Study of polar desert carbon yields many questions

On Ellesmere Island high in the Canadian Arctic sits the Dome: a rocky, polar desert mountain that Steven Siciliano thought would make a great reference site for studies of greenhouse gas (GHG) fluxes from soil. To the University of Saskatchewan soil scientist, the Dome’s sparse vegetation signaled a dearth of soil organic matter and microbial activity. And because of this, he hypothesized, GHG emissions would also be negligible compared with those in Arctic soils blanketed in mosses or willows. He was wrong. “What we found was that these systems were pumping out as much greenhouse gas as places like wetlands. And that kind of shocked us because we looked around and there were no plants. Everything appears to be inactive,” he says. “So that’s when we started trying to figure out what on earth was causing this.”

Further investigation has only yielded more questions. In the May–June 2015 issue of the Soil Science Society of America Journal (http://bit.ly/1KKidFC), Siciliano and his students Martin Brummell and Amanda Guy reported finding a deep layer of carbon-rich soil in certain areas of frost-churned ground on the Dome. But, curiously, soil respiration and GHG emissions in these enriched zones were actually lower than in other locations nearby.

The results are significant for two reasons. First, they may help refine estimates of carbon stocks in frozen soils of the world’s polar deserts—vast regions of permafrost that are considerably understudied compared with other Arctic ecosystems, such as tundra. In the Canadian Arctic, for example, polar deserts make up 25% of the ice-free land. And yet, “there hasn’t really been any work in these systems in the Canadian High Arctic looking at soil organic carbon to depth,” Guy explains. “Typically, measurements have only happened in the first 10 cm of soil. So we’ve missed that pool at depth completely.”

Moreover, should permafrost in polar deserts begin to thaw due to climate change, its stored carbon may not break down quite as quickly as scientists have assumed. “When people started this research, we had this naïve idea that all the carbon in the Arctic would thaw and just turn into CO₂ or methane,” Siciliano says. “But a key message from our work is that the type of carbon may be more important [to decomposition rates] than the amount of carbon.”
Decoding Diapirs

As their name implies, polar deserts receive scant precipitation, and their plant cover is typically less than 5%. Like many other permafrost soils, polar desert soils are also often frost-churned, or cryoturbated, resulting in striking areas of patterned ground, including circular patches called frost boils.

The centers of some frost boils, in turn, contain “diapirs”: upward intrusions of permafrost soil that form a distinctive dome shape underground and bring dissolved organic carbon and nitrogen up from below. Siciliano thought diapirs might be a “fertile microsite” for the high GHG fluxes he’d recorded in some polar desert locations. So he set out with his students to measure the actual carbon content of the presumed enrichment zone: the belowground diapir surface.

There was just one problem. “You definitely can’t see it,” Guy says with a laugh. “Elsewhere in the lower Arctic and certain other locations you can see this uplift of organic material. But it’s not detectable visually in the polar deserts [we study].”

To spot this invisible carbon layer, Guy and Siciliano therefore turned to visible and near-infrared (vis-NIR) spectrophotometry. The technology acquires a vis-NIR spectrum for a soil sample and then employs models to convert the spectral data into estimates of carbon content. Working with a company that makes tractor-mounted vis-NIR devices for farmers, Siciliano acquired a smaller version that can be flown by helicopter into remote locations and backpacked into field sites. He, Brummell, and Guy then tested it on 560 frost boils on the Dome.

As expected, the researchers found evidence of diapirism under 17% of the frost boils—that is, a layer of organic carbon about 30 cm deep. Siciliano is still puzzled by the second result, though: These sites had lower rates of soil respiration despite their higher carbon levels.

“What the heck is going on with these diapirs? I don’t quite know. But this is what I think,” he says. “The nature of the carbon in the diapirs must be fundamentally different. And the C horizon [the permafrost layer that pushes upward in diapirism] may be more important for these polar deserts than we originally thought.”

In the meantime, Guy has been working with 10,000 additional spectral measurements she made on the trip. Her first task has been to develop and refine models for converting the field-collected spectra into percent carbon estimates. Next, she’ll examine the actual amounts and distribution of carbon across the team’s field site—and hopefully pave the way for others to do the same. Because what her work with Brummell and Siciliano shows is that permafrost soil still holds many surprises, even in places seemingly as barren as the Dome. But unearthing the unexpected also means collecting a lot of data.

“Quantifying the carbon pools in the High Arctic has been limited by the number of samples we have. So we really wanted to get a whole lot of measurements up there and it would have been completely unfeasible, obviously, to send 10,000 samples south,” Guy says.

“That’s why we wanted to see if we could use this instrument,” she adds. “And so far it’s looking pretty promising.”

Above: Amanda Guy using visible and near-infrared (vis-NIR) spectrophotometry. Right: Frost boils are circular patches of ground resulting from cryoturbation in permafrost soil. The centers of some frost boils contain “diapirs”: upward intrusions of permafrost soil that form a distinctive dome shape underground and bring dissolved organic carbon and nitrogen up from below.

Dig Deeper

Check out the related Soil Science Society of America Journal article at http://bit.ly/1KKidFC