CHONDRULE SHAPES IN 3-D: PANCAKES VS. BASEBALLS INDICATE PREFERENTIAL COMPRESSION OF REDUCED VS. OXIDIZED CV CHONDRITES

T.J. Fagan[1*], R. Aoki[1], M. Uesugi[2] and A. Tsuchiyama[3,4], [1]Dept. Earth Sci., Waseda University, Tokyo, Japan. [2]Japan Synchrotron Radiation Research Institute (JASRI, SPring-8), Hyogo, Japan. [3]Division Earth Planet. Sci., Kyoto Univ., Kyoto, Japan. [4]Research Org. Sci. Tech., Ritsumeikan Univ., Shiga, Japan ([*]fagan@waseda.jp).

Introduction: The distribution of Fe and Ni into metals, sulfides and silicates was used to divide CV3 chondrites into oxidized and reduced ($CV3_{red}$) groups [1], and the oxidized CV3s were subsequently divided into Allende-like ($CV3_{oxA}$) and Bali-like ($CV3_{oxB}$) groups [2]. The $CV3_{oxA}$ group has undergone higher temperatures of metamorphism than the $CV3_{red}$ group based on infrared spectra of organic matter [3] and recrystallization of olivine in amoeboid olivine aggregates (AOAs, [4]). It has been argued that at least one early impact event on the CV parent body closed pores and expelled ices from the part of the body where $CV3_{red}$ chondrites originated, limiting fluid-rock interaction during metamorphism [5,6]. In this project, we test the early shock hypothesis by characterizing deformation textures in a set of $CV3_{oxA}$ and $CV3_{red}$ chondrites using 2-D and 3-D techniques.

Analytical Methods: *Polished thin section observations.* Chondrule shapes and modes of chondrite components (mostly matrix, chondrules, Ca-Al-rich inclusions [CAIs], and AOAs) were determined in polished thin sections (pts) of the $CV3_{red}$ chondrites Efremovka (2 pts), Leoville (1 pts) and Vigarano (3 pts), and the $CV3_{oxA}$ chondrites Allende (2 pts) and Axtell (1 pts). Elemental X-ray maps of the pts were collected by electron probe microanalysis (EPMA) using a JEOL JXA-8900 microprobe at Waseda University. Plane-polarized light (PPL) mosaics were also collected from each pts. The elemental maps and PPL images were input as layers into Adobe Illustrator. Long and short axes of chondrules were drawn and modes of chondrite components were determined on a grid in overlying layers in the Illustrator file for each pts.

X-ray computer tomography. X-ray computer tomography was conducted using an ELE SCAN instrument at Kyoto University for one sample each of Efremovka, Vigarano and Allende. Materials with contrasting linear attenuation coefficient (LAC) were imaged and output as stacked two-dimensional tiff files. Boundaries of chondrule-like objects with low LAC values in each tiff file were traced using Adobe Photoshop. The traced files were reassembled using SLICE software [7], which was also used to fit ellipsoids to the traced objects, with a = minor, b = intermediate and c = major axes.

Results: Matrix abundances can be represented by modal ratios of matrix/inclusions (m/i), where "inclusions" = objects such as chondrules, CAIs and AOAs [8]. Matrix abundances of the CV3 chondrites in this study fall into three groups: (1) $CV3_{red}$ Leoville and Efremovka (m/i = 0.3–0.4); (2) $CV3_{red}$ Vigarano (m/i = 0.7–0.8); (3) $CV3_{oxA}$ Allende and Axtell (m/i = 0.9–1.4). Similar values were determined by [8] for Leoville (m/i = 0.42), Vigarano (m/i = 0.63) and Allende (m/i = 1.31). The three groups defined by matrix/inclusions correlate with porosities determined by [9]: Efremovka and Leoville, 0.6–2.1% porosity; Vigarano, 8.3% porosity; Allende and Axtell, 22–23% porosity. Two-dimensional chondrule shapes determined from pts are somewhat ambiguous, but can be divided into the same three groups, with chondrules of Leoville and Efrmovka having the highest aspect ratios, those of Vigarano appearing less elongate in thin section, and more equant chondrules in Axtell and Allende.

Distinct clastic domains with abundant broken chondrule fragments were identified in two of the Vigarano pts. One of these clastic domains is bounded by a micro-fault that off-sets a CAI and a chondrule.

The X-ray tomographic data show that Efremovka and Vigarano chondrules vary from somewhat equant to oblate (pancake-shaped), with most axial ratios $b/c > 0.6$ and $a/b < 0.8$, whereas Allende chondrules are more equant (baseball-shaped) with most axial ratios $b/c > 0.7$ and $a/b > 0.8$). Furthermore, short axes of the Efremovka and Vigarano chondrules are clustered, whereas short axes of the Allende chondrules are scattered.

Implications for Deformation: The relatively low matrix/inclusions ratios and pancake-shaped chondrules are consistent with the interpretation that $CV3_{red}$ chondrites come from a part of the CV parent body that was deformed during an impact event that closed pores in matrix domains [5,6]. Vigarano was not as pervasively compressed as Leoville and Efremovka, but underwent cataclastic deformation along micro-faults. Though Allende and Axtell have undergone some shock deformation [10], compression was relatively weak, leaving matrix pores open for fluid flow and fluid-rock interaction during metamorphism of the $CV3_{oxA}$ chondrites.

References: [1] McSween H.Y.,Jr. (1977) *GCA* 41: 1777–1790. [2] Weisberg M.K. et al (2006) in Lauretta D.S. and McSween H.S.,Jr. (editors) *MESS II*, p. 19-52. [3] Bonal L. et al (2006) *GCA* 70: 1849-1863. [4] Komatsu M. (2015) *MaPS* 50: 1271-1294. [5] Rubin A.E. (2012) *GCA* 90: 181-194. [6] MacPherson G.J. and Krot A.N. (2014) *MaPS* 49: 1250-1270. [7] Nakano T. et al (2006) *Japan Synchrotron Radiation Institute*, http://www-bl20.spring8.or.jp/slice. [8] Ebel D.S. et al (2016) *GCA* 172: 322-356. [9] Macke R.J. et al (2011) *MaPS* 46: 1842-1862. [10] Forman L.V. et al (2016) *EPSL* 452: 133-145.