Project Title: Interpretations of Polar Environments at the Nanoscale

Primary Applicant: Ross Lieblappen, Vermont State University:
Ross.Lieblappen@VermontState.edu

Project Background and Justification

X-ray computed tomography (CT) provides non-destructive 3D imaging and analysis of internal structure for any porous media. Our team utilizes CT imaging to probe permafrost and sea ice for microbes in samples collected from Alaska, Canada, and Greenland. Recent advances in this technology now allow for imaging at the nanoscale, where we ultimately seek to visualize microorganisms inhabiting the pore spaces. By characterizing this structure, we will further our understanding of how microbial communities relate to their environment, and how changes such as
increased freeze/thaw cycles in a changing climate may impact their health and microbial function. In
addition to imaging the permafrost and sea ice, we extract DNA from samples to examine microbe diversity to connect the physical and biological characteristics of cores from different sites and by depth. This work will provides the first images of permafrost and sea ice at the nanoscale.

The knowledge gained in developing the nano-scale imagine techniques to characterize permafrost,
snow, and sea ice, and then locate microbes will help answer a variety of applied research questions.
These include, but are not limited to:

- How do microorganisms impact material properties of permafrost soils, snow, and sea ice? Do they contribute to the strength by altering the microstructure? Does their orientation have any
  impact on the material properties?
- What can nano-scale parameters of structure tell us about the overall strength of the material?
  Can quantities such as pore connectivity or pore sizes be used to determine the ability to install
  infrastructure on various terrain?
- How might material properties change as a result of climate change? What is the influence of
  freeze-thaw cycles on the distribution of microbial communities and biologic processes? How
  significantly do freeze-thaw cycles impact the microstructure and subsequent material strength
  of various media?
- What microbes are there in permafrost and sea ice, and based on their growth niche, which will
  be most likely to perish when environmental conditions change?

We are only just beginning to realize the critical importance of sub-micron level detail on the structure and biological function within various environmental media. In a changing climate, nowhere
is this more operationally essential than in the Arctic. Microbes are ubiquitous in Arctic ecosystems,
but their precise microstructural location and distribution remains unknown. Increased freeze-thaw cycling in permafrost stresses this environment, resulting in changes to the microbial community

function. This work attempts to leverage existing resources and advances in imaging capabilities to
improve our scientific understanding of these biogeochemical processes.

Field Research and Methodology
The entire scope of this project involves fieldwork across the Arctic, covering Alaska, Canada, and Greenland. For this season's fieldwork, we plan to spend one week in Eureka, NU June 19 – 25, 2026 and one week in Resolute, NU June 26 – July 3, 2026. We will select 3-5 permafrost locations outside of town and accessible by truck or ATV at both locations. As much as possible, we will seek to co-locate field sites with previous permafrost studies for comparison with the literature and traditional ecological existing knowledge. Similarly, if sea ice conditions are sufficient, we will select 3-5 sea ice coring locations at these sites. Both sea ice and permafrost cores will be approximately 1 m in length and 7.5 cm in diameter. All cores will be shipped back to Vermont at sub-eutectic temperatures until imaging as described above.

Sharing Results:
While in Nunavut, we plan to share our work with the local community via public presentations and
outreach events in the local school in Resolute if welcomed. For any community where we complete fieldwork, we prioritize sharing our research with the local community and thoroughly enjoy the exchange of ideas at such gatherings. For example, while in Utqiagvik, Alaska in February 2025, we presented at a
community dinner gathering as well as with the local high school. We try to get students using our drills to core their own samples of either permafrost and sea ice, and let the students get hands on
experience looking at the ground beneath them. We completed similar activities while in Cambridge Bay in May 2025, taking high school students out onto the sea ice and discussing what we can find in our samples.

Additionally, we plan to publish the scientific findings of this work in peer-reviewed academic journals
and present at both scientific conferences and with the general public. Already we have presented at the
American Geophysics Union annual meeting (2024 and 2025), as well as local presentations at Vermont State University. We also have given presentations at the local schools here in Vermont.