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# Consideration of geomorphological uncertainties with terrestrial cosmogenic nuclide dating (TCND): combining Schmidt-hammer and 10Be dating, Southern Alps, New Zealand

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As the importance of glaciers as key indicators of global change has increased during recent years, investigating Holocene glaciers chronologies has gained higher attention accordingly. One reason is the need for a better understanding of the climate - glacier relationship. Comparative studies play a major role in this field of research owing to the natural diversity of glacier behaviour. Detailed Holocene glacier chronologies are, furthermore, necessary to verify and eventually adjust glacier models indispensable for many attempts to predict future glacier changes. The Southern Alps of New Zealand are one of the few key study areas on the Southern Hemisphere where, in general, evidence is still sparse compared to its Northern counterpart. Improvement and reassessment of the Late Holocene glacier chronology in this region is, therefore, an important goal of current research.

Recently, terrestrial (in situ) cosmogenic nuclide (10Be) surface exposure dating has been increasingly applied to Holocene moraines in New Zealand and elsewhere. In the context of numerical ("absolute") dating techniques, terrestrial cosmogenic nuclide dating (TCND) seems to have been established as an alternative to the previously dominating radiocarbon (14C) dating of organic material (plant remains, organic-rich soil layers etc.) buried beneath or within moraines. Precision and time resolution achieved by the newest laboratory standards and procedures (Schaefer et al. 2009) is truly a milestone and will promote future attempts of TCND in any comparable context. Maybe, TCND has the potential to at least partially replace radiocarbon (14C) dating in its dominating role for the "absolute" dating of Holocene glacial deposits.

By contrast, field sampling for TCND often lacks appropriate consideration of geomorphological uncertainties. Whereas much effort is made with the high precision results achieved in the laboratory, the choice of boulders sampled on Holocene moraines is often purely made "by vision". Especially in regions like the Southern Alps affected of considerable neo-tectonic activity and paraglacial erosion, post-depositional movement of any boulders on moraine ridges cannot be excluded a priori. On base on these considerations, an attempt to combine TCND with Schmidt-hammer measurements for the dating of Holocene moraines and the reconstruction of a regional glacier chronology has been developed (Winkler 2009). Cosmogenic 10Be dating delivers 'absolute' ages for the exposure of boulder surfaces, i.e. the same surface tested with the Schmidt-hammer relative-age dating technique. Therefore, Schmidt-hammer measurements can successfully endorse the selection of representative boulders for TCND and effectively avoid sampling boulders that have been exposed to post-depositional movement (e.g. rotation). Additionally, the number of boulders sampled for TCND can be reduced, positive in the light of economic and conservational considerations.

Results from the application of this combined 'multi-proxy-approach' at a number of individual glaciers in Westland/Tai Poutini and Mt Cook/Aoraki National Parks of the Southern Alps proof its potential. At least three 'Little Ice Age'-type events culminating around 2,300, 1,600, and 1,000 years ago and predating the "Little Ice Age" have been confirmed. The construction of a dating curve based on both Schmidt-hammer and cosmogenic (10Be) dating results shows high significance and demonstrates the high potential of this attempt.

References:

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