ORIENTED MINERAL TRANSFORMATION IN A DARK INCLUSION FROM THE LEOVILLE METEORITE.

P. C. Buchanan1, M. E. Zolensky2, M. K. Weisberg3,4,5, K. Hagiya6, T. Mikouchi7, A. Takenouchi7, H. Hasegawa7, H. Ono7, K. Higashi7, K. Ohsumi8; 1Geology, Kilgore College, 1100 Broadway, Kilgore, TX 75662, USA (pbuchanan@kilgore.edu); 2ARES, NASA Johnson Space Center, Houston, TX 77058, USA; 3Kingsborough Community College, Brooklyn, NY USA; 4CUNY, NY, NY USA; 5American Museum Natural History, NY, NY USA; 6University of Hyogo, Hyogo, Japan; 7University of Tokyo, Tokyo, Japan; 8JASRI, Hyogo, Japan.

Introduction: Dark inclusions (DIs) in chondrites and achondrites are dark gray to black fragments that include a wide variety of materials that have experienced very different petrologic histories. Based on the law of inclusions, they are rocks that accreted prior to and are older than their host meteorites and possibly represent an earlier generation of material. The origin of these inclusions and their relationship to their host meteorites are not always clear. They are interesting in that they represent lithologies that experienced different parent body histories than their host meteorites and are either exotic components or originated from different regions of the meteorite parent body. In many cases, DIs in CV chondrites have been altered to greater degrees than their host meteorites suggesting pre-accretionary alteration [e.g., 1,2,3]. However, there is debate concerning whether or not these DIs record an earlier era of aqueous alteration and subsequent thermal metamorphism, and how these processes may have also affected the host CV materials. The present study is a description of a dark inclusion found in the Leoville meteorite (specifically, thin section USNM 3535-1). This inclusion has some interesting features that have considerable relevance for this discussion.

Data and Discussion: Leoville was found in Decatur County, Kansas, USA [4]. It is an aggregate, including a CV3 matrix with included CAIs, dark inclusions, and achondritic fragments. There is a preferred orientation of chondrules in the matrix material [5, 6]. Some authors have suggested that the matrix of the meteorite represents reduced CV3 material [e.g., 7]. Kracher et al. [8] noted that the meteorite is an accretionary breccia and that the dark inclusions within the breccia display evidence of variable amounts of hydrous alteration. Brearley et al. [9] have documented phyllosilicates in these dark inclusions and described textures. Ebel et al. [10] have analyzed textural characteristics of the various components of Leoville by X-ray image analysis.

We were alerted to a dark inclusion (Fig. 1) in thin section USNM 3535-1 by Denton Ebel. It contains a variety of features, including CAIs, veins, and possible chondrules. The veins end abruptly at the edge of the inclusion indicating emplacement prior to incorporation of the inclusion into Leoville (red arrow in Fig. 1). In the upper right-hand corner (as viewed in Fig. 1), we discovered a group of enigmatic Ca-, Fe-rich silicate grains (red rectangle and Fig. 2). These grains are relatively large and euhedral to subhedral. Electron probe data for these grains are similar, in some ways, to Ca-, Fe-rich olivine (kirschsteinite). However, a couple of compositional traits are anomalous: Al_2O_3 abundances are relatively high at 1.0-1.2 wt. %. Stoichiometric calculations indicate that Fe is depleted relative to an anhydrous kirschsteinite composition. This results in low totals that range from 95% to 96%.

Edges of these Ca-, Fe-silicate grains are serrated and are transforming to wispy, fine-grained silicates (Fig. 3). Electron probe data for these silicates are similar to porous olivine of intermediate Mg# (Mg# is approximately 65). However, these silicates have a relatively high Al_2O_3 content of ~3.5 wt. %. Totals are low and are understandable because some porosity is apparent in the BSEI images. In some cases, these wispy silicates have conjoined boundaries with the Ca-, Fe-silicates (Fig. 4). These relationships seem to occur in two directions within the Ca-, Fe-silicate grains (arrows in Fig. 3), suggesting an oriented transformation.

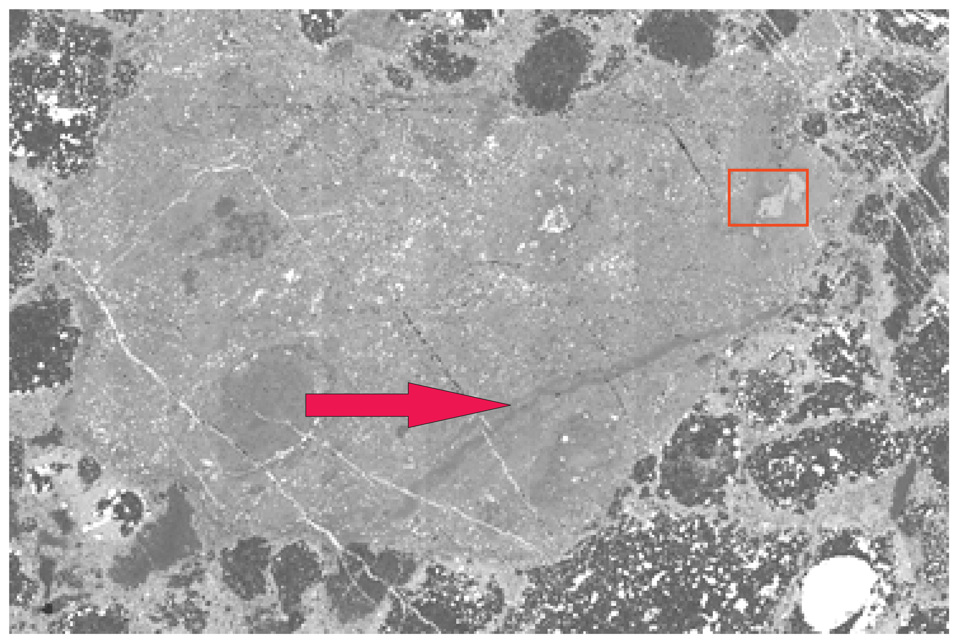

Fig. 1. BSEI of a dark inclusion in the Leoville thin section USNM 3535-1. The clast is ~6 mm across. The red rectangle marks the area of Fig. 2.

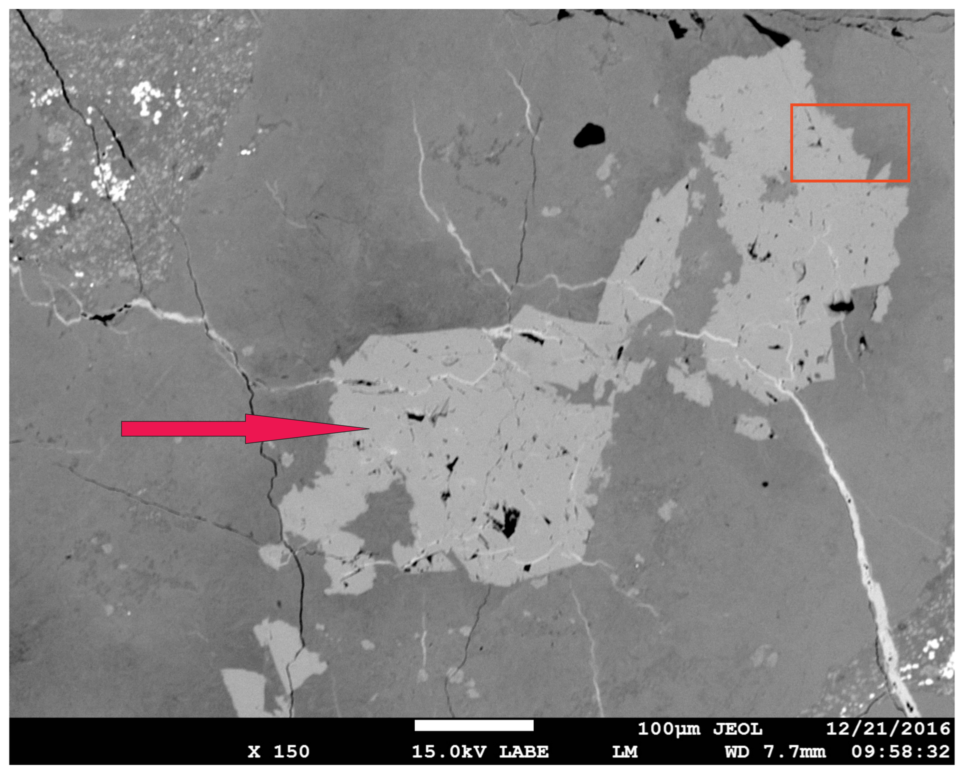

Fig. 2. BSEI: Euhedral to subhedral Ca, Fe-silicate grains (red arrow) in the dark inclusion seen in Fig. 1. The red rectangle marks the area seen in Fig. 3.

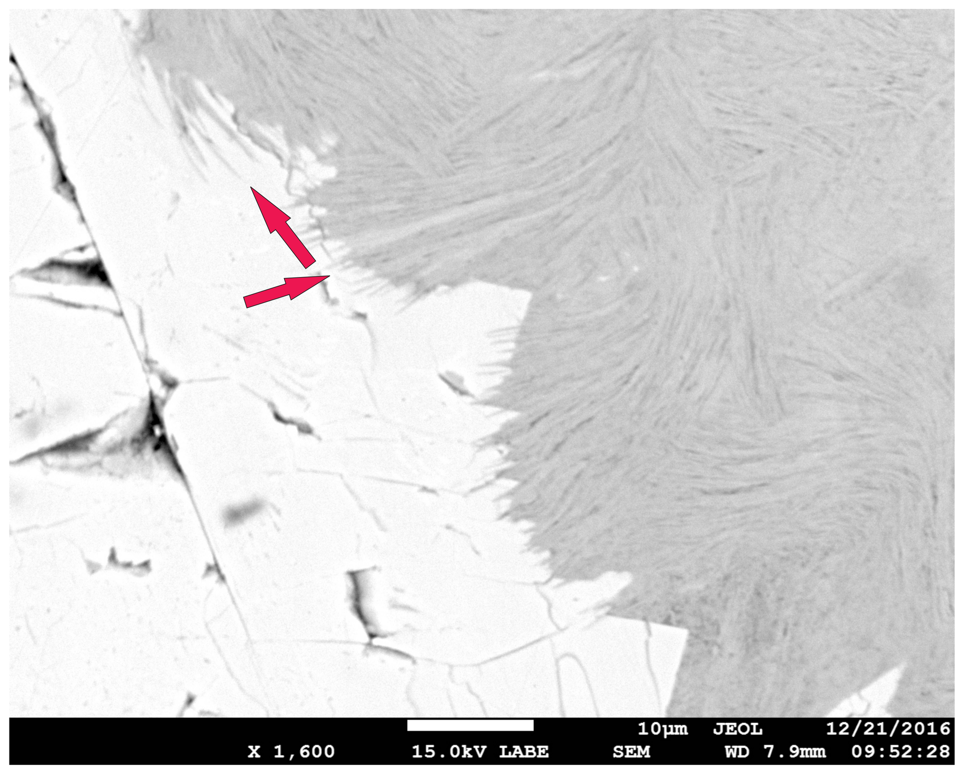

Fig. 3. BSEI: Transformation of the Ca-, Fe-silicate to wispy, fine-grained silicates. The transformation seems to be oriented in two distinct directions (red arrows).

We suggest that the features seen in this area of the dark inclusion in USNM 3535-1 result from transformation of the Ca-, Fe-silicate to the wispy silicates surrounding these grains. Our preferred explanation is that the original transformation was from the Ca-, Fe-silicate to phyllosilicates. A later dehydration event (thermal or impact metamorphism) converted all or part of the phyllosilicates to fine-grained olivine of intermediate composition, preserving the phyllosilicate morphology. We verified this contention for the flaky, fine-grained matrix and veins (Figs. 1&5) in the Leoville DI, by collecting X-ray powder diffraction patterns of these materials at beamline 37XU, SPring-8 (Hyogo, Ja-pan). These patterns were indexed to olivine, with cell parameters a=4.752(6), b=10.305(12), c=6.016(8)Å. It is possible, though unlikely, that some phyllosilicates remain among the wispy materials, as well as matrix and veins. Thus, the dark inclusion had a complex history of aqueous and thermal alteration prior to its incorporation into the Leoville host.

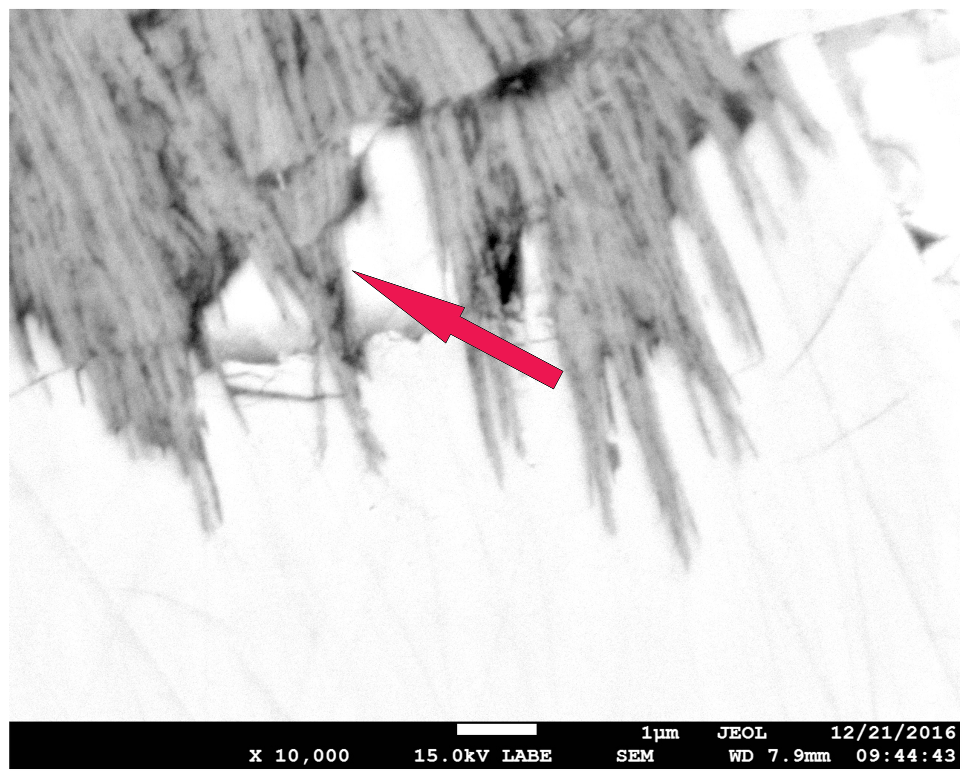

Fig. 4. BSEI: Close-up of the boundary between the serrated edge of the Ca-, Fe-silicate and wispy silicate. Note the conjoined boundary between the two minerals at the tip of the red arrow.

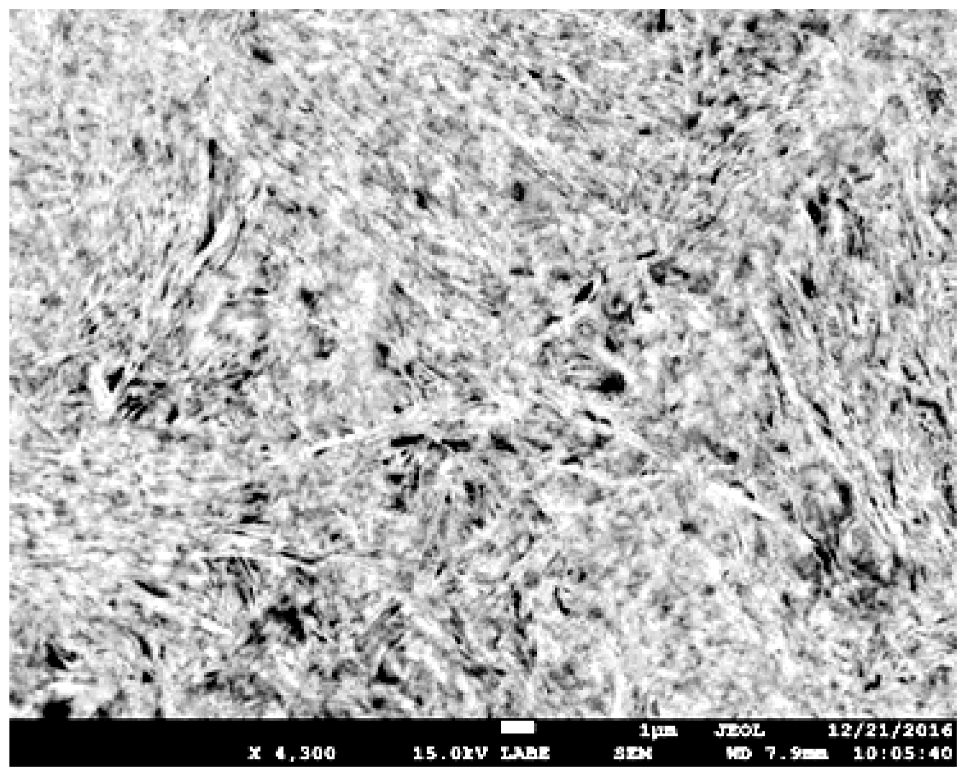

Fig. 5. BSEI closeup of olivine pseudomorphs after phyllosilicates in the vein shown (arrowed) in Fig. 1.

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