Biogeochemical Characteristics of Ancient Permafrost in Newly Excavated Sections of the Fox Tunnel, Alaska

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The CRREL Permafrost Tunnel near Fairbanks, Alaska, was initially excavated in the mid-1960s. Permafrost is syngenetic ice and carbon rich loess with ice wedges, segregated ice, reticulate-chaotic ice, and some large thermokarst cave ice features attributed to sudden permafrost thaw. Recently, ~150 m of excavation uncovered a variety of features representing permafrost formation and subsequent degradation between 18,000 and 44,000 years ago.

Permafrost soils contain twice as much carbon as earth's atmosphere and large mercury stores. Features in the Tunnel provide insight into biogeochemical characteristics and processes of permafrost formation and degradation over time. Microbial and biogeochemical characteristics of permafrost soils provide insight into how carbon, other nutrients, and metals may be processed in thawed permafrost soils.

Using light distance and ranging (LiDAR) we surveyed ice features exposed in the Tunnel and quantified their three dimensional volumes. Return intensity values from different laser wavelengths allowed us to quantify exposed ice features versus ice cemented silt. Based on these measurements, we collected more than 300 SIPRE cores of frozen silt and massive ice features in the Tunnel and from modern permafrost above the Tunnel. Thawed soil and water ice were analyzed for major ions, trace metals, stable water isotopes, microbial composition, carbon and nitrogen.

Major ion and trace metal concentrations are higher in ice wedges than replacement ice. Water stable isotopes of ice wedges are roughly 4 per mil lower than replacement ice features suggesting ice wedge degradation during warm climatic periods. The microbiome changed dramatically across different aged permafrost and may indicate differential use of carbon substrates. Carbon and nitrogen concentrations are far greater in replacement ice implying current models and estimates of carbon and nitrogen stocks may under-represent the current global permafrost pool.