Climate at the onset of the Antarctic ice-sheet growth:

a detailed analysis of ice-buried glacial cirques

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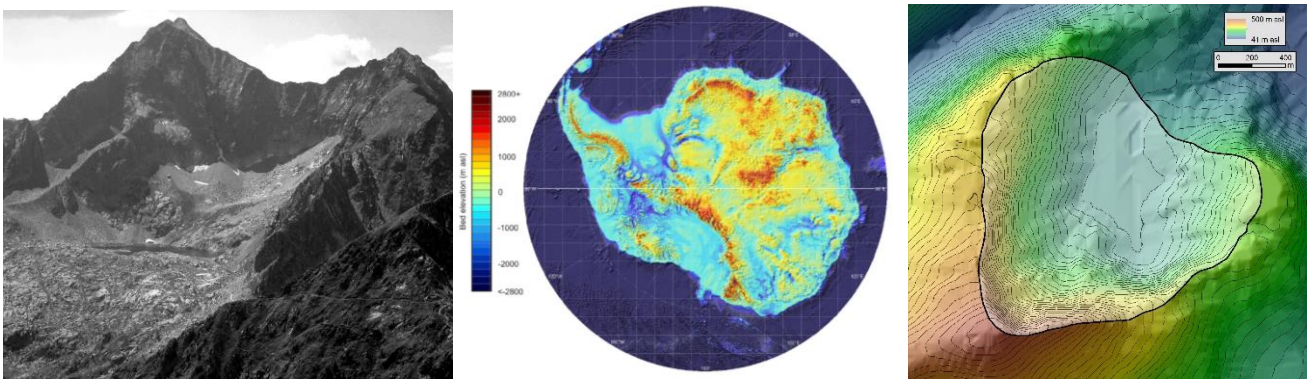

Left: *Example of a glacial cirque in the Western Alps*
Middle: *BEDMAP2 Antarctic sub-ice topography (after Fretwell et al., 2013)*
Right: *example of mapped cirque from a digital terrain model (after Spagnolo et al., 2017)*

Background and Rationale

A better knowledge of how the Antarctic Ice Sheet grew and evolved is essential to understanding its complex relationship with climate. This may be achieved by investigating Antarctic subglacial topography, which is known, in places, to preserve landscapes largely shaped by earlier "alpine-style" periods of glaciation, when climatic and environmental conditions were notably different from the present. This PhD project aims to map, morphometrically analyse and date this buried landscape, with a specific focus on glacial cirques, in order to develop a clearer picture of the Antarctic subglacial environment prior to full ice-sheet glaciation.

Cirques are armchair-shaped hollows carved by small glaciers and are ubiquitous in glaciated mountain landscapes. Cirques preserved beneath the Antarctic Ice Sheet are therefore linked to the time when this continent was characterised by alpine-style glaciation. Cirque morphometric analysis, as demonstrated in many settings worldwide, can shed light on the palaeoclimatic and environmental conditions that dominated during their formation, i.e. prior to, and likely at the onset of, ice-sheet glaciation.

Until recently, the lack of high resolution subglacial topographic data has limited the study of Antarctic cirques. However, two new lines of evidence developed from remote sensing have recently opened up Antarctica's subglacial landscape to meaningful geomorphological analysis. The first development has been the acquisition of ever higher resolution surface elevation data, which drape over subglacial landscape, including cirques. The second emerging evidence is provided by airborne radar data, which can be used to validate the surface imagery and in some regions has been acquired at sufficient resolution to grid the ice-sheet bed to sub-km resolution. Together, these data provide a rich resource but have, to date, been little used for glacial geomorphological interpretation and investigation of past climates.

Aim and Key Research Questions

This PhD project will utilise high-resolution surface and subglacial topographic data from the Antarctic Ice Sheet to identify and map glacial cirques beneath the current ice sheet. Cirque metrics will be extracted with state-of-the-art GIS techniques and cirque glaciers will be reconstructed and analysed in order to shed light on the palaeoenvironmental and climatic conditions prior to the onset of ice sheet expansion. Specific questions to be addressed include:

1. How did palaeotemperatures during Antarctic alpine-style glaciations differ from today? This will be investigated by calculating cirque equilibrium line altitudes and converting these into palaeo mean summertime temperatures
2. Are the reconstructed temperatures compatible with hypothesised alpine style glaciations during the Eocene or are they suggestive of a more recent origin for the cirques? This will be investigated by comparing the temperatures derived in (1) with those from other palaeotemperature proxies

3. How were ELA patterns related to factors such as latitude, distance from the coast, solar radiation etc. during Antarctic alpine-style glaciation? This will be investigated by analysing statistically the spatial distribution of cirque elevation and aspect metrics
4. Are cirques that have been buried under an ice sheet for several million years morphologically different from those that have experienced minimal or no ice sheet glaciation? This will be addressed by comparing the newly mapped Antarctic cirques with available databases of ice-free cirques in various worldwide settings

Additional information

The supervisory team has a long history of collaboration and comprises: Matteo Spagnolo, the lead supervisor, has a long standing interest in glacial geomorphology and landscape morphometry; Iestyn Barr has worked extensively on glacial cirques and related palaeoclimatic reconstructions with Spagnolo; Rob Bingham has investigated the bed of the Antarctic Ice Sheet for many years and will facilitate access to, and help with the interpretation of, radar surveys; Brice Rea has worked on subglacial erosion processes and glacier-climate indices, and in collaboration with Barr and Spagnolo, has recently developed a GIS tool for automatic extraction of cirque metrics which are of crucial importance to this project.

The student will be based in the School of Geosciences at the University of Aberdeen, one of the ancient (founded in 1495) public research universities of the UK. Here, they will be integral part of the Cryosphere and Climate Change Group. The student will be expected to travel to and spend time working at the University of Edinburgh and the University of Belfast with co-supervisors R. Bingham and I. Barr. There, the student will be encouraged to integrate into the Edinburgh Glaciology and Land-Surface Dynamics, and Belfast Environmental Change research groups.

As part of the training and progression elements of the PhD, the student will be expected to contribute to teaching within the School of Geosciences in Aberdeen, including field trips where appropriate, and to present their work at national (e.g. International Glaciological Society British Branch, British Society for Geomorphology, UK Arctic/Antarctica symposia, SURGE) and international conferences (e.g. EGU, AGU, INQUA).

The student will also become a member of the vibrant SAGES graduate school, which offers opportunities to further enrich the PhD studentship experience, including a dedicated school retreat. They will be involved fully in the SURGE grouping of trans-Scots glaciologists. Other specific summer schools and visits to relevant research groups in the UK and abroad will be encouraged.

Aberdeen offers a unique location within the UK to enjoy outdoor activities and wildlife, while also maintaining the cultural attraction of a large city. It is the ideal gateway to some of the most beautiful sceneries in Northern Europe, including the world-famous Scottish Highlands. It is served by the UK national railway system and a well-linked international airport.

This project involves the application of remote sensing and GIS techniques. The data required are available to the supervisory team, and all necessary facilities are found at the University of Aberdeen.

Application details

We seek a passionate student with a suitable Undergraduate and/or Masters Degree qualification equipped with quantitative skills in Earth Sciences, Physical Geography and/or Physical Sciences. The deadline for applications is Friday February 10th. The two best candidates amongst all applicants will be interviewed in Edinburgh between the 21st-24th February, 2017. Recruitment will be co-ordinated by the University of Aberdeen. In order to apply, applicants should send a CV (including 3 references) and a covering letter to m.spagnolo@abdn.ac.uk. The PhD is funded in full by SAGES (Scottish Alliance for Geoscience, Environment and Society) and the School of Geosciences -University of Aberdeen for UK/EU students. Overseas students are also welcome to apply but, they will have to cover international fee differential (around £10k per year).

References (further reading):

Aniya, M.,Welch, R., 1981. Morphometric analyses of Antarctic cirques from photogrammetric measurements. Geogr. Ann. Ser. B 63 (1/2), 41–53.
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Rose, K.C., et al. 2013. Early East Antarctic Ice Sheet growth recorded in the landscape of the Gamburtsev Subglacial Mountains. Earth Planet. Sci. Lett., 375, 1–12
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