Europlanet TA Scientific Report

PROJECT LEADER

Project number: 20-EPN2-017
Name: Dr. Gordon Bromley
Home Institution: University of Galway (NUIG)
TA Facility visited: TA2.10 Stable Rare Gas and Radiogenic Isotope Facility (SGRIF), CRPG, France

Project Title: **Resolving critical uncertainties in the impact of geomagnetism on in situ cosmogenic nuclide production via long-term calibration**

Scientific Report Summary.
(plain text, no figures, maximum 250 words, to be included in database and published)

Cosmogenic nuclide (CN) surface-exposure dating (SED) has revolutionised geomorphology in recent years, enabling the direct determination of both the rate and age of Earth surface-processes. However, SED relies on strict quantification of CN production rates (PRs) for both the time-period and location in question; for many sites and times periods such data is rare. As a result, calculated exposure ages may vary significantly depending upon the assumptions and model schemes employed in calculations. The impact of geomagnetic field variability on nuclide production is particularly uncertain. The goal of this project is to test explicitly the methods used to calculate exposure ages, and to assess their viability over space and time. To do this, we measured cosmogenic helium-3 within a series of Peruvian lavas of varying age at the Stable Rare Gas and Radiogenic Isotope Facility, CRPG (France). Paired with later Ar/Ar age determination, we are using these new cosmogenic helium data to produce a series of discrete CN production rates from a single geographic region, and so will assess the variability of nuclide production through time. Our preliminary results indicate the research plan is viable: cosmogenic helium data from single lava flows are internally consistent. Lavas analysed range in age from ~1.6 ka to ~175 ka, and so provide a dataset that spans a period sufficient to assess changes in PR and the potential impact of magnetic field variability on CN PRs. We anticipate sharing final project results within a peer-reviewed, open-access publication within the calendar year.

Full Scientific Report on the outcome of your TNA visit

Introduction:

Cosmogenic nuclide (CN) surface-exposure dating (SED) is a key tool in geomorphology, one that relies on strict quantification of CN production rates (PRs) for both the time-period and location in question. For many applications such data is rare, thus necessitating the use of 'scaling frameworks' to estimate the exposure age of a given landform based on previously attained PRs from other regions. There is as yet no consensus on how best to apply these scaling frameworks, and the choice of one over another can lead to significant differences in SED results and interpretations. Particularly uncertain are the potential impacts of magnetic field variability on the rate of CN production through time, and the effects of atmospheric pressure change (e.g., elevation) on nuclide production. This project is testing explicitly the impacts of magnetic field variability and elevation on SED through establishing a series of discrete nuclide production rates from multiple lavas of varying age from a single region in low-latitude Peru. The impact of magnetic field variability is theorised to be greatest within the tropics, and the high relief of the tropical Andes offers the opportunity to sample single landforms over a wide span in elevation. Through this research, project leaders Bromley and Jackson will use the resultant data to establish the viability of existing scaling frameworks in SED through space and time, thus strengthening our ability to assess the timing and rate of Earth surface processes around the globe.

Material and methods:

Bromley and Jackson previously visited Peru's Central Volcanic Zone in 2018 and 2019 to collect lava samples for cosmogenic helium-3 SED. Jackson and Bromley prepared samples for measurement prior to Jackson's arrival at the SGRIF facility. This preparation included crushing and pulverization of bulk lava samples, isolation of target pyroxene minerals grains through physical (density separation, magnetic susceptibility), and purification of pyroxene grains through surface etching via hydrofluoric acid leaches (after methods as described by Bromley et al., 2015). Jackson travelled to the SGRIF facility in October, 2022 to measure helium-3/4 ratios in these prepared samples using the facility's noble gas mass spectrometer (NGMS). At SGRIF Jackson prepared aliquots of each sample for NGMS analysis, measuring each aliquot into aluminium packets for later incineration. For certain samples, particularly those lavas presumed to be of age ≤ 25 ka, Jackson prepared multiple aliquots to allow for the statistical evaluation of (potentially) low-helium targets.

Results:

Jackson was trained to operate the NGMS and completed the analysis in full under the oversight of host institution staff. Jackson analysed 23 sample aliquots from three separate lavas and additional surficial boulders, as well as the CRONUS helium-3 pyroxene standard of known value to check for potential instrument drift. The CRONUS standard returned helium-3/4 ratios and helium concentrations consistent with their known value. This indicates that sample aliquot measurements are robust and have not been affected by potential instrument error.

Preliminary results indicate that the samples from individual lavas return internally consistent values/exposure ages. For example, three aliquots of sample 08 from the 'PDL' lava return exposure-ages within analytical error, as do two aliquots from PDL sample 05 (Fig. 1; Table 1). The PDL samples altogether span nearly 1 km in elevation, and will be used to establish the viability of unique scaling frameworks to account for atmospheric pressure change. The youngest lava yet analysed (VOV) returns a preliminary exposure age of ~600 years (VOV). The 'MLA' lava, in contrast, returns ages ~175 ka (Fig. 1). The

calculated ages of this lavas, with others, will be used to establish the viability of scaling frameworks to account for magnetic field variability though time. At present, the 'true' age of these landforms remains to be established, as different scaling schemes return significantly different exposure ages (Table 1). During 2022, Bromley prepared and submitted separates from each lava flow for Ar/Ar, with which we will establish the most-accurate means of calculating surface-exposure ages for each lava. Finally, we will apply these results to interpretations of glacial and volcanic landforms in the region.

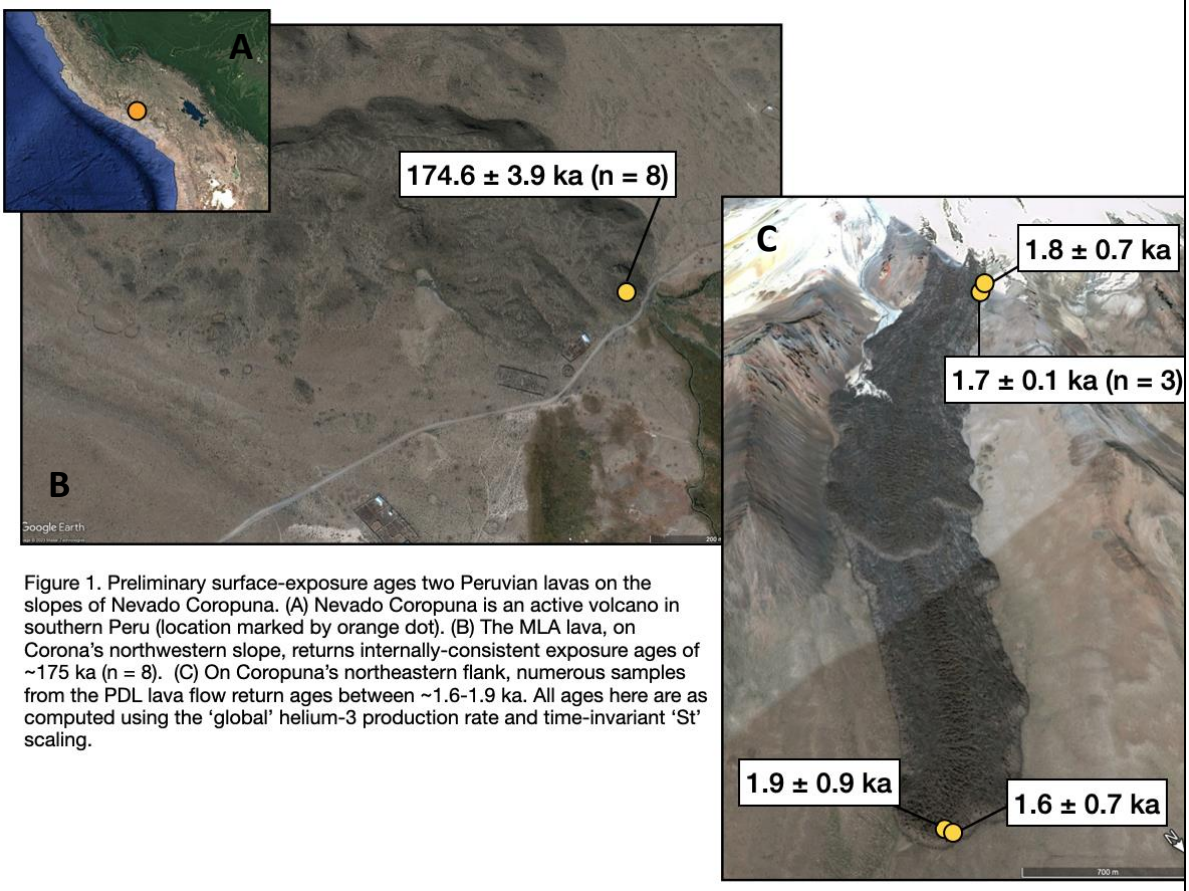


Figure 1. Preliminary surface-exposure ages two Peruvian lavas on the slopes of Nevado Coropuna. (A) Nevado Coropuna is an active volcano in southern Peru (location marked by orange dot). (B) The MLA lava, on Corona's northwestern slope, returns internally-consistent exposure ages of ~175 ka (n = 8). (C) On Coropuna's northeastern flank, numerous samples from the PDL lava flow return ages between ~1.6-1.9 ka. All ages here are as computed using the 'global' helium-3 production rate and time-invariant 'St' scaling.

Table 1. Calculated surface-exposure ages for aliquots of two measured samples (MLA-19-02 and PDL-18-08). Measurements are internally consistent, but the choice of scaling scheme impacts the resultant age calculation significantly. Ages shown here are as calculated using the 'global' mean helium-3 production rate as provided by version 3 of the CRONUS online calculator of Balco et al. (2008 and subsequently updated).

	St Scaling		Lm Scaling		LSDn Scaling	
Sample ID	Exposure Age	Uncertainty	Exposure Age	Uncertainty	Exposure Age	Uncertainty
MLA-19-02a	171304	4662	138296	3763	128440	349
MLA-19-02b	172241	4606	139135	3720	129099	345
MLA-19-02c	172241	4690	139135	3788	129099	351
MLA-19-02d	170368	4568	137482	3686	127778	342
PDL-18-08a	1629	189	2359	273	1702	19
PDL-18-08b	1708	96	2506	141	1788	10
PDL-18-08c	1674	179	2443	261	1751	18

- Give details of any publications arising/planned (include conference abstracts etc)

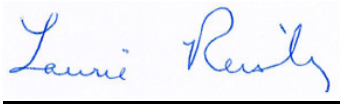
The project leaders plan to publish project results in a high-impact, peer-reviewed, open-access research journal (e.g, the EGU journal *Geochronology*). Jackson and Bromley also plan to share results and results in-progress at forthcoming meetings of the *American Geophysical Union* (2023) and the *Goldschmidt* conference (2024).

- Host confirmation

Please can hosts fill in/check this table confirming the breakdown of time for this TA project:

Dates for travel to accommodation for TA visit (if physical visit by applicant)	Start Date of TA project at facility	Number of lab/field days spent on TA Visit pre-analytical preparation	Number of days in lab/field site for TA Visit	Number of days spent in lab for TA Visit data analysis	End Date of TA project at facility	Dates for travel home (if physical visit by applicant)
Departed: 15 Oct Arrived: 15 Oct	17 Oct, 2022	[0]	[5]	[0]	21 Oct, 2022	Departed: 22 Oct Arrived: 25 Oct

The host is required to approve the report agreeing it is an accurate account of the research performed.

Host Name	CRPG Nancy, SGRIF facility (Noble Gas CRPG platform)
Host Signature	**PH Blard (Host at Noble Gas lab)**  **Laurie Reisberg (CRPG Europlanet coordinator)** 
Date	

- Project Leader confirmation

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Project Leader Name	Dr. Gordon Bromley

Project Leader Signature	
Date	7/2/2023