Europlanet TA Scientific Report

PROJECT LEADER

Project number: ***20-EPN2-009***
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TA Facility visited: ***Laser Fluorination System, Open University (UK)***

Project Title: **High-precision oxygen isotope composition of Martian meteorites and their components – insights into the accretion history of Mars**

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

Analyses of Martian meteorites and their components predicts the existence of three main geochemical reservoirs on Mars, namely an enriched crust, a complementary depleted lithospheric mantle, and, lastly, a primitive asthenospheric mantle. Investigating the oxygen isotope composition of these reservoirs is critical for a full understanding of the accretion history of Mars. The $\Delta^{17}O$ composition of ~0.3‰, defined by the SNCs is believed to reflect the primary planetary composition of the Martian mantle (1). However, analyses of ancient (>4.5 Ga) individual zircons and minerals from the NWA 7533 regolith breccia, record $\Delta^{17}O$ values that are characterized by a much heavier $\Delta^{17}O$ composition and thus different from the SNCs (2,3). A population of young zircons (<1.5 Ga), also from NWA 7533, are derived from a primitive reservoir located in the deep Martian interior, as they are characterized by chondritic-like initial Hf isotope composition (4). The oxygen isotope composition of a single grain from this population, indicate that this reservoir may be characterized by a different $\Delta^{17}O$ than the SNCs. If correct, the SNCs might not be representative of the bulk martian composition, but plausibly reflecting interaction with a heavy $\Delta^{17}O$ surface reservoir. Therefore, a main objective behind this study was to obtain high-precision oxygen isotope composition of 10 SNC meteorites to potentially detect $\Delta^{17}O$ heterogeneity. However, initial results show no isotopic variability, thus suggesting that the SNC source reservoir has not experienced interaction with surface reservoir, or that any heterogeneity has been erased.

Full Scientific Report on the outcome of your TNA visit

Since the discovery of oxygen isotope variability among different Solar System bodies, oxygen isotopes have become an important tool for recognizing genetic relations between meteorite groups. Mars is a planetary embryo that completed its accretion within the first 5 Myr after Solar System formation (5), and isotopic and geochemical investigation of Martian meteorites and their components, suggest that Mars consist of three main reservoirs, namely an enriched crust, a complementary depleted lithospheric mantle and a primitive asthenospheric mantle. A better understanding of the oxygen isotopic composition of these reservoirs is critical for a full understanding of the accretion history of Mars. Most of our understanding of the formation and evolution of Mars, come from meteorites that formed by melting of the martian mantle. This includes the shergottite, nakhlite and chassignite (SNC) group, which formed over the last ~2.5 Gyr of the planet's history. The oxygen isotope composition of these SNC meteorites is also believed to reflect the primary planetary composition with a $\Delta^{17}O$ of ~0.3‰. However, analyses of ancient (>4.5 Ga) individual minerals, including zircons, from the NWA 7533 regolith breccia, record $\Delta^{17}O$ values that are characterized by a much heavier $\Delta^{17}O$ composition than the SNCs (2,3). These ancient minerals record $\Delta^{17}O$ values up to ~2.5 (3), and are believed to reflect interaction with an early atmosphere/hydrosphere. In NWA 7533, another population of young zircons have been identified as reporting U-Pb ages up to 1.5 Ga, and Hf isotope systematics characterized by chondrite-like initial $^{176}Hf/^{177}Hf$ composition (4). This population implies the presence of a primitive reservoir in the deep Martian interior. Preliminary investigation of the $\Delta^{17}O$ composition of a single zircon from this young zircon population, indicate that this reservoir may be characterized by an oxygen isotope composition distinct from that of the SNCs. If correct, the oxygen isotope composition of the SNCs might not reflect the bulk martian composition and plausibly reflect interaction with a heavy $\Delta^{17}O$ reservoir, such as the martian crust.

Therefore, one of the main objectives behind this study and TA visit, was to reinvestigate the $\Delta^{17}O$ composition of 10 selected SNCs, using high-precision techniques allowing to resolve small isotopic differences. Approximately 100 mg aliquots of crushed samples were sent to Open University (OU) for sample preparation, which included 2 days for leaching the samples in EATG to efficiently remove alteration products, without shifting the oxygen isotope composition of the samples.

In June 2021, two rounds of analyses were performed by the OU lab without my attendance due to COVID-19 travel limitations. The results showed homogeneity among the SNCs, and thus no real isotopic variability. This variability in results is very similar to that obtained from replicate analyses of homogenised terrestrial standards. The average $\Delta^{17}O$ value for all SNCs is 0.313±0.010, implying the lack of detectable $\Delta^{17}O$ variability.

Given the homogeneity in the high-precision $\Delta^{17}O$ values among the different SNCs, we decided to not proceed with the final round of measurements. As our main objective was to investigate any isotopic variability to potentially trace any interaction with a heavier $\Delta^{17}O$ reservoir, these new results indicate that, 1) the SNC source reservoir has not experienced any interaction with surface reservoir, or 2) that any heterogeneity has been erased by a large-scale melting event.

References

1-Ali et al. 2016, Meteorit. Planet. Sci. 51, 981-995. **2**-Nemchin et al. 2014, Nature Geosci 7, 638-642, **3**-Deng et al. 2020, Sci, Adv. 6, eabc4941, **4**-Costa et al. 2020, PNAS, 117 (49) 30973-30979. **5**-Dauphas and Pourmand, 2011, Nature 473, 489-492

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

- 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: n/a – Virtual visit Arrived:	23-05-21	2	7		11-06-21	Departed: n/a – Virtual visit Arrived:

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

Host Name	**Ian Franchi**
Host Signature	
Date	**25 Nov 2022**

- Project Leader confirmation

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YES

Project Leader Name	**Siw Egdalen**
Project Leader Signature	
Date	**23/11/22**