# Europlanet TA Scientific Report

**PROJECT LEADER**

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| **Project number:** 20-EPN2-052 | |
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| **TA Facility visited: NanoSIMS 50L-NSIMS (UK), The Open University, UK** | |

# Project Title: Water in silica-bearing iron meteorites: implications for early Solar System dichotomy

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


Understanding the volatile inventory of the earliest SS is inseparable from understanding which sources contributed to the volatiles of the oldest and relatively dry non-carbonaceous (NC) objects formed in the inner SS, and if they were different from wet carbonaceous (CC) materials, formed in the outer SS. Two questions remain largely unanswered in this respect: **(i) What are the abundances and isotopic composition of volatiles in the oldest NC objects and (ii) What were their sources?** These questions can be answered by investigating some of the oldest objects in the SS, namely, the NC iron meteorites. Here we focused on understanding water abundance and its isotopic composition in some of the oldest NC **silica bearing iron meteorites** (IVA type): Muonionalusta, Gibeon and Steinbach. Other investigated irons did not contain any silica. The lowest water content was measured in Gibeon (< 10 ppm) and Muonionlusta (15–20 ppm), while minerals in Steinbach contained significantly more water (40–120 ppm). The δD values for Gibeon show a large range and greater uncertainties, due to low measured water contents. The δD values in Muonionalusta and Steinbach cluster between ~0–300 ‰. In fact, silica phases in both minerals cluster between ~0–200 ‰, while low-water cpx in Steinbach shows the highest δD values (200–300 ‰). The difference in δD values between mineral phases in Steinbach likely reflects the difference in their crystallisation history, where opx may have lost H resulting in increased D/H ratio (higher δD) due to degassing. Overall, the source of water in these NC irons is very similar to that of the Earth and the chondrites, while low-D reservoirs have not been detected.

## 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.**
We have checked following meteorites for presence of silica obtained from the Natural History Museum in Vienna, Austria: Campo del Cielo, Landes, Toluca, Muonionalusta, Gibeon and Steinbach.
Meteorites that contained silica and were analysed for H and D/H: Steinbach, Gibeon 1 and Gibeon 2 (Natural History Museum in Vienna, Austria) and Muonionalusta (Royal Ontario Museum, Canada). All analysed meteorites are IVA type. The sample preparation procedure was extensive, it was carried out prior to the visit by staff at the Open University and involved the following steps. Existing mounting resin was entirely removed (Steinbach, Gibeon) by cutting with a thin bladed diamond circular saw and/or grinding until all the resin was removed from this surface. This particular step was required as we had no knowledge of this resin or how effective a solvent removal may be (our limited experience suggests old resin (even after a couple of years) becomes increasingly difficult to remove by solvent). The samples were then ultrasonicated with solvents (acetone?). For the purpose of polishing the sample surface, they were then placed in 1-inch Viafix resin mounts that were polished in water-free medium using aluminium oxide and mono propylene glycol.
To improve the final polish, all samples (including Muonionalusta) were polished with diamond paste in presence of water. As a final step, manual polishing with 0.25 µm diamond paste on a polishing cloth was performed. The samples were then pressed in indium using a hydraulic press using established techniques at the Open University. Because of differing sample geometry a brass ring mount was employed for Gibeon A1 and A2 and an aluminium holder for Steinbach.
Final characterisation of the samples was then required prior to NanoSIMS measurements. This was done using the TESCAN CLARA analytical FEG SEM at the Open University. The prepared samples were imaged to provide SE and BSE images needed for identifying and locating areas of interest for the NanoSIMS analytical work, as well as EDS for mineral recognition. Steinbach meteorite contains orthopyroxene (opx) and silica in addition to Fe-minerals, while Gibeon and Muonionalusta contain only silica minerals in addition to iron. Different silica polymorphs were identified using Raman spectroscopy at the Open University.
Samples were coated with ca. 20 nm of Au and placed in the vacuum oven at ca. 60 °C for at least several days before being introduced into the NanoSIMS vacuum for several more days before analysis. The NanoSIMS analytical campaigns took place in November and December. The visit was curtailed short because of technical problem with the instrument, and was completed virtually a few weeks later. We performed H and D/H measurements of the silica grains, using San Carlos olivine to monitor the background $H_2O$ contribution (varied between 1.6 to 3.8 ppm). The calibration line was obtained by analysing nominally anhydrous mineral standards containing 128–441 ppm $H_2O$ (Opx10, KBH-1-Opx, Cpx21, and Cpx15).

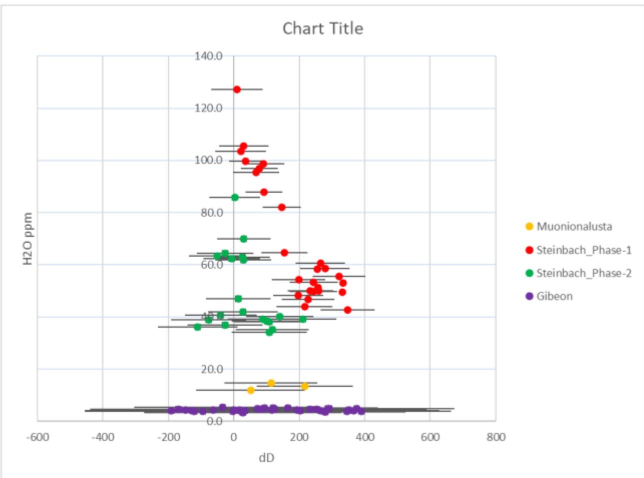


**Figure 1. $H_2O$ – δD plot of the analysed meteorites.**

We obtained $H_2O$ contents and δD values for nearly 100 spots in the three meteorites (Fig. 1). The lowest water content was measured in Gibeon (< 10 ppm) and Muonionlusta (15–20 ppm), while minerals in Steinbach contained significantly more water (40–120 ppm). The δD values for Gibeon show a large range and greater uncertainties, due to low measured water contents. The δD values in Muonionalusta and Steinbach cluster between ~0–300 ‰. In fact, silica phases (Phase 2 in Fig. 1) in both minerals cluster between ~0–200 ‰, while low-water cpx in Steinbach (Phase 2 in Fig. 1) shows the highest δD values (200–300 ‰). The difference in δD values between mineral phases in Steinbach likely reflects the difference in their crystallisation history, where opx may have lost H and increased its D/H ratio (i.e. gained higher δD) due to degassing. Overall, the source of water in these NC irons is very similar to that of the Earth and the chondrites, while low-D reservoirs have not been detected.
These values have not yet been corrected for the cosmic ray contributions, but due to low exposure ages (CREs; *ca* 20 Ma), the effect is expected to be negligible.

## - 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:<br>13-11-22<br><br>Arrived:<br>13-11-22<br><br>Virtual visit<br>28-11-22 to 20-12-22 | 14-11-22 | 2 - sample prep<br><br>3 days SEM | 7 | | 20-12-22 | Departed:<br>21-11-22<br><br>Arrived:<br>21-11-22 |

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

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| **Host Name** | |
| **Host Signature** | |
| **Date** | **21 March 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**

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| **Project Leader Name** | **Ana Černok** |
| **Project Leader Signature** | Ana Černok |
| **Date** | **March 20th, 2023** |