PHOSPHATE MINERALOGY OF PETROLOGIC TYPE 4-6 L ORDINARY CHONDRITES. J. A. Lewis and R. H. Jones, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, NM 87131. jlewis11@unm.edu.

Introduction: Phosphate minerals occur as secondary products in equilibrated ordinary chondrites. The presence of fluids during metamorphism may influence the occurrence and composition of these minerals. There are two phosphate minerals: apatite, $Ca_5(PO_4)_3X$, and merrillite, $Na_2(Mg,Fe^{2+})_2Ca_{18}(PO_4)_{14}$. The X anion site in apatite typically contains F, Cl, and OH. Measuring the relative abundance of these anions in apatite helps us to understand the composition and evolution of fluids present on OC parent asteroids during metamorphism.

Occurrences and compositions of apatite and merrillite have been studied previously in H and LL ordinary chondrites [1-3]. This study extends the previous work to L chondrites, allowing for direct comparisons between all three OC classes.

Samples and Methods: We studied phosphate minerals in Santa Barbara (L4), Elenovka (L5), and Bruderheim (L6). All three are falls and Elenovka and Bruderheim have low to moderate shock levels (S3 and S4 respectively). The shock level for Santa Barbara has not yet been determined.

We examined textures using SEM and analyzed individual grains with quantitative electron microprobe (WDS) techniques according to the method described by [3].

Results: The three L chondrites in this study show a similar size distribution of phosphate grains ranging from 20 to 300 μm. The average size for apatite is 100 μm, and merrillite grains are slightly larger with an average of 130 μm. Merrillite is more common than apatite in all three chondrites, for example in Bruderheim about 70% of the phosphate grains are merrillite and 30% are apatite. Typical textures of apatite are illustrated in Fig. 1. Fine-scale fracturing is common in types 4 and 5, e.g. Figs. 1a and b. Fracturing is also present but much less common in type 6.

Both apatite and merrillite are commonly found in direct contact with large metal and sulfide grains (Fig. 1b) as well as along the rims of holes (Fig. 1c). There does not seem to be any preferred association with a single silicate phase and both phosphate minerals occur randomly with olivine, pyroxene, and feldspar.

We did not observe the two phosphates occurring together, with the exception of a single grain in the L4 Santa Barbara in which merrillite and apatite are intergrown (Fig. 1a). This texture is different from the reaction relationship seen between apatite and merrillite in type 4 H and LL chondrites [1-3].

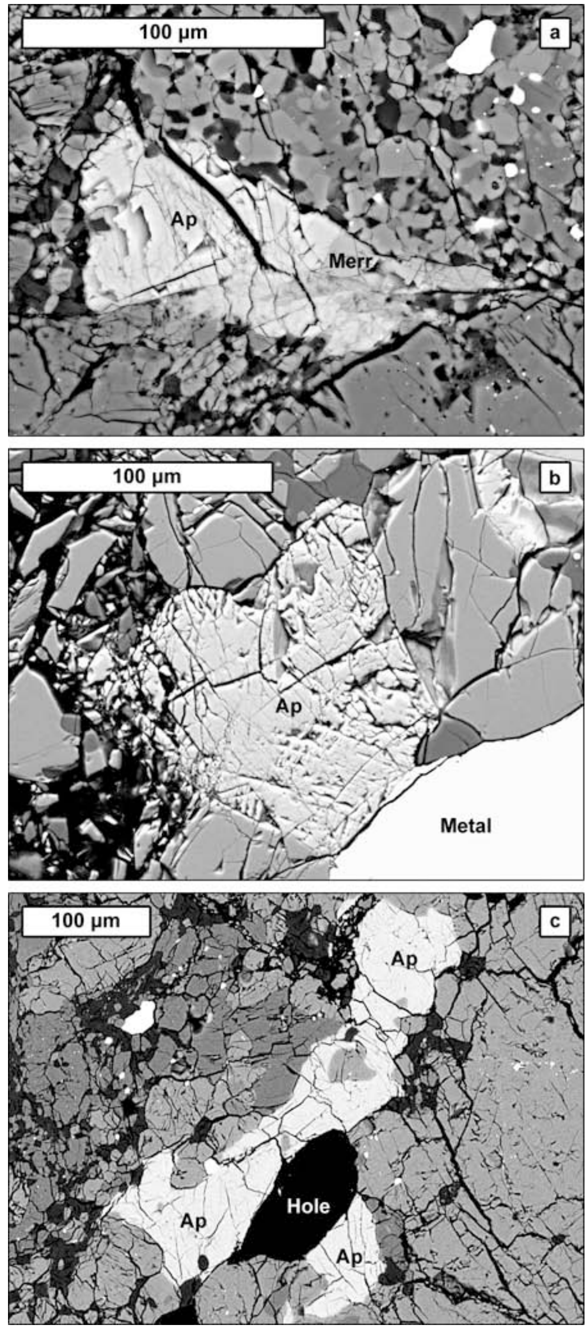

Figure 1: Occurrences of apatite (Ap) in L ordinary chondrites: a) Santa Barbara (L4), apatite in contact with merrillite (Merr), the slightly darker mineral; b) Elenovka (L5), apatite in contact with a metal grain; c) Bruderheim (L6), apatite along the rim of a hole.

WDS analyses of apatite (Figure 2) show average Cl/F ratios of 12.1, 10.5, and 8.8 wt% or 6.5, 5.6, and 4.7 atom percent for Santa Barbara, Elenovka, and Bruderheim respectively. Cl and F showed a similar range in values across all three samples irrespective of petrologic type. An average of 15% of the X anion site is not occupied by Cl or F. SIMS analyses of apatite in LL chondrites with similar compositions have shown that OH is low in abundance [3], so we label the third apex of the X anion ternary as "other" on Figure 2.

Merrillite compositions in L4 Santa Barbara show a range of Mg/(Mg+Fe) values from 0.69-0.95, whereas the range is much smaller in L5 Elenovka and L6 Bruderheim (0.89-0.95 and 0.84-0.94 respectively).

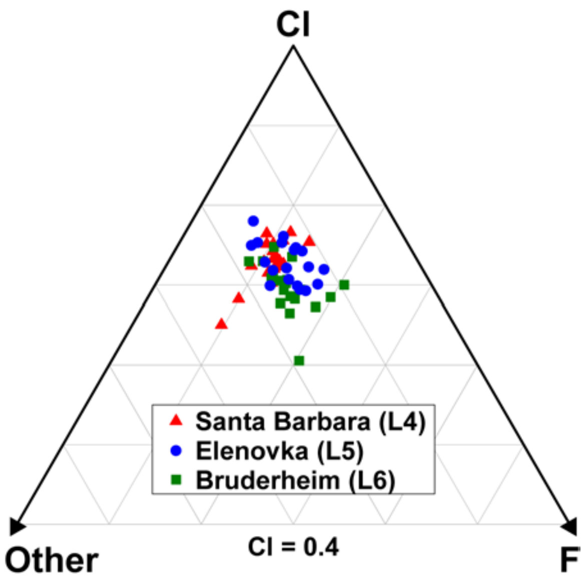

Figure 2: Electron microprobe analyses of apatite in types 4-6 L ordinary chondrites. Each point is a single analysis. Cl and F were analyzed directly and "Other" represents X-site anions calculated by difference.

Discussion: Apatite compositions in L chondrites are intermediate to H and LL chondrites (Fig. 3). This suggests the presence of distinct fluid compositions on each of the ordinary chondrite parent bodies. There is also no significant compositional equilibration trend for apatite with increasing petrologic type in the L group. This suggests that apatite formed during or after metamorphism and is consistent with analysis of both H [1] and LL [3] chondrites. In contrast, merrillite Mg/(Mg+Fe) values in L chondrites do show a possible trend of compositional equilibration from L4 to L5/L6, suggesting that merrillite could have formed at an earlier stage than apatite.

Within the L group, there may be a slight trend toward higher Cl content in apatite with lower petrologic type (Fig. 2). A similar but more pronounced trend is also seen in the H4-6 breccia Zag [4] and suggests evolution of a fluid towards more Cl rich compositions, possibly as the fluid migrates to shallower depths in the parent body.

Phosphate mineral grains do not show significant differences in size or texture across the petrologic types in the L chondrites we studied. This is different from both H and LL chondrites which show progressive textural equilibration with increasing petrologic type. This may indicate that phosphate mineral growth in L chondrites occurred after peak metamorphism. It is also possible that the samples we studied are not representative of the entire range of metamorphic conditions.

Textural and compositional changes in secondary feldspar also occur during metamorphism [5,6]. Studies of feldspar show that the metamorphic environment in the H group is different from that of the L and LL groups. Combining observations from feldspar and phosphate minerals indicates that metamorphic environments on the three OC parent bodies were each subtly different and that differences can likely be attributed to the compositions and availability of fluids.

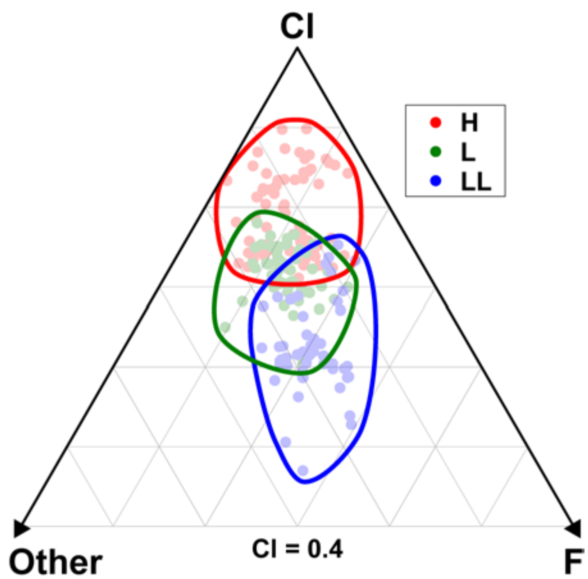

Figure 3: Apatite compositions in equilibrated H [1], L (this study), and LL [3] chondrites. Each point is a single analysis and each outlined field is a single group, containing analyses from petrologic types 4-6.

References: [1] Jones R. H. et al. (2012) *LPS XLIII*, Abstract #2029 [2] Dreeland L. A. and Jones R. H. (2011) *LPS XLII*, Abstract #2523 [3] Jones R. H. et al. (2011) *LPS XLII*, Abstract #2464 [4] Jones R. H. et al. (2011) *LPS XLII*, Abstract #2435 [5] Kovach H. A. and Jones R. H. (2010) *Meteorit. Planet. Sci.*, *45*, 246–264. [6] Gallegos J. and Jones R. H. (2011) *74th Met. Soc.*, Abstract #5433