

# Origin and Abundance of H<sub>2</sub>O in Ordinary Chondrites

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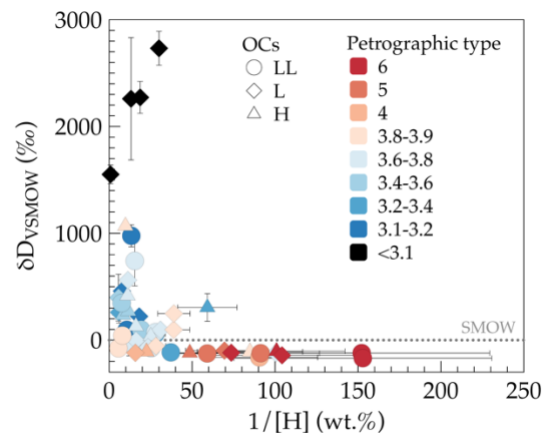
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**Introduction:** The origin of water in ordinary chondrites (OCs) is a long-standing debate. Only few least-altered unequilibrated ordinary chondrites (UOCs) contain hydrous minerals thought to have formed by low-temperature parent body processing [1]. These primitive UOCs also display whole rock and/or *in-situ* H isotopic composition ( $\delta D$ ) similar to that of comets or interstellar ice [2, 3]. This suggests that D-rich outer disk H<sub>2</sub>O ice was transported in the inner region of the solar nebula and preserved in the LL OC parent body during the first millions years of Solar System history [3, 4]. Alternatively, the high D-enrichments measured in bulk in primitive LL UOC can be also associated to parent body processes, such as thermal metamorphism accompanied by the escape of H<sub>2</sub> during metal oxidation [5, 6]. If correct, then this model implies that OC water may have been initially depleted in D and influx of D-rich H<sub>2</sub>O from the outer Solar System towards inner solar system bodies was limited [2, 6]. To test the influence of thermal metamorphism on the H isotopic variations in OCs, here we report the bulk H concentrations and H isotopic composition of a suite of low weathered Antarctic (B $\leq$ ) and falls OCs (H, L, LL) that span the entire range of metamorphic grades [7].

**Methods:** H abundance and H isotopic compositions of bulk OCs were determined using the Thermo Scientific EA IsoLink deltaV IRMS System at CRPG laboratory (Nancy, France) following the approach described in [8]. Typically ~6-10mg of OCs were crushed into powder, weighted in tin capsules and degassed under vacuum at 120°C for 48h in a degassing canister to remove absorbed atmospheric water. After dehydration, the degassing canister was opened in a N<sub>2</sub>-flushed glove box and samples were transferred into a custom sealed, auto-sampler pre-flushed with He. Samples experienced pyrolysis at 1450°C on a EA glassy carbon reaction tube. After chromatographic separation, the extracted H<sub>2</sub> was introduced into the mass spectrometer and its H abundance and  $\delta D$  value were characterized.

**Results:** Data from bulk H extraction are presented in Fig. 1. UOCs with petrographic type (PT) <3.1 are the most D- and H<sub>2</sub>O-rich relative to all OCs analyzed in this study, with  $\delta D \approx +1550$  to  $+2730$ ‰ and [H]  $\approx 0.033$ – $1.190$  wt.%. UOCs with PT  $\geq 3.1$  display variable  $\delta D$  values and H contents, with  $\delta D \approx -120$  to  $+1070$ ‰ and [H]  $\approx 0.010$ – $0.179$  wt.%. Equilibrated ordinary chondrites (EOCs) are the most D- and H<sub>2</sub>O-poor relative to UOCs, with  $\delta D \approx -170$  to  $-100$ ‰ and [H]  $\approx 0.007$ – $0.063$  wt.%.

**Discussion:** The least-metamorphosed UOCs (PT <3.1) host the highest bulk  $\delta D$  values recorded so far in OCs, while the most metamorphosed EOCs (PT  $\geq 4$ ) show the lowest  $\delta D$  values. As shown in Fig. 1, our data do not support the assumption that residual OCs water become progressively enriched in D due to loss of isotopically light H<sub>2</sub> induced by parent body processing [5, 6]. Our results rather suggest that D-rich components in OCs are very sensitive to thermal metamorphism and are preserved only in the least-metamorphosed UOCs that experienced metamorphic temperature peak  $\leq 250$  °C [9]. UOCs contain thermally recalcitrant D-rich organic components [10], and clay minerals (smectite) that dehydrate at low temperature (i.e., >300 °C [11]). Thus, it is possible that the bulk D-rich signatures measured in pristine UOCs mostly reflect the presence of D-rich hydrous minerals formed through aqueous alteration, which escape thermal metamorphism >300 °C. Alternatively, the least-metamorphosed UOCs may have also incorporated more D-rich organic components compared to more metamorphosed UOCs. Further analyses of H, C and N on bulk OCs and insoluble organic matter will provide further constraints on the suggested scenario.



**Fig. 1** - Distribution of the H content and  $\delta D$  values measured in bulk OCs as function of their petrographic type. H contents and  $\delta D$  values decrease progressively with increasing degree of metamorphism. Error bars represent the  $2\sigma$  uncertainties.

**References:** [1] Alexander C.M.O'D. et al. (1989) *EPSL* 95:197–207. [2] Alexander C.M.O'D. et al. (2012) *Science* 337:721–723. [3] Piani L. et al. (2015) *EPSL* 415:154–164. [4] Alexander C.M.O'D. et al. (2018) *SSR* 214:36. [5] Alexander C.M.O'D. et al. (2010) *GCA* 74:4417–4437. [6] Sutton S. et al. (2017) *GCA* 211:115–132. [7] Bonal L. et al. (2016) *GCA* 189:312–337. [8] Vacher L.G. et al. (2020) *GCA* 281:53–66. [9] Busemann E. et al. (2007) *MAPS* 42:1387–1416. [10] Remusat L. et al. (2016) *EPSL* 435:36–44. [11] Eschrig J. et al. (2021) *84th Annual Meeting of the Meteoritical Society*, abstract #6095.