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Lithium isotopes trace subglacial and proglacial weathering dynamics in rapidly deglaciating Arctic catchments in Kongsfjorden (Svalbard)

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Rapid glacier retreat in the Arctic enhances chemical weathering and erosion both beneath glaciers and across newly exposed proglacial landscapes, where highly reactive sediments are subjected to intense surface processes. We investigate lithium isotopes (δ^7Li) as tracers of silicate weathering in stream waters from several glaciated catchments in the Kongsfjorden region (Svalbard), underlain by mixed shale, sandstone, and carbonate lithologies. Hydrochemical data from subglacial outlets and proglacial streams fed by ice-cored moraines indicate that weathering is dominated by both carbonate and silicate weathering driven largely by sulfide oxidation, whereas carbonic acid weathering plays a minor role. Sampling was conducted during peak melt seasons in two contrasting years: one relatively cold and one anomalously warm. Subglacial streams at glacier termini exhibit low Li concentrations (0.03 to 0.17 µmol L^{-1}) and a narrow δ^7Li range (14.9 to 17.0‰), significantly heavier than the average shale bedrock (−2‰), indicating substantial isotope fractionation during subglacial weathering. In contrast, proglacial streams show higher Li concentrations (0.38 to 4 µmol L^{-1}) and a wide δ^7Li range (−2.1 to 16.7‰). The lowest δ^7Li values coincide with intense sulfide oxidation promoting mineral dissolution under acid mine drainage-like conditions. Box modeling of shale weathering suggests that Li isotope fractionation in these catchments is controlled by the balance of silicate dissolution and secondary mineral formation under near steady-state conditions promoted by high water-rock ratios. Subglacial weathering signatures are consistent with strong Li uptake via adsorption onto Fe (oxyhydr)oxides, with a smaller contribution from clay mineral formation. Proglacial signatures range from systems dominated by Fe (oxyhydr)oxides to those characterized by enhanced silicate dissolution. Meltwater export to Kongsfjorden carries δ^7Li values between 11.3‰ and 16.4‰ for dissolved Li with slightly higher values for the warmer year, reflecting increased proglacial contributions and greater silicate dissolution during enhanced melting. Overall, Fe (oxyhydr)oxide formation linked to sulfide oxidation exerts a primary control on Li isotope signatures. These processes influence not only Li cycling but also the delivery of nutrients and potential contaminants to Arctic fjord systems under ongoing climate warming.