Using cosmogenic radionuclide exposure ages to document late-Holocene spatial-temporal variability in Svalbard glaciers and their relationship to Arctic climate change

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Background: Glaciers are ideal archives to reconstruct past integrated temperature and snowfall changes. Yet determining how Arctic glaciers will respond to current and future climate warming and attendant feedbacks of sea-ice retreat requires a longer time perspective that cannot be found in the historic observational record. In particular, Arctic warming will likely drive sea-ice retreat, which can also increase winter precipitation. The latter could partially offset or even reverse the effects of a warmer climate on some Arctic glaciers. Indeed, recent surface mass balance modeling simulates that Svalbard glaciers, one of the heaviest glaciated Arctic regions, have yet to show emergent behavior in response to human-induced climate change. *Numerous late-Holocene moraines exist outside of the historical glacier limit from the Little Ice Age (LIA; 1400-1900 C.E.) on Svalbard, which provide an ideal laboratory to determine how Svalbard glaciers respond to climatic change in the absence of anthropogenic forcing.* At present, it has been proposed that the glacier advances that deposited these moraines occurred during periods of sea-ice retreat, with the attendant increase in precipitation driving glacier advance. However, the timing of moraine deposition is very poorly constrained.

Methods and Outcomes: We will date late-Holocene pre-LIA moraines in three regions, complimenting our published ^{10}Be exposure age data in west Spitsbergen and the only other published data in south Spitsbergen. Based on the existing data, we hypothesize that Svalbard glaciers underwent a regional retreat ~1.6 ka in response to oceanic/atmospheric warming and attendant sea-ice retreat. The new moraine records spanning south to north Spitsbergen and from the wet western coast to the dry interior will provide glacier chronology transects to address two simple but fundamental research questions. *1) Was late-Holocene pre-LIA glacier retreat synchronous or random on the island? 2) And if synchronous, was glacier retreat concurrent with regional climate warming and sea-ice retreat?* Such questions have only recently been possible to address due to significant advances in ^{10}Be and in-situ ^{14}C surface exposure dating. *Results will help delineate the timing and magnitude of glacier response to past climatic change (particularly sea-ice retreat) and assess whether current glacier retreat*

is anomalous with respect to natural variability, a potentially transformative result. Results will also fill a critical gap in Arctic glacier history, necessary for assessing the possible causes of the LIA. The new geochronologic and geospatial glacier dataset will provide a baseline against which recent and projected ice-margin changes can be compared, serving as a target for glacier and climate models. They will also document the timescale and magnitude of Svalbard glacier response to natural climate variations in the absence of anthropogenic forcing, critical for detecting emergent glacier behavior in response to global warming.

Training: This is a multidisciplinary project, with significant training in field, laboratory, and analytical methods. This project will provide development of skills and experience across the geosciences, including glacial geomorphology, paleoclimatology, geo- and radiochemistry, nuclear physics, and glaciology. Skills will be developed in field data collection (for glaciers on Arctic glacier on Svalbard, Norway), chemistry and accelerator mass spectrometry laboratory procedures (in the UK and Australia), as well as regional climatology and numerical modelling methods. Importantly, integrating data and observations at the intersections of these disciplines will be a unique quality of this project. Thus the studentship will provide a unique experience to undergo rigorous training combined with participation in a program of significant societal relevance. **A passion for science that matters to society is critical.** The student will collaborate with international project partners in academia, government, and industry, and establish skills and networking connections important for further career opportunities in any of these scientific realms.

Selected References:

Granger, D.E., Lifton, N.A., Willenbring, J.K., 2013, A cosmic trip: 25 years of cosmogenic nuclides in geology, *Geological Society of America Bulletin*, 125, 9-10, 1379-1402.

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