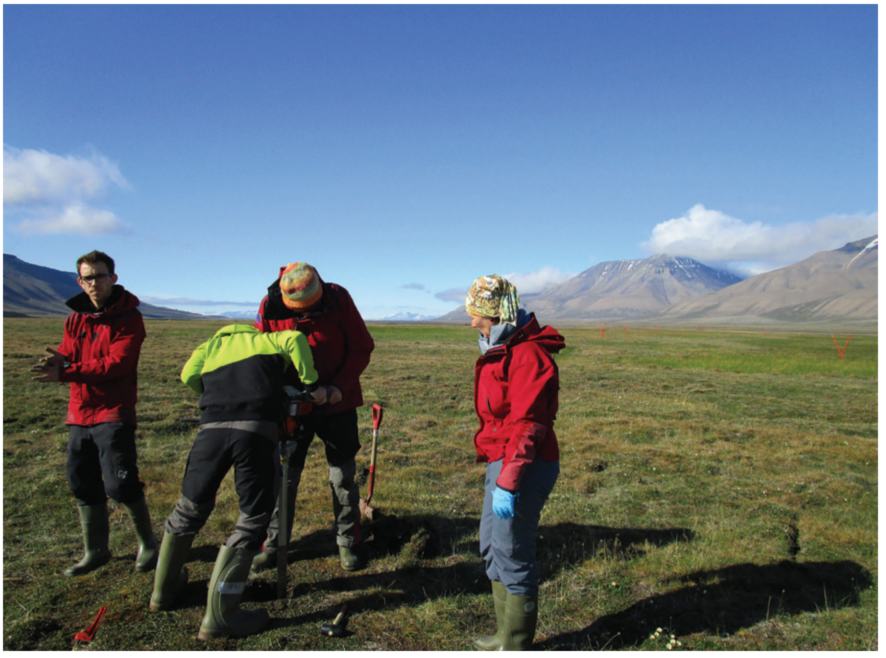
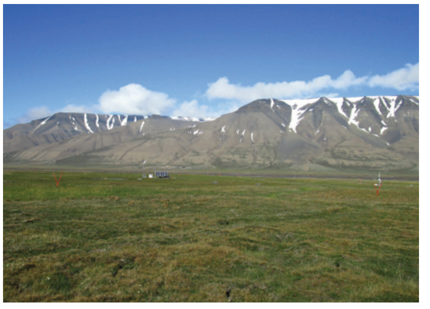
Microbial organisms are seasonally frozen and preserved within the Arctic permafrost. When the climate warms, they become active, and contribute to processes that stimulate the release of carbon deposits as greenhouse gases. To analyse the function of microbes in this cycle, researchers are examining their unique ecosystem and its interaction with the local climate





The role of Arctic microbes in climate change

Due to the vast carbon reserves sequestered within Arctic soils, the carbon cycles of these areas must be understood if the risks of global warming are to be accurately assessed. Permafrost stores carbon within the ground, creating scattered deposits that collectively form vast 'reservoirs'. Although they cover only nine percent of the Earth's total landmass, permafrost soils may in fact contain between 25 to 50 percent of the globe's soil organic carbon. Following thawing and soil movements, this carbon is eventually exhumed and released back to the surface. It is then either absorbed by vegetation, or enters the atmosphere and water before it is reclaimed by the soil. Since it is atmospherically discharged in the form of methane or carbon dioxide, Arctic carbon has been identified as both a potential symptom and driver of global warming.

Several processes are involved in stimulating the carbon's release, including seasonal thaws, forest fires, soil erosion and vegetation growth. A recent research project coordinated by the University of Bergen has sought to examine the role of microorganisms in the earth. "For many years, I've been examining arctic soil, particularly the 'active layer' of permafrost, which is subject to thawing and refreezing," explains Professor Lise Øvreås, the project leader. "During this period I've witnessed a lot of surprising activity and diversity there. As soon as it thaws, the whole structure of the permafrost changes. Methane and greenhouse gases are emitted, but this catalyst also stimulates dormant microbes frozen in the permafrost. They wake up and contribute to some of the processes that are driving the whole carbon cycle. In our project, we focused on how to better understand these microbes by examining their physiology and the mechanisms which control them as communities."

Conducted between 2013 and 2015, the project examined a frozen core of excavated permafrost removed from two metres beneath the Arctic soil. Half of the sample consisted of the active layer, with the other segment comprising permafrost. "During our analysis we sliced the core into thin sections" explains Øvreås. "This was so that we could not only examine the genes of microbial organisms located there, but also scrutinise transition zones between the active layer and permafrost. DNA and genomic analysis was carried out, to measure attributes of the microbial community, which exhibited distinct changes in the cores. Our samples were also subjected to additional thermographic computer analysis so that we could discern physical and chemical changes within the segments. We will also imminently be trying to stimulate microbes from the permafrost, to test if they are partly responsible for the release of methane and carbon dioxide."

Despite occupying conditions hostile to most lifeforms, the permafrost microbes have revealed themselves to be remarkably resilient, says Øvreås. "Organisms have been studied which can actually function in extreme cold; at around minus 17 degrees," she says. "They have adapted to surviving under harsh conditions, although they need water to function. As soon as this becomes available, along with certain nutrients, their processes resume. A Californian group conducted experiments on incubating permafrost microbes, which had been frozen for more than 10,000 years. After a couple of hours of stimulation, they could see that the whole system was revitalised, and gases were exchanged through microbial respiration." This is one important source of carbon release – as is the death of the microbes, which liberates carbon through decomposition.

> "Once we know more about the organisms, we can begin to project the consequences of temperature changes in the Arctic upon them, and what kind of processes they might stimulate"

"So far, our results, which we're currently preparing for publication, suggest a dramatic change in the Arctic microbial community," continues Øvreås. "The preliminary findings show that one sort of organism is dominating the environment, which seems to be driving the communities we find there. The organism itself is similar to a spore-forming microorganism familiar from other climates, like the Canadian Arctic and Siberia. Although the entity we have identified is similar, and seems to occur in four different types, it is previously uncategorised and distinctive. At the moment, we're trying to assemble a genomic puzzle by theoretically defining its genes, without having it in culture. In order to achieve this difficult task, we will compare it to the known microbes we believe are most similar, using state-of-the-art sequencing technology."

Following this phase of the project, PhD student Oliver Müller will put the microbes into culture and conduct extensive laboratory tests intended to divulge relations with their permafrost habitats. This should reveal further attributes of the newly isolated microbes, such as their metabolic potential and lifestyles. Incubation experiments are an important part of these activities, and will reveal how communities of frozen microbes can be reanimated and potentially function as agents of climate change in future. "Once we know more about the organisms, we can begin to project the consequences of temperature changes in the Arctic upon them, and what kind of processes they might stimulate," anticipates Øvreås. "To substantiate these forecasts, we'll also carry out further cultivation and activity measurements on the microbes".

Having spent seven months engaged in microbial research at the Janet Janssons lab at the Lawrence Berkeley National Laboratory in California, Øvreås is keen to continue her research into Arctic microbiology after the conclusion of her current project, and engage in fruitful international collaborations. "The Arctic carbon cycle is an intricate and complex chain of processes and events, about which much remains unknown," summarises Øvreås. "There are many dissimilar types of carbon. So, as a result of permafrost changes, you could potentially encounter several cascades of different reactions. Because microbes can perhaps be regarded as the ultimate drivers for these, it's vital for us learn more about the processes which involve them, and how they interact with each other, to predict the possible impacts of climate change."★

PROJECT PARTNERS

- Professor Janet Jansson, Biological Science Division, Pacific Northwest National Laboratory, USA
- Professor Carsten Suhr Jacobsen, Center for Permafrost studies, University of Copenhagen, Denmark
- Professor Bo Elberling, Center for Permafrost studies, University of Copenhagen, Denmark

AT A GLANCE

Project Information

Project Title:
Microorganisms in the Arctic – Major drivers of biogeochemical cycles and climate change

Project Objective:
To meet the future challenges of rapid climate change in the arctic, it is crucial to improve our understanding of the underlying mechanisms that controls the microbial diversity in low temperature environments and the possible impact climate variability will have on the interactions between permafrost dynamics and greenhouse gas emissions.

Project Duration and Timing:
2013-2016

Project Funding:
Norwegian Research Council
Fulbright Arctic Chair

MAIN CONTACT

Professor Lise Øvreås
Lise Øvreås received her PhD in 1998 from University of Bergen, Norway. Her research interests are genetic diversity and population dynamics of microorganisms in their natural environments, population ecology and community ecology; natural variation in the in the microbial community composition and also the regulation of biodiversity and adaptability of a microbial community to external stress factors. Current work is focused on studies of microbial diversity in cold environments in the polar ocean and in permafrost.

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