Europlanet TA Scientific Report

PROJECT LEADER

Project number: 20-EPN2-064
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TA Facility visited: Vrije Universiteit Amsterdam Geology and Geochemistry radiogenic and non-traditional stable Isotope Facility GGIF (NL)

Project Title: High-precision isotope analysis of individual melt inclusions: reassessing the compositional variability of Earth's mantle

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

In a unique approach, we acquired high precision Nd isotope data on well-characterized sample sets of silicate melt inclusions (MI) from the islands of Gough and Tristan da Cunha in the South Atlantic ocean. These data were collected using a Thermo Scientific Triton *Plus* TIMS at the VU Amsterdam. Melt inclusions from single or multiple olivine crystals were analysed and the new data provide insights into the magnitude, origin, and mode of sampling of the isotopically diverse materials that represent Earth's mantle. The most prominent finding of this study is the extended isotopic variability of mantle melts, indicating that the mantle itself is more heterogeneous than assumed from studies of lavas (i.e. whole rocks). Further, the new data from melt inclusions entrapped in lavas from different islands greatly extend the known isotopic variation not only from individual eruption centres but also on a global scale. Although observed small-scale mantle heterogeneity may exist down to the meter-, perhaps even cm-scale, the former also implies that distinct isolated large-scale (100's km) reservoirs in Earth's mantle (and other rocky planets) may not exist. Instead, the efficiency of mantle mixing via convection with time plays a more important role than previously thought; indeed, the existence of the full spectrum of mantle heterogeneity may be captured within single eruptions. As a consequence, the significance of large-scale distinct mantle domains detected by seismic imaging is questioned by our findings.

Full Scientific Report on the outcome of your TNA visit

We encourage you to add figures to your report, which should be approx. 1 page of text plus figures.

Silicate melt inclusions (MI) are melts trapped during crystal growth. Although MI represent comparatively small samples – on the order of tens to a few hundred micrometres across – they are ubiquitous in magmatic assemblages, also in meteorites from terrestrial planets other than Earth (e.g. 1, 2). Their chemical and isotopic compositions provide novel insights into the compositional diversity of the interior of rocky planets, such as (Earth's) silicate mantle, that is not attainable from studying bulk-rock samples, such as lavas.

The olivine crystals containing MI chosen for this study originate from well-characterised lava suites from the islands of Tristan da Cunha and Gough, both located in the South Atlantic ocean. Five lavas from Tristan da Cunha and two lavas from Gough were studied for MI. These lavas have radiogenic isotope (Sr-Nd-Hf-Pb) characteristics representing the enriched spectrum of Earth's heterogeneous mantle. Prior to the analytical work carried out at the VU Amsterdam, host crystals and MI have been analysed for their major- and trace-element compositions by means of electron microprobe (EMPA) and laser-ablation inductively-coupled-plasma mass-spectrometry (LA-ICP-MS) and for their Sr isotope ratios using a Neptune *Plus* MC-ICP-MS at the Institut für Mineralogie, WWU Münster.

Due to their small size – most inclusions were 50 micrometers or smaller – the amount of the analyte extractable was often to small (<<30 pg of Nd) to be measured for isotope ratios. Instead, several inclusions as captured in single olivine crystals were analysed. By comparison to the host lavas, the new isotope data from melt inclusions obtained during this study reveal isotopic variability extending that of the erupted lavas (Fig. 1).

The occurrence of diverse melts within individual eruption centres of a typical ocean island basalt setting is evidence for small-scale mantle heterogeneity, perhaps down to the cm scale. The outcome of this isotopic investigation of MI has major implications for our general perception of terrestrial geochemical cycles and the preservation of chemical heterogeneities in the mantle of rocky planets in general. Applied to other terrestrial planets, i.e., Mars, from where meteorites are available, the approach chosen and demonstrated here can deliver new and independent insights into the processes that govern planet formation and evolution. The outcome of the new data including their modeling will be published jointly in a high-ranked international science journal towards the end of 2022.

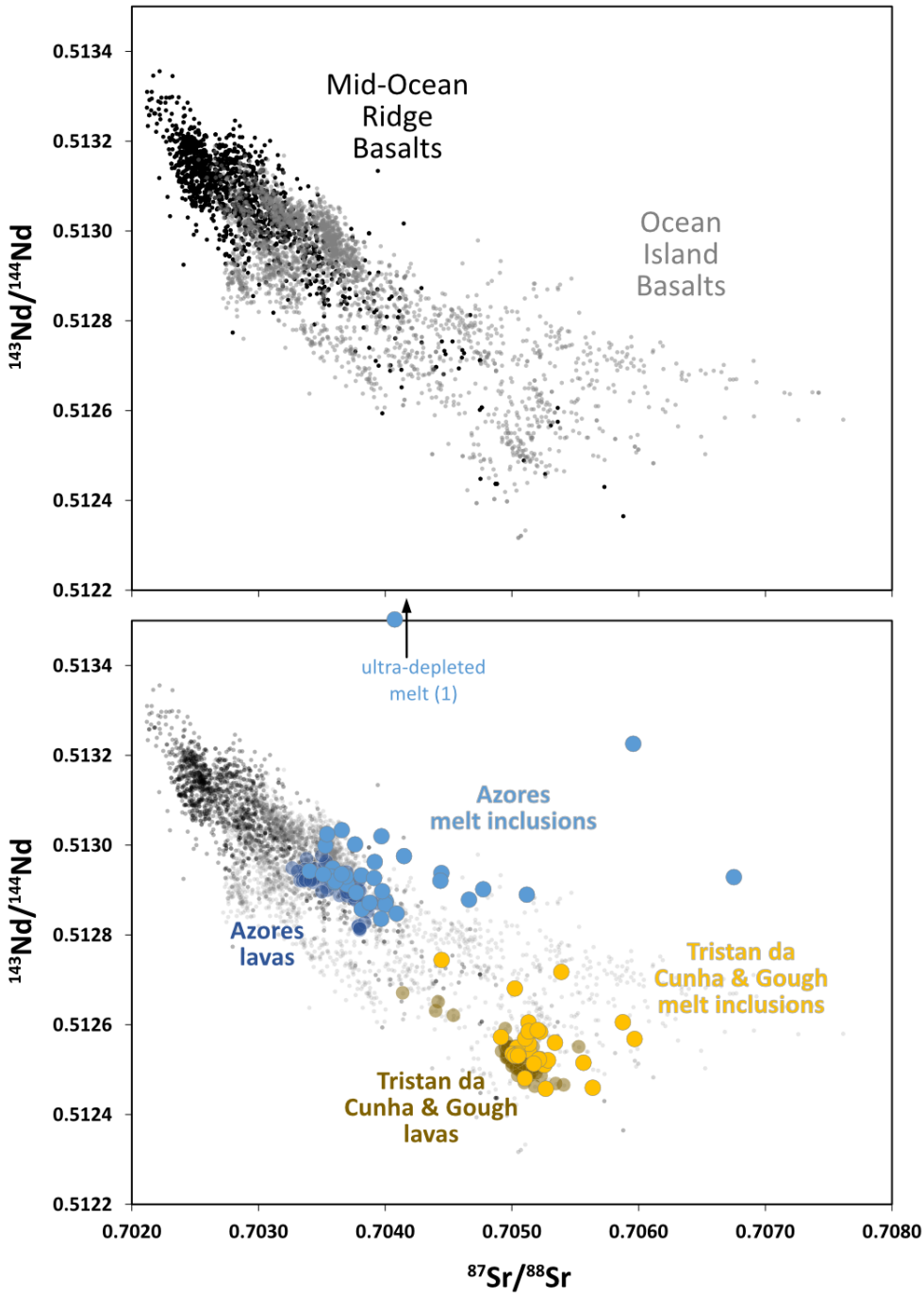

Figure 1: Radiogenic Nd-Sr isotope ratios of melt inclusions (lighter blue and yellow colours) from the islands of Tristan da Cunha and Gough island indicate variability beyond the established ranges (i.e. as derived from lava compositions, darker coloured symbols). Note that only a few lavas of each location were studied for melt inclusions, but an extended variability is recorded in these trapped melts that is not seen in the host lavas. A similar data set from the Azores is shown for comparison ((1) Stracke et al. 2019, Nature Geoscience.)

1. Peslier, A.H. et al. (2010) Geochimica et Cosmochimica Acta 74, 4543–4576. doi: 10.1016/j.gca.2010.05.002
2. Sonzogni, Y., Treiman, A. (2015). Meteoritics & Planetary Science 50, Nr 11, 1880–1895. doi: 10.1111/maps.12516

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

Abstracts:

Böhnke M, Genske F, Berndt J, Stracke A: Isotopic and chemical analysis of individual melt inclusions. Goldschmidt Conference 2022, Hawaii.

Planned submission for publication:

Böhnke M, Genske F, Koornneef J, Stracke A: Source heterogeneity of Tristan da Cunha and Gough island inferred from melt inclusions. to be sumitted to Chemical Geology.

- 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: 14-11-21 Arrived: 14-11-21	15-11-21	[O]	5	[0]	19-11-21	Departed: 19-11-21 Arrived: 19-11-21

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

Host Name	
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Date	

- Project Leader confirmation

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Project Leader Name	Felix Genske
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Date	2.05.2022