

# Linking climate change to ecosystem assembly and functioning

As part of a collaborative project, **Professor Byron Adams** (Brigham Young University) and colleagues **Diana Wall** (Colorado State University), **Noah Fierer** (University of Colorado), **Berry Lyons** (The Ohio State University) in the USA, and **Ian Hogg** (Polar Knowledge Canada) are investigating settings in the Transantarctic Mountains to understand how land-based ecosystems have responded to climate change. The team is seeking to find out how communities of soil organisms changed and re-assembled as they emerged from the last ice age.

**T**he Transantarctic Mountains extend 3,000 miles across Antarctica and are among the largest mountain chains in the world. This expanse is home to large outlet glaciers such as the Beardmore and Shackleton Glaciers. Today, Antarctica's ice sheets are known to be receding, as an aftermath of the Last Glacial Maximum (LGM) around 21,000 years ago. The LGM was the most recent period when the Earth's ice sheets were at their greatest extension, occurring after a period of cooling during the Pleistocene epoch.

How endemic organisms survived during these glacial events has been a previously neglected question. Even in this region's apparent desolation, there are networks of life unfolding within the soils. Antarctica's remote landscapes are of great interest to scientists, with natural settings that are largely unspoiled by human activity. Now, a multi-collaborative project, funded by the National Science Foundation (USA), is investigating the environmental factors that have hosted life here, and how ecosystems reacted to glacial events before, during,

and after the LGM. To do this, the team is using advanced surface dating techniques and 'omics' tools to reveal the response of soil ecosystems to altering climates, and discover how soils might have hosted life when nearly all of the currently ice-free areas of Antarctica were completely covered by ice.

## THE RESPONSE OF SOIL ECOSYSTEMS AFTER GLACIAL RECESSION

The ice-free areas of Antarctica provide a patchwork of relatively simple, yet habitable soil ecosystems, which makes it an ideal model for scientific study. The team has been investigating the little understood question of how ecosystems in this area have changed in response to glacial recession by considering the biotic and abiotic factors at play. Climate, species interactions and habitat suitability may drive the origins and structures of ecological communities, but little is known about how ecosystems respond to climate-driven environmental changes. It is supposed that glacial retreat after the LGM left behind new habitats for life forms to re-colonise and the team has made

inroads into this field of knowledge. For example, they have shown the importance of liquid water and soil leaching resulting from glacial melt for maintaining suitable habitats for microscopic organisms such as nematodes.

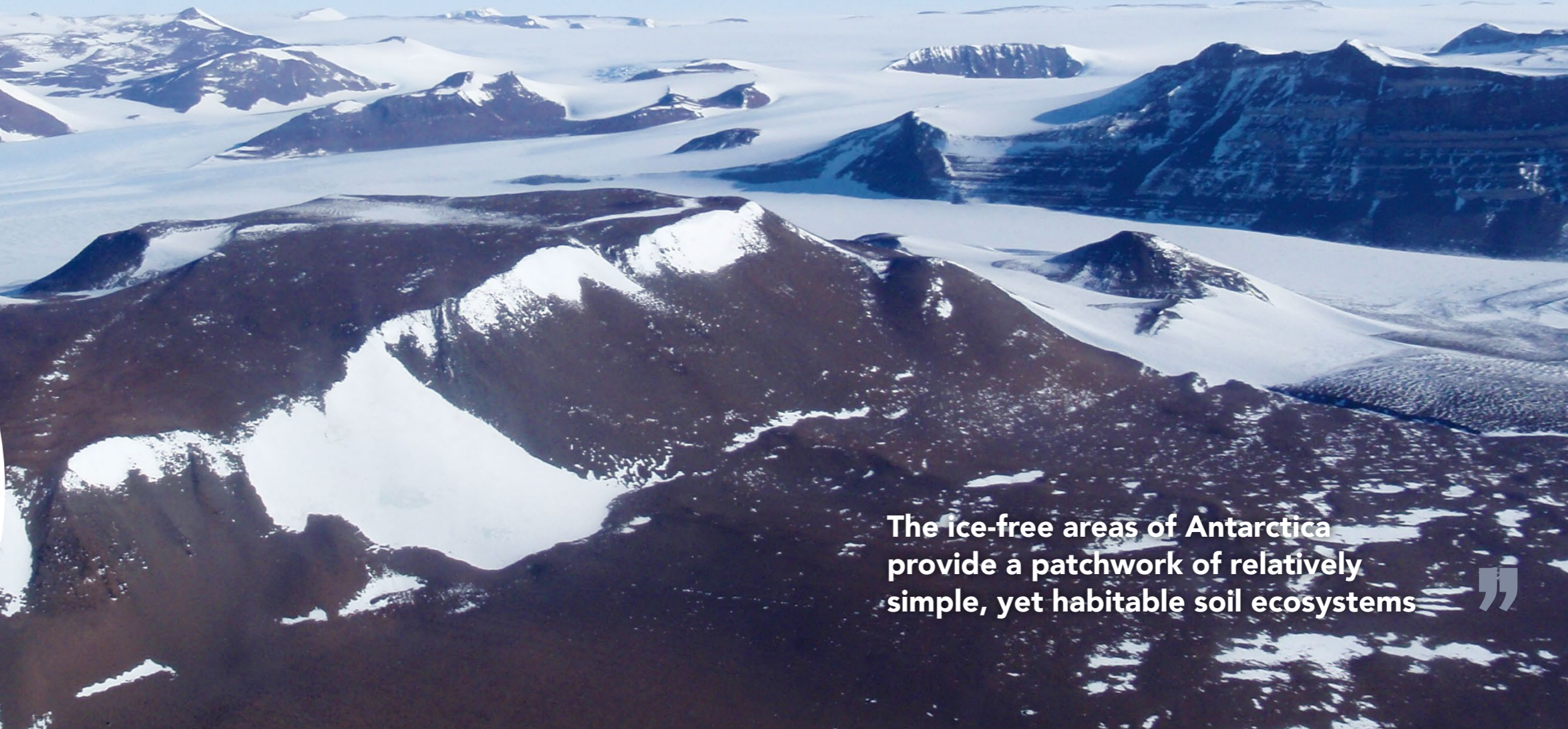
## SURVIVORS IN THE SOIL

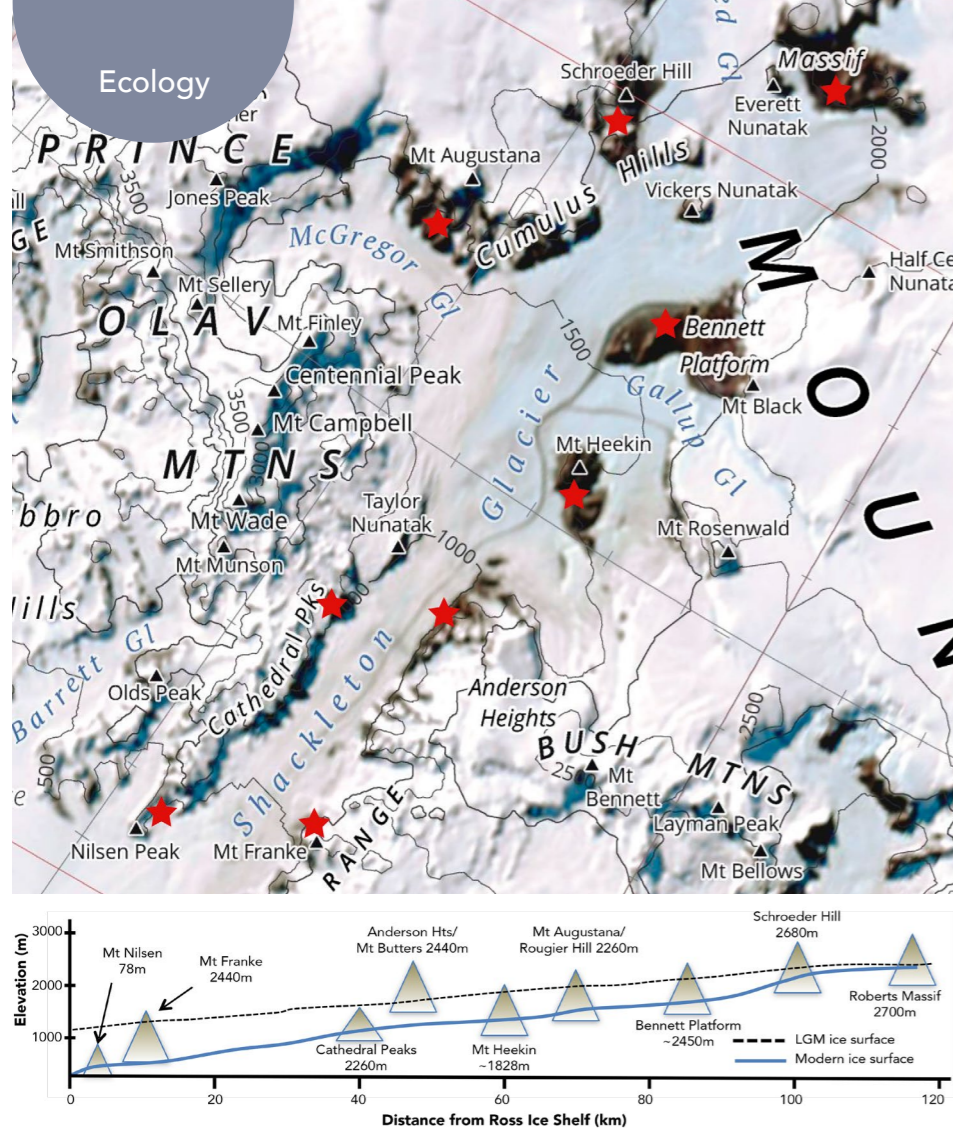
Soils are vital for the functioning of ecosystems, running processes such as greenhouse gas absorption and organic matter degradation. Soil ecosystems respond to climate-driven disturbances such as altering temperatures and atmospheric compositions, which can occur over thousands to millions of years. In shorter time-scales they may be affected by physical events such as being wetted, induced by glacial melt. As a result of warming since the LGM, receding glaciers left behind varied patches of soils across Antarctica, holding unique geochemistry, and ecological communities. In addition to the cold, the presence of salt and the low carbon content of the soils adds to the harshness of this setting. Soluble salts have a weathering effect on soils, but in high concentrations can make

terrestrial environments unsuitable for most organisms.

How invertebrates survived during various glacial events of the LGM is a prime question raised by the research team. While they can observe that nematodes generally survive by going into a state of dormancy – named "anhydrobiosis" – during dry and cold extremes like the LGM, it is assumed that invertebrates must have found places of refuge during the ice ages. Non-glaciated soil settings existed at high elevations in the Transantarctic Mountains during the LGM; the research team suspected that refuges may be present in these high-elevation, ice-free regions. However, in a study of the ice free areas in the Beardmore Glacier region, they identified high concentrations of nitrate salts in the high-elevation soils. Despite these exposed regions being free of ice, the high salt content in the soils would have been unsuitable habitats for invertebrates. The scientists are now curious as to whether appropriate habitats can be found in other high-altitude regions of the Antarctic or whether there are alternative ways in which ecosystems functioned through the Pleistocene.

The ice-free areas of Antarctica provide a patchwork of relatively simple, yet habitable soil ecosystems





Above: Map of the Shackleton Glacier; red stars indicate features to be studied. Below: Schematic representation of present and LGM surface profiles of Shackleton Glacier. LGM reconstructions are based on modelled and measured mean upper limits of the East Antarctic Ice Sheet. All features have terrestrial ecosystems that were most likely exposed during the Pleistocene except for Mt. Nilsen, Cathedral Peaks, and the vast majority of Mt. Heekin. Adapted from "Central Transantarctic Mountains: McMurdo Dry Valleys to Wisconsin Range" by Brad Herried, Polar Geospatial Center, Reference ID: ANT REF-MS2006-001.

## THE NEXT STEP – AN EXCURSION TO SHACKLETON GLACIER

In an upcoming excursion to the Shackleton Glacier region of the Transantarctic Mountains, the team will be digging into these questions on how climate-driven events such as the LGM have impacted ecological communities in the soil. Here, they will collect field samples at various elevations above and below the previous maximum extent of the glacier. The largely untouched, 'ice-free' features of this area will provide them with an ideal representation of how terrestrial ecosystems have responded to glacial recession in the past. This will

help address their question of how living organisms respond to glacial recession, and perhaps inform models of how they may do so in the future. One hypothesis is that complex interactions between organisms would have increased as the ice receded. By connecting physical factors with biodiversity and ecosystem data, the team suspect that patterns of community structure may emerge at various scales. To define these frameworks, they will be observing communities in real-time, using technological advances in DNA sequencing and bioinformatics. The sequence analyses of genes can be used to recover and depict the evolutionary histories and

**These simple terrestrial ecosystems allow soil communities to be surveyed in unprecedented detail, to an extent not feasible in more species-rich ecosystems** ”

## Q&A

### Is the use of DNA sequencing tools a novel method for investigating soil ecosystems in the Antarctic?

DNA sequencing sees frequent use in Antarctic ecosystems to characterise biodiversity. However, our work is novel in that we are also interested in characterising specific genes that confer important ecological functions of the organisms that possess them. In order to do this we are not only sequencing environmental DNA so thoroughly that we can reconstruct the entire genome of every species in each sample, but by sequencing the transcriptomes of each organism in the sample we'll get a very precise picture of the functional role each species plays in the ecosystem as well.

### Can your research insights and methods be applied to other regions of the world?

We hope that by figuring out how these relatively simple soil communities have responded to gradual global warming since the Pleistocene, our work can inform predictive models and ongoing research that aims to better understand

and mitigate the impact of rapid climate change on natural and managed ecosystems, such as in agriculture and forestry.

### What features and patterns are you expecting to find at Shackleton Glacier, and how may they differ to the Beardmore Glacier?

Due to logistic constraints our previous work at the Beardmore Glacier allowed only a few hours on the ground at three different features. This year the National Science Foundation is providing us with helicopter support to nine different areas in the region, allowing us to collect and analyse a greater number of samples across a larger spatial scale, and from areas for which we can obtain accurate surface exposure dates. Thus, we predict that we can recover consistent patterns of ecosystem assembly and functioning along a spatial and temporal gradient since the LGM.

### What do you think will be the main challenges faced by your team at Shackleton Glacier?

Although we have access to excellent

maps, aerial photographs and satellite imagery (provided by the Polar Geospatial Center), very few people, if any, have actually been on the ground at the locations where we need to work and so we'll need to be really flexible in terms of how and where we set up our sampling transects.

### How do you think Antarctica's environment and ecosystems will alter in the near future?

Global and regional climate models predict amplified warming throughout the Transantarctic Mountains. While we predict increased warming to result in increased glacial meltwater, resulting in warmer, wetter soils and hospitable habitat, some of our previous experimental work shows that warmed soils can also become drier, resulting in poorer habitat and decreased ecosystem functioning. It will be important to monitor these regions of Antarctica in the coming years.

## Detail

### RESEARCH OBJECTIVES

The team's work focuses on the interaction between climate and ecosystems. In particular, they are interested in working out how phylogenetic history, functional diversity, and abiotic environmental components influence ecosystem-level responses to climate change.

### FUNDING

NSF

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