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Combination of in situ cosmogenic nuclide (10Be) and Schmidt-hammer dating for the investigation of Late-Holocene lateral moraines in the Southern Alps of New Zealand

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The investigation of Holocene glacier chronologies in high mountain regions is important for use of glaciers as indicators for climate change. Only detailed Holocene glacier chronologies offer the opportunity to improve our knowledge on the relationship between glaciers and climate factors, and to verify models of the future glacier development. The Southern Alps of New Zealand represent the southern hemispheric study area within the complex comparative current research project "MaMoGla" (Holocene and recent dynamics of maritime mountain glaciers). Among other goals, new methodological attempts to date the dominating lateral moraines in the Southern Alps in order to revise existing glaciers chronologies have been integrated in this project.

The need for improvement of the existing Holocene glacier chronology of the Southern Alps/New Zealand is mainly caused by methodological uncertainties and the focus on Tasman Glaciers as unreliable key locality. Previously, radiocarbon (14C) dating of organic material (plant remains, organic-rich soil layers etc.) buried beneath or within the complex lateral moraines was the predominating 'absolute' dating technique applied. In addition to older studies using the measurement of weathering rind thickness on boulders, the potential of the Schmidt-hammer as relative-age dating technique has clearly been demonstrated by the successful application on several lateral and latero-frontal moraine sequences in the Mt Cook/Aoraki National Park. The relatively homogenous and weathering/erosion-resistant bedrock yielded comparatively small standard errors and, thus, a relatively high time resolution of up to 200 – 300 years. Supported by statistical treatment of the raw field data, the Schmidt-hammer provided sufficient information to group the individual moraine ridges into moraine sequences and relate them to separate Little Ice Age-type events. However, the final 'absolute' age dating of the moraine sequences remained open. As an 'absolute' age of the boulder surfaces was needed to allow the construction of a dating curve by reliable fixed points to, radiocarbon (14C) dating could not provide those information because of the lack of organic material indisputable be related to the glacier advance forming the moraine ridges.

On base on these considerations, this study comprises the first attempt to combine in situ (terrestrial) cosmogenic nuclide (10Be) surface exposure dating with Schmidt-hammer measurements for the dating of Holocene moraines and the reconstruction of a regional glacier chronology. Cosmogenic 10Be dating has the important advantage of delivering an 'absolute' age for the exposure of boulder or bedrock surfaces, i.e. the same surface tested with the Schmidt-hammer. One disadvantage of cosmogenic nuclide exposure dating is, however, the limited number of boulders sampled due to high costs. From this background, a combination with the Schmidt-hammer technique seems ideal as the latter could provide measurement of a large number of boulders. The Schmidt-hammer measurements can, on the other hand, help with the selection of representative boulders for cosmogenic nuclide (10Be) surface exposure dating avoiding boulders that have been exposed to post-depositional movement (e.g. rotation).

Results from the application of this combined 'multi-proxy-approach' at Strauchon Glacier in Westland/Tai Poutini National Park and Hooker Glacier in Mt Cook/Aoraki National Park on large lateral moraine complex with several individual moraine ridges proof its potential. Three pre-'Little Ice Age' moraine sequences each related to an individual Late-Holocene Little Ice Age-type event unambiguously distinguished by Schmidt-hammer

measurements provides cosmogenic (10Be) ages of 2,400/2,500 a BP, c. 1,700 a BP, and c. 1,000/1,100 a BP. The preliminary construction of a dating curve based on both Schmidt-hammer and cosmogenic (10Be) dating results shows high significance and confirms the successful application of this attempt. Although subsequent cosmogenic 10Be-dating is necessary to confirm the first preliminary results, the attempt to combine 'absolute' cosmogenic surface exposure dating and the relative age-dating technique of the Schmidt-hammer is a promising alternative to radiocarbon dating for the investigation of Holocene glacier chronologies.