Revealing Complex Exposure Histories of Arctic Landforms Using In-situ 14C and 36Cl

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In-situ produced cosmogenic nuclides can be used to determine ages of glacial landforms and features if processes of glacial erosion and deposition remove previously accumulated nuclides. But under cold-based ice conditions, common in the Arctic, such removal is often incomplete, which results in inheritance of cosmogenic nuclides from previous exposure episode(s). This creates a complex exposure system in which multiple episodes of exposure are separated by periods of burial under ice. The duration of exposure and burial episodes can be determined by using two or more cosmogenic nuclides. Here, we propose an approach that uses in-situ 14C and 36Cl, and present preliminary results for late Quaternary depositional glacial landforms from the High Arctic.

Our approach takes advantage of the difference in half-lives of 14C (5730 y) and 36Cl (301 ky). It assumes two periods of exposure separated by a period of burial under cold-based, non-eroding ice. Both nuclides accumulate during periods of exposure. The long-lived 36Cl remains approximately constant during short periods of burial; thus, its concentration reflects the cumulative exposure. But the short-lived 14C decays during periods of burial; its concentration reflects the length of exposure and burial. The critical information is in the difference between the measured concentrations of the two nuclides. In case of continuous exposure, the two nuclides give the same ages. In case of burial, 14C is depleted because of decay. These two nuclides together provide information about the duration of burial and exposure.

We analyzed boulder samples from the east coast of Ellesmere Island and from Stor Island, just off the west coast of Ellesmere Island. The samples have the same surface exposure history: first exposure for 33-42 ky, burial for about 22 ky, and second exposure for 10 ky. These data indicate two deglaciation events: at 10 ky (consistent with other deglacial data from this region) and at 65-74 ky (end of cold stage 4; consistent with other regional and global records of paleoclimate). These results indicate that the combination of 14C and a longer-lived nuclide (36Cl, 26Al, 10Be, 3He, 21Ne) can be used to unravel complex exposure histories of late Quaternary glacial surfaces.

AGU, Fall 2000 Meeting, Session U03

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Photo 1 - Carey Islands
Photo 2 - Fort Conger
Photo 3 - Stor Island