

H ISOTOPIC COMPOSITION OF PHOSPHATES IN H4 CHONDRITES. M. Telus¹, C.M.O'D. Alexander¹, E.H. Hauri¹ and J. Wang¹ ¹DTM, Carnegie Institution of Washington (mtelus@carnegiescience.edu)

Introduction: There is growing evidence that fluids circulated in the ordinary chondrite parent bodies prior to and during metamorphism. For H chondrites, evidence for fluids is from aqueous alteration of chondrules [1] and from rare halite grains in regolith breccias Zag (H3-6) and Monahans (H5) [2-3]. The source of this fluid is not clear and the role of fluid during metamorphism is not completely understood. Phosphate minerals, Cl-apatite, $(\text{Ca}_{10}(\text{PO}_4)_6(\text{Cl})_2)$ and merrillite $(\text{Ca}_9\text{NaMg}(\text{PO}_4)_7)$, are abundant in ordinary chondrites. They formed as a result of metamorphism and subsequent diffusion of P and Ca, possibly facilitated by fluids in the parent body [4]. They may provide a tool to understand the role of fluids during metamorphism.

Fast- and slow-cooled H4 chondrites may provide some insight into fluid-rock interactions in asteroid parent bodies since they experienced similar peak temperatures but different cooling histories. Although Cl-apatite and merrillite are nominally anhydrous ($\text{H}_2\text{O} < 100$ ppm), δD of up to 17,000‰ have been reported [5]. Here, we present preliminary results from a comparative study of the H-isotopic compositions of phosphates from Ste. Marguerite and Sena, which cooled at $>10,000$ C/Myr and 20 C/Myr, respectively, based on metallographic cooling rates [6].

Samples: In Ste. Marguerite, merrillite and Cl-apatite (50-100 μm) are often intergrown. Many grains have embayed textures. Phosphates from Sena are larger (50-200 μm) and occur as separate grains (i.e., merrillite and Cl-apatite are not intergrown). They often have reaction textures along the grain boundaries. Examples are shown in Fig. 1.

Analytical Techniques: Phosphate grains were identified via X-ray EDS mapping with a 1 nA beam on the FE-SEM at DTM. Sena and Ste. Marguerite thin sections were gold coated prior to SIMS analyses with the NanoSIMS 50L at DTM. We analyzed *in situ* H, D, and ^{12}C on electron multipliers in multicollection mode at a mass resolving power of 2000 using a Cs^+ primary beam of ~ 2 nA. The primary beam was rastered over a $20 \times 20 \mu\text{m}^2$ area prior to analysis and then reduced to a $10 \times 10 \mu\text{m}^2$ area during analysis. Beam blanking was used to further reduce surface contamination. Real time images were examined before and after each measurement to ensure that there were no cracks in the analysed areas. A few olivine grains from Sena and Ste. Marguerite were also analyzed. Terrestrial apatite standards with varying H_2O and C contents [7] and Suprasil quartz glass (1 ppm H_2O) were also ana-

lyzed for quantification of instrumental D/H fractionation and assessment of H_2O blank.

The data were corrected for deadtime, H_2O blank and instrumental mass fractionation. Delta values for D/H ratios were calculated relative to standard mean ocean water (SMOW). Uncertainties (1σ) include errors propagated from the statistical uncertainties of the analyses, standardizations and blank corrections.

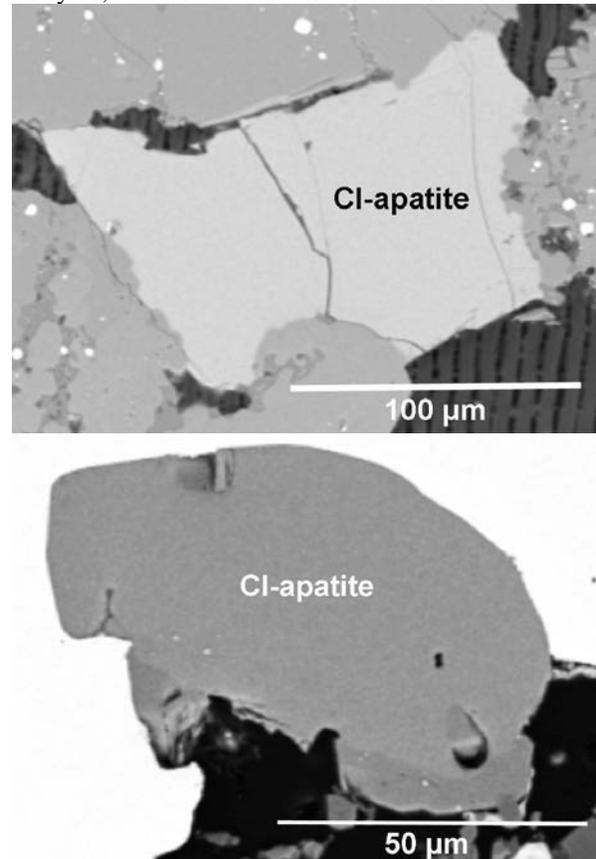


Fig. 1. Typical Cl-apatite grains from Sena (top) and Ste. Marguerite (bottom).

Results: The H contents are similar for Cl-apatite and merrillite (~ 70 -100 ppm). Sena has more variability in H content. The C contents are very low (only a few ppm), but Sena has systematically more C than Ste. Marguerite. Sena has a lower H/C ratio than Ste. Marguerite, indicative of increasing metamorphism.

For Sena, there is some obvious heterogeneity in the H isotopic compositions of phosphate grains (Fig. 2). The compositions of Cl-apatite grains range from +300 ‰ to +500 ‰, ~ 200 ‰ higher than for the merrillite grains whose compositions range from -100 ‰ to

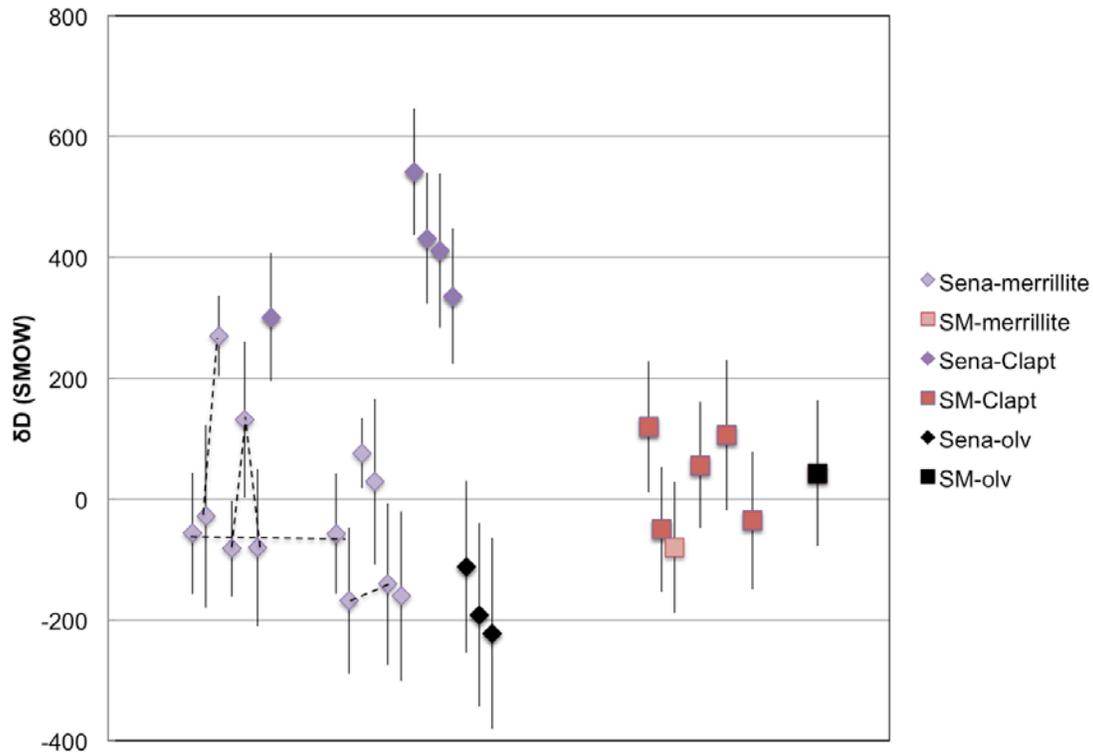


Fig 2. H isotopic composition of merrillite, Cl-apatite (Clapt) and olivine from H4 chondrites Sena and Ste. Marguerite (SM). Most of the δD (relative to SMOW) are consistent with terrestrial composition, except Cl-apatite from Sena which are $\sim +200\%$ enriched in D. The uncertainties are 1σ .

+300‰. There also appears to be heterogeneity within some of the merrillite grains (see tie lines). The composition of olivine is $\sim -200\%$.

Phosphate grains in Ste. Marguerite are much smaller, and as a result only a few grains could be analyzed. All are Cl-rich apatite, except one. Based on these few analyses, there are no differences in the H isotopic composition of Cl-apatite, merrillite, and olivine.

Discussion: Since these phosphate grains have very low H abundances, terrestrial contamination is a potential problem. We took a lot of care to avoid contamination (see Analytical Techniques). We were able with ion imaging to avoid cracks in all analyses. Terrestrial δD values range from -500% to $+10\%$ [8]. Terrestrial contamination (from cracks) can result in lower D/H ratios and higher H content [5]. We do not see any correlation between D/H ratios and H or C content, indicating that terrestrial contamination of our analyses by cryptic cracks is unlikely. However, we cannot rule out H isotopic exchange which would not produce a correlation with H content. Electron beam damage from X-ray mapping is a possible source of artifacts in H isotope analyses – the sections have been intensely mapped as indicated by beam damage of the epoxy. It

is unlikely [9], but additional tests are necessary to determine if this is an issue for our samples.

The D/H ratios for Cl-apatite grains from Sena are clearly distinct from terrestrial values. The reason for the differences in D/H between merrillite and Cl-apatite for Sena is not clear, but it may have to do with differences in their formation [4]. Phosphates from Ste. Marguerite are all consistent with terrestrial compositions. The reasons for differences in δD between Sena and Ste. Marguerite are also unclear. They may reflect differences in the degree of metamorphism, differences in fluid-rock interactions, or differences in the fluid compositions, but terrestrial contamination cannot be ruled out. Analyses of more H4 chondrites and also H5s and H6s are warranted.

References: [1] Grossman J.N. et al. (2000) *MAPS* 35, 467-486. [2] Zolensky M.E. et al. (1999) *Science* 285, 1377-1379. [3] Rubin A.E. et al. (2002) *MAPS* 37, 125-141. [4] Jones R.H. et al. (2014) *GCA* 132, 120-140. [5] Yanai K. et al. (2012) NIPR, The 35th Symposium on Antarctic Meteorites (abstract). [6] Scott E.R.D. et al. (2013) *GCA* 136, 13-37. [7] McCubbin F.M. et al. (2012) *Geology* 40, 683-686. [8] Lécuyer C. et al. (1998) *Chem. Geol.* 145, 249-261. [9] Barnes J.J. et al. (2013) *Chem. Geol.* 337-338, 48-55.