Arctic investigations of boulders and bedrock surfaces preserved beneath non-erosive glacial ice using paired ^{10}Be and ^{26}Al analyses

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Abstract

Landscapes preserved beneath cold-based, non-erosive glacial ice violate assumptions associated with simple cosmogenic exposure dating. Because bedrock surfaces and boulders plucked from those surfaces are not deeply eroded during glaciation, they contain nuclides from previous periods of exposure. Analyses of cosmogenic nuclides in samples with complex exposure/burial histories yield simple exposure ages that are older than expected and complex age distributions; hence, alternate approaches are required to constrain the multi-stage histories of samples from such landscapes. To study the exposure and burial history of long-preserved landscapes in the Arctic, we employed paired analysis of ^{10}Be and ^{26}Al in three locations: Upernavik, central-western Greenland; Thule, northwestern Greenland; and Cumberland Sound, southern Baffin Island, Canada. We assess our data using two-phase exposure/burial models, multi-phase forward models, and Monte Carlo simulations to constrain uncertainties.

Bedrock surfaces, sampled at two sites, exhibit evidence of long-lived subaerial weathering and have simple 10Be exposure ages up to 104 ka in Upernavik and 160 ka on Baffin Island. Simple exposure ages tend to increase with elevation, suggesting more effective erosion in the fjords and longer-term preservation of the uplands. Minimum-limiting total histories calculated with ^{26}Al/^{10}Be range up to 1 My in Upernavik and several My on Baffin Island, with periods of exposure representing ~20% of the total history. High-elevation bedrock surfaces at both sites indicate long-lived preservation by cold-based ice over numerous glacial/interglacial cycles.

Boulders, sampled at all three sites, also contain nuclides from previous periods of exposure, presumably because they were plucked from subglacially-preserved bedrock surfaces and/or recycled through different generations of till. Simple 10Be exposure ages of boulder samples are up to 46 ka in Upernavik, 78 ka in Thule, and 79 ka on Baffin Island, and yield multi-modal age distributions. Simple exposure ages of boulders tend to under-estimate bedrock ages in the cases of paired bedrock/boulder samples. Minimum-limiting total histories calculated with 26Al/10Be range up to 600 ky in Upernavik, 700 ky in Thule, and several My on Baffin Island, with periods of exposure representing only a small portion of the total history. Forward numerical models suggest that boulders have been repeatedly reworked, likely experiencing partial or complete shielding during interglacial periods because of rotation and/or burial by till.

The landscapes we assess here preserve histories of hundreds of thousands to millions of years, and represent a complex interplay of interglacial exposure, subglacial preservation beneath cold-based ice, periglacial processes, and subaerial weathering. Although such landscapes represent methodological challenges, they contain valuable information about long-term variations in glacial extent and climate.