A polar, arid, glacial-periglacial-paraglacial landsystem for James Ross Island

Bethan Davies, Neil Glasser, Jonathan Carrivick, Mike Hambrey, John Smellie

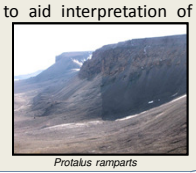
bdd@aber.ac.uk

1. Rationale

- Polar deserts are now, and would have been at the LGM, important and widespread landsystems in both the northern and southern hemispheres.
- The interrelationship of processes (glacial, periglacial, paraglacial) is poorly understood. In particular, there have been few studies of cold-based glaciers on soft beds.
- This new landsystem here can be used as a modern analogue to interpret landforms deposited in palaeo environments.
- Palaeo ice sheet reconstructions require a thorough understanding of current and past processes and subglacial conditions. There is sparse information regarding the subglacial thermal regime during the LGM in the northern Antarctic Peninsula.

2. Aims and Objectives

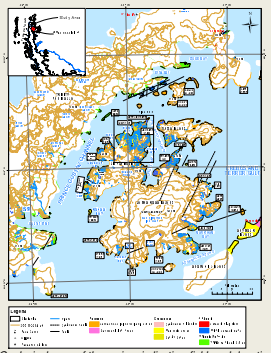
1. To describe and determine past and present sediment-landform process relationships;
2. To provide a modern analogue to aid interpretation of palaeo landsystems;
3. To present new data regarding the character and behaviour of the Antarctic Peninsula Ice Sheet through the LGM and Holocene.



Protalus ramparts

3. Study area

- Our geographical focus is the Ulu Peninsula, James Ross Island, which has a well-preserved record of glacier fluctuations, but one that is largely unexploited.
- James Ross Island is composed of Cretaceous sedimentary strata, overlain by the Neogene James Ross Island Volcanic Group, which comprises basalt deltas (forming mesas), tuffs, and glacigenic diamictites.
- The Ulu Peninsula is largely ice-free, with several large glaciers draining Dobson Dome. Precipitation is around 200 m per year and mean annual temperatures are -5℃ to -7.5°C, making this a polar desert.
- Granite erratics from Trinity Peninsula are reported to be distributed across the island.



Geological map of the region, indicating field work location. Source regions of granite erratics are shown in red.

Basecamp by Monolith Lake. Lookalike Peaks and the large, degraded ice-cored moraine of Whisky Glacier are in the background.

Neogene tillites are well preserved on the island, and were redistributed as glacial erratics across the surface. Some of these tillites contain granite boulders, which could have been reworked by Quaternary glaciers. This one was part of the boulder train.

Monolith Lake with San Jose Pass in the distance, looking towards Santa Martha Cove. Note the smoothed and sculpted slopes, across which are distributed rare granite erratics.

4. Methods

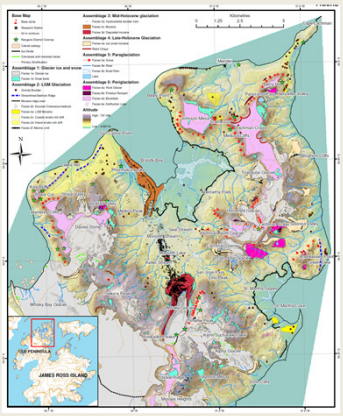
4.1 Field Methods

- 7-week onshore field campaign (January to March 2011) with one field camp at Monolith Lake, Ulu Peninsula, James Ross Island.
- Geomorphological mapping, structural glaciology, sedimentological analysis, logging of ice-cored facies.
- 101 shape-roundness and lithology counts, each of 50 clasts, on a variety of different landforms.

4.2 Remote-Sensing Methods

- Data sources: ASTER and SPOT-5 satellite imagery, BAS aerial photographs, and DEMs created by the SPIRIT programme and by the Czech Geological Survey.
- Detailed geomorphological and glaciological maps were created for the study region.
- Identification of features followed standard procedures (Glasser et al., 2008; 2009).
- These maps were 'ground-checked' during fieldwork.

5. Landsystem Development



Geomorphological map of the Ulu Peninsula, Brandy Bay region.

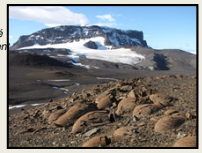
Facies 6d. Blockfield on top of Lachman Mesa.

There are six sediment-landform assemblages.

Assemblage 1: Glacier ice and snow.

a. Glaciers (cirque, dome, tidewater, valley)
a. Perennial snow

Facies 4a: San José Glacier and prominent ice-cored moraines.



Assemblage 2: Last Glacial Maximum

a. Drift sheet with isolated granite boulders;
b. Sandstone and siltstone breccia;
c. Coastal drift sheet with abundant erratics;
d. Patches of drift on sculpted cols and passes, with abundant erratics;
e. Moraine fragments and ridges;
f. Marine terrace.

Assemblage 3: Mid-Holocene.

a. Boulder train from Whisky Glacier to Brandy Bay;
b. Drift sheet (basalt pebble-cobble gravel);
c. Moraine in Brandy Bay;
d. Degraded moraine (in front of Whisky Glacier).

Assemblage 4: Late Holocene.

a. Ice-cored moraines
b. Abandoned cirques

Assemblage 5: Paraglacial.

a. Scree slopes;
b. Rivers, streams and lakes;
c. Pebble-boulder lags;
d. Spits;
e. Beaches and coastal boulder lags.

Assemblage 6: Periglacial.

a. Rock glacier;
b. Protalus rampart;
c. Freeze-thaw products;
d. Blockfields on mesas;
e. Slope processes.

6. Discussion

6.1 A glacial-paraglacial-periglacial landsystem

Geological and glaciological studies on James Ross Island resulted in the development of a new landsystem model, which will aid interpretation of other palaeo-glaciated environments.

LGM glacial sediments have been reworked throughout the Holocene by paraglacial and periglacial processes.

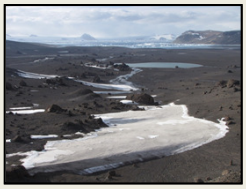
Abundant meltwater, streams and freeze-thaw encourages periglacial processes, including patterned ground, gelifluction and frost shattering.

6.1 The Antarctic Peninsula Ice Sheet during the LGM

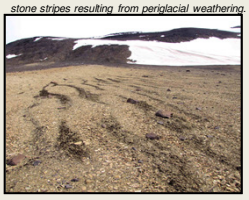
The glacial drift sheets here suggest difference s in the thermal regime under the LGM ice sheet:

- Facies 2a. Widespread basalt cobble-gravel. Deposited by a cold-based ice sheet; slow sheet-flow. Typical sediment-landform assemblage, similar to that found in the Dry Valleys, East Antarctica.
- Facies 2b. Scoured bedrock; slow flow under a cold-based ice sheet.
- Facies 2c: Erratic-rich drift on cols and passes. Warm-based ice sheet; slow sheet flow. Obstacles and focussed flow encourage basal melting.
- Facies 2d: Erratic-rich drift in coastal regions. Warm-based ice sheet; ice streaming. Lateral margins of the Prince Gustav Ice Stream during the LGM. Sharp boundaries in the thermal regime result in sharp onshore facies transitions.

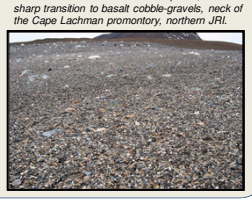
Facies 3a: hyaloclastite boulder train. Photo taken from the crest of Whisky Glacier moraine, looking towards Brandy Bay.



Facies 2b: sandstone breccia. Note the basalt stone stripes resulting from periglacial weathering.



Facies 2d: coastal erratic-rich deposits, with a sharp transition to basalt cobble-gravels, neck of the Cape Lachman promontory, northern JRI.



7. Conclusions

- This holistic and systematic sediment-landform study on the Ulu Peninsula, James Ross Island, has used detailed sedimentary descriptions, geomorphology and clast shape-roundness and lithology data to present the first landsystem model for the northern Antarctic Peninsula.
- The availability of water leads to significantly different sediment-landform assemblages than in other, drier and colder, parts of Antarctica. Periglacial and paraglacial processes have significantly modified the glacial landscape.
- This research presents new data for the interplay between cold-based and warm based ice, and presents significant new data regarding subglacial conditions and the basal thermal regime during LGM glaciation.
- This data challenges the paradigm that cold-based glaciers do not erode or deposit, but rather result in an identifiable sediment-landform assemblage.

The team. From left: Bethan Davies, Alan Hill (FGA), Neil Glasser and Jonathan Carrivick.

8. Acknowledgements

We gratefully acknowledge the logistical support provided by BAS. We were deployed by the *RRS Ernest Shackleton* and uplifted by the *RRS James Clark Ross*. We thank Alan Hill (BAS FGA) for assistance in the field. This project is funded by NERC grant AFI 9/01 (NE/F012942/1). We thank the Czech Geological Survey for providing access to their 2006 DEM, aerial photographs and map. The team acknowledge support from Alpkit, who provided down jackets and other clothing.