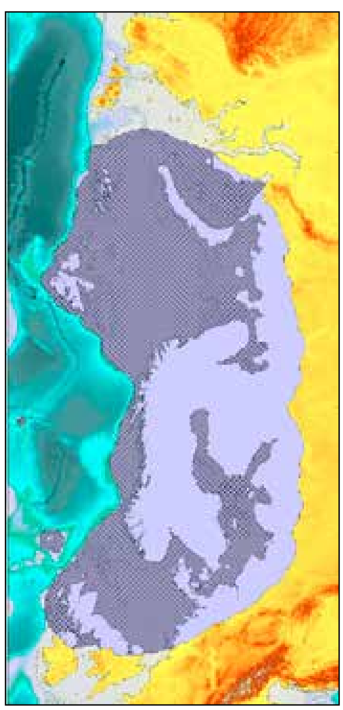
Ice loading



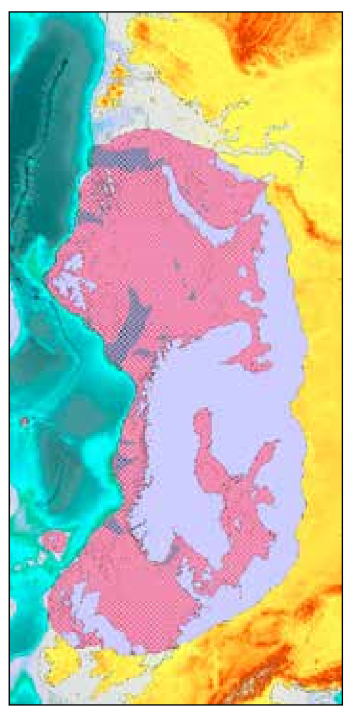
Subglacial temperature



Isostatic depression



Subglacial methane HSZ at full glacial



Methane HSZ deglaciation

Examples of numerical modelling of the Barents Sea ice sheet through the ice ages. Ice sheet development and parameters that are important for hydrate stability conditions. Bottom right: Distribution of methane hydrate stability zone (gray) during glacation and deglaciation.

Scientific highlights

A key part of our work is to develop numerical models of the Weichselian ice sheet development in the Arctic, and to deliver detailed empirical datasets against which model outputs can be constrained.

Our work depends on the analysis and integration of a wide range of datasets including: 3D/2D seismic, high-resolution seafloor bathymetry, and sediment cores to provide information on former ice sheet extent, dynamics and interaction with hydrate systems.

In 2014 we completed a cruise to Bjørnøyrenna in the Barents Sea. We identify this area as a potential CAGE supersite, since we can observe gas hydrate controlled leakage of methane from deep hydrocarbon reservoirs to the water column and atmosphere.

We also identified a novel regulation of ice stream dynamics by gas hydrates with potential implications for ice stream stability in the Greenland and Antarctic Ice Sheets.

We have finalized agreements for collaboration with institutions in Russia, Murmansk Arctic Geological Expedition (MAGE) and VNIIOkeangeologia in St. Petersburg, allowing access to essential empirical datasets from the previously disputed zone in the central Barents Sea and from the Eastern Barents and Kara Sea.

Weichselian numerical models of ice sheet development in the Arctic form a key part of our work. In 2014 we collated a dataset of boundary conditions (e.g. climate, geothermal, topography/bathymetry) and constraining geophysical datasets (geomorphological mapping, absolute dates) for future modelling. This work formed the basis for a publication of a major review of the Barents Sea domain in early 2015.

Our research team applies coded validation tools for model outputs e.g. flow directions and ice margin positions.

Moreover, we do preliminarily sensitivity experiments of the Eurasian Ice Sheet model and quantification of parameters important for hydrate stability conditions (ice loading, subglacial temperature, isostatic depression).

Infrastructures:

CAGE uses geophysical and geological infrastructure built up through previous activities at UiT. We look to further develop new high-resolution geophysical technology in acquisition, processing and interpretation of the subsurface. We have a good access to the UiT's ice-going Research Vessel Helmer Hanssen. We also expect to have good access to the new ice-breaker Kronprins Haakon, which is planned to be launched in 2016 with Tromsø as a port.

Recruitment

- Nikolitsa Alexandropoulou, started her PhD to update and refine the Neogene stratigraphic framework for the Svalbard–Barents Sea margin.
- Monica Winsborrow started as a researcher to work on integration of Russian Barents Sea datasets and investigation of gas hydrate-ice sheet interactions. ■

Alun Hubbard's boat Gambo in front of a glacier. Photo: A. Hubbard.

The Power of Ice

Ice has weighed heavy on the Arctic for at least two million years. And now it's rapidly retreating. Present studies of ice sheets in Greenland and Antarctica help us unravel the past. The past provides perspective on the future.

Text: Maja Sojtaric

We are just coming out of an ice age, as remarkable as it may sound. The Quaternary period, as geologists call it, has also been called The Great Ice age and it is the period that we currently live in. It started 2,7 million years ago and has sporadically covered the higher latitudes with ice. Culminating in the last glacial maximum, some 25.000 years ago, when Northern Europe and America were covered with ice sheets up to 4 km thick. Just imagine that somebody smacked Mont Blanc on top of Denmark.

The Barents Sea in the Arctic, now deep and secretive, was covered by just such a massive ice sheet 25 millennia ago. This ice soaked up the water: The levels of all of Earth's oceans dropped by 120 metres. Ice sheets and their outlet glaciers forever changed the face of the Earth. Deep fjords of Norway were bulldozed. Other mega terraforming also took place: Submerged on the continental shelf in the Barents Sea are enormous troughs carved by ice streams, large fast-moving tongues of ice draining from these ice sheets. This phenomenal power of ice is on going today in Antarctica and Greenland. No wonder it is attractive to scientists and adventurers alike. Professor Alun Hubbard at CAGE is both.

The berg that sank Titanic

On the west coast of Greenland is the outlet glacier that once gave birth to the most famous iceberg of all, the one that sank the luxury ship Titanic. In that same fjord Hubbard's humble boat Gambo spent several winters 100 years later. Looking at images of Gambo, a small vessel with the red Welsh dragon on the bow, you could rightfully ask what had possessed the glaciologist to let this seemingly fragile thing spend the winter next to a giant, groaning wall of ice. You could easily fit hundreds of Gambos in the famous vessel praised as unsinkable.

"On a small boat you can do whatever you want. Such as observe Greenland's glaciers in the frigid winter months, which nobody else does." says Hubbard.

No only did Gambo stay afloat, but also provided the basecamp for the collection of new winter data.

The melting Greenland

Greenland's ice sheet is melting at a record rate and is the largest contributor to global sea level rise. In 2014 it lost 500 cubic kilometres of ice to the ocean, much of which was in the form of calving bergs. The scene of Gambo's frosty endeavour was Store Glacier, one of the largest and fastest moving marine terminating glaciers in West Greenland. But as opposed to its many neighbours, it doesn't serve as a good example of retreating ice sheet due to climate change: It's 500 meter calving front has been in the same position for close to 50 years.

"The stability of Store glacier is what makes it interesting. It allows us to calibrate the natural processes that make glaciers tick. We then incorporate this knowledge into our models at CAGE to better understand natural systems that glaciers are a part of." Hubbard explains.

What makes glaciers calve and melt in Greenland is the violent encounter with another force of nature: The North Atlantic Current. This tropical warm water is attributed to up to 50% of the loss of mass from the marine edges of Greenland ice sheet.

When two forces collide

It seems logical that tropical ocean water carried around by the North Atlantic Current can melt ice. But it is not that simple, the warm water runs deep. You need a catalyst that brings it to the glacier front, and the glacier itself provides that. If you look carefully at the seawater at the front of a glacier it will often appear as if it is boiling. Plumes of fresh water shooting out from the ice cause this bubble bath effect. The reaction between salinity and density of the warm and cold water create prefect conditions for the upwelling of warm Atlantic water from depths of 400 metres.

"The ocean is doing most of damage to the front of the glacier. And it is happening in the winter too, even though we can't see it because the fjords are frozen."

The source of the fresh water is the surface melting of the ice sheet, which is prevalent in the summer with warm temperatures. But it also comes from the friction created by glacier's movement, heating up the base. And that continues throughout the winter months. "Ocean water contains much more energy than air. The atmosphere cools in winter, but the deep ocean waters keep warm to fuel continued melting of the glacier front even throughout long frigid months."

The end of the ice age

The very same processes undermined the massive ice sheet in the Barents Sea. For much of the Quaternary the ice sheet weighed heavy on what is now the sea bottom. Then it started retreating rapidly by the same violent encounter with warm, salty water conveyed by the North Atlantic Current. (This is supported by several paleontological studies from CAGE professor Tine Rasmussen and her group. See link)

Professor Karin Andreassen at CAGE leads the team of modellers, glaciologists, and geologists that Alun Hubbard is a part of. The team looks at 3D seismic records of the seabed, paleontological discoveries and present day processes to discern what happened to the Barents Sea ice sheet from its maximum extent to complete demise.

"Field data of today are integrated in modelling experiments that help us create snapshots, time slices of the past." says Andreassen.

What happened to methane?

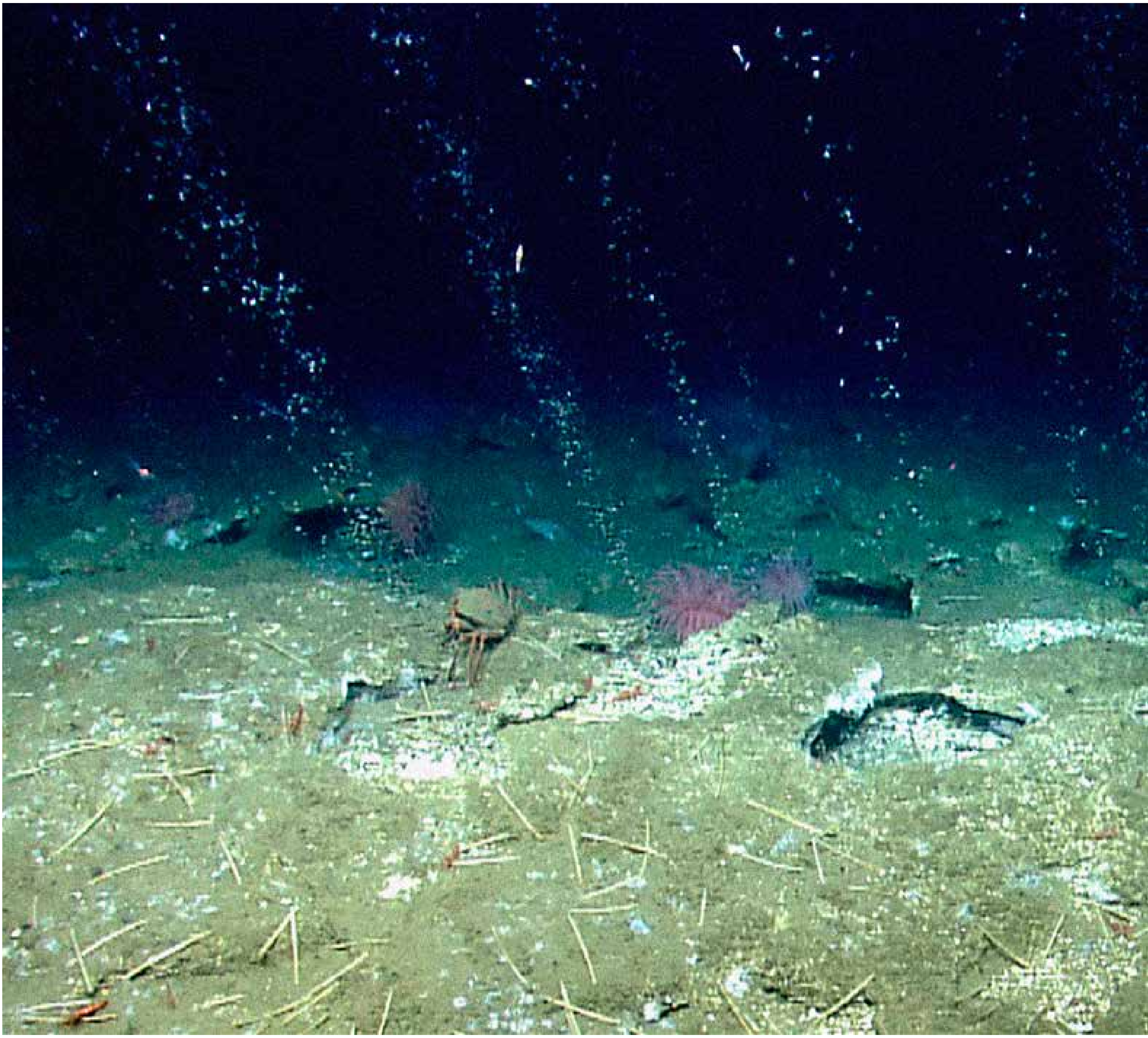
Professor Andreassens group is particularly interested in what happened to the methane hydrates, a solid ice form of the greenhouse gas under the ocean floor. Under the immense pressure and cold temperatures of the ice sheet this volatile structure was created and remained stable for millions of years under the Barents Sea bottom. But then ice sheet collapsed. Now the stability zones are constrained to narrow slivers of deepest ocean. (see figures)

"When the ice disappeared, the enormous pressures exerted by the ice sheet were released. The floor became warmer as the ocean once again occupied the basin. This destabilized the methane hydrates. And when they melt, we get explosive flares that release a very potent greenhouse gas into the ocean." says Andreassen.

Why does it matter?

The present helps us understand the past. And that could be more important to our future than we know. We don't know enough about the events of deglaciation in the Barents Sea, says Andreassen. But we better learn. Because the planet's ice sheets are still retreating. And under all that pressure, there is methane hydrate.

"Barents Sea during the last glacial maximum is much like the ice sheet in West Antarctica today. There are several studies that suggest that there are large methane hydrate reservoirs under West Antarctica. That makes it very important to learn why the Barents Sea ice sheet varied through time and what happened to the methane hydrate in the past." ■



On land and near the ocean surface, sunlight provides the energy that allows photosynthesis. But the dark depths of the ocean, where sun never shines, are also teeming with life. Many microbes have evolved chemosynthetic (instead of photosynthetic) processes that create organic matter by using oxygen in seawater to oxidize hydrogen sulfide, methane, and other chemicals that seep out of the ocean floor. Photo: NOAA Okeanos Explorer Program/USGS

WORK PACKAGE 3:

Modern Seabed Group

It is uncertain how methane release from gas hydrates affects life on the seabed. The overall purpose of the Modern Seabed Group is to quantify the effects of such release on biological communities associated with the seabed. We examine benthic organisms, communities, food webs, and geochemical proxies to understand the range of biological responses to varying intensities of natural hydrocarbons seeping from marine sediments in the Svalbard/Barents Sea area over time and space.

Team Leader: JoLynn Carroll

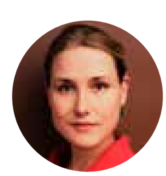
JoLynn Carroll is a marine geochemist who studies marine geochemistry, benthic biology, and environmental pollution. She is an adjunct professor at the Department of Geology, UiT The Arctic University of Norway, and assistant director at Akvaplan-niva, a research-based company providing advisory services and research in aquaculture and marine and freshwater environments.

JoLynn Carroll holds a PhD in marine science from the University of South Carolina in Columbia, USA, and has also studied innovation leadership at the Norwegian Business School. ■

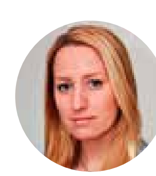
William G. Ambrose, Jr.
Visiting professor

Michael Carroll
Researcher

Wei-Li Hong
Postdoctoral researcher



Friederike Gründger
Postdoctoral researcher



Emmelie Åström
PhD-stipendiat

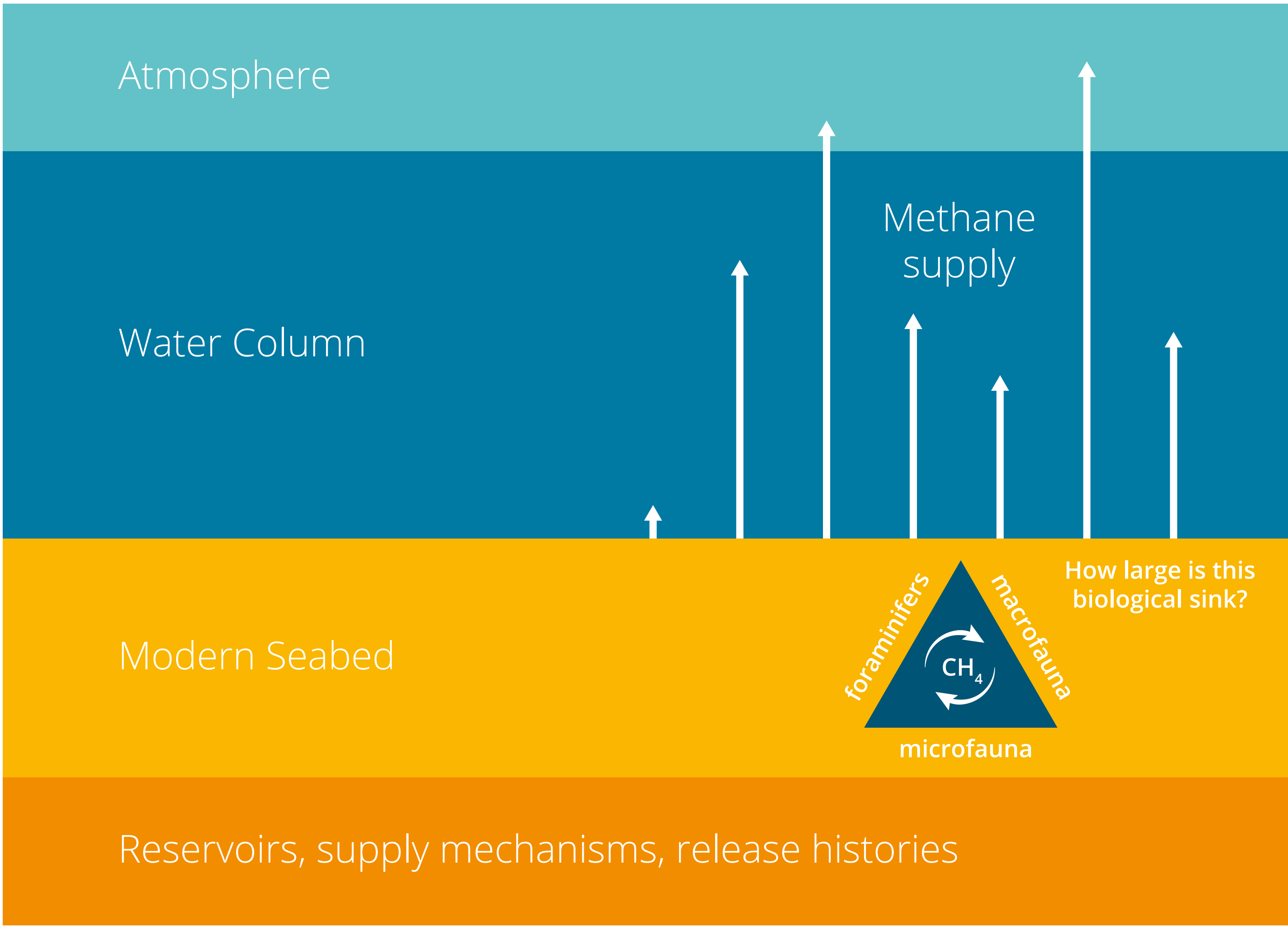


Illustration: JoLynn Carroll & Torger Grytå

Scientific highlights

In 2014 we have established Modern Seabed Group (MSG) through recruitment of core personnel in Arctic, marine, benthic ecology, food web analysis, sclerochronology, microbiology, and geochemistry.

Throughout our field activity in 2014, we have done preliminary sampling a 5 different Arctic seep locations spanning water depths from 90 to1700 meters in order to identify key locations for long term investigation.

We have made many direct observations of bacteria, microorganisms and macrofauna at the sites of seafloor methane release. Combined with basic sediment characteristics and sediment geochemistry, this provided us with a necessary framework for assessing methane ecosystem effects.

Quantitative analyses of species composition and community structure along a gradient of methane intensity provide us with an understanding of the intensity and spatial extent of methane influence.

We used stable isotopic analyses to trace methane-derived carbon in the biosphere; from this we can assess the extent to which methane is utilized as an energy source in the marine ecosystem. In situ rate measurements of methane utilization by seep-associated microbial communities provides us with evidence of methane sequestration from the environment into the marine biosphere.

We are doing controlled laboratory studies which will help us elucidate the range of potential climate-associated effects on methane seep communities. Modeling of sediment and geochemical parameters in the porewater, provide us with rate estimates for key biogeochemical reactions.

We are also developing and testing benthic biological monitoring technologies, such as sclerochronology (the analysis of mollusk shell rings), as indicators of biological responses to different types of hydrocarbon leakage.

These activities provide a well-constrained understanding of the range of biological responses and associated effects over multiple temporal and spatial scales to varying intensities of methane leakages from marine sediments.

Discovery of three new species

- Primary Production – We have isolated and identified the presence of methane oxidizing bacteria in sediments and seawater
- Consumers – We have discovered specialized, seep-associated fauna (polychaetes, bivalves) present in high abundance in methane-rich areas.
- Community structure – We have identified strong community-level effects of methane seeps on faunal structure that differ in the deep-sea and shelf. We have discovered up to three novel (undescribed) species of a seep-associated bivalve.

Strategy plan

The activities in the Modern Seabed Group will contribute to an overall assessment of the fate and effect of methane in the Arctic marine environment. We have developed a strategy document to guide our activities in the future.

In the coming years we plan to:

- Describe the composition and function of microbial communities at methane seep-related sediments in areas of the Arctic.
- Image seep areas off Western Svalbard.
- Determine metabolic activity rates of methanogenic, methanotrophic and sulfate-reducing microorganisms that inhabit Arctic methane seep sediments.
- Establish microbial microcosms to investigate activity or community changes caused by different methane concentrations and increasing temperatures.
- Investigate the carbon cycling around the sulfate-methane-transition-zone by integrating information from sediment and pore water geochemistry with numerical modeling.
- Constrain centurial methane emission events from the Vestnesa Ridge pockmarks with geochemical proxies
- Construct a food web for an Arctic methane seep site.
- Investigate already identified shell beds in other cores from the Arctic ocean floor.

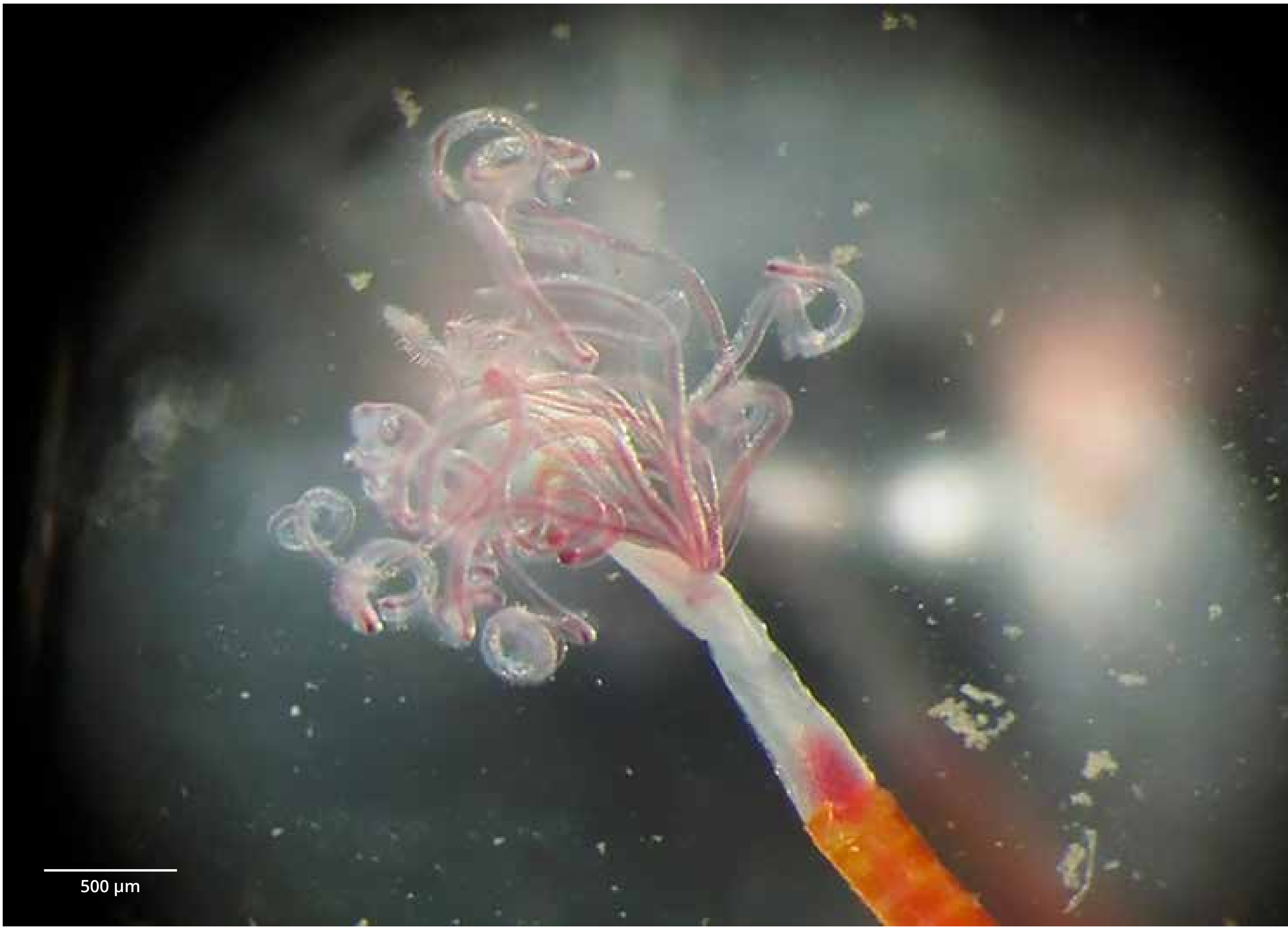
Further investigate the observations of localized high pelagic biological activity/biomass in methane plume areas, that suggest a link between methane emission and biological processes in the water column.

Infrastructures

Infrastructures used to support these CAGE activities include an accredited (ISO9001) benthic faunal sorting and identification laboratory, a chemical analysis laboratory accredited for hydrocarbon analyses in sediments and seawater and a microbiology laboratory with cultivation facilities and molecular genetic identification.

We are in negotiation to obtain the use of a benthic lander including a benthic flux chamber for methane flux measurements at the sediment-water interface. Akvaplan-niva maintains a laboratory and equipment for sclerochronological processing and analysis. For experimental work in a laboratory setting, Akvaplan-niva maintains a marine laboratory facility with flowing seawater and temperature regulation which allows experimental work to elucidate processes and to quantify flux rates.

Such work, performed under controlled and continuously monitored conditions, is needed to complement field measurements. Field investigations utilize advanced coring technologies equipped with camera and video capabilities. ■



A tubeworm living close to the cold methane seeps at the bottom of the ocean. Also called siboglinid. Photo: Emmelie Linea Åström

Studying unknown climate culprit under the ocean floor

Methane. Remember the name. A climate gas much more harmful than CO_2. But tubeworms and bivalves at the sea bottom may save us yet.

BY: Asbjørn Jaklin/Nordlys
(Excerpt of an article that appeared in connection to Arctic Frontiers conference 2015)

Welcome to the dark, strange and mysterious world in the depths of the Arctic Ocean. While the sunlight is the engine for eco systems further up in the ocean, methane gives nourishment to bacteria, worms and bivalves on the ocean floor.

Methane is a simple gas, it's also called swamp gas, found in increasing amounts in our atmosphere. A lot of it stems from the agriculture. But enormous amounts are also tied down in the soil layers on land and on the bottom of the ocean.

Warmer climate increases the expulsion of methane from the ocean floor. That which is not eaten by organisms at the bottom, may bubble up to the surface.

Possible new species of bivalve belonging to the family of Thyasiridae was found in Storfjord area Barents Sea 350 m of water depth in July 2014. Photo: Graham Oliver – National Museum of Wales UK

For many years we have heard how dangerous CO_2 is for climate. NB! Methane is a 25 times more potent climate gas than CO_2.

Excellent research

Over 40 scientists from 20 countries at the UiT The Arctic University of Norway are now studying the effects of methane release on life in the ocean, and on the climate. It is a grand effort that will be going on for the ten years, as a Centre of Excellence. This is a scheme by Norwegian Research Council that funds research centres so that they can build up research on high international level.

Centre for Arctic Gas Hydrate, Environment and Climate is the name. Abbreviated to CAGE.

"Fascinating," says work package leader JoLynn Carroll at CAGE "We are discovering new species on the ocean floor. This is truly basic research."

Stable while frozen

Gass hydrates are chemical compounds of water and gass. This is how methane is stabilized in the layers of soil, on land and in the oceans.

The concern is that increased temperatures due to climate change will melt the ice and release the methane.

In the ocean methane has a special function as food for bacteria, worms and bivalves.

"We believe that these ecosystems on the bottom of the ocean can effect released methane so that it decreases the negative effect of the gas on the climate budget. Our research aims to figure out how big this effect is." says Carroll.

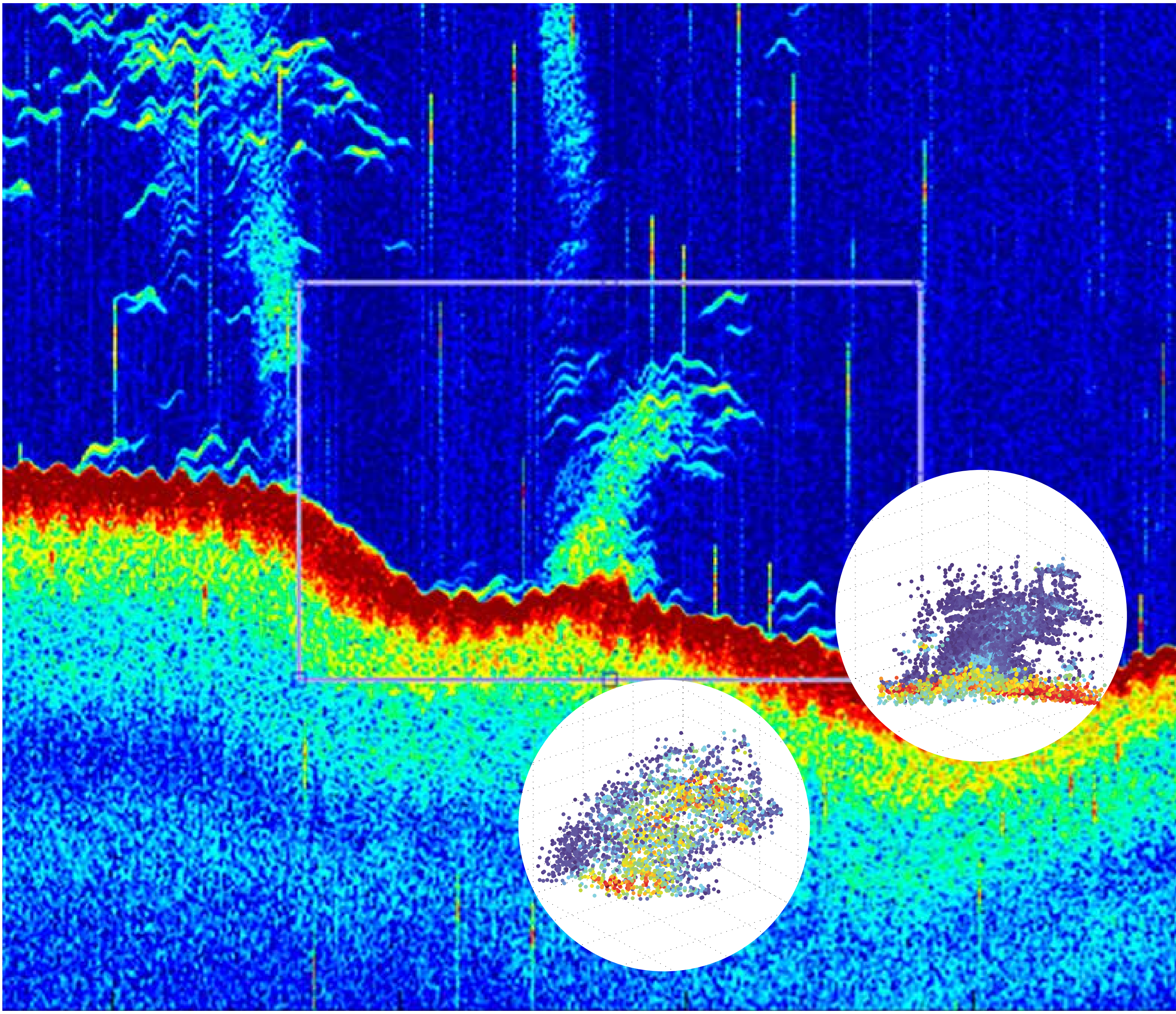
West of Svalbard

Scientists at CAGE are conducting fieldwork in the ocean west of Svalbard, and at the Storfjord- and Bjørnøyrenna north in the Barents Sea.

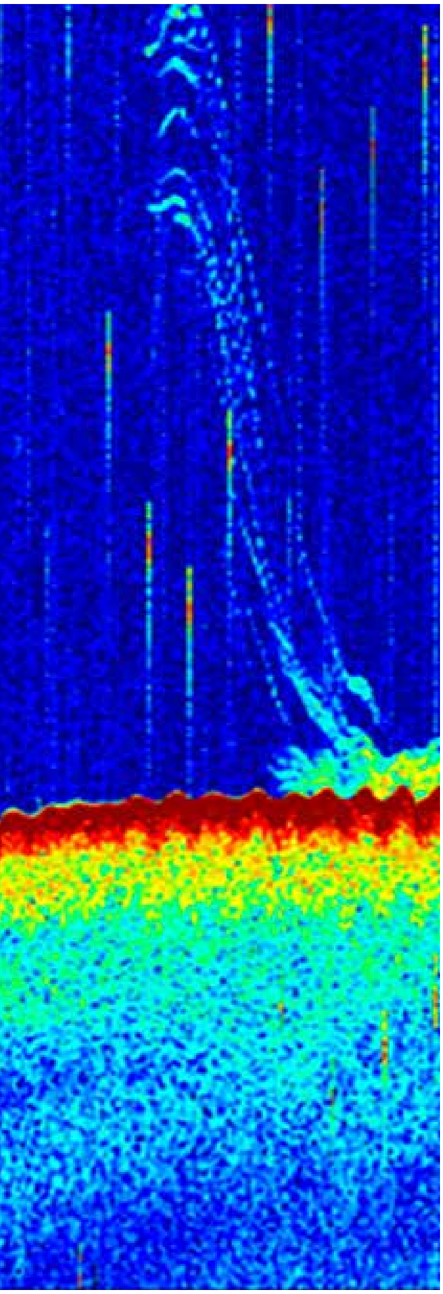
The marine eco systems here have been studied for many decades. But until now the scientists have concentrated their efforts on the sun driven system, where the photosynthesis causes a boom in the production of biomass during the light summer season.

Carroll and her colleagues study life in the ocean from 80 to 1000 meters. Sunlight does not penetrate that far down.

"We are studying an alternative eco system where expulsion of methane from the ocean bottom is the energy source. The gas is the source of life for bacteria in the sediments and tube worms and bivalves on the ocean floor", says Carroll. ■



Gas bubbles in the water column are detected and located with an acoustic method: a calibrated split beam echosounder. Bubbles seen in the echograms form streams or so called "flares" (boxed in this figure), which are post-processed to quantify gas release from the seafloor. The recorded echosounder signal is edited, removing signals from the seafloor: Fish, critters, and interference from other instruments, before calculating gas flow rates from individual flares. The right circle shows an unedited flare and the left shows the corresponding edited flare. We use the edited flare data to calculate gas flow rates: red is strong, and blue is a weak signal. Illustration: CAGE. Text: Pär Jansson.



WORK PACKAGE 4:

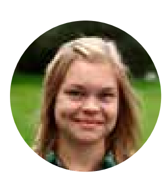
Water column

We quantify local and regional methane release from the seabed into the water column in Arctic areas around Svalbard. Our aim is to examine the present day release variability of methane on time scales from hours to years. We study how this release responds to oceanographic changes. This is achieved through observatories deployed in targeted areas where methane release is known, as well as during in-situ observations on research cruises. Measurements from the seabed, the air and from land stations, along with modelling analysis, will provide needed insights into sources of elevated methane concentrations and the reason for their variability.

Team Leader: Bénédicte Ferré

Bénédicte Ferré is a physical oceanographer whose research activities span from sediment resuspension and transport to oceanographic data analysis associated with methane release. She holds a PhD degree in oceanography from the University of Perpignan, France. She was a post-doctoral researcher at the United States Geological Survey in Woods Hole, USA, before joining the Department of Geology at UiT The Arctic University of Norway in 2008 and CAGE in 2013. ■

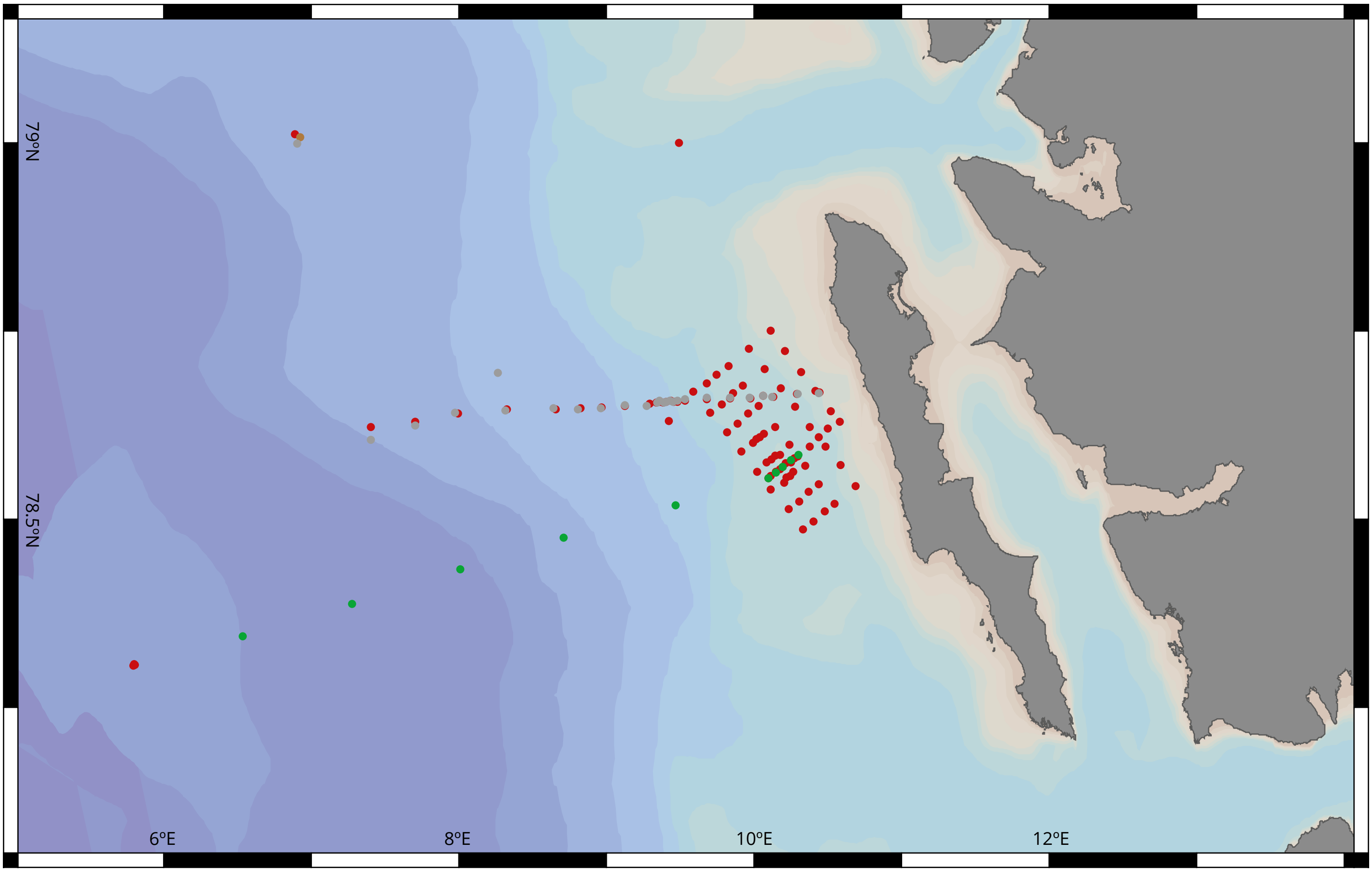
Jens Greinert
Visiting professor



Anna Silyakova
Postdoctoral researcher

Anoop Mohanan Nair
Engineer

Pär Gunnar Jansson
PhD candidate



Oceanographic stations western Prins Karls Forland. All stations were from 2014 cruises.

Scientific highlights

Development of sea floor observatories together with Kongsberg Maritime was one of the main events in 2014.

The contract with Kongsberg was signed on October 6th and the kick-off meeting occurred on October 30th to finalize the plan and design.

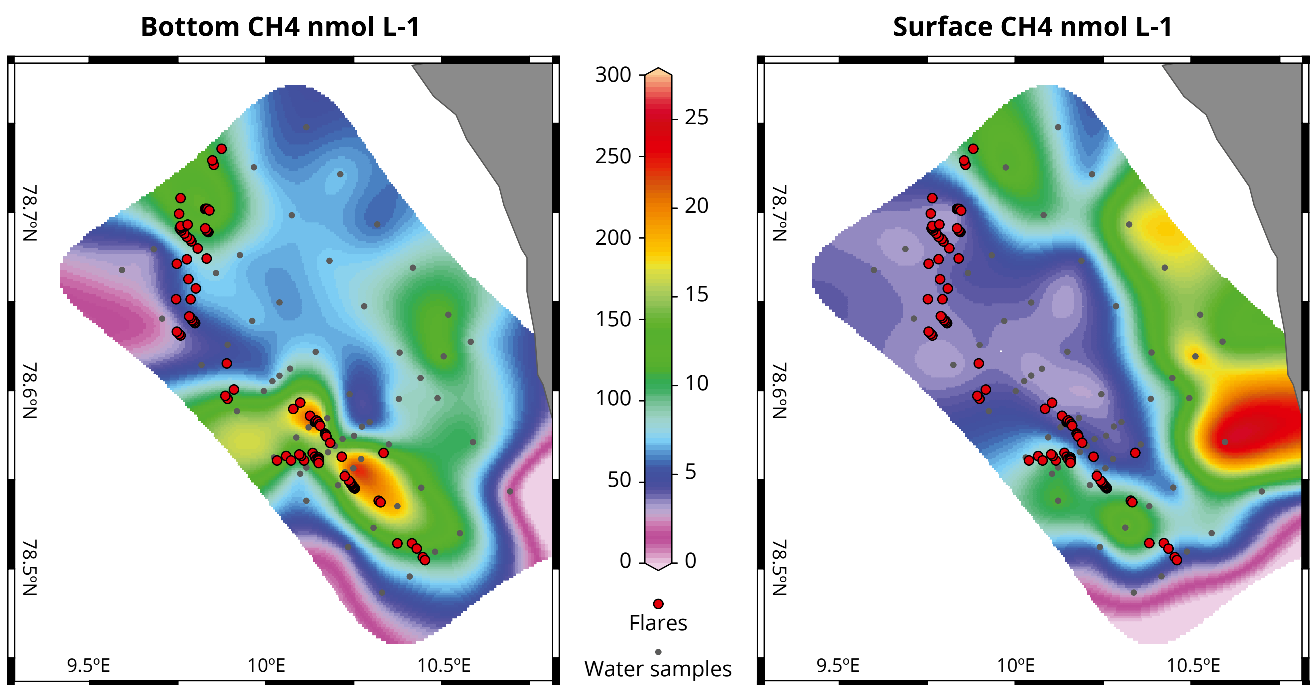
Kongsberg Maritime is building two trawl proof landers including the following instruments: ADCP, CTD, hydrophone, echosounder, turbidimeter, methane-, pH-, and fluorimeter, CO_2, and O_2 sensors, and telemetry.

A telemetry communication is installed in order to download data to the ship when. Throughout spring 2015 we will test the lander in fjords near Tromsø for telemetry, instrumentation and release system, using RV Helmer Hanssen to deploy and retrieve the lander.

Both ocean observatories will be deployed in Fram Strait offshore Svalbard in the beginning of July 2015.

A new hypothesis

Two cruises in 2014 conducting oceanographic measurements and collecting water samples for dissolved methane and nutrients allowed us to propose the “Seep-Fertilisation Hypothesis”. Most of the samples were analysed for dissolved methane onboard the research vessel using the gas chromatograph from GEOMAR (Germany). Some of the samples from the cruises were sent to GEOMAR for further analyses. All water samples for nutrient concentration were sent to and analysed at the Institute of Marine Research in Bergen. Our new



Bottom (left) and surface (right) methane concentration on a shallow area western Prins Karls Forland. Note the different scale between graphs. Small grey dots are water samples. Red dots represent identified flares from the echo sounder mounted on the ship.

hypothesis, developed together with John Pohlmann (USGS, Woods Hole) and Jen Greinert (GEOMAR), suggests that methane release from seeps increases ocean productivity causing a drawdown of CO_2 from the atmosphere. Large areas can become a potential carbon sink.

The cruises were very successful. Oceanographic stations including water samples and CTD cast are shown in the figure, where red dots represent stations from June, green dots from July and brown from October.

Along with these data, we analysed echo sounder data for flare detection and gas flux quantification.

Preliminary results from the shallow area (80–150m) highlight high methane concentration on the ocean bottom (<300nmol/l) but no major increase at the surface. About 165 flares were identified with fluxes ranging from 1 to 3000 ml/min.

Infrastructures

1. Gas Chromatograph

In order to analyse water samples for dissolved gas content (C_1–C_6 hydrocarbons (incl. methane), CO_2), essential for several of our teams. We purchased a gas chromatograph in December 2014. The instrument will arrive in May 2015, and will be used in the land-based laboratory as well as on the research vessel.

2. Open-path CH_4 sensor LI7700

As a part of N-ICE2015 cruise in close collaboration with the Norwegian Polar Institute (NPI), an open-path methane analyser from Li-COR (LI7700) was acquired to be integrated with the Campbell Eddy covariance system owned by NPI. Integration was done at IT-AS (ITAS Instrumenttjenesten AS), and the entire system is now in the Arctic Ocean to measure methane flux from sea ice surface and waters below.

3. CONTROS CH_4 sensor

One of the CH_4 sensors from CONTROS that were included in the ocean observatory.

Recruitment

Pär Jansson started his PhD in May 2014 to work on echo sounder data and modeling of bubble transport. His co-supervisor is Jens Greinert from GEOMAR (Germany). ■

Director Jürgen Mienert signed the contract with Arild Brevik from Kongsberg Maritime. Also present were team leader in charge of ocean observatories, Benedicte Ferré (centre) and oceanographer Anna Silyakova, post.doc (left). Photo: Maja Sojtaric

The observatories will include several instruments, be self-contained and wirelessly connected to the surface, sending data on a regular basis to CAGE scientists. Instruments will monitor methane release from the seabed to the water column as well as CO_2 ocean acidification and circulation. Photo: Kongsberg Maritime.

Building state of the art ocean observatories

The technology company Kongsberg Maritime is building two ocean observatories for CAGE. Observatories will be deployed in Fram Strait offshore of Svalbard this year, to monitor major methane leaks from the seabed.

Text: Maja Sojtaric
[Previously published on cage.uit.no]

"*It is the first time that research is being done on the entire methane emission system from the seabed to the atmosphere.* To measure these emissions we need new high-technology instruments that are on the forefront of development." says Benedicte Ferré, who is the team leader for the water column research and responsible for the observatories.

Pioneering work

Recently CAGE signed a contract with Kongsberg Maritime to build two observatories that will eventually sit on the seabed off the coast of Svalbard for an entire year. The observatories will include several instruments, be self-contained and wirelessly connected to the surface, sending data on a regular basis to CAGE scientists. Instruments will monitor methane release from the seabed to the water column as well as CO_2, ocean acidification and circulation. The data from these observatories will give significant information that will help understand processes related to climate change.

At the forefront of technology

"We need a company on the forefront of technology to build this pioneering instrumentation. Kongsberg was a good choice for us, because of their experience with relevant industries, among other things." says Ferré.

Kongsberg is better known for its extensive development of infrastructure for space technology as well as for maritime and hydrocarbon industries. The contract with CAGE is a further step into development of Arctic environmental observation.

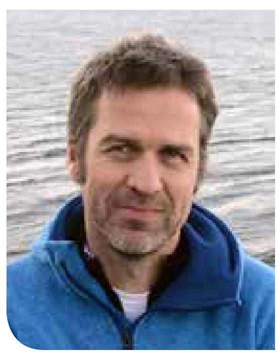
"The maritime industry has in recent years gone through several major R&D programs within subsea environmental monitoring, and underwater sensor networks. The observatories to be delivered to CAGE, fit very well into the track record as a hands-on exercise in environmental monitoring and our environmental team are very excited to start this collaboration with CAGE, said Arild Brevik, Kongsberg Maritime Subsea Division upon signing the contract. ■

Methane-derived carbonate crust formation is a striking phenomenon that occurs in places where methane seeps from the ocean floor. These crusts are called authigenic which means that they are formed in the place where they are found. This means that they can tell a story about the past and current methane leakage at the floor of the ocean. This carbonate crust was found offshore Vesterålen. Photo: Jochen Knies.

WORK PACKAGE 5:

Paleo Methane History

Neogene to Pleistocene. The main goal of this work package is to investigate the timing of hydrocarbon leakage in the high Arctic. Did it happen abruptly, or did it occur periodically over millions of years. The research will be conducted on various time-scales including pre-glacial and glacial environmental settings and will provide new knowledge on the impact of tectonic and climatic events on stabilities of gas hydrates and deeper hydrocarbon reservoirs.

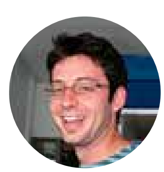


Team Leader: Jochen Knies

Jochen Knies is a senior researcher at the Geological Survey of Norway in Trondheim. He does marine geological and environmental investigations along the continental margin of Northern Norway, the Barents Sea, Svalbard and the Arctic Ocean.

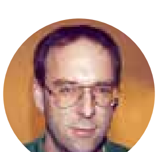
Jochen holds a PhD degree in marine geology from the University of Bremen. He was a post.doc at Alfred Wegener Institute for Polar and Marine Research, Germany, and a visiting professor at the University of Hawaii, USA. ■


Joel Johnson
Visiting professor

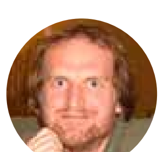

Antoine Cremiere
Postdoctoral researcher

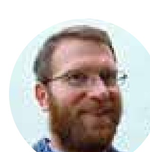

Soma Baranwal
Postdoctoral researcher

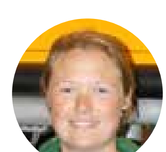

Terje Thorsnes
Researcher


Reidulv Bøe
Researcher

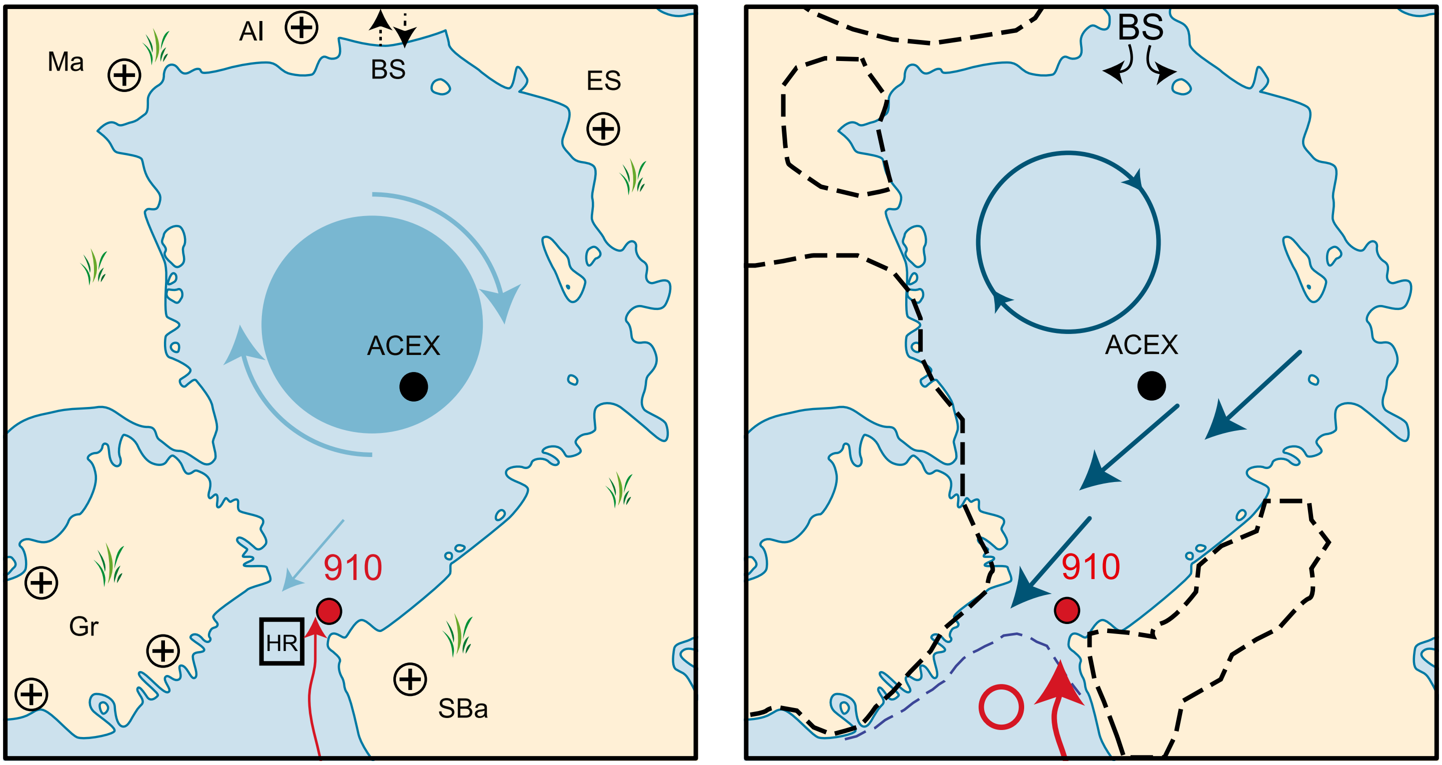

Shyam Chand
Researcher


Karl Fabian
Researcher

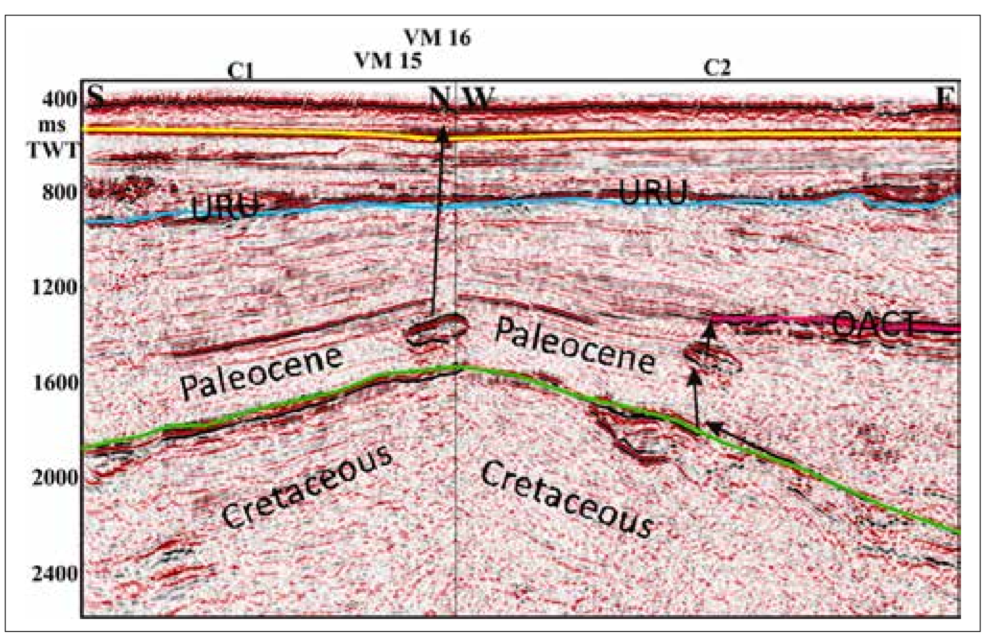

Aivo Lepland
Researcher


Simone Sauer
PhD candidate


Kärt Upraus
PhD candidate



Pliocene Arctic sea ice reconstruction (left: 5 million years ago; right: 2.6 million years ago).



Fluid flow pathways, exemplified by 3D seismics on Veslemøy High, SW Barents Sea.

Examples of phosphatized microfossils whose consistent cylindrical shape is indicative of a biogenic origin, typically attributed to methanotrophic archaea in a seep-influenced setting

Scientific highlights

Our newly developed and robust chronology for the Plio-Pleistocene in the Arctic allowed us to reconstruct the emergence of the modern sea ice cover in the Arctic Ocean. This achievement provides important baseline knowledge for climate modelling of future scenarios. We will continue this work on Pliocene sea ice reconstructions in the Arctic Ocean by applying coupled Pliocene climate and ice sheet modelling in collaboration with the University of Leeds, U.K.

We discovered and reconstructed two major cold-vent sites on the Lofoten margin and southwestern Barents Sea, that became apparently active after the last ice age. We integrated ROV and forefront acoustic technologies and advanced geochemical analysis. A multi proxy study of methane-derived carbonate crusts using petrographic, geochemical and isotopic tools has the overarching aim to explore the potential of crusts as archives of past methane fluxes.

One of our other highlights is a 2.0 billion year old venting system in NW Russia, which shows the presence of a highly diverse microbial community. This community consists of modern-like methanotrophic archaea and sulfur metabolizing bacteria in phosphorous-rich setting. Recent geological fieldwork and drillcore sampling in Russia provided unique evaporate and phosphorite materials for studying environmental consequences of Earth's oxygenation.

We will continue our study on the oldest phosphorites on Earth and test if the oxygenation of the Earth at 2.4 billion years led to an increase in the sulphate and oxygen concentrations of oceans. This would have created widespread habitats for sulphur oxidising bacteria and their associated microbial consortia, which in turn led to the worldwide advent of phosphogensis.

Infrastructures

A new 2G cryogenic rock magnetometer funded through CAGE is now installed and ready to use at the Geological Survey of Norway. It will allow (1) to improve the late Cenozoic paleomagnetic timescale and (2) study fossil gas hydrate systems by means of seep-related authigenic greigite formation in the Arctic. The new facility will be available for graduate and PhD students as well as Post doc fellows from all national and international partners.

Recruitment

Kärt Üpraus started her PhD on formation of ~2 billion year old worldwide phosphorites and the role of sulphur cycling.

Related projects

- Natural hydrocarbon emissions and their relation to neo-tectonics and glacial dynamics (2012–2015), Knies, J. (Project leader). Funding: RWE-Dea Norge
- Neotectonics and fluid flow processes – Phase III 2013–2016 – Studies of carbonate crusts, Thorsnes, T. (Project leader). Funding: Lundin Norway.

Arctic sea ice is important habitat for several Arctic species, such as the Polar Bear. Photo: USGS.

Arctic sea ice emerged 2,6 million years ago

“We have not seen an ice free period in the Arctic Ocean for 2,6 million years. However, we may see it in our lifetime.” says marine geologist Jochen Knies. He has studied the historic emergence of the ice in the Arctic Ocean. The results were published in Nature Communications in 2014.

Text: Gudmund Løvø (NGU) / Maja Sojtaric (CAGE)

Four to five million years ago, the extent of sea ice cover in Arctic was much smaller than it is today. The maximum winter extent did not reach its current location until around 2.6 million years ago. This new knowledge can now be used to improve future climate models and future scenarios for methane release and carbon cyling.

“We have not seen an ice free period in the Arctic Ocean for 2,6 million years. However, we may see it in our lifetime. The new IPCC report shows that the expanse of the Arctic ice cover has been quickly shrinking since the 70-ies, with 2012 being “the year of the sea ice minimum”, says marine geologist Jochen Knies.

He is a research scientist at CAGE and Geological Survey of Norway (NGU).

In an international collaborative project, Jochen Knies has studied the trend in the sea ice extent in the Arctic Ocean from 5.3 to 2.6 million years ago. That was the last time the Earth experienced a long period with a climate that, on average, was warm before cold ice ages began to alternate with mild interglacials.

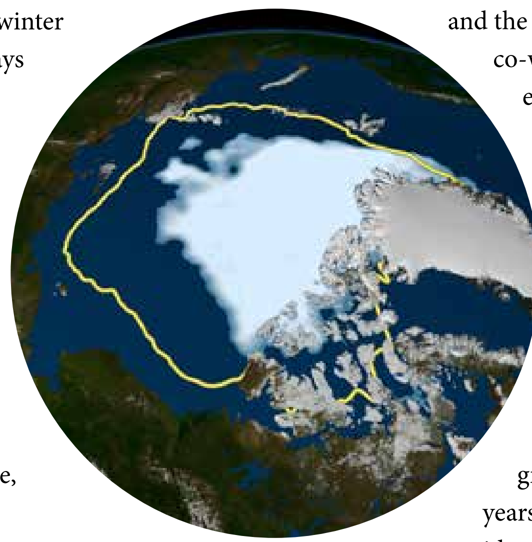
Fossils reveal past sea ice extent

"When we studied molecules from certain plant fossils preserved in sediments at the bottom of the ocean, we found that large expanses of the Arctic Ocean were free of sea ice until four million years ago," Knies tells us.

"Later, the sea ice gradually expanded from the very high Arctic before reaching, for the first time, what we now see as the boundary of the winter ice around 2.6 million years ago," says Jochen Knies.

Arctic Ocean likely to be completely free of sea ice

The research is of great interest because present-day global warming is strongly tied to a shrinking ice cover in the Arctic Ocean. By the end of the present century, the Arctic Ocean seems likely to be completely free of sea ice, especially in summer.



This may be of major significance for the entire planet's climate system. Polar oceans, their temperature and salinity, are important drivers for world ocean circulation that distributes heat in the oceans. It also affects the heat distribution in the atmosphere. This will allow a driect escape of greenhouse gas methane from open ocean waters to the atmosphere but also direct exchanges between carbon sources and sinks.

Trying to anticipate future changes in this finely tuned system, is a priority for climate researchers. For that they use climate modeling, which relies on good data.

"Our results can be used as a tool in climate modelling to show us what kind of climate we can expect at the turn of the next century. There is no doubt that this will be one of many tools the UN Climate Panel will make use of, too. The extent of the ice in the Arctic has always been very uncertain but, through this work, we show how the sea ice in the Arctic Ocean developed before all the land-based ice masses in the Northern Hemisphere were established," Jochen Knies explains.

Seabed samples from Spitsbergen

A deep well into the ocean floor northwest of Spitsbergen was the basis for this research. It was drilled as part of the International Ocean Drilling Programme, (IODP), to determine the age of the ocean-floor sediments in the area.

Then, by analysing the sediments for chemical fossils made by certain microscopic plants that live in sea ice and the surrounding oceans, Knies and his co-workers were able to fingerprint the environmental conditions as they changed through time.

"One thing these layers of sediment enable us to do is to "read" when the sea ice reached that precise point," Jochen Knies tells us.

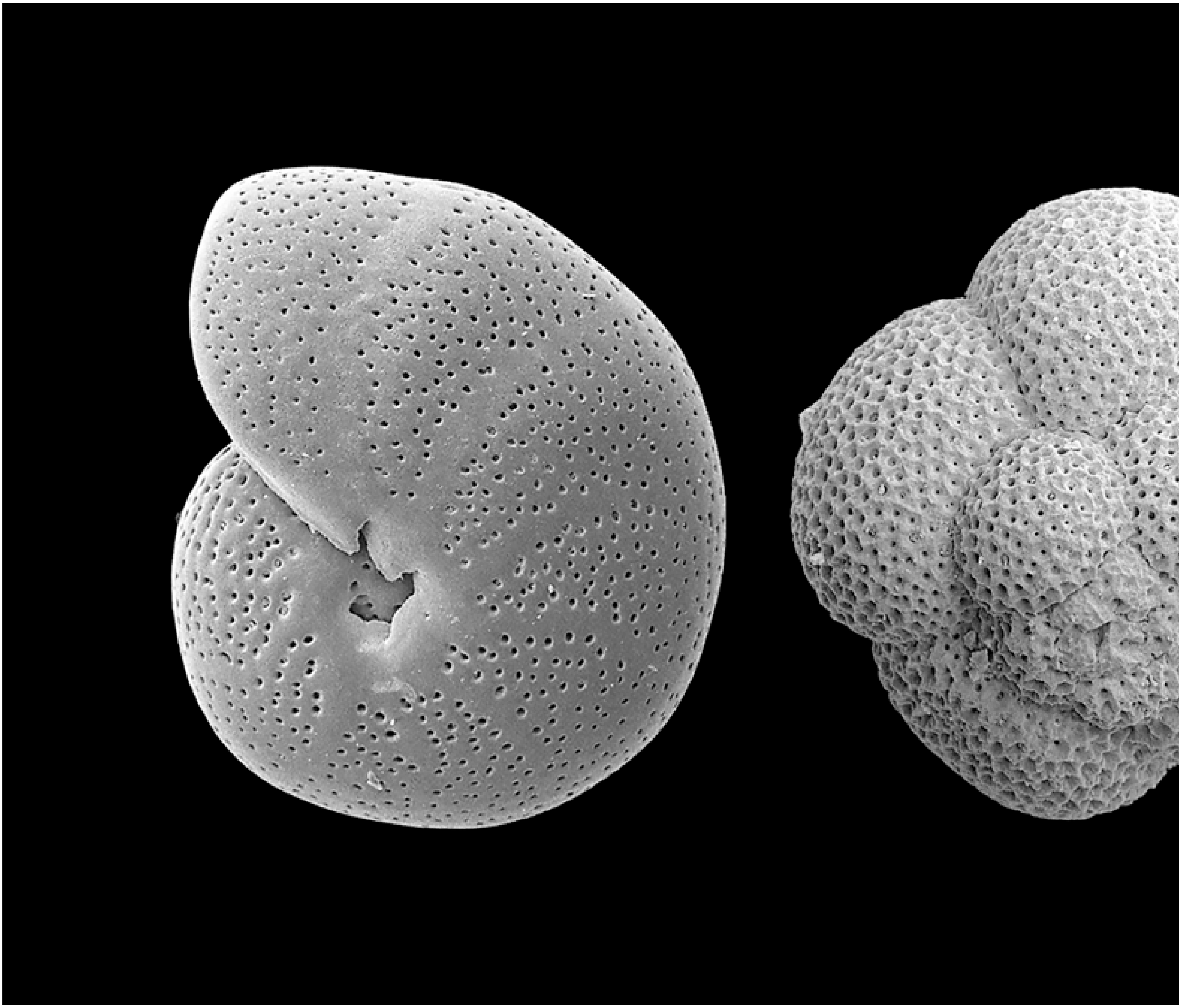
The scientists believe that the growth of sea ice until 2.6 million years ago was partly due to the considerable exhumation of the land masses in the circum-Arctic that occurred during this period. "Significant changes in altitudes above sea level in several parts of the Arctic, including Svalbard and Greenland, with build-up of ice on land, stimulated the distribution of the sea ice," Jochen Knies says.

"In addition, the opening of the Bering Strait between America and Russia and the closure of the Panama Canal in central America at the same time resulted in a huge supply of fresh water to the Arctic, which also led to the formation of more sea ice in the Arctic Ocean," Jochen Knies adds.

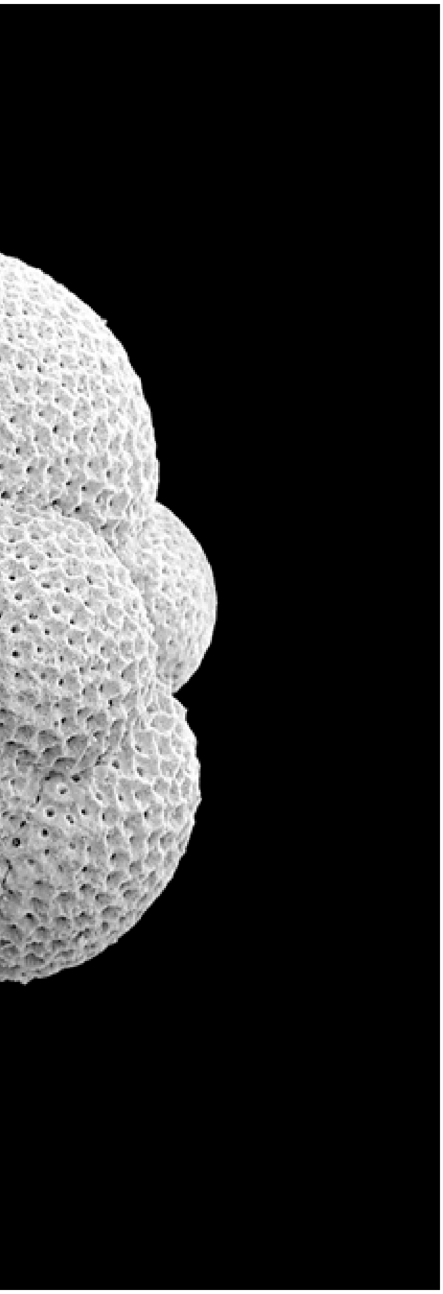
All the large ice sheets in the Northern Hemisphere were formed around 2.6 million years ago.

International effort

Scientists at CAGE, UiT The Arctic University of Norway, NGU, University of Plymouth, Universitat Autònoma de Barcelona, Stellenbosch University in South Africa and Institució Catalana de Recerca i Estudis Avançats in Barcelona have collaborated in this work. ■



Foraminifera are crucial for understanding climate of ages gone by. When they die the shells become a part of the ocean sediment. The temperature of their lifetime stays inscribed in the chemistry of their shells, making them micro-thermometers that reveal thousands of years of climate change. Photo: Tine Lander Rasmussen.



WORK PACKAGE 6:

Pleistocene to present

Methane, ocean acidification and CO2. We monitor ocean acidification related to methane emissions. We follow the development in known areas of methane seeps, by yearly sampling of benthic foraminifera communities, microscopic organisms that are sensitive to methane emissions. We also study fossils of foraminifera in sediment cores together with surface samples to reconstruct methane emissions related to climate and oceanographical changes.

Team Leader: Tine Lander Rasmussen

Tine Rasmussen is a professor at the Department of Geology, UiT The Arctic University of Norway. Her research includes paleoceanography, paleoclimate, paleoecology, micropaleontology, abrupt climate and oceanographic changes, long time series, Arctic, and sub-Arctic areas.

Tine Rasmussen has a PhD in marine micropaleontogy from the University of Aarhus (Denmark). She has worked at Royal Netherlands Institute for Sea Research, University of Copenhagen (Denmark), Woods Hole Oceanographic Institution (USA), Lund University (Sweden) and The University Centre in Svalbard. ■

Giuliana Panieri
Associate professor

Chiara Consolaro
Postdoctoral researcher

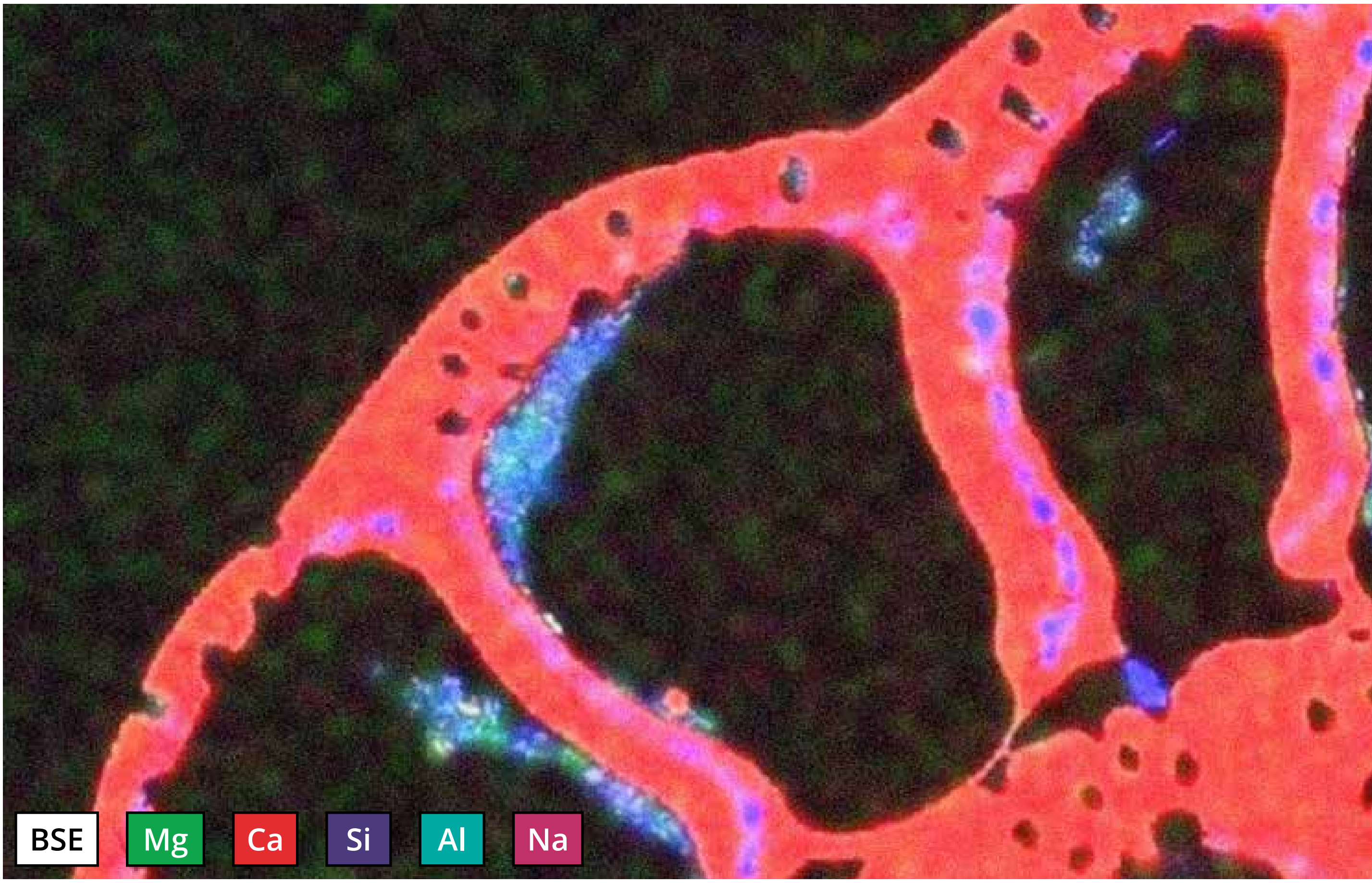
Katarzyna Zamelczyk
Postdoctoral researcher

Edel Ellingsen
Research engineer

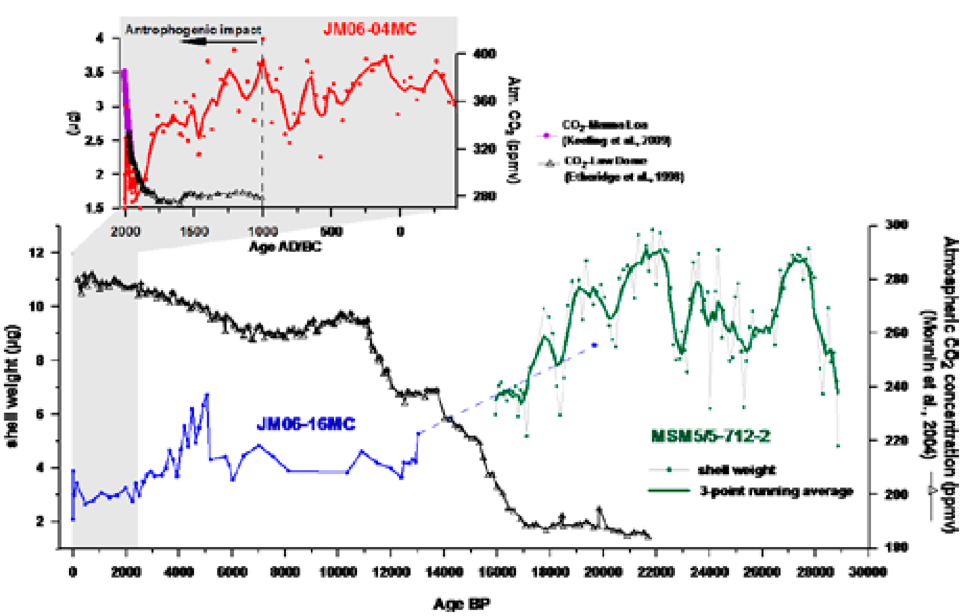
Mohamed Ezat
PhD candidate

Kamila Sztybor
PhD candidate

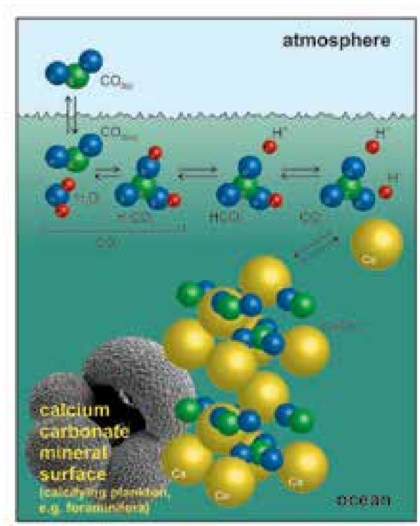
Andrea Schneider
PhD candidate



Scanning Electron Microscope (SEM) micrographs showing a detail of the shell of Melonis barleeanum, benthic foraminifera. Detailed inspection of the foraminifera shell provides useful information on primary calcification and secondary precipitation of methane-derived authigenic carbonate occurring at methane seep sites. The study highlights the importance of using advanced microanalytical techniques to investigate this unique bioarchive. Text and image: Giuliana Panieri.



Shell weight records from sediment cores (Zamelczyk et al., 2012; 2013; 2014) from the Fram Strait compared to atmospheric CO_2 concentration (Monnin et al., 2004; Etheridge et al., 1998; Keeling et al., 2009).



Reconstruction and quantification of planktonic foraminifera response to changes in surface ocean chemistry due to shifts in concentration of atmospheric CO_2 from the past 30,000 years to the present day in the northern North Atlantic

Scientific highlights

We monitor development in seep areas by annual sampling to study eventual changes in methane release and ocean acidification related to methane emissions. Sediment cores and surface samples are studied to reconstruct methane emission in the past in relation to climate and oceanographic changes.

Past bottom water temperatures are reconstructed by means of Mg/Ca ratios, oxygen isotopes and transfer functions on benthic foraminiferal species. Bottom current activities are reconstructed using sortable silt and mineral magnetics. Ocean acidification related to emission of greenhouse gases to the atmosphere and emission of methane to the water column in the past and present is studied by means of boron isotopes, B/Ca ratios and shell weight of foraminifera.

In 2014 we had cruises to Vestnesa, Storfjorden, the Barents Sea and fjords and shelf off Tromsø for sediment sampling, plankton towing and water sampling for chemical analyses of pH, CO_2, CH_4, inorganic nutrients and particulate and dissolved organic content.

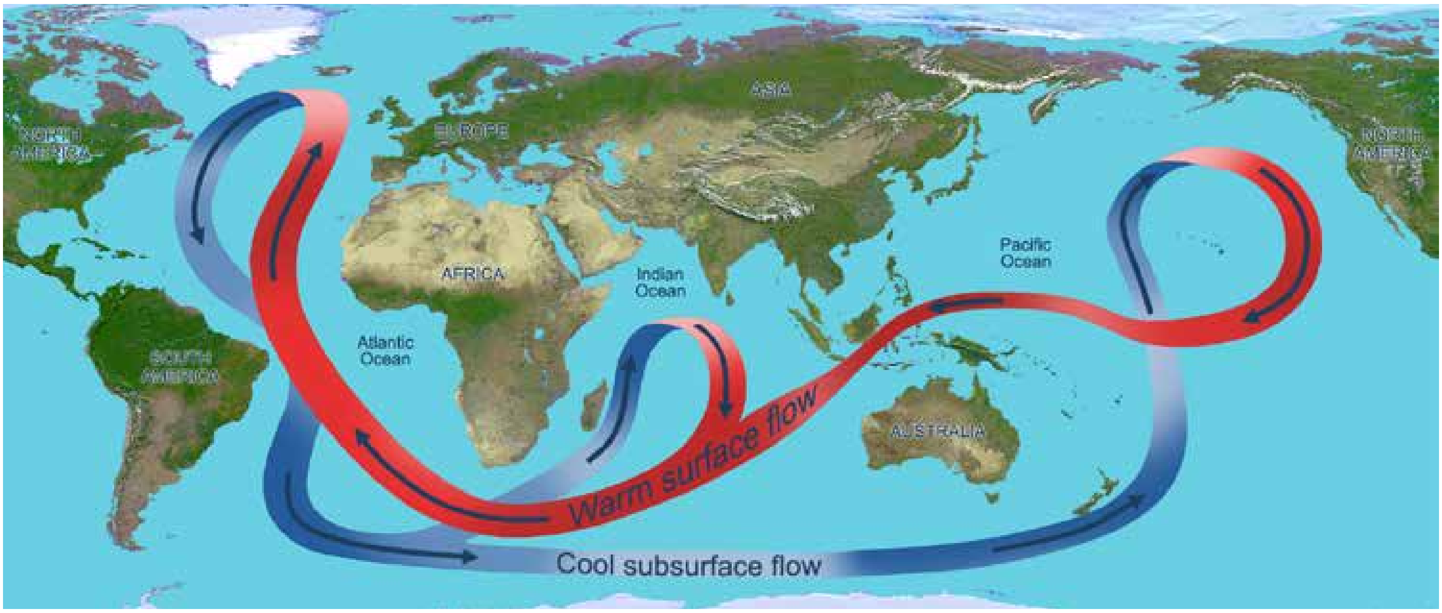
To provide records for the global background signal of greenhouse gases and climate change, areas largely unaffected by methane are studied as control areas.

Geochemical records from measurements of the foraminifera shells and fauna analyses will help us evaluate the changes in methane emissions, while studies of living and fossil species distribution and abundance of the benthic foraminifera community in methane seep areas will indicate the degree of methane release through time.

We have performed sediment and fauna analyses throughout 2014 including: carbon-14 datings, isotope analyses (18-O, 13-C, 11-B), element analyses (Mg/Ca, B/Ca, Sr/Ca ratios). Major parts of these analyses were performed on research stays at Columbia University, NY, USA (M. Ezat), at Alfred Wegener Institute, Bremerhaven, Germany (K. Zamelczyk), at Aarhus University, Aarhus, Denmark (T.L. Rasmussen), at Universitat de Barcelona, Barcelona, Spain (G. Panieri). These analyses will continue in 2015 as well.

Infrastructures:
A new plankton net (HydroBios) allowed to improve sampling at sea. A major investment including a new laboratory scientist will allow to run thermoscientific MAT 253 Stable Isotope Ratio Mass Spectrometer System equipped with Flash HT Plus elemental analyzer, GasBench II, and ConFlo IV universal continuous flow interface for clumped isotopes purchased, to be installed in 2015. There are only two such advanced laboratories in Norway, one at the Bjerknes Centre at the University of Bergen, and one at CAGE at UiT The Arctic University of Norway in Tromsø.

Recruitment:
Andrea Schneider has been recruited to a PhD position in February 2014. She will work on a thesis entitled:"History of seafloor methane emissions and their relationship with Pleistocene climate change".



Colloquially referred to as the Gulf Stream, the warm North Atlantic Current is partly responsible for our mild North European winters. It flows into the Nordic seas, where it cools down in winter and releases heat to atmosphere. It becomes denser and sinks to the bottom of the Nordic seas. It forms an important part of the global circulatory system of ocean currents.

Gulf Stream submerged during the last Ice Age

The warm Atlantic water continued to flow into the icy Nordic seas during the coldest periods of the last Ice Age infuencing deep-water gas hydrate stability.

Text: Maja Sojtaric/cage.uit.no

An ice age may sound as a stable period of cold weather, but the name deceives. In the high latitudes of the Northern Hemisphere, the period was characterized by significant climate changes. Cold periods (stadials) switched abruptly to warmer periods (interstadials) and back.

“It is widely thought that during cold periods of the last Ice Age the warm Atlantic water had stopped its flow into the Nordic Seas. The results of our recent study suggest that the Atlantic water never ceased to flow into the Nordic Seas during the glacial period,” says Mohamed Ezat, PhD at Centre for Arctic Gas Hydrate, Environment and Climate (CAGE) at UiT, The Arctic University of Norway.

The study, published in Geology*, documented that bottom water actually warmed up to up to 5°C at 1200 m depth in the Nordic seas during the cold stadials. Cold bottom water temperatures of 0,5°C was observed during the warm interstadials, which is fairly similar to what we have today.

How is this possible?

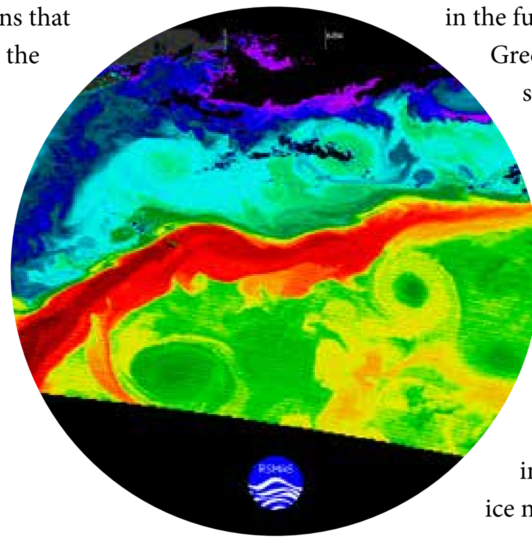
So the air was getting colder, but the deep ocean water was getting warmer, during the coldest periods of the Ice Age. How is this possible?

Colloquially referred to as the Gulf Stream, the warm North Atlantic Current is partly responsible for our mild North European winters. It flows into the Nordic seas, where it cools down in winter and releases heat to atmosphere. It becomes denser and sinks to the bottom of the Nordic seas. It forms an important part of the global circulatory system of ocean currents.

“Cold, deep water from this little area of the Nordic seas, less than 1% of the global ocean, travels the entire planet and returns as warm surface water. This has been a fairly stable process for the last 10 000 years. The events here are significant for the entire ocean system. But if we go back to the Ice Age things were quite different," says professor Tine Rasmussen, also from CAGE.

Warm water under the ice

The reason was that ice sheets across Scandinavia and North America produced a large amount of fresh melt water from icebergs. This means that the surface water could not achieve the required density to sink – this is a process that depends on salinity. The warm Atlantic water was saltier, and therefore heavier and subducted at depth and reached to the bottom, actually heating up beneath a lid of ice and melt water, that prevented the release of heat to the atmosphere.



"Warm water was there, but deep under the cold, icy surface. So the climate experience was colder, as the atmospheric records from Greenland ice cores show. But what eventually happened, is that the warm water reached a critical point, surged upwards to the surface, and contributed to the abrupt warming of the surface water and atmosphere," says Ezat.

Micro-thermometers

Prof. Rasmussen suggested this already in 1996** and a conceptual model was published in 2004***.

"Our results were debated, because we didn't have exact temperature measurements. Ezat and co-authors applied a new method to measure the exact temperature from the sediment cores collected north of the Faroe Islands," says professor Rasmussen.

The temperature is measured in the shells of single celled organisms called benthic foraminifera. When they die the shells become a part of the ocean sediment. The temperature of their lifetime stays inscribed in the chemistry of their shells, making them micro-thermometers that reveal climate of the ages gone by.

"The amount of magnesium in the shells of specific species of foraminifera depends primarily on temperature. By measuring the ratio of magnesium to calcium we can estimate changes in temperature. We were lucky to find a continuous record of well-preserved benthic species for the analyses," says Ezat.

Significant for future climate

Understanding what happened with our ocean systems during the Ice Age, helps us understand what may happen to them if ice on Greenland and Antarctica melts in the future. Fortunately, the ice sheet over Greenland is much smaller than the ice sheet during the Ice Age and thus with less potential to seriously disturb the system.

"It is however, imperative to consider recent localized changes around Greenland and Antarctica in the light of our results. The basal melting due to subsurface warming represents an important component of the current ice mass loss," Ezat points out.

"Also, increase of melt water in the East Greenland Current may cause a weakening in the deep convection in the Nordic Seas. This may cause a warm subsurface inflow that may reach bottom on the East Greenland slope. Such a scenario, though very uncertain, has the potential to influence the stability of gas hydrates on the slope."

Gas hydrate is essentially frozen methane gas under the ocean floor. If it melts in both deep and shallow water areas it has a potential to release huge amounts of this hyper potent greenhouse gas.

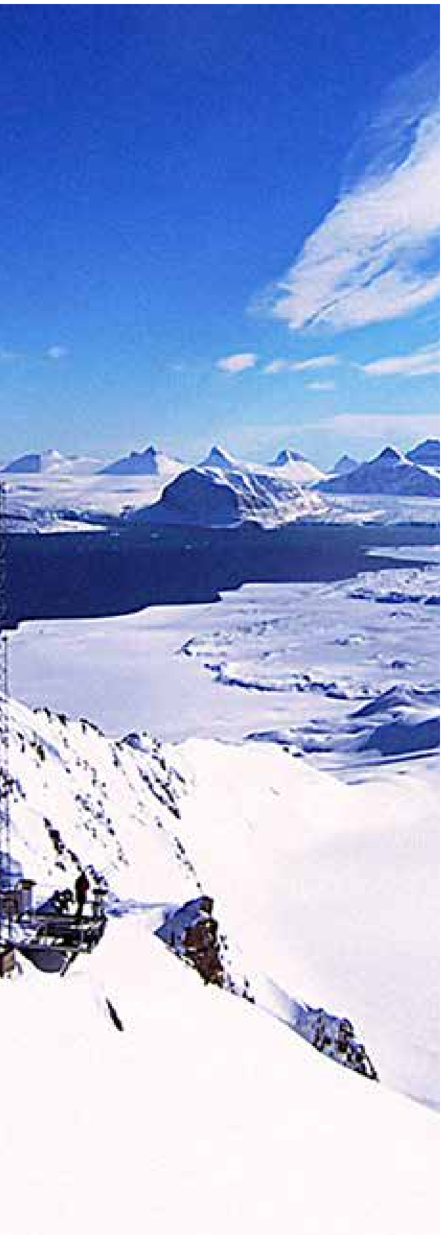
References:

* Persistent intermediate water warming during cold stadials in the southeastern Nordic seas during the past 65 k.y. Mohamed M. Ezat, Tine L. Rasmussen and Jeroen Groeneveld. Geology, 2014.

** Circulation changes in the Faeroe–Shetland Channel correlating with cold events during the last glacial period (58–10 ka). T. L. Rasmussen, E. Thomsen, L. Labeyrie, and T.C.E van Weering, Geology, 1996.

*** The role of the North Atlantic Drift in the millennial timescale glacial climate fluctuations. Rasmussen, T.L., and E. Thomsen, Palaeogeography, Palaeoclimatology, Palaeoecology, 2004.

The atmospheric observatory on Zeppelin Mountain, near Ny-Ålesund, Svalbard. At 79° N, the station is located in an undisturbed Arctic environment, away from major pollution sources. Influence from local pollution sources is also limited by the observatory's location at 474 metres above sea level, which means that most of the time it is above the local inversion layer. The unique location of the observatory makes it an ideal platform for the monitoring of global atmospheric change and long-range pollution transport. Photo: Ove Hermansen/NILU



WORK PACKAGE 7:

Atmosphere

Part of the MOCA project. How much of the methane that is stored as gas hydrate in the seabed actually reaches the atmosphere? It is in the atmosphere that the greenhouse gas can have most significant impact on global warming. Current scientific results show a large diversity in the flux of methane from ocean to the atmosphere. Our objective is to quantify the present effects methane from gas hydrates has on the atmosphere, and potential climate impacts of the gas in the decades and centuries to come.

Team Leader: Cathrine Lund Myhre

Cathrine is a researcher at NILU – Norwegian Institute for air research and the project leader of the MOCA project. She has a PhD in in physical chemistry from University of Oslo, Norway. Her main research is on atmospheric compositional change and atmospheric measurements. In particular she works with natural and anthropogenic emissions of greenhouse gases and aerosols. She studies and their sources, concentrations and long term trends, especially in Arctic and Sub-Arctic regions. ■

Jürgen Mienert
Professor, CAGE, UiT

Gunnar Myhre
Researcher, CICERO

Andreas Stohl
Researcher, NILU

The modified BAe 146-301 large Atmospheric Research Aircraft (the ARA) is owned by the Natural Environment Research Council, UK. Photo: Facility for Airborne Atmospheric Measurements (FAAM)

Scientific highlights

In the summer of 2014, we carried out a well-coordinated, successfull ship- and aircraft- campaign. All instruments for measuring greenhouse gas and fluxes worked well at both the ship and aircraft sensor installations. This includes the sampling of air for trace gas and isotopic analysis, and all the related procedures. All samples are at NILU (Oslo), for analysis and manuscripts for highly ranked scientific journals and conferences are underway.

During the campaign, the weather offshore Svalbard was calm and on our side. Thus, the most ambitious flights above sea surface were possible, with the aircraft going as low as 15 m above the sea over large areas. It was even possible to be on route together with *RV Helmer Hanssen*, though at a different speed (600km/hr aircraft versus 20km/h ship).

No long range transport episodes of industrial pollution seem to have influenced our measurements, neither at the ship offshore Svalbard or Zeppelin station on land. This is a great advantage as we are studying the natural sources and fluxes of greenhouse gas methane.

This campaign has provided us with new and important climate data that national and international teams are working on. The (Picarro) installations on board *RV Helmer Hanssen* allowed to measure for the first time methane concentrations for both ocean surface water masses and atmosphere including flight measurements. The national and international research work was driven by the desire to gain more knowledge about the transport of greenhouse gas from a potentially enormous but virtually unknown Arctic region of natural driven ocean-floor gas seeps.

Joint project

CAGE and MOCA (Methane emissions from the Arctic Ocean to the Atmosphere: Present and Future Climate Effects) have joint forces togheter with Norwegian Institute for Air Research (NILU) and Center for International Climate and Environmental Research (CICERO)

When atmospheric teams meet ocean teams through joint projects, one of the most important links are climate modellers. A group of climate modellers from CICERO and NILU will use accurate methane measurements from both the ocean and atmosphere to model and quantify the amount of CH_4 released from the ocean to the atmosphere above.

The modelling results will provide scenarios of potential future climate effects from destabilization of methane hydrate deposits in a warming world, and will focus on scenarios in 2050 and 2100.

Infrastructure:

This unique research cooperation combines landbased measurements using Zeppelin station on NW Svalbard, ship-based measurements aquired with RV Helmer Hanssen at UiT The Arctic University of Norway, and aircraft-based measurements aquired by research aircraft from Universities of Cambridge and Manchester (FAM and MAMM projects). ■

Screenshot of the integrated positioning system at FAAMs research aircraft during low flight west of Svalbard. The ambitious flight plan meant to cross over all the points marked "D" in the figure. The medium-sized aircraft flew constantly approximately 100 meters above sea level, but descended to about 15 meters for profiling. The skilled pilots used spare fuel tanks to repeat passages over the area where scientists believe methane seeps out, and thus doubled the amount of data collected. The measurements from the aircraft will be used together with the results from the ship, to consider methane flux at sea level in the Arctic.
Illustration: Torger Grytå/NILU

Using Ship, Aircraft in Search for Methane Emissions

The amount of methane in the atmosphere is increasing. Is the seabed one of the sources for the greenhouse gas? To answer this question, CAGE is measuring methane from ocean to atmosphere, using some truly cool gadgets.

Text: Maja Sojtaric/cage.uit.no

The seabed releases huge amounts of methane to the ocean. We don't know how much is released and reaching the atmosphere and whether it is one of the major sources for the greenhouse gas. It is still unknown, how much is coming from thawing offshore permafrost and how much is coming from hydrate dissociation. In the summer of 2014 Cage led a big research campaign, collecting methane measurements from seabed to ocean to atmosphere, in close collaboration with colleagues at Norwegian Institute for air research (NILU), Center for International Climate and Environmental Research – Oslo (CICERO), and Cambridge and Manchester University, UK.

Potential future climate effects

MOCA-project, funded by the Norwegian Research Council is an ideal partner. It applies advanced measurements and modeling to quantify the amount and present atmospheric impact of methane originating from hydrates. Research ship, aircraft, underwater installations, and Zeppelin observatory on Svalbard, are some of the tools used to find out if methane emissions from the ocean floor, affect our atmosphere.

The sources and amount of gas that reaches the atmosphere from the ocean are still a mystery. Carbon cycles are very complex processes.

An impressive and successful flight campaign

The measurements started in mid-June, when UiTs research vessel Helmer Hanssen set out on a six-week long cruise to undertake marine and atmospheric measurements in regions of northwestern Svalbard.

CAGE had already placed the monitoring equipment on the seabed in this location, to measure ocean currents, temperature and methane emissions.

A research aircraft joined RV Helmer Hanssen during the first week of July, measuring variations in methane concentration in the atmosphere.

This is the first time at this location, that such air and sea measurements of methane were done simultaneously. The aircraft was impressively operated by colleagues from University of Cambridge, flying as low as 15 meters above the sea surface. ■

One of the stops on our field trip to Italy were mud volcanos at Salse di Nirano. Photo: Maja Sojtaric.

The Arctic Marine Geology and Geophysics Research School

The Arctic Marine Geology and Geophysics Research School (AMGG), led by CAGE staff, provides researchers and students in-depth knowledge of Arctic marine geology and geophysics, and gas hydrate in cooperation with the Department of Geology.

The Research School offers cruises, seminars, international workshops, and courses through which it trains a new generation of scientists. The aim is to understand the multiple facets of how methane release impacts the marine environment and climate system.

Highlights of 2014

March–April

Winter School on Sea Ice Variability in the Arctic – Past and Present Conditions, was a collaboration between CAGE and the National Research School in Climate Dynamics (ResClim). International and national speakers were invited to cover topics about geological and geophysical aspects of sea-ice in the Arctic. They gave lectures on reconstructions of past sea ice extent, oceanography, basic sea ice physics, interactions between sea ice ocean and air, and remote sensing. In addition, specific case studies on cutting edge sea ice related topics were presented. 13 PhD students attended.

Annual AMGG workshop. The purpose of the annual workshop provides the students with the opportunity to present their project and explore various aspects of the research process in a supportive environment with supervisors.

Course in ArcGis. Denise Rüther, Sogn og Fjordane University College. The course combines theoretical lectures, practical exercises and examples.

June

Associated workshop to the AMGG research school cruise. The workshop consisted of a series of lectures by CAGE researchers and invited guest lecturers; in addition, PhD students presented their projects. Given the very different topics presented the discussions were very stimulating and the students received a feedback from experienced researchers.

Leader: Associate professor Giuliana Panieri

Giuliana is research leader at CAGE and Associate professor in environment and climate at the Department of Geology, UiT The Arctic University of Norway. She holds a PhD degree in Paleontology, University of Modena and Reggio-Emilia, a Research Post-Doctorate, University of Bologna. She has professional experience from the University of Barcelona (Spain), the University of Oldenburg (Germany), LSU Louisiana State University (USA), ISMAR CNR (Italy), and as a micropaleontology consultant for petroleum companies. She is using micropaleontology and geochemistry to study present and past methane emissions and methane hydrate dissociations. She seeks to answer questions regarding the timing, periodicity, and intensity of methane emissions with the final goal of assessing their evolution through time. She has published several peer-reviewed articles on these topics and has been invited to national and international conferences.

See AMGG website: http://amgg.uit.no

AMGG has 28 PhD- students, 13 Post-docs, and 21 supervisors.

"Symposium: Methane-rich marine environments: Ecology and geochemistry" consisted of talks covering the different aspects of methane-rich environments, from biogeochemistry, microbiology, micropaleontology, and methane derived carbonate, also from other continental margins. Among the international speakers (Helge Niemann, Antonine Cremiere, Soma Baranwal), Emeritus Barun K. Sen Gupta, pioneer in the study of micropaleontology in methane seep environments, presented data from the Gulf of Mexico and stimulated a very interesting discussion with students.

AMGG research school cruise on board of RV Helmer Hanssen. The cruise brings PhD students and Master Students together with leaders from CAGE for extended periods of study and interaction. Target area: West-Svalbard Margin focusing on gas hydrates, fluid leakage systems and its biological, geochemical and environmental impacts.

Activities: students received class instruction and experience in the field of Arctic research; Mini-projects to be performed in collaboration with CAGE leaders and expedition members. During the cruise, students compiled reports on a given topic required for evaluation subsequent to the cruise.

September

"Fluid emission fossil analogues" field trip, Italy. Scope of the field trip is to study fossil cold seep features exposed along the external part of the Northern Apennines as analogues to modern marine features. After the field trip, all participants agreed that CAGE PhD students would benefit from a similar field trip since they can see at real scale the proportion of fluid emissions features and use fossil analogues to refine interpretation of similar features in present day marine environments as seen in seismic and bathymetry data.

October

AMGG submitted two proposals in 2014: *Research School on CHanging Climates in the coupled Earth SyStem (CHESS)*. Proposal to the Research Council of Norway for a national research school, 2016–2023. CHESS is approved for funding by RCN with a budget: 71 607 000 NOK. CAGE is a partner in the national consortium.

PIRE: International Assessment of Earth System Impacts of the Thawing Arctic (ESITA). Partnerships for International Research and Education (PIRE), pre-proposal to National Science Foundation (NSF).

December

CAGE Christmas seminar. CAGE leaders presented 2014 achieved goals and 2015 plans. During the poster session, all students presented their PhD projects. ■

Our communications coordinator, Maja Sojtaric. Photo: Torger Grytå

Outreach and communication

As you have seen through the stories in this report we are dedicated to reaching out to general public with our research. Climate and environment issues are of crucial interest for the public and we take our responsibilities as stewards of this knowledge seriously.

We maintain our own web page, cross publish our material to UiT's webpage, and strive to do so in both Norwegian and English.

We use international press services such as alphagalileo.org and eurekalert.com to disseminate our research to a greater audience. In addition we subscribe to Norwegian and Nordic services such as forskning.no, geoforskning.no and sciencenordic.no. Our communications coordinator facilitates press contact with national and international media, as well as manages our social media: Facebook, Twitter and Instagram.

Our scientists gave several presentations in 2014 to different audiences, such as representatives from the Norwegian Parliament and international delegations that visited Tromsø. They participate in press conferences (EGU 2014), give talks at international events (AGU 2014), contribute to blogs, and events such as Forskningsdagene. CAGE also collaborates with The University Museum in Tromsø on the next permanent exhibition on geology, in which several of our scientists will appear, and which has school children as primary target group.

In 2014 we started with our Brown Bag Seminars, where both invited speakers and our own students give talks on chosen subjects. The seminars are open for the entire UiT community, and are maintained by two PhD students (Kate Waghorn, Emmelie Åström) together with our communications coordinator.

Communications coordinator: Maja Sojtaric has worked for a decade as science journalist and editor at UiT's science magazine Labyrint. She acts as an communications advisor for our scientists, gives workshops, and writes our stories. Occasionally she snaps a photo or two. ■

Outreach highlights

Norwegian outlets:

NRK Radio (Norwegian public broadcaster)
Metangass i Arktis truer klimaet. August 20, 2014.

NRK Søndagsrevyen (Sunday News Review)
Frykter konsekvenser av metanutslipp. September 14, 2014.

Teknisk ukeblad
Nye sensorstasjoner skal overvåke metanutslipp på havbunnen i Arktis. October 14, 2014.

Nordlys
-- Dette er ikke noe en kjøper på Biltema. October 12, 2014.

Labyrint
Hvorfor valgte du leirevulkaner? Issue 03, October 2014

Labyrint
Utforsker vulkanens hemmeligheter. Issue 03, October

Geoforskning.no
Store metanutslipp under siste istid. May 2, 2014.

Forskning.no
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– Public booth on sclerochronology, William G.Ambrose, CAGE Visiting Professor.
– Oceanography for school children on board RV Johan Ruud, Pär Jansson PhD, CAGE.

Press Conference:
"The changing Arctic", EGU General Assembly, Vienna, Austria, April 2014. Giuliana Panieri, Associate Professor CAGE.

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Anna Silyakova. "Biogeochemistry of methane in the Arctic Ocean". *AMGG Research School Workshop*, Tromsø, June 11–13, 2014.

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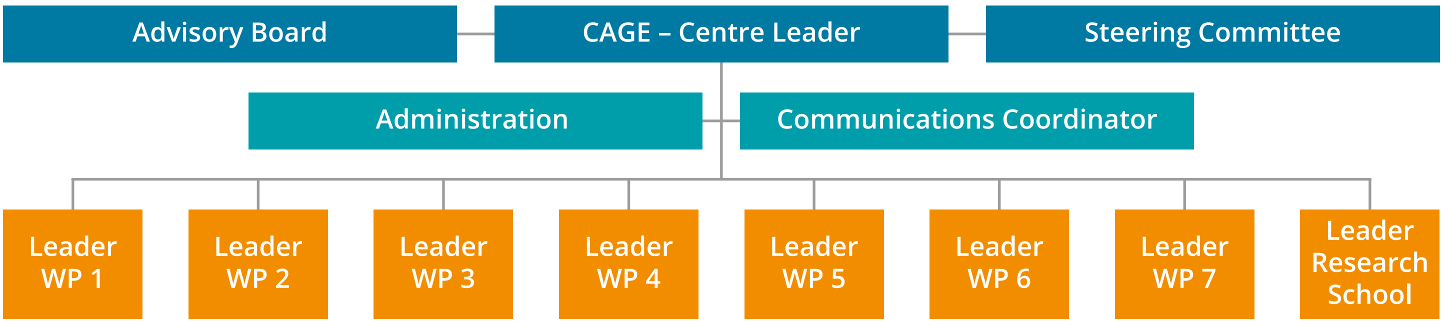
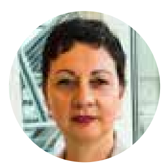


Steering Committee

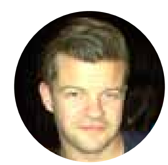
Kenneth Ruud
Prof., Pro-Rector for Research and Development, UiT

Morten Hald
Prof. Dean NT-faculty, UiT



Nalan Koc
PhD, Research Director, Norwegian Polar Institute

Morten Smelror
PhD, Adm. Director, Norwegian Geological Survey



Jarle Husebø
PhD, Senior researcher, unconventional resources, STATOIL

Advisory board meets CAGE team

Early career scientists, as well as work package leaders, presented our recent scientific efforts to the Advisory Board in January 2015. From left back: Professor Gerald Haug (Board member from University of Zürich/ Max Plank Institute), Thorbjörg Hroarsdottir, Jürgen Mienert, Tine Rasmussen, Stefan Bünz, professor Georgy Cherkashov (Board member – University of St. Petersburg/ VNIIOkeanologia), Karin Andreassen, professor Antje Boetius (Board member, Alfred Wegener Institute/Max Plank Institute) Wei-Li Hong, JoLynn Carroll, Giuliana Panieri, Heidi Roggen (Reasearch Council of Norway). From left front: Anna Silyakova, Andreia Plaza Faverola, Benedicte Ferre, Monica Winsborrow and Jochen Knies. Photo: Maja Sojtaric

Other advisory board members not present at this meeting: Drs Timothy Collett / Carolyn Ruppel, USGS and Dr. Scott Dallimore, Geological Survey of Canada.

Personnel

There are 49 percent women and 51 percent men in our scientific staff. This is way above the average of 21 percent women in STEM fields in the OECD countries, and significantly above the average of 16 percent in Norway. More than 60 percent of our staff are PhD students and early-career scientists.

Senior scientific staff:
Jürgen Mienert, professor
Karin Andreassen, professor.
Tine L. Rasmussen, professor.
Alun Hubbard, professor.
Stefan Bünz, associate professor.
Giuliana Panieri, associate professor
JoLynn Carroll, adjunct professor
Cathrine Lund Myhre, senior scientist.
Leonid Polyak, adjunct professor.
William Ambrose, visiting professor
Joel Johnson, visiting professor.
Jens Greinert, visiting professor.

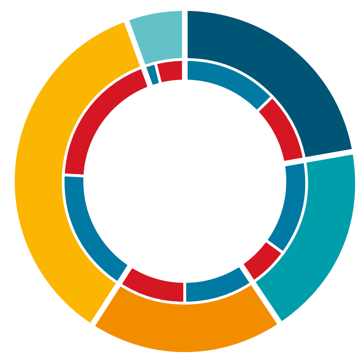
Researchers:
Bénedicté Ferré.
Jochen Knies
Monica Winsborrow
Michael Carroll.
Shyam Chand.
Andreia Plaza Faverola
Terje Thorsnes
Reidulv Bøe
Karl Fabian
Aivo Lepland

Postdoctoral Researchers:
Soma Baranwal
Antoine Cremiere
Sunil Vadakkepuliyambatta
Peter Franek
Henry Patton
Frederike Gründiger
Anna Silyakova
Wei Li Hong
Chiara Consolaro
Katarzyna Zamelczyk

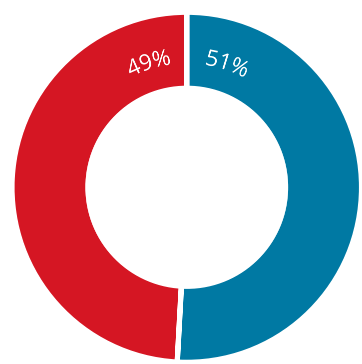
PhD Candidates:
Pavel Serov
Sandra Hurter
Giacomo Osti
Alexandros Tasianas
Alexey Portnov
Sunny Singroha
Kate Waghorn
Emilia Daria Piasecka
Mariana da Silveira Ramos Esteves
Eythor Gudlaugsson
Calvin Shackelton
Nikolitsa Alexandropoulou
Emmelie Linnea Åström
Pär Gunnar Jansson
Simone Sauer
Kärt Üpraus
Mohamed Ezat
Kamila Sztybor
Andrea Schneider

Adminstrative and technical staff:
Maja Sojtaric, communications coordinator
Anoop Mohanan Nair, engineer.
Edel Ellingsen, research engineer.

CAGE supervised Master students:
Håkon Mikalsen, Yohannes Tesfay, Aleksander Wiik, Olga Agafanova, Adrian Lium-Wickler, Anders Edvardsen, Anna-Maria Hatland, Ingvild Westvig Myrvang, Carita E. Eira Varjola, Janita Nordahl, Torbjørn Kristiansen, Daniel Tesfamariam, Nils Karlsen, Lisa Mathisen, Lena Mathisen, Björg Jónsdóttir, Erna Osk Arnardottir, Karoline Myrvang, Vårin Trælvik Eilertsen, Boriss Kovalenko, Christine Lockwood, John Sverre Løvaas, Frank Jakobsen, Anders Edvardsen.



Staff and gender



Gender

Budget

Cost plan (in NOK 1000)	2014	NFR	UiT
Payroll and indirect expenses	29.698	9.714	19.984
Procurement of R&D services (NGU)	100	100	
Other operating expenses	21.534	10.520	11.014
Totals	**51.332**	**20.335**	**30.997**

Collaborations

CAGE is collaborating on different levels with several national and international research institutions and offshore industries.

National

Geological Survey of Norway (CAGE partner)
University of Oslo
University of Bergen
University Centre in Svalbard
Institute of Marine Research
Norwegian Polar Institute
University of Nordland
Norwegian Institute of Water Research
Department of Arctic and Marine Biology, UiT The Arctic University of Norway
Nordic Environmental Nucleotide Network (NENUN)
Norwegian institute for Air Research (NILU)
AkvaplanNiva

Other collaborations

Norwegian Petroleum Directorate
Statoil
Kongsberg Maritime
Norwegian Defence Research Establishment, FFI
Lundin Petroleum
Integrated Ocean Drilling Program, IODP.

International

Woods Hole Oceanographic Institute, USA
Harvard University, USA
Lamont-Doherty Earth Observatory, USA
Byrd Polar Research Centre, Ohio State University, USA
Bates College, USA
Oregon State University, USA
University of New Hampshire, USA
United States Geological Survey (USGS), USA
University of Cambridge, UK
St. Andrews University, Scotland, UK
Durham University, UK
Bangor University, UK
Leeds University, UK
University of East Anglia, UK
University of Warwick, UK
Swansea University, UK
National Oceanographic Centre NOC, Southampton, UK
British Antarctic Survey, UK
University of Manchester, UK
British Geological Survey (BGS), UK
Institut francais de recherche pour l'exploitation de la mer (IFREMER), France
Le Centre national de la recherche scientifique (CNRS), France
University of Ghent, Belgium
Geological Survey of Canada (GSC), Canada
Federal Institute for Geosciences and Natural Resources, Germany
MARUM, University of Bremen, Germany
GEOMAR Helmholtz Centre for Ocean Research, Germany
Alfred Wegener Institute, Germany
VNIIOkeangeologia, Russia
Murmansk Arctic Geological Expedition (MAGE), Russia
Moscow State University, Russia
Winogradsky Institute of Microbiology, Russia
Istituto Nazionale di Oceanografia e di Geofisica (OSG), Italy
Institute of Marine Sciences, Barcelona, Spain
Geological Survey of Denmark and Greenland, Denmark
University of Aarhus, Denmark
University of Vienna, Austria
Stockholm University, Sweden

Joel Johnson, visiting professor

My guest research stay in CAGE, during a one year sabbatical from the University of New Hampshire, provided me with an extraordinary opportunity to work with a large group of methane hydrate scientists, to collect new data, and to advance our understanding of methane hydrate systems in the Arctic.

As a one-year guest researcher in CAGE, I had the time and support to focus on data collection, during two CAGE-led research cruises, data analysis, and manuscript preparation. The resulting data formed the basis for two high profile papers that are now in press (2015).

I also helped collect and analyze several sediment cores, and with CAGE support, presented preliminary results from this work at two international meetings in 2014. Samples from these cores and continued analyses continues this collaboration and will result in additional publications. The research success during my guest appointment in CAGE was enabled by the collaborative and open research environment that CAGE promotes, the in-person interactions and discussions I had with several CAGE scientists throughout the year, and the unprecedented field access, via the CAGE/UiT research vessel Helmer Hanssen, to the Arctic Ocean region.

Photo: Kai Mortensen.

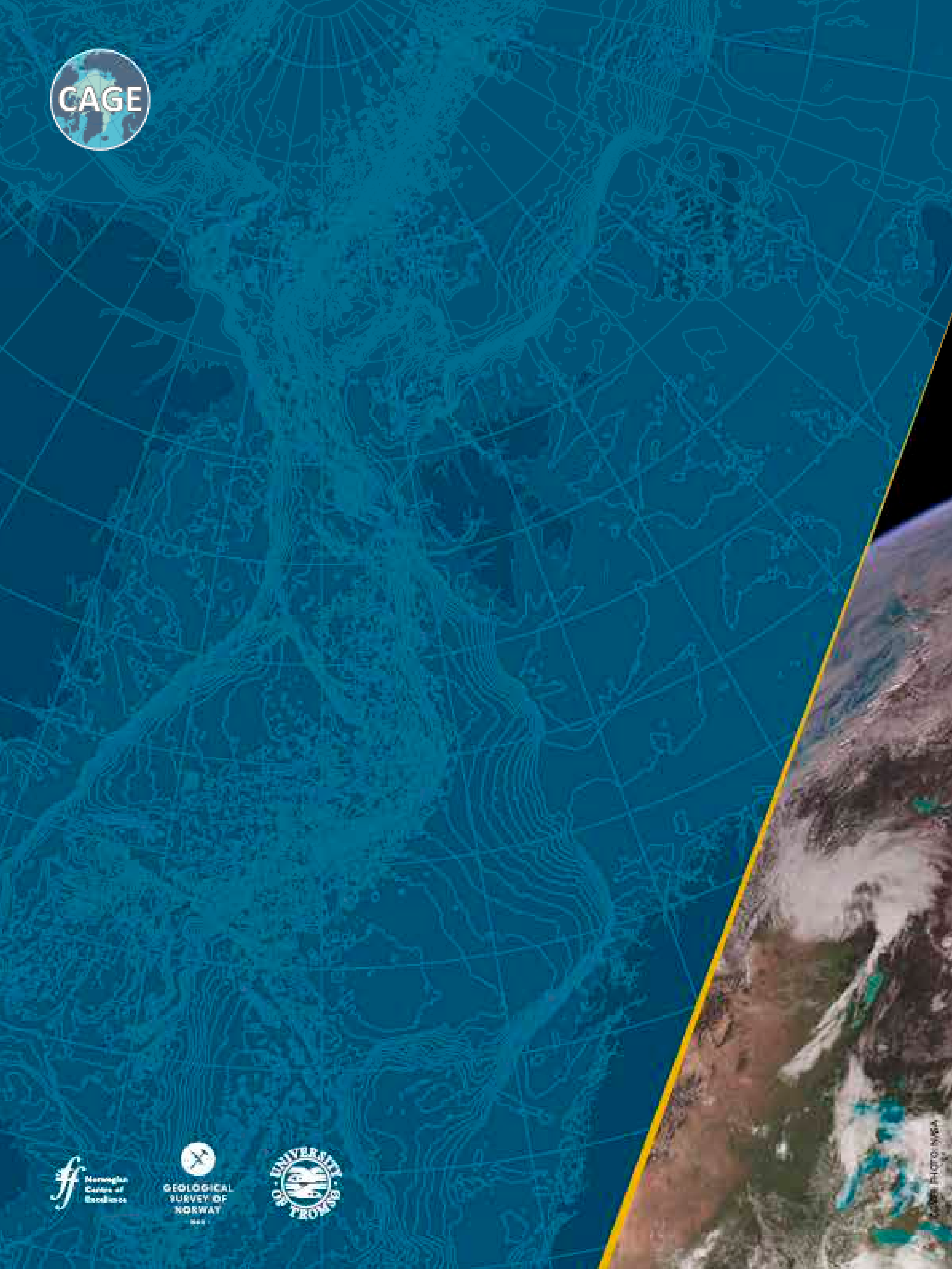
Follow us

For regular updates on CAGE activities follow us on:

- www.cage.uit.no
- facebook.com/cageuit
- @cage_coe
- @cage_coe

CAGE Christmas seminar 2014

We aim to arrange an annual conference in December where students and senior scientists present their scientific progress to their collegues. The Christmas Seminar 2014 was a success, attended by most of the staff. It led to increased integration between work packages and better overview of future scientific priorities.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Norwegian Centre of Excellence
GEOLOGICAL SURVEY OF NORWAY
UNIVERSITY OF TROMSØ
PHOTO: NASA