Antarctic geological Boundary Conditions (ABC)

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We also hope to have offshore bathymetric and erosion/provenance expertise join – if possible with European or Asian affiliations and likely non-ECR.

Main related INSTANT Theme
Earth-Ice Interactions

Sub-committee title:
Antarctic geological Boundary Conditions (ABC)

Vision statement:
Our vision is to use the geomorphological and geological record to better understand ice behaviour in Antarctica.

Preface:
This document outlines the objectives of the ABC sub-committee of INSTANT and explores how it will support INSTANTs objectives. The document outlines a range of possible outputs and activities before then indicating some proposed work packages. The 1-year and 4-year plan for ABC follows at the end, building on how the work packages will begin to be delivered. This document has been assembled by the sub-committee steering group (named above) and we fully expect the work packages and associated activites to evolve in discussion with the broader community once ABC is properly 'launched' (likely in early 2022).

Objectives
Our aim is to expand knowledge of critical geological boundary conditions on- and offshore, and understand their significance for Antarctic Ice Sheet stability. Geological and geomorphological information beneath the ice sheet and adjacent ice shelves and oceans tells us not only about previous behaviour, but about current and future controls on the ice sheet and ocean system. This is because the shape, lithology, permeability and strength of the bed both record and influence the pattern of ice flow and rate of ice discharge to the margin. We also recognise that the snapshot of the geological boundary conditions we see today has evolved over time, and that it will continue to do so, initiating feedbacks with ice behaviour in the future. We will refine understanding of the geological boundary conditions of Antarctica by:

- Continuing to improve maps of modern subglacial topography and bathymetry – interpreting the landscape in respect of past and present ice flow.
- Developing improved reconstructions of past topography and bathymetry by quantifying erosion and deposition patterns, vertical movements in the landscape, and past ice sheet fluctuations reconstructed from seismic and sedimentary records. We will also link offshore sediment provenance analysis to onshore erosion and ice flow patterns and 'fingerprint' geological source areas of detrital material
- Explore geophysical and geological data to enhance our understanding of the long-term geological evolution of Antarctica and to understand interactions in the critical zone where interactions between the geological substrate, the atmosphere and ice occur and thus influence feedbacks between the landscape and ice flow.
- Enhancing understanding of the distribution of water at the base of the ice sheet via modelling and geophysical data analysis, and the potential for changes in water supply, for example from groundwater and/or basal melting (links to geothermal heat flux sub-committee).
- Mapping subglacial bedrock geology to using geophysical and geological data to understand longer-term tectonic boundary conditions and crustal heat production (links to geothermal heat flux sub-committee).
- Integrate and 'translate' geologic characteristics into continent-wide data and machine-learning products that can be used as inputs to numerical ice sheet models.

These objectives will develop new integrative conceptual models that can drive forward knowledge of ice sheet behaviour. In particular, we target robust numerical solutions suitable for incorporation into numerical ice sheet approaches. For example, by linking our understanding of geology, sediment distribution, topography and water distribution, we might better understand controls on the pattern of basal slip. If we understand the geology and the way the ice interacts with it over time, we can aim to produce better reconstructions of past Antarctic topography that might allow us to better model ice-sheet behaviour during past warm periods. Feedbacks between geology and ice behaviour can therefore be better understood and integrated into modelling frameworks.

How this can support INSTANT main theme(s) (max 4000 char).

The proposed theme will produce maps of present and past geological boundary conditions in forms suitable for incorporation into numerical modelling approaches testing the past, present and future response of the ice sheet and shelves to changing climate and ocean conditions. In particular, this sub-committee might help address a range of priority research questions as highlighted below (italics indicate possible input from this sub-committee):

Ocean-Ice interactions:

- What is the role of bathymetry in heat exchange between the ice and the ocean? *Needs improved bathymetry maps (past and present) and sub-ice shelf cavity maps.*
- What is the role of ocean dynamics at the margins of ice shelf cavities? *Relies on better bathymetric and cavity maps.*
- How do marine sediment records inform us about past variability? – *Needs better understanding of bathymetry, offshore stratigraphy, and depositional patterns (e.g. linked to palaeo topography) as well as a better understanding of the spatial distribution of onshore geology to enable source-to-sink fingerprinting.*

Earth's land surface-Ice interactions:

- What are the subglacial properties and processes relevant for past and future ice dynamics? *Needs knowledge of the ice bed and the processes operating at that interface, as well as spatial heterogeneity of heat and water fluxes*.
- What is the role of geological controls and erosion and sedimentation on ice sheet dynamics? *Needs understanding of coupled evolution (e.g. feedbacks) of the ice sheet and its bed, on and offshore.*

- How do glaciological, geological and geophysical records inform us about ice sheet and landscape? *Needs knowledge of subglacial geology, investigations of provenance (e.g. erosion and deposition), and basin evolution.*

By bringing together geological aspects of basal boundary conditions, we will be better placed to address stakeholder engagement by developing an integrated suite of basal boundary conditions that can be used in numerical models to explore uncertainty in ice sheet response to warming climate using past warm periods to guide understanding the future.

Activities

- We anticipate the following activities
- Workshop on modelling and geological inputs in conjunction with modelling and chronology sub-comms
- Identification of existing databases for storing data and encouragement to the community to update these. An example is the Petro-Chron Antarctica database for geology.
- Session at SCAR AGU and OSC
- Focussed workshop on translating potential fields to 'geology'. E.g. 'Potential fields for dummies – and discussion of whether they can be made more relevant to controls on ice behaviour or as model inputs Perhaps linked to Geothermal Heat Flux sub-comm.
- Focussed workshop on exploring the onshore landscape record. E.g. offshore bathymetric and seismic data are used in a framework to understand past ice behaviour in terms of the palaeo landforms, but the onshore geomorphology is not so closely examined.A workshop would explore the use of radio echo sounding data alongside remote-sensing approaches using products like REMA and Radarsat to better map subglacial topography. This workshop is confirmed and has funding via Durham University, with potential partner funding from the Universities of Newcastle and Edinburgh if required.
- Workshop to explore development of potential new approaches to relate geology to parameters that ice models care about (e.g. geothermal heat flux).

Possible Outputs

A white paper on Antarctic geological Boundary Conditions and their importance for ice sheet behaviour (e.g. defining what we know and what we would like to know)
A series of hypothesis maps linking geological data/interpretationsto ice behaviour – e.g. linked to heat flow, basal sliding etc
Initiate a community-accessible subglacial 'geology' database that ties with a publication to produce the first 'stable' version and is then updatable using version-controlled software (e.g. GitHub) and that can be linked to, or interrogated by, models including machine learning frameworks, or linked to other databases (e.g. PertroChron Antarctica.
Possible development of grants to conduct work – e.g. Marie Curie Action.
Further reconstructions of past topography.
A central webpage that communicates the relevant outputs and ongoing projects.

Support required

Financial support is probably minimal unless a workshop will be run – in which case support facilities may need to be paid for.

Potential Work Packages:

WP1. Reconstructing past ice extent and retreat from offshore bathymetry and stratigraphy:

- Assimilate marine geophysical (esp. seismic) and core data to produce 3D maps of sedimentary architecture. This might identify buried chronologically-constrained sediment packages or landforms exposed at the seafloor. (Links to WP3, WP6, and WP7).
- Interpreting the offshore landscape in respect of past and present ice flow using bathymetric and seismic data.
- Using the above to understand patterns of erosion, and deposition in the landscape and to determine areas that have remained protected and unchanged over time.
- Linking to work of Chronology/Proxy Sub-committee.

WP2. Reconstructing past ice flow regimes from subglacial topography:

- Satellite data, RES and potential field data analysis to map subglacial and sub ice shelf topography/bathymetry in increased detail.
- Development of machine learning methods for integrating data and mapping subglacial topography.
- Using the above to understand patterns of erosion, protection and deposition in the landscape.

WP3. Develop erosion/provenance database.

- Bring together/review all Antarctic offshore sediment (e.g. IRD) provenance studies and connect to patterns and timing of ice flow and erosion changes.
- Develop approaches to sediment provenance “fingerprinting” and its application to interpretation of ice sheet change

WP4. Mapping and characterising subglacial geology.

- To compile a subglacial bedrock geology map that is complimentary to, or continues, SCAR GeoMAP beneath the ice.
- Using potential field data, landscape morphology information and outcrop/subglacial sampling techniques to map and characterise geology and to use this to update databases like GeoMAP and PetroChron Antarctica.
- Interpret potential fields and/or subglacial geology map in terms of friction, heat production, porosity, density etc.
- Use machine learning analysis of post-glacial landscapes to connect paleo geological knowledge with the subglacial environment.

WP5. Enhancing understanding of the influence of water upon landscape evolution via modelling and geophysical data analysis.

- Using RES data and outcome from geology characterisation project to understand presence of water and therefore its influence on landscape evolution and ice flow.
- Understand likely ability of the ice-sheet bed to sustain active hydrogeology, and investigate potential for influence on ice sheet dynamics
- Link to Heat Flux subcommittee (or pass to Heat Flux subcomm).

WP6. Develop and test models of glacial erosion and deposition with different controlling forces.

- Couple/incorporate erosion and deposition processes into existing ice sheet models.
- Modelling programme to investigate specific feedbacks with loading changes and ice sheet flow and grounding line stability.

WP7. Improving reconstructions of past topography and bathymetry:

- Follows from WP1-6 above
- Use erosion model and geological/provenance database to understand topographic change.
- Apply geophysical modelling to understand vertical movements in the landscape in response to load changes and to explore distribution and activity of faulting.

WP8. Understanding interactions between the landscape and ice flow.

- Follows from WP1-7 above
- Ice sheet modelling component to test influence of landscape evolution on ice flow (or spin out to wider community).
- Conduct tests on basal friction influence on ice and landscape evolution using the geologic map (WP4) as a constraint.

1-year plan:
The first year is dedicated to initiating ABC and developing the Work Packages. The first year will end in a workshop during the SCAR Open Science Conference in India. The goals are:

Initiating ABC:
We plan to have an online ABC 'launch' at which we will aim to have time for discussion around the various planned work packages. During this steering committee members will chair breakout rooms with jamboards with the aim of refining the science objectives within the work packages and assigning key researchers to conduct the work packages, including a leader for each.

Work Package Development:
Following the launch, we will task the work package teams to begin planning with a target of being able to use the SCAR Open Science Conference to discuss how these will progress.

Personnel:
An ongoing issue is the lack of buy-in from the offshore and geology communities. We will use the launch to explore that. However, we will also encourage members of ABC to develop projects (e.g. grant applications or PhD studentship projects) which address and deliver on ABC objectives.

Linked Workshop:
As a direct response to ABC planning, the 4th GEomorphological Template for Past Antarctic Ice Dynamics (GeTPAID) workshop will take place at Durham University during the first half of 2022. This will explore links between subglacial topography, tectonics/structure, erosion and ice flow. This workshop will target work packages 2 and 4 in particular. Funding from Durham University Department of Geography has been secured, with the offer of additional funding from Newcastle University and Edinburgh University if needed. Activities will also be linked to the work of the SCAR AntArchitecture.action group.

ABC and Modelling Workshop:
We will explore the possibility for a workshop on modelling and geological inputs (*year 1)* in conjunction with modelling and chronology sub-comms.

Conference sessions:

ABC will have a session at AGU 2021 and will also plan one at the SCAR Open Science Conference 2022. A workshop/discussion will also be planned for SCAR OSC.

4-year plan:

Over the next 4 years, we expect that we will have completed a number of the work packages, and will have made significant progress on others. We expect that some new work packages will evolve alongside INSTANT's scientific evolution.

We envisage a number of possible activities over the next 4 years:

- A workshop in conjunction with the modelling sub-committee in which we hope to explore the geological linkages with ice sheet modelling boundary conditions.
- Development of a white-paper that explores the links between geological boundary conditions and ice sheet modelling and possible routes to improving model inputs for improved outcomes.
- Identification and development of a data / resource management 'platform (e.g. GHub or something strongly linked to SCAR) as a base for resources developed by ABC (e.g., 'geological maps') that we want to be easily accessible / usable by the community. Existing databases could be linked or hosted as required (e.g. PetroChron Antarctica).
- A series of workshops at appropriate international conferences (e.g. ISAES, SCAR OSC, EGU, AGU) to maintain momentum.
- Supporting the development of international geophysical expeditions or cruises, and depending on the outcome of early work packages ABC may itself develop proposals where knowledge gaps and opportunities are identified (e.g. via IODP).