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Subglacial topography and its importance for the growth and long-term stability of the West Antarctic Ice Sheet

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Department of Geography, Durham University

In partnership with: Newcastle University and Glasgow University

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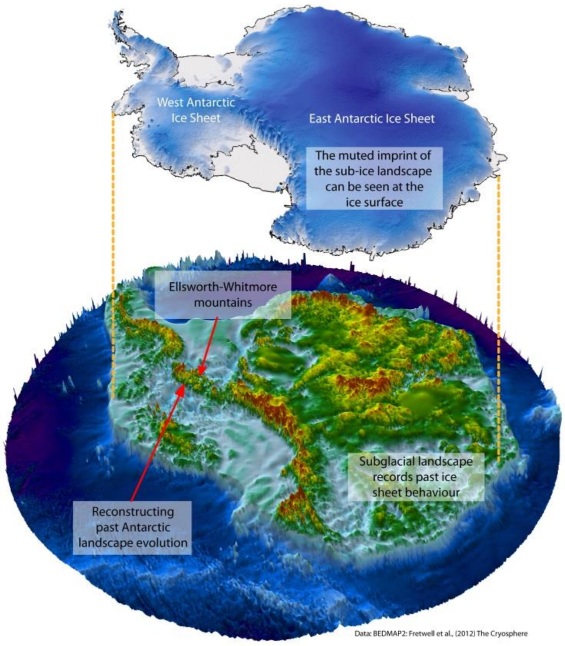
Key Words	**Antarctica, Ice-sheet stability, subglacial topography, tectonics, numerical modelling**

Overview

The West Antarctic Ice Sheet (WAIS) is one of the largest bodies of ice in the world and rests on a bed largely below sea level (see figure), making it potentially susceptible to rapid fluctuations in extent and volume. Changes in WAIS stability have significant implications for global sea level, and accelerations in mass-loss have been observed in its fast-flowing outlets (ice streams) and ice shelves. However, these satellite-based observations are short in duration and consequently, the understanding of what *controls* long-term WAIS stability has been limited.

This aim of this project is to understand the role of landscape evolution in controlling WAIS stability. Quantifying the influence of subglacial topography is crucial to any meaningful understanding of the controls on long-term (hundreds to millions of years) ice-sheet fluctuations [1,2]. Consequently, improving knowledge of the ice-sheet bed, and its evolution, is crucial for understanding of WAIS behaviour since its inception at least 14 million years ago.

Recent work [3] shows that innovative processing of existing high-resolution imagery of the ice-sheet surface can detect the morphology of highland regions buried beneath the WAIS. Therefore, potential sites of initial ice-sheet growth, patterns of tectonic landscape evolution and signals of past ice behaviour and extent may all be recorded in such imagery.



This project will apply a geomorphological approach to characterise patterns of glacial erosion and tectonic evolution recorded in this imagery. Three significant unknowns will be addressed: 1) Where did WAIS initially grow? 2) How has WAIS been controlled by evolving topography? and 3) How does ice behave within a reduced-mass WAIS?

Methodology

The project will exploit the power of geographical information systems (GIS) and numerical ice-sheet models to understand the interactions between long-term landscape evolution and ice flow in Antarctica. Freely-available satellite ice-surface imagery will be used to extract the distribution of valleys and ridges beneath WAIS in the Ellsworth-Whitmore Subglacial Highlands (see figure). At exposed nunataks, existing field, dating and denudation data [4] will provide quantitative constraints upon patterns of long-term landscape evolution. Existing ice-penetrating radar datasets available for West Antarctica will provide further ground-truthing for subglacial feature mapping and elevations.
Output will be interpreted in the context of bedrock erosion, tectonics and ice-sheet basal thermal regime which provides information on the scale of past ice sheets which eroded the topography. The geomorphological analysis will be placed in a chronological context using cosmogenic isotope and thermochronologic data, allowing mapped landscape elements to be linked to the history of WAIS. These analyses will be combined to develop a framework for topographic evolution of West Antarctica. The student will use this as the basis for a series of numerical modelling experiments exploring the sensitivity of the WAIS to changes in past bed topography.

Timeline

Year 1: develop an understanding of WAIS behaviour and controls; refine a GIS methodology for subglacial mapping.
Year 2: Apply analysis to central West Antarctica; identify sites of potential ice-sheet growth where ancient mountains may be preserved; interpret palaeo-ice-sheet configurations; receive training in application of numerical models.
Year 3: interpret tectonic landscape signals; conduct ice-sheet modelling experiments; develop writing skills; draft publications; present outcomes to IAPETUS and at international conference; draft thesis.
Year 4: Submit thesis; finalise publication manuscripts; attend international conferences.

Training & Skills

Techniques of geomorphic mapping, GIS analysis, numerical modelling and high-performance computing will form the core of this project. Applicants must be numerate with some previous experience of mapping or GIS. However, specific training in all aspects of work will be delivered in Durham, and via internationally recognised 'summer schools'.
The student will be supported in broader skills training via the award-winning Career and Research Development (CARD) group at Durham (thesis writing, writing for publication, presentation skills, enterprise skills etc.) and will benefit from cross-disciplinary training provided as part of IAPETUS. The training is designed to ensure that the student becomes a well-rounded scientist who is comfortable working independently and in teams.

References & Further Reading

[1] Jamieson, S.S.R. and Sugden, D.E. 2008. Landscape evolution of Antarctica. In: Cooper et al., (eds.) *Antarctica: A Keystone in a Changing World*.

[2] Jamieson, S.S.R. et al, 2010. The evolution of the subglacial landscape of Antarctica. *Earth and Planetary Science Letters.*

[3] Ross, N., et al. 2013, The Ellsworth Subglacial Highlands: Inception and retreat of the West Antarctic Ice Sheet, *Geological Society of America Bulletin*.

[4] Bentley, M.J. 2010, The Antarctic palaeo record and its role in improving predictions of future Antarctic Ice Sheet change. *Journal of Quaternary Science*.

Further Information

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Mike Bentley, Email: m.j.bentley@durham.ac.uk Tel: +44 (0) 191 33 41859 Web: https://www.dur.ac.uk/geography/staff/geogstaffhidden/?id=329 to discuss any aspect of this project.