High precision surface exposure dating (Ref IAP2-18-52)

University of Glasgow, Scottish Universities Environmental Research Centre
In partnership with University of Stirling, Biological & Environmental Sciences

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Key Words
- Cosmogenic Isotope Geochronology; Glacial geology

Overview

Average surface air temperatures have been rising everywhere on Earth over the last century and are predicted to continue to rise for at least the next century. One of the clearest indicators of this warming is the shrinking of glaciers and the marked reduction of sea ice in the Arctic, where atmospheric warming is most pronounced. Melting of sea ice does not contribute to sea level rise, but meltwater from land-based glaciers and ice caps ends up in the oceans and is a major contributor to sea level rise. How fast will glaciers and ice caps melt? Will they disappear in decades, adding all of their water rapidly to the oceans, or will the melting occur over a longer time span, with a less rapid but equal amount of sea level rise. For the 150 million people living within 1 m of high tide, and those concerned about maintaining trillions of pounds worth of global coastal infrastructure, answering the question of how fast glaciers and ice caps will melt and contribute to sea level rise is important.

This project will determine how fast ice caps can melt by analysing the collapse of the ice cap that existed in Scotland about 11600 years ago and disappeared at a time when temperatures rose by 8°C, the same as the temperature rise predicted for the Arctic by 2100. By measuring how quickly the ice cap disappeared we will learn how fast present day equivalent sized ice masses subjected to similar warming could disappear, thus providing data needed for sea level rise models to make more informed predictions.

Figure 1. (left) Multi-Cathode Source of Negative Ions by Caesium Sputtering (MC-SNICS) to produce ion beams from cosmogenic nuclide samples, (middle) 5 million volt accelerator to break up molecular interferences, and (right) positive mass spectrometry (PIMS) ion source.
To quantify how fast the Scottish ice cap collapsed we need to be able to determine the rate of change of the former ice mass. We will use surface exposure dating with the cosmogenic nuclides $^{10}$Be and $^{26}$Al produced in the mineral quartz in rock by cosmic rays, that is, when the rock is exposed to the sky. Conversely, the production of the nuclides in quartz stops when the rocks are covered by a few metres of ice. Surface exposure dating is the only technique available to directly date when landforms become exposed as ice melts. We will measure the concentration of these nuclides in glacially abraded and plucked rock surfaces and glacially transported boulders, located at the maximum, intermediate and minimum extent of the ice cap. Because we know how fast the cosmogenic nuclides are produced in quartz, we can use the measured cosmogenic nuclide concentration to determine when the sampled rock surface became exposed from under the ice. In other words, we can determine when the ice disappeared from the sample site. The age difference between the maximum and minimum ice extent provides the retreat rate which will be integrated with independently dated climate proxy archives to look for causal relationships.

**Methodology**

To be able to test the hypothesised rapid collapse of the Scottish ice cap we first need to improve the surface exposure dating technique from the current routine 2-3% to 1% or better measurement precision for $^{10}$Be and $^{26}$Al in quartz. Analytical improvements to the accelerator mass spectrometry (AMS) that is currently used to measure $^{10}$Be and $^{26}$Al will allow us to resolve the rate of ice cap collapse. However, there are some questions for which AMS is unlikely to provide the necessary precision. To resolve if the decline of the ice cap was steady or episodic requires the development of an entirely new methodology for measuring $^{26}$Al by positive ion mass spectrometry (PIMS) invented and being pioneered at the Scottish Universities Environmental Research Centre (SUERC). Pushing the boundaries of conventional AMS and developing Al PIMS has the potential for leading to a paradigm shift in how Earth and Environmental scientists determine the rate of natural processes and determine the age of landforms. This newly developed, world leading analytical technique will then be applied to answer important questions on how rapid deglaciation rates can be.

**Timeline**

**Year 1:**

Refining key research questions and establishing hypotheses; sample site selection; fieldwork; training in core geochemistry, accelerator mass spectrometry skills, and PIMS skills; testing AMS ion source operation using different sample matrices and AMS cathode configurations; PhD progression presentation.

**Year 2:**

AMS and PIMS ion source optimisation; field sample preparation; data analysis; statistical modelling; presentation at national conference.

**Year 3:**

Further data analysis; lead authorship of key manuscript(s); presentation at international conference (e.g. AGU, EGU); thesis preparation and write-up; thesis submission for examination.

**Training & Skills**

This is a unique PhD opportunity for an analytically minded candidate, offering direct access to unique technologies and providing highly desirable specialist and complementary interdisciplinary skills. Specifically, training will be provided in field sampling for surface exposure dating; laboratory sample preparation; cosmogenic-nuclide analysis by AMS and PIMS; data reduction; numerical data interpretation and statistical modelling. The successful candidate will also receive training in oral and poster presentation skills & paper, grant application and thesis writing, etc.

The skills developed throughout this project will make the candidate a world leader cosmogenic isotope dating, AMS and PIMS analytical techniques and glacial geology. Any one of these skills will create many opportunities for a highly successful research career anywhere in the world.

**References & Further Reading**


**Further Information**

For further information, or informal enquiries, contact Dr Richard Shanks richard.shanks@glasgow.ac.uk or Dr Derek Fabel derek.fabel@glasgow.ac.uk