RGS - IBG Postgraduate Research Grant Report

Thickness constraints of the Patagonian Ice Sheet over the last glacial cycle using surface exposure dating

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Abstract

This study provides critical empirical field based constraints of the vertical extent of the Patagonian Ice Sheet over the last glacial cycle (110-10 ka). In-situ produced terrestrial cosmogenic nuclides beryllium-10 (^{10}Be), aluminium-26 (^{26}Al) and chlorine-36 (^{36}Cl) are used to date the surface exposure of erratic boulders and/or bedrock, reflecting the timing of vertical ice abandonment/retreat. 57 rock samples were collected along vertical transects from 7 ridges/summits between 500-1750 m.a.s.l. at the eastern margin of the Southern Patagonian Ice Field (SPIF; 49°S, 73°W). The exposure ages will yield age-ice-elevation correlations, rates of ice surface lowering, and volumetric configurations of the Patagonian Ice Sheet at 49°S over last glacial cycle. Together with geomorphological mapping, the palaeglaciology and climatology of southern Patagonia, southern South America will be reconstructed.

Research Background

Changes in ice surface elevation of the Patagonian Ice Sheet (PIS) during the last glacial cycle are a major unknown in current glacial reconstructions based on chronologies of ice margin fluctuation (Kaplan *et al.* 2007, 2011; Glasser *et al.* 2011; Fig. 1A) and ice sheet models (Hulton *et al.* 1994, 2002). Empirical data on ice surface elevation and lowering is critical because (1) thinning may occur before marginal retreat thus recording the commencement of large scale climate shifts earlier than evident from glacial extent studies, (2) the 3-D ice topography (thick/thin ice) is an important component of, and has strong effects on, local/global circulation patterns, and (3) relating ice volume fluctuations to eustatic sea level requires accurate chronological data on lateral and *vertical* ice limits.

The numerically simulated central palaeo-PIS thickness at the last glacial maximum (LGM) ranges between 2000-2500 m. In addition a maximum volume of 500,000 km^3 equating to 1.2 m of eustatic sea level has been modeled (Hulton, *et al.* 2002). Under the modelled conditions the core area of the PIS (located between 52-43˚S) requires several thousand years of mass loss to attain its present form as the Southern Patagonian Ice Field (SPIF; Fig. 1A & B). Empirical data on *vertical* ice extent and *thinning* rates are required to validate and refine the numerical models.

Methodology

The *in-situ* produced cosmogenic nuclides ^{10}Be, ^{26}Al and ^{36}Cl are used to date the surface exposure of bedrock and erratic boulders providing a chronology of vertical ice down waisting. The technique relies on rare nuclides being produced at known rates in the Earth's surface by secondary cosmic ray bombardment. The nuclides are extracted from the mineral lattice of rock samples, and their concentration is measured using accelerator mass spectrometry (AMS). The resulting nuclide concentration is converted to a surface exposure age (see Gosse & Phillips 2001 for an extensive review and Dunai, 2010).

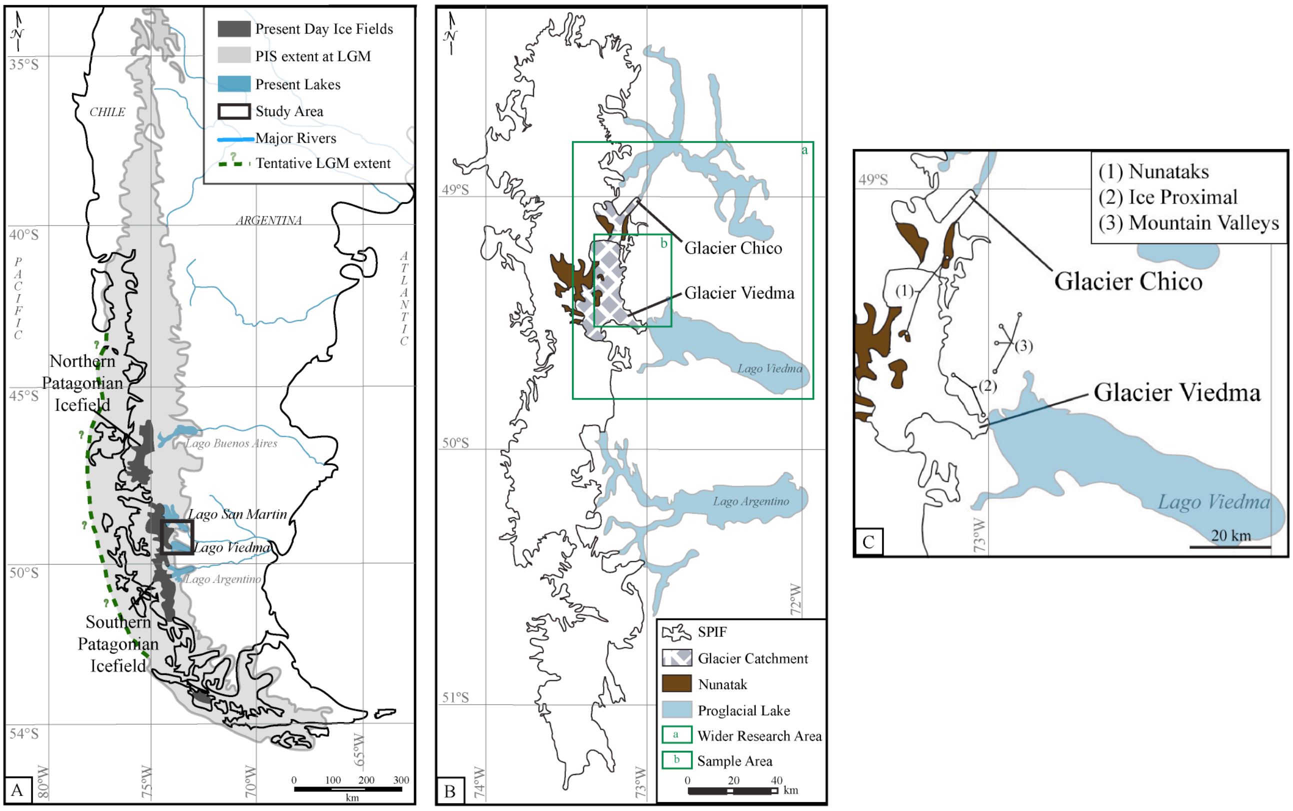

Fig. 1 | A) Maximum extent of the Patagonian Ice Sheet at the LGM (26-16 ka; adapted from Rabassa, 2008), location map of the Southern Patagonian Ice Field (SPIF) and the study area at 49˚S. B) Present day SPIF extent, Viedma & Chico Glacier catchment area. a) wider research area (~12,000 km^2) b) area where samples for surface exposure dating were collected (~1,500 km^2). C) Vertical mountain transects from where SED samples have been obtained.

Research was conducted on and adjacent to the central eastern margin of the SPIF, which constitutes the largest mass of ice in the southern hemisphere outside of Antarctica (Fig. 1). The site was selected because it was at the former latitudinal centre of the PIS, it is currently at the core of the SPIF, and ice thickness measurements and subglacial trough profiles are available making it suitable for palaeo-ice thickness reconstructions (Rivera & Casassa, 2002).

The field campaign was conducted over a period of 60 days. A total of 70 erratic/bedrock samples for surface exposure dating (SED) were collected along vertical transects of 7 ridges/summits between 500-1750 m.a.s.l. (Tabel 1, Fig. 2). 57 samples have been selected for SED. Samples were obtained from three distinct zones (Fig. 1C, Table 1): Nunataks, peaks that are completely surrounded by the SPIF; ice proximal sites which are adjacent to Glacier Viedma; distal localities occupied by cirque glaciers located in the mountain range to the north/east of Glacier Viedma.

Fieldwork was conducted in collaboration with Dr. Andrew Hein from Edinburgh University and Lic. Lucas Ruiz from the Argentinean Institute of Nivology, Glaciology and Climate Science, Mendoza. Simon Brun & Maria Pomes from Patagonia Hikes, El Chalten, were solicited for logistical and field support during the Nunatak expedition on the SPIF.

All rocks have been separated mineralogocially at the University of Glasgow and have been and currently are being processed to AMS targets at the NERC-Cosmogenic Isotope Analysis Facility, Scottish Universities Environmental Research Centre, East Kilbride.

Sample Location	Amount of Samples	Vertical Range (m)
Soto Nunatak, Chile	1 erratic, 3x erratic-bedrock pair	400
Witte Nunatak, Argentina	5 bedrock, 2x erratic-bedrock pair	500
Paso del Viento (ice-proximal)	10 erratics, 1x erratic-bedrock pair	850
Paso Huemul (ice-proximal)	1 bedrock, 3x erratic-bedrock pair	1000
Tunnel Valley (distal to SPIF)	1 bedrock, 2 erratics	300
Pizarras Ridge (distal to SPIF)	10 erratics	900
Chalten Valley (distal to SPIF)	3 erratics, 1x erratic-bedrock pair	300

Table 1 | 57 rock samples selected for SED including the vertical range from current ice surface to highest sample at 7 mountain transects.

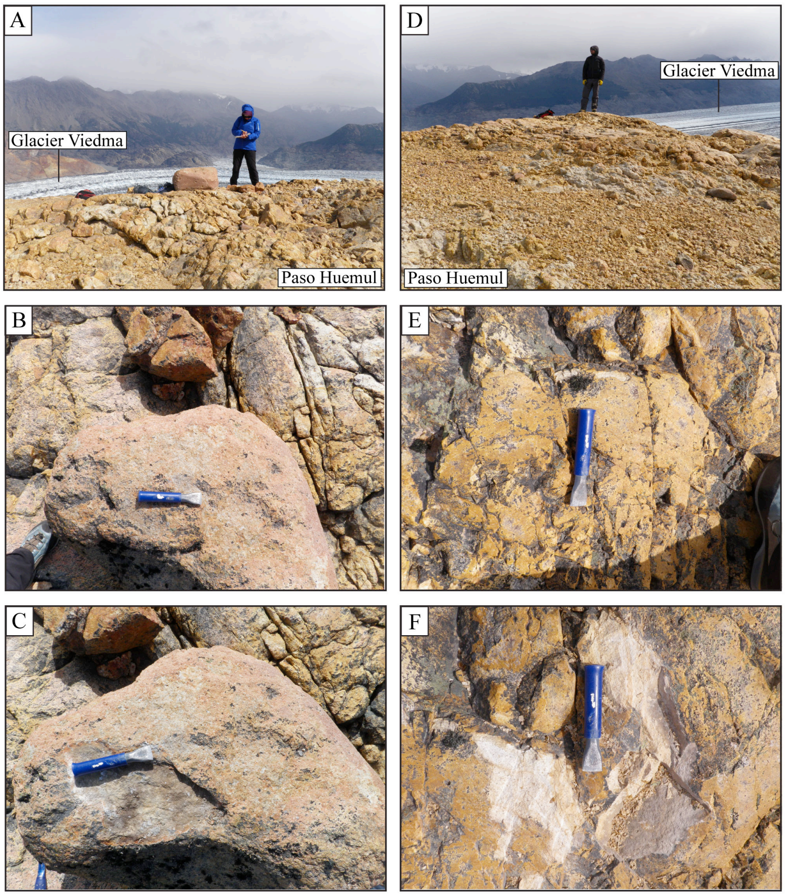

Fig. 2 | A) Erratic on bedrock at Paso Huemul (1100 m.a.s.l.). Picture taken towards south by L. Ruiz. B-C) Rock before and after sampling for SED. D) Bedrock at Paso Huemul (1100 m.a.s.l). Picture taken towards south-west. E-F) Bedrock before and after sampling for SED. Chisel indicates North.

Preliminary Results

The first AMS results were reported back in mid-November 2012. Minimum exposure ages have been calculated as corrections for snow shielding and erosion are still to be performed. Ages range between the late Holocene (0.55 ka) on Nunataks 200 m above the current ice surface to the late Pleistocene (45 ka) 700 m above the current ice surface in ice-proximal localities (Fig. 1C, Table 1). Further AMS results are expected for January 2013.

Output to Present

- Fabel, D., Geiger, A., Glasser, N. NERC-CIAF Grant 9117.0412 (£30,600) for 35 samples excluding multiple nuclide measurements (total of 46 AMS measurements).
- Publications for the QRA Newsletter and BSG Geophemera have been submitted. References will be provided once received.
- School of Geographical & Earth Sciences Progression Conference Presentation.
- Supervision of two higher school pupils funded by the Nuffield Foundation Science Bursary Scheme. They worked on improving the mineral separation techniques required for exposure dating using samples from this project. Results of the experiments were presented at the anual Nuffield Foundation Conference, September 2012, Edinburgh.
- Construction of a Website for the project is underway providing more accessible/detailed information regarding the project. The URL will be supplied to the Society once the website goes online.

References

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Playita Camp Night 1: Lago Electrico

First steps onto the Southern Patagonian Ice Field via Glaciar Marconi.

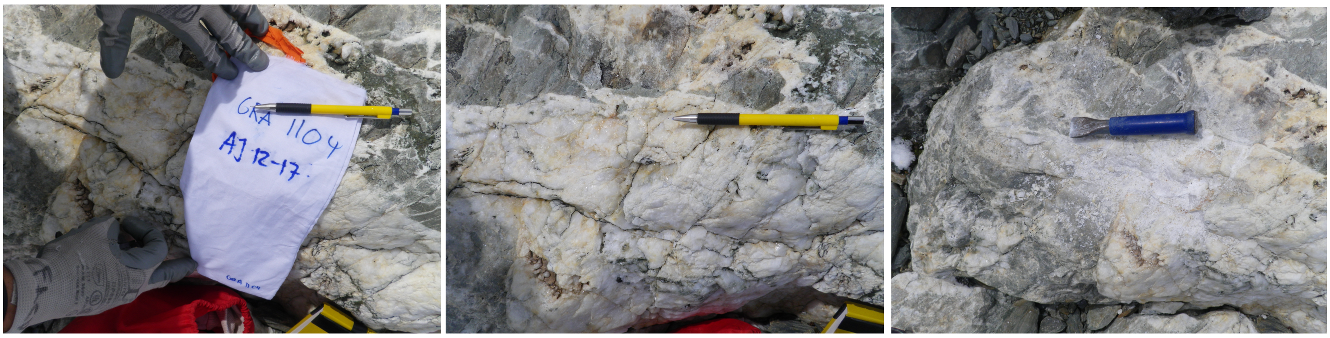
Paso Marconi. Fitz Roy highest peak in the distance. Cerro Marconi Norte to the right (2210m).

Refugio Eduardo Garcia Soto: Chilean Research Station on Nunatak Soto

Picture taken from Soto Nunatak over SPIF towards North. Glacier Chico visibly draining NE.

Picture taken from Soto Nunatak over SPIF towards SW. Nunatak Witte in centre (~17km away).

Erratics on top of Nunatak Soto. Unsorted, angular to round boulder deposits with varied lithologies.



Nunatak Witte bedrock sample (quartz vein). Foto with sample ID, before sampling and after sampling for SED. Chisel/pencil pointing towards north.

Financial Breakdown

What	Details	Amount (£)
Travel (flights)	to/from Buenos Aires	1083.50
	to Rio Gallegos	144.20
	to Buenos Aires	107.00
	Flight Change (BA)	146.00
	Xtra Weight (BA)	39.60
Travel	Coach	199.00
Travel	Taxi	55.00
Accommodation	Hostel	214.00
Internet/Phone		73.00
Laundry		13.00
Food (including field assistants)	2.5 months	1196.50
Expedition	Overall Cost	3624.23
X-tra Expedition	4x Porters	700.00
Plastic box for rock shipment	6x boxes	47.00
Rock cutting	3x large boulders	42.00
Rock shipment	DHL	1300.00
Satellite Phone	90 minutes talk time	150.00
TOTAL		**9134.03**
Pre-fieldwork Budget		8113.10
Difference Budget + Total Expenses		1020.93
Total Grants Awarded*		6550.00
Total Personal Expenses		2584.03
* Carnegie Research Expenses Grant	Travel	600.00
* QRA New Researchers Award	Rock shipment	500.00
* British Society of Geomorphology	Travel	1000.00
* Carnegie Research Grant	Expedition + Food	2200.00
* RGS-IBG PG Research Award	Expedition	2000.00
* McCorkell Travel Scholarship	CONICET Collaboration	250.00