

## BRECCIATION IN CI CHONDRITES: UNCOUPLED D/H AND ELEMENTAL RATIOS IN INDIVIDUAL FRAGMENTS - EVIDENCE FOR A LOW VARIABILITY IN D/H RATIO AFTER ALTERATION.

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**Introduction:** CI chondrites represent one of the most important materials in cosmochemistry as the abundances of the moderately volatile to refractory elements are closest to those of the solar photosphere. Therefore, the composition of CI chondrites is regularly used as a reference value (e.g. [1]). Nevertheless, the CI chondrites are extensively brecciated and altered by aqueous fluids [2-6]. In detail, CI chondrites exhibit extreme heterogeneity on a sub-mm scale (Fig. 1). Although CI chondrites are affected by various episodes of aqueous alteration (e.g. [7]), all episodes apparently took place in a closed system because the composition of CI chondrites is still similar to that of the Sun.

**Analytical Techniques:** We reviewed a polished thin section (PL92533) of the Ivuna CI chondrite using SEM and selected various lithologies for further measurements of their D/H ratio at the Max Planck Institute for Chemistry in Mainz using a Cameca NanoSIMS 50, utilizing a primary Cs<sup>+</sup> beam with a primary ion current of 25-30 pA. IMF corrections were done using synthetic C<sub>30</sub>H<sub>50</sub>O.

**Results:** Previous work has shown that CI chondrites are variable in their major and trace element concentrations on the sub-mm scale due to variations of their mineralogy e.g. in the modal abundance of magnetite ranging from 1.1% to 4.5% (Fig. 1a; [4]). The most abundant opaque phases in CI chondrites (magnetite and pyrrhotite) are heterogeneously distributed and embedded into a complex intergrowth of phyllosilicates as their main mineral phases [3,4]. The selected lithologies of Ivuna show a variation in  $\delta D$  from -178 to +104 ‰ (with counting statistical errors of ~20 ‰ for individual measured spots), averaging at ~ -70 ‰, which is slightly below the values of bulk CI chondrites [8]. A correlation between  $\delta D$  and various ratios of main elements was not observed (e.g. Fig. 1c). Elemental ratios obtained from the clasts are variable and differ from those of bulk Ivuna (Fig. 1b). One Fe-poor lithology shows the highest variation in  $\delta D$  ranging from -100 to +104 ‰. This also represents the maximum value obtained in the studied thin section of Ivuna and is well above the median  $\delta D$  value of -95 ‰.

**Discussion:** Despite the high mineralogical variability of the investigated thin section of Ivuna, the  $\delta D$ -values of various lithologies do not correlate with any elemental ratio, implying a narrow range of hydrogen isotopy. This may be explained by the extensive aqueous alteration experienced by the CI chondrite lithologies. During this process volatile elements (especially hydrogen) may have been easily redistributed. Multiple aqueous alteration episodes are evidenced by mineralogical aspects, such as the occurrence of complex carbonate vein fillings [7] and the textural contexts of magnetite and pyrrhotite, which probably precipitated in different events [4]. Mn-Cr dating of carbonate of the Orgueil CI chondrite implies an extensive alteration period starting at 3-4 Ma after CAI formation and lasting for ~4 Ma [5,9].

**Conclusion:** The decoupling of  $\delta D$  from any elemental ratios can be explained by the volatility of hydrogen, which is easily redistributed within the matrix of Ivuna. The variability of major element abundances is a result of a heterogeneity in the mineralogy of the starting material of the CI chondrite lithologies, which was inherited on a sub-mm scale throughout all alteration episodes and brecciation events.

**References:** [1] Anders E. and Grevesse N. 1989. *Geochim. Cosmochim. Acta* 53:194-200. [2] Kerridge JF. 1996. *EPSL* 29:194-200. [3] Tomeoka K. and Buseck P. 1988. *Geochim. Cosmochim. Acta* 52:1627-1640. [4] Morlok A. et al. 2006. *Geochim. Cosmochim. Acta* 70:5371-5394. [5] Endress M. et al. 1996. *Nature* 379:701-703 [6] Bischoff A. et al. 2006. *Meteorites and the Early Solar System II* (eds. D.S. Lauretta and H.Y. McSween Jr.), 679-712, Univ. of Arizona, Tucson. [7] Endress M. and Bischoff A. 1996. *Geochim. Cosmochim. Acta* 60:489-507. [8] Alexander C.M.O'D et al. 2012. *Science*. 337:721-723. [9] Hoppe P. et al. 2007. *Meteoritics & Planet. Sci.* 42:1309-1320. **Acknowledgement:** This work is partly funded by the SFB-TRR 170: Late accretion onto terrestrial planets.

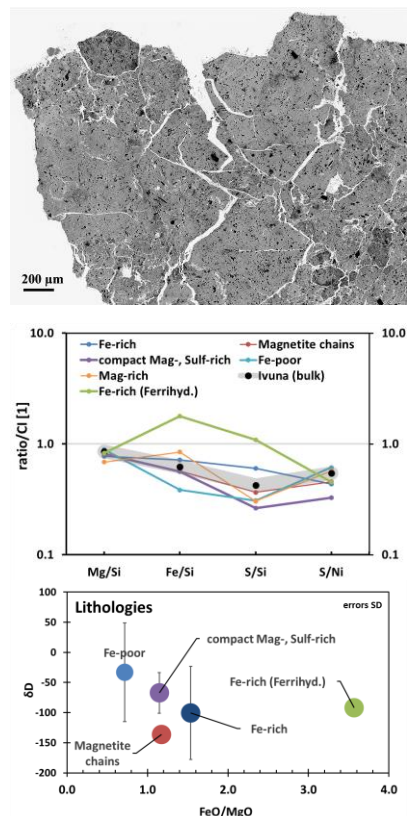


Fig. 1: (a) Inverted BSE-image of a section of Ivuna showing various lithologies (darker=more Fe). (b) Various elemental ratios of selected lithologies and bulk Ivuna obtained by SEM-EDX differ from bulk CI values [1]. (c) No correlation between average  $\delta D$  and FeO/MgO can be observed for different lithologies within standard deviation of several spots. Mag= magnetite; Sulf=Sulfide; Ferrihyd.=Ferrihydrite.