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Is organic matter found in glaciers similar to soil organic matter? A detailed molecular-level investigation of organic matter found in cryoconite holes on the Athabasca Glacier

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Cryoconite is a dark-coloured, dust-like material found on the surfaces of glaciers. Cryoconite has received much interest recently because cryoconite holes, which are produced by accelerated ice melt, act as habitats for microbes on glacier surfaces and accelerate ice melt. To the best of our knowledge, cyroconite organic matter (COM) has not yet been chemically characterized at the molecular level. In this study, organic matter biomarkers and a host of Nuclear Magnetic Resonance (NMR) techniques were used to characterize COM from the Athabasca Glacier in the Canadian Rocky Mountains. The research questions that were targeted by this study include: 1) what are the sources of COM on the Athabasca Glacier; 2) are there any biomarker and/or NMR evidence for microbial community activity in the cryoconite holes; and 3) is the COM structurally similar to terrestrial OM?

Solvent extracts contained large quantities of fatty acids, n-alkanols, n-alkanes, wax esters and sterols. A large contribution of C23, C25 and C27 relative to C29 and C31 n-alkanes suggests that allochthonous COM is mainly from lower order plants (mosses, lichens). This is confirmed by the absence of lignin phenols (after copper (II) oxidation) in extracts and NMR analyses of COM. Solution-state 1H NMR reveals prominent signals from microbial components, while solid-state 13C Cross Polarization Magic Angle Spinning NMR analysis shows an atypically high alkyl/O-alkyl ratio, suggesting that COM is unique compared to organic matter found in nearby soils. The NMR results suggest that COM is dominated by microbial-derived compounds which were confirmed by phospholipid fatty acid analysis, which showed a significant microbial contribution, primarily from bacteria and minor microeukaryotes. Both biomarker and NMR data suggest that COM likely supports active microbial communities on the Athabasca Glacier and that COM composition is uniquely different than that found in terrestrial environments. Our data indicate that windblown or meltwater fluvial OM rich materials from adjacent peatlands or mosses and lichens developed on tundra soils can be trapped and preserved in cryoconite holes in glaciers and may be an important mechanism for promoting active bacterial colonies in glacial environments both modern and ancient. Given that such material is incorporated within the glacier in the accumulation zone or flushed by meltwaters into subglacial environments, reworked COM may provide nutrient sources for active microbial communities found within and under glaciers.