ELBERT AND SAINT-SÉVERIN: LL6 (S4) CHONDRITES WITH CONTRASTING SHOCK HISTORIES.

R.C. Hugo[1], A.M. Ruzicka[1], and A.E. Rubin[2]. [1]Portland State University, Portland, OR; hugo@pdx.edu, [2]University of California – Los Angeles.

Introduction: We utilized optical microscopy (OM), transmission electron microscopy (TEM), and electron backscatter diffraction (EBSD) methods with a focus on the mineral olivine, to study the shock histories of two LL6 chondrites – Elbert and Saint-Séverin. Although both meteorites are classified [1] as shock-stage S4, our results show that they have significantly different shock histories.

Methods: Using OM we assigned a weighted shock stage to each specimen according to the method of Jamsja and Ruzicka [2]. We mapped thin sections using EBSD to determine deformation intensity via misorientation maps, crystallographic texture via pole figures, and mesoscale slip plane analysis via crystal rotation figures. Areas of interest were prepared via Focused Ion Beam lift-out technique for TEM analysis of dislocation character and density.

Results: *Elbert* is a relatively uniform, fine-grained specimen with a weighted shock stage of S4.4 ± 0.9 (n=35 grains), featuring many olivine grains with S4 characteristics and a considerable proportion (28%) with S5 or S6 characteristics. EBSD slip plane analysis shows that **c**-type slip predominates, with evidence for slip on multiple slip planes or unconstrained cross-slip. TEM evidence reveals a dislocation structure of **c**-type dislocations with long, straight screw segments and relatively short, straight edge segments (Fig. 1). This is consistent with slip constrained to {hk0} planes, indicating relatively cool shock temperatures. Dislocation densities range from 1×10^{13}–5×10^{14} m^{-2}, consistent with an S4 or higher shock stage. We found no evidence of thermal recovery or annealing.

Saint-Séverin has a brecciated texture, with low-porosity clasts separated by higher porosity interclast regions. Olivine grains in clasts range from S2 to S4, with a corresponding weighted shock stage of S3.2 ± 1.2 (n=247). EBSD misorientation maps show that plastic strain is heterogeneously distributed both among and within clasts, in agreement with OM data indicating a large dispersion of deformation. However, EBSD slip-plane analysis suggests that the six distinct clasts in our specimen experienced similar slip system temperatures. TEM evidence reveals a predominance of curved and looped **c**-type dislocations within the clasts (Fig. 1), with no evidence of thermal recovery or annealing, suggesting that the clasts were deformed at a moderately elevated temperature. Dislocation densities in these clasts range from 1×10^{10} – 5×10^{13} m^{-2}, consistent with S2-S4 shock values. In highly deformed regions between clasts, however, we found fine-grained olivine with a high proportion of **a**-type dislocations. These **a**-type dislocations are arranged in sub-planar arrays forming subgrain boundaries, whereas **c**-type dislocations are randomly distributed. Dislocation densities in these regions are 1×10^{13} – 1×10^{14} m^{-2}.

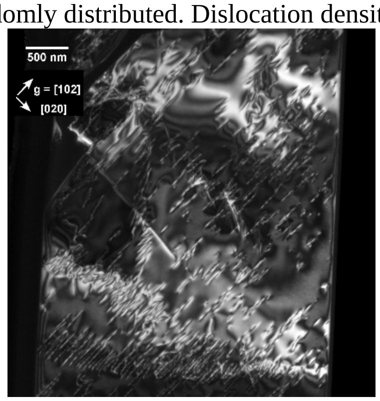
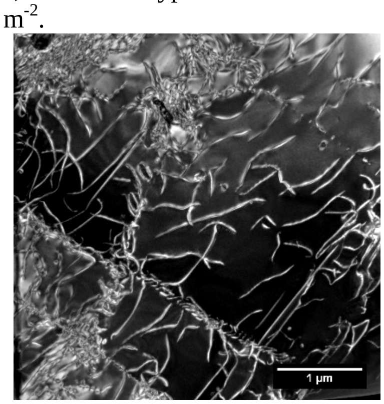


Fig.1 Contrasting dislocation microstructure in olivine from Elbert (left, showing mainly straight **c**-type screw dislocations) and from Saint-Séverin clasts (right, showing many curved **c**-type dislocations). TEM images, scalebar = 0.5 µm at left and 1 µm at right.



Discussion: Although both meteorites are shock-stage S4 and neither shows evidence for post-shock annealing, they otherwise experienced significantly different shock histories. Elbert experienced a strong shock from a cold initial to a cold ending state with no significant shock-induced heating. Shock deformation may have involved some crushing of grains to result in a predominantly small grain size. In contrast, Saint-Séverin shows evidence for elevated temperature during shock and rapid post-shock cooling. Within the clasts, **c**-type slip with extensive cross-slip and/or dislocation climb suggests that temperature was moderately elevated but insufficient to activate high-temperature slip systems. In interclast areas, the high proportion of **a**-type dislocations suggests high temperature deformation, and high dislocation densities suggest high temperatures were caused by localized shock heating in what were likely shear zones. The clastic structure of Saint-Séverin implies a complex history in which low-porosity clasts were lithified prior to a final shock event that produced the dislocation microstructures we observed. This complex history may have led to the seemingly contradictory histories previously inferred [3,4].

References: [1] Stöffler D. et al. (1991) *Geochimica et Cosmochimica Acta* 55, 3845-3867. [2] Jamsja N. and Ruzicka A. (2010) *Meteoritics & Planetary Science* 45, 828-849. [3] Ashworth J.R. (1981) *Proceedings of the Royal Society London A* 374, 179-194. [4] Leroux H. et al. (1996) *Meteoritics & Planetary Science* 31, 767-776.