

OXYGEN AND HYDROGEN ISOTOPIC EVIDENCE FOR THE EXISTENCE OF SEVERAL C1 PARENT BODIES IN THE EARLY SOLAR SYSTEM. M. Patzek¹, A. Bischoff¹, P. Hoppe², A. Pack³, R. Visser⁴, and T. John⁴, ¹Institut für Planetologie, University of Münster, Wilhelm-Klemm-Str. 10, D-48149 Münster, Germany. ²Max-Planck-Institut für Chemie, Hahn-Meitner-Weg 1, D-55128 Mainz, Germany. ³Universität Göttingen, Geowissenschaftliches Zentrum, Goldschmidtstr. 1, D-37077 Göttingen, Germany. ⁴Freie Universität Berlin, Institut für Geologische Wissenschaften, Malteserstr. 74-100, 12249 Berlin, Germany. E-Mail: markus.patzek@uni-muenster.de.

Introduction: CI- and CM-like clasts have been identified in various chondrite breccias as well as in brecciated differentiated meteorites (e.g. [1-5]). Possibly, they provide material, which is not sampled by bulk meteorites and can help shed light on processes in the early Solar System. This material is potentially very primitive, since it may have escaped major heating processes in the Solar System. Previous investigations of CI-like clasts found in various brecciated meteorites indicate a similar mineralogy when compared to common CI chondrites. However, there are differences in the mineral chemistry and the abundance of characteristic phases such as phyllosilicates, magnetite, pyrrhotite, and relic olivine and pyroxene grains. In this study the bulk oxygen isotope compositions and D/H signatures of these clasts are determined to be able to evaluate a possible origin of the water incorporated into the respective parent bodies.

Methods: We obtained the oxygen isotope composition of five volatile-rich, CM-like clasts in four howardites [Northwest Africa (NWA) 6695, NWA 7542, NWA 8736, and Mount Pratt (PRA) 04402], three volatile-rich, CI-like clasts from the polymict ureilite Dar al Gani 164, and four CI-like clasts from the paired CR chondrites Acfer 059, 097, and 311 by IR-Laser fluorination at the University of Göttingen, Germany following established techniques.

Additionally, we obtained the D/H signatures of carbonaceous chondrites Ivuna, Essebi, Bells, and Tagish Lake and of different CI and CM-like clasts from Elephant Moraine (EET) 83309, NWA 7542, Al

Rais (CR chondrite), and Sahara 98645 (H chondrite) by using the Cameca NanoSIMS 50 ion probe at the Max Planck Institute for Chemistry in Mainz. D/H signatures were measured in imaging mode on 20 x 20 μm^2 areas utilizing a primary Cs^+ beam with a beam current of ~ 4 pA on pre-sputtered areas.

Negative secondary ions of H, D, ^{12}C , $^{12}\text{C}^{14}\text{N}$, and ^{28}Si have been collected in a combined multi-collection/magnetic peak switching mode. No e-gun was required, since no significant charging on the samples was observed. The samples were cleaned for 30 min in ultrasonic bath with ethanol prior to carbon coating and heated at $\sim 80^\circ\text{C}$ for 3 hrs in the NanoSIMS airlock at starting pressure $p < 10^{-6}$ Torr. Periodically, C₃₀H₅₀O and Ilimaussaq Amphibole have been measured for their D/H ratio to determine the instrumental mass fractionation (-280 and -270 ‰, respectively).

Epoxy resin on one sample has been measured in order to be able to evaluate possible epoxy contamination in cracks. During data processing apparent cracks and fractures cross-cutting the analyzed area were excluded from further processing.

D/H Signatures: A contribution by epoxy to the D/H measurements appears unlikely based on the obtained D/H vs. C/H ratios (e.g., Fig. 1a). The weighted average δD -signatures of Ivuna, Essebi, Bells, Tagish Lake, and Al Rais are on average slightly higher when compared to bulk determinations. This is, however, expected since the determination of D/H ratios by utilizing Cs^+ primary ions enhances the yield of D and H ions from organic molecules over that from phyllo-

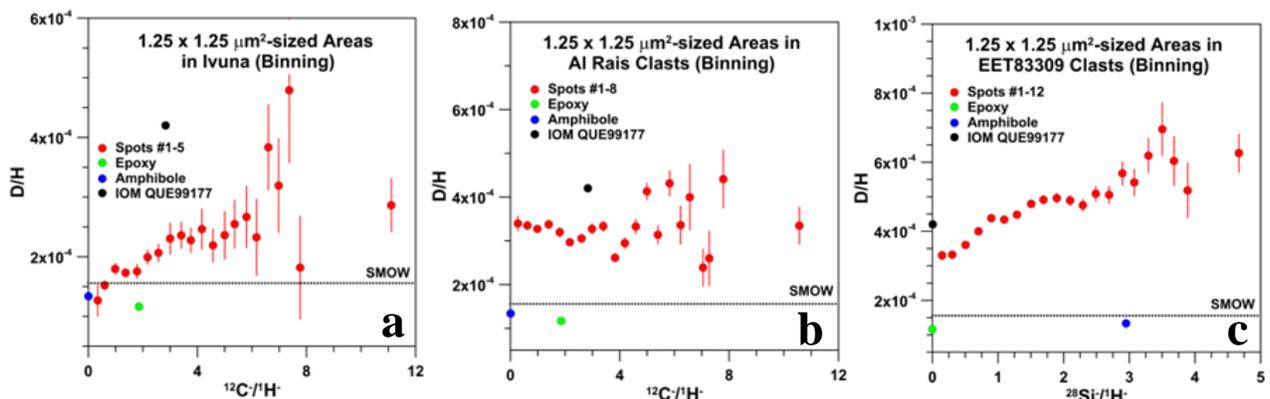


Fig. 1. (a) D/H vs. C/H ratio of Ivuna showing a positive correlation (b) D/H vs. C/H of CI-like clasts in the CR chondrite Al Rais. There is no apparent correlation between these ratios. (c) D/H vs. Si/H ratio of CI-like clasts in the polymict ureilite EET 83309 showing a good correlation of these two ratios. Bin sizes are 0.2 for Si/H- and 0.4 for C/H-.

silicates. IOM extracts of carbonaceous chondrites have generally higher D/H ratios than the respective bulk sample [6]. Clear correlations between the D/H and C/H ratios are only observable for Ivuna, Bells, and Tagish Lake (cf. Fig. 1a). However, for almost all analyzed samples, we observe a positive correlation between D/H and Si/H (cf. Fig. 1c). In general, the D/H signature of aqueously-altered carbonaceous chondrites is very complex and does not reflect a simple two-component mixing of a water component with comparably low D/H and organic matter with a high D/H. To explain our obtained D/H data, a Si-rich, H-poor, and C-poor component with a higher D/H is required. This might be an intimate mixture between very D-rich organics and hydrated phyllosilicates. The CI-like clasts in the polymict ureilite EET 83309 exhibit a D/H ratio of ~ 1850 ‰ on average, which is higher when compared to CI-like clasts (“dark inclusions”) in the CR chondrite Al Rais (~ 1050 ‰). The C/H ratios of the CI-like clasts from all studied samples are comparable.

CI-like clasts in NWA 7542 and Sahara 98645 exhibit average δD signatures of ~ 270 ‰ and ~ 100 ‰, respectively. A CM-like clasts from NWA 7542 has SMOW-like δD signature.

Oxygen Isotope Composition: CM-like clasts from the polymict eucrite and howardites range in $\delta^{18}O$ from 5.5 to 9.2‰ and in $\Delta^{17}O$ from -3.2 to -2 ‰. These data are in agreement with data obtained by previous authors and overlap with oxygen isotope bulk compositions of “common” CM-type meteorites (Fig. 2; [7,8]).

CI-like clasts from CR chondrites range in $\delta^{18}O$ from 6.9 to 9.2 ‰ and in $\Delta^{17}O$ from -2 to -1.5 ‰. They plot close to the array defined by bulk CR chondrites (Fig. 2).

CI-like clasts from ureilites range in $\delta^{18}O$ from 11.8 ‰ to 12.5 ‰ and in $\Delta^{17}O$ from 1.26 ‰ to 0.86 ‰. They plot on the extension of the CCAM and close to carbonaceous chondrite fragments from Almahata Sitta and a CI-like clast from the Nilpena polymict ureilite (Fig. 2; [9,10]). Their position on the CCAM might reflect variable water/rock ratios of the samples.

Take Home Messages: *CM-like clasts from HEDs* are clearly fragments of CM chondrites. This is demonstrated by mineralogy, D/H ratios, and O-isotopes.

CI-like clasts from HEDs are slightly more enriched in D when compared to Ivuna. Bulk oxygen isotope compositions of this type of clasts in HEDs are not available due to their generally small size.

CI-like clasts from ordinary chondrites have a SMOW-like D/H signature and their bulk oxygen isotope composition determined on a clast in the

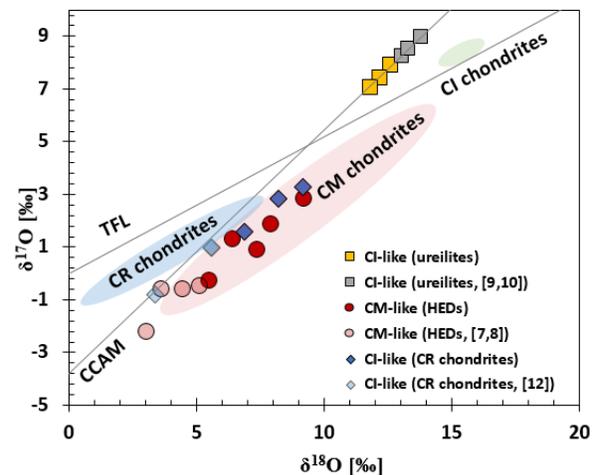


Fig. 2: Oxygen isotope diagram showing the obtained data points as well as literature data. CCAM= Carbonaceous Chondrite Anhydrous Mixing line; TFL= Terrestrial Fractionation Line.

H chondrite Zag plots apart from common CI chondrites [11].

CI-like clasts in CR chondrites are slightly more enriched in D (~ 1050 ‰) compared to bulk data of the CR host rock. Taking the oversampling of hydrogen from organics when using a Cs^+ ion beam into account the D/H ratio of CI-like clasts may be similar to CR chondrite bulk. Their oxygen isotope compositions plot very close to the array defined by bulk CR chondrites.

CI-like clasts in ureilites are heavily enriched in D when compared to other carbonaceous chondrite materials known so far. They probably formed from ^{16}O -rich silicates and ^{16}O -poor ices from close to or beyond the snowline. These ices are isotopically unfractionated (e.g. plotting on the CCAM) with regard to oxygen isotopes, which is unlike those incorporated into the CI, CR, and CM chondrites.

All the CI-like clasts share a similar mineralogy and experienced similar aqueous alteration conditions, but formed in different isotopic reservoirs. Thus, they are rather C1- than CI-like and clearly represent different C1 parent bodies.

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