

### FLUIDS ON THE LL CHONDRITE PARENT BODY: EVIDENCE FROM THE BO XIAN CHONDRITE

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**Introduction:** Metamorphism on the ordinary chondrite parent bodies has long been considered to take place in the absence of fluids. However, there have been several independent suggestions that fluids may have been present [e.g. 1-3]. We recently found clear evidence for late-stage fluid interactions within feldspar grains in two LL chondrites, Bjurböle (LL4) and Bo Xian (LL3.9/4) [4]. Here we describe further studies of the Bo Xian chondrite that support our contention that fluids played a significant role during metamorphism on the LL parent body.

**Observations:** We have studied one thin section of the Bo Xian chondrite (UNM 265). *Feldspar.* Easily recognizable (relict) chondrules contain coarse-grained plagioclase with An/Ab ratios that vary from chondrule to chondrule [4]. Within anorthitic plagioclase we observed thin parallel lamellae that appear to be similar to the nephelinization textures observed in carbonaceous chondrites [e.g. 5]. However, examination of TEM/FIB sections of these lamellae shows that they consist of two amorphous phases, one rich in Si and Al, and one a chlorine-rich aluminosilicate phase. This indicates that feldspar has been leached along crystallographically controlled planes as a result of reaction with an aqueous fluid. *Phosphates.* Two phosphate minerals are present in Bo Xian. Merrillite occurs commonly as small grains (<50  $\mu\text{m}$ ) in association with metal and sulfide. This is consistent with an origin for merrillite as the product of oxidation of P from metal. Chlorapatite is rare, but we observed a large (200  $\mu\text{m}$ ) irregularly shaped grain that occurs in association with olivine and pyroxene within a chondrule fragment. Preliminary electron microprobe analyses indicate that this grain has at least 50% of the X site anions as OH. The grain contains numerous pores, and has a texture very similar to terrestrial apatites that have been interpreted as forming in dissolution / reprecipitation reactions [6]. We observed similar features in LL6 chondrite St. Séverin [7]. Apatite in Bo Xian appears to record evidence for the presence of a halogen-rich fluid. *Olivine / pyroxene.* Within the chondrule fragment that contains the large chlorapatite grain, olivine occurs as a thick overgrowth on the edges of enstatite grains, suggesting that it is the product of fluid-assisted reactions similar to those described in the Allende chondrite [8]. Similar occurrences of olivine are observed throughout the Bo Xian thin section, including olivine that occurs as a thick rim around a relict CAI.

**Conclusions:** Observations from different minerals in Bo Xian all point to pervasive alteration by a halogen-bearing fluid that persisted to late stages of metamorphism. The presence of fluids has significant implications for our understanding of the thermal history of the LL parent asteroid.

**References:** [1] Alexander C.M.O'D. et al. 1989 *Geochim. Cosmochim. Acta* 53:3045-3057 [2] Dunn T. L. et al. 2010 *Meteoritics & Planetary Science* 45:139-160 [3] Zolensky M.E. et al. 1999 *Science* 285:1377-1379 [4] Jones R.H. and Brearley A.J. 2010 Abstract #2133. 41st Lunar and Planetary Science Conference [5] Tomeoka K. and Itoh D. (2004) *Meteoritics & Planetary Science* 39:1359-1373 [6] Engvik A. K. et al. 2009 *Lithos* 112:236-246 [7] Jones R. H. and Dreeland L. 2010. Abstract #1972. 41st Lunar and Planetary Science Conference [8] Housley R.M. and Cirlin E.H. 1983 *In Chondrules and their Origins*, LPI.