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Advances in cosmogenic surface exposure dating: Using combined in situ 14C-10Be analysis for deglaciation scenarios

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Cosmogenic nuclides are routinely used to investigate deglaciation histories by exposure dating of rock surfaces after glacier retreat. For bedrock surfaces that have been efficiently eroded by glacier ice, the most commonly applied cosmogenic 10Be isotope has proven to give reliable estimates of the integrated time of surface exposure since major ice decay. Due to its long half-life (∼1.4 Ma), however, 10Be does not record short episodes of intermittent surface cover, e.g. during phases of glacier readvance, which might have interrupted the general deglaciation trend. To detect such cases of "complex exposure", 10Be-based dating can be combined with the analysis of the short-lived (5730 a) in situ cosmogenic 14C nuclide.

We present two examples, in which combined in situ 14C-10Be analysis has been successfully applied to reconstruct in detail post-LGM surface exposures histories - in the Swiss Alps [1] and in Antarctica [2].
In a study on the Gotthard Pass, Central Swiss Alps, in situ 14C-10Be exposure dating was combined with extensive mapping of glacial erosional features. Data from both cosmogenic nuclides are in overall good agreement with each other confirming continuous exposure of the Gotthard Pass area throughout the Holocene. Some slightly younger in situ 14C ages compared to the corresponding 10Be ages are interpreted to result from partial surface shielding due to snow cover. Constraining the average Holocene snow depth from the in situ 14C data allowed to apply an appropriate snow shielding correction for the 10Be exposure ages. Integration of the snow-corrected exposure ages with field observations provided a detailed chronology of a progressive downwasting of ice from the maximum LGM ice volume with a gradual reorganization of the ice flow pattern and a southward migration of the ice divide.

In a study on the evolution and reorganization of ice streams entering the Weddell Sea, Antarctica, during the last deglaciation, ice sheet modelling was combined with in situ 14C and 10Be analysis. While modelling results revealed a major reorganization of the ice streams over the last 20 ka, cosmogenic nuclide data from glacial erratics were used to reconstruct past terrestrial ice surface elevations. Consistently younger in situ 14C ages compared to 10Be ages, are interpreted as evidence for complex exposure histories. Different exposure scenarios created from the in situ 14C-10Be nuclide inventory agree on the occurrence of an extended ice cover on the dated erratics after initial deposition, followed by subsequent re-exposure.

References:
[1] Hippe et al. (2014), Quat. Geochronol. 19, 14-26. [2] Fogwill et al. (2014), Antarct. Sci. 26, 674-686.