Bacteria release climate-damaging carbon from thawing permafrost

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Along the thaw gradient, surface water is a rusty red, caused by microbes releasing iron and carbon compounds Credit: Monique Patzner

A new study based on scientific sampling of a rusty carbon sink at a permafrost peatland at Sweden has revealed that iron minerals fail to trap organic carbon, a vast source of CO_2 and methane not included in global warming forecasts.

The study, conducted by researchers from the Universities of Tübingen and Bristol conducted their investigation site at Stordalen mire, Abisko, Sweden appears in *Nature Communications* today.

Around a quarter of the ground in the northern hemisphere is permanently frozen. These areas are estimated to contain about twice as much carbon as the world's current atmosphere. However, these permafrost soils are increasingly thawing out as the Earth becomes warmer.

The research team, led by Professor Andreas Kappler, and Monique Patzner of the Center for Applied Geoscience, and Dr. Casey Bryce—now at the University of Bristol—in collaboration with Professor Thomas Borch at Colorado State University, investigated the way this development affects the microorganisms in the soil. They worked on the assumption that thawing increases the availability of organic carbon for microorganisms to process, in turn releasing vast amounts of carbon dioxide and methane. These gases accelerate the greenhouse effect, leading to further permafrost thawing in a vicious cycle.

Rising temperatures lead to collapse of intact permafrost soils, resulting in landslides and the widespread formation of wetlands. In this latest study, the team investigated what happens to the carbon trapped in the soil when the permafrost thaws out.

"The organic material naturally present in the samples accumulated as peat over thousands of years. With permafrost thaw, microbes become active and are able to decompose the peat," says Professor Kappler. "We also know that iron minerals preserve organic carbon from biodegradation in various environments—and thus they could be a carbon sink even after the permafrost has thawed." The reactive iron is present as a kind of rust and might be expected to trap the organic material in what the scientists call a "rusty carbon sink."

Drill core of the active layer of the peatland Credit: Monique Patzner

There, samples of the soil porewater and drill cores were taken of the active layer along a permafrost thaw gradient. The research team examined how much organic material was bound to reactive iron minerals, how stable these Fe-C-associations are with permafrost thaw, and whether the microorganisms present could use the material as a source of food and energy. The team also carried out experiments in the laboratory in Tübingen.

The team found that microorganisms are apparently able to use the iron as a food source, thereby releasing the bound organic carbon into the water in the soil. That means the rusty carbon sink cannot prevent the organic carbon from escaping from the thawing permafrost. Based on data available from elsewhere in the northern hemisphere, researchers expect their findings will be applicable for permafrost environments worldwide.

The lead author of the publication, Monique Patzner, summarizes: "The rusty carbon sink is only found in intact permafrost soils; this sink is lost during permafrost thaw." Now the researchers are seeking to find out how this facilitates greenhouse gas emissions and thus global warming. "It appears that the previously iron-bound carbon is highly bioavailable and therefore, bacteria could immediately metabolize it into greenhouse gas emissions," says Patzner. "This is a process which is currently absent from climate-change prediction models and must be factored in."

Dr. Bryce, who is continuing her research within the School of Earth Sciences at Bristol University, added: "We have identified that naturally occurring rust traps carbon in Arctic peatlands and potentially inhibits its release to the atmosphere as a greenhouse gas. However, as permafrost melts the rust is dissolved by bacteria and the associated carbon released. This study represents an exciting advance in our understanding of how interactions between organic matter, metals and microorganisms can regulate loss of carbon from peatlands with important consequences for climate feedbacks in the Arctic."

The researchers involved in this study are now looking at how they might establish the identity of the microorganisms responsible for mineral loss, the fate of the liberated carbon and the consequences for greenhouse gas emissions.

Dr. Bryce added: "We are also working on establishing how dynamic interactions between iron minerals and carbon are during freeze-thaw or drying-wetting cycles. We are also utilizing some of the lessons learned in the Arctic to peatlands in the UK which are currently experiencing extreme degradation."

More information: Monique S. Patzner et al. Iron mineral dissolution releases iron and associated organic carbon during permafrost thaw, *Nature Communications* (2020). DOI: 10.1038/s41467-020-20102-6

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