Europlanet TA Scientific Report

PROJECT LEADER

Project number: 20-EPN2-011
Name: Alice Stephant
Home Institution: Istituto di Astrofisica e Planetologia Spaziale (IAPS/INAF; Italy)
TA Facility visited: NanoSIMS 50L-NSIMS at Open University (UK)

Project Title:

Water abundances and hydrogen isotopic ratios of pyroxenes in achondrite meteorites

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

One of the major unresolved questions in the field of cosmochemistry is to understand the source(s) and timing of volatile delivery in the inner Solar System. The goal of this project was to examine primitive achondrites which volatile inventory has not yet been investigated, in order to determine what portion of these volatiles was incorporated in the early stages of the Solar System history, relative to late-veneer delivery. In this regard, primitive achondrite acapulcoites and lodranites were selected as they sample a common parent body, hence allowing to also investigate the effect of various degrees of planetary differentiation on volatile abundances and isotopic compositions. Using the NanoSIMS 50L at the Open University, we analysed chlorine and water content, as well as their associated isotopic composition in phosphates from three acapulcoites and two lodranites. Our results suggest that the acapulcoite-lodranite parent body incorporated a similar source of volatiles than ordinary chondrites, which chemical composition is similar to the chondritic precursor of acapulcoites and lodranites, arguing for a common reservoir of both Cl and H in the inner Solar System.

Full Scientific Report on the outcome of your TNA visit

Primitive achondrites were among the first planetesimals to form, serving as building blocks of our Solar System and thus are key witnesses for the origin of water and other volatiles in the inner Solar System. Knowing their Cl and H abundances, and their isotopic composition relative to solar, chondritic and terrestrial values would significantly improve our knowledge on the timing and the source(s) of the volatiles delivery to the inner Solar System. Moreover, an important but scarcely studied parameter is the effect of melting and differentiation processes on hydrogen and chlorine concentration and isotopic composition of a planetesimal. Primitive achondrite acapulcoites and lodranites are key targets for this project as being the best-studied examples of a partially melted parent body, recording a range in planetary differentiation degree, from 1% up to 20% partial melting. Moreover, hydrogen (H) and chlorine (Cl) abundances and isotopic compositions in their phosphates have not been previously reported in acapulcoites and lodranites.

Cl abundance and its isotopic composition of 15 apatites were measured using the Cameca NanoSIMS 50L at the Open University, UK using a protocol modified after Barrett et al. (2019) following two modes: spot analyses for larger apatites found in Acapulco, NWA 10074 and Dhofar 125 and imaging for apatites where sizes were lower than 50 µm in Lodran, NWA 11970 and Dhofar 125. For spot and imaging analyses, $^{1}H^{-}$, $^{18}O^{-}$, $^{35}Cl^{-}$, $^{37}Cl^{-}$, $^{40}Ca^{16}O^{-}$ secondary ions were measured using a Cs^{+} primary beam. NanoSIMS measurements of D/H ratios and H_2O concentrations in 10 phosphates from Acapulco, Dhofar 125 and NWA 10074 were performed using a recently refined protocol at the OU for low water contents in lunar MIs (Stephant et al., 2021). H^{-}, D^{-}, $^{13}C^{-}$ and $^{18}O^{-}$ secondary ions were measured by spot analyses. Data processing of the analyses measurements was done immediately following each analysis, which allow to check each measurement after it has been performed. In total, 10 days of analyses were necessary. Due to the COVID pandemic, this was a virtual visit as agreed to by the EuroPlanet administration. The NanoSIMS analyses were conducted from the 24th of March to the 4th of April 2022 and from the 22nd to 25th of August 2022.

Apatite chlorine contents in acapulcoites and lodranites vary from 0.48±0.02 to 6.53±0.33 wt. % Cl. In terms of $\delta^{37}Cl$ values, acapulcoites and lodranites retain a restricted range, with an average value of 0.9±0.8 ‰ (n= 25; 1SD) (Fig. 2). The water contents in phosphates from Acapulco, NWA 10074 and Dhofar 125 are H-poor, i.e., from 6.1±0.7 to 53.5±6.5 µg/g H_2O and display negative trends in their H_2O–δD systematics, with δD values ranging from –239±249‰ to +2133±456‰ (Fig. 3). These negative H_2O–δD trends can be ascribed to H degassing.

Our results suggest that thermal metamorphism and partial melting (up to 20%) did not induce any significant chlorine isotopic fractionation. Based on these results, we are able to demonstrate that acapulcoite-lodranite parent body had a similar chlorine composition as ordinary chondrites, with which their share many chemical similarities. Concerning, water abundance and isotopic composition of apatites, further work has been done on nominally anhydrous minerals to interpret the full story of hydrogen in these primitive achondrites.

Our results on chlorine are being interpretated and will be submitted soon in Geochemical Perspectives Letters. The hydrogen apatite results have been added to the nominally anhydrous mineral NanoSIMS measurements and the study has been submitted for publication in Earth and Planetary Science Letters.

References

Barrett et al. (2019) GCA, 266, 582–597
Stephant et al. (2021) GCA, 297, 203–219

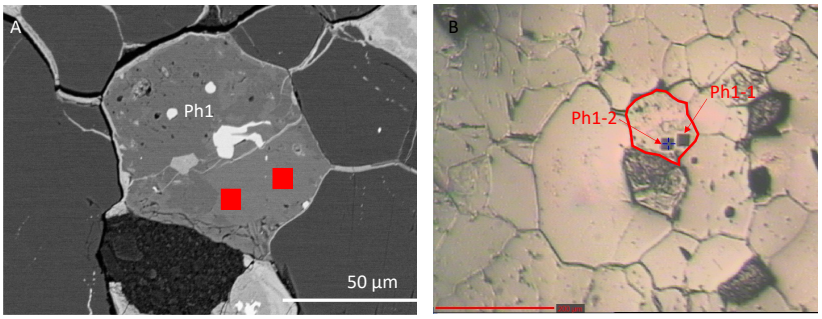


Fig. 1 - Examples of some NanoSIMS spots on Dhofar 125 apatite (numbered and highlighted by red boxes) shown in backscattered electron (left) and opaque (right) images.

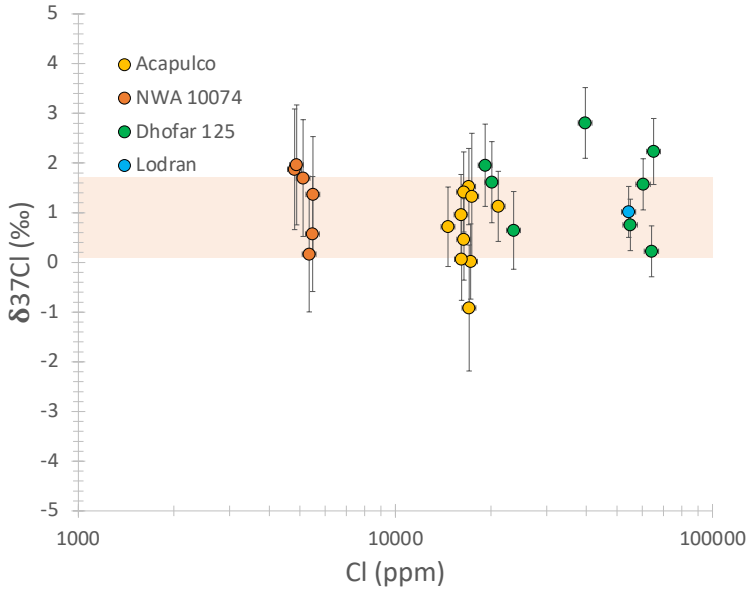


Fig. 2 – Chlorine abundance (ppm) and isotopic composition ($\delta^{37}Cl$ in ‰) of three acapulcoites and two lodranites. The orange band represent the average for all measured apatites in this acapulcoites-lodranites

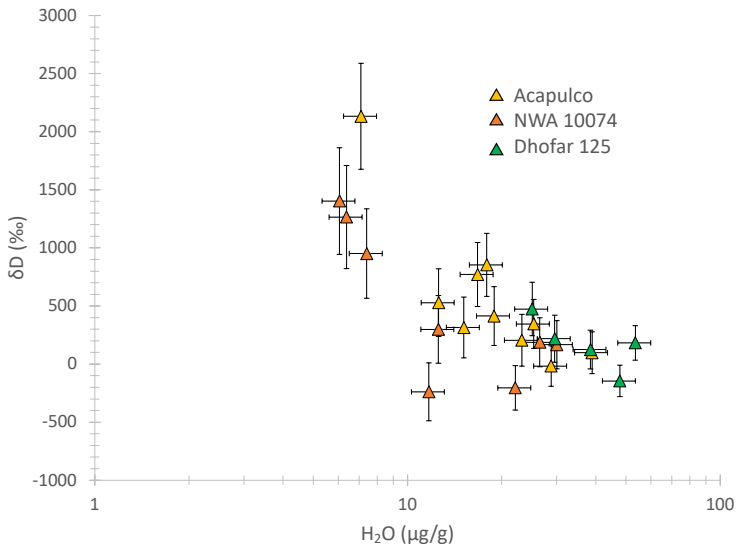


Fig. 3 – Water contents (µg/g H_2O) and δD values of apatites in acapulcoites.

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

Chlorine systematics in primitive achondrite acapulcoites and lodranites. A. Stephant, M. Anand, X. Zhao, J. Davidson, C. Carli, I.A. Franchi. In preparation for Geochemical Perspectives Letters.

Hydrogen in acapulcoites and lodranites: A unique source of water for planetesimals in the inner Solar System, A. Stephant, X. Zhao, M. Anand, J. Davidson, C. Carli, T. Cuppone, G. Pratesi, I.A. Franchi. Minor revisions in Earth and Planetary Science Letters (03/2023)

- Host confirmation

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

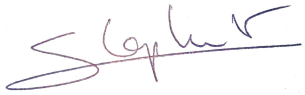
Dates for travel to accommodation for TA visit (if physical visit by applicant)	Start Date of TA project at facility	Number of lab/field days spent on TA Visit pre-analytical preparation	Number of days in lab/field site for TA Visit	Number of days spent in lab for TA Visit data analysis	End Date of TA project at facility	Dates for travel home (if physical visit by applicant)
Virtual visit	24-03-22	0	10	0	25-08-22	Virtual visit

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	24 April 2023

- Project Leader confirmation

Do you give permission for the full version of this TA Scientific Report (in addition to the 250 word summary) to be published by Europlanet 2024 RI on its website and/or public reports? YES

Project Leader Name	Alice Stephant
Project Leader Signature	
Date	26/04/2023