Variable shock deformation within the CV3 chondrites based on chondrule shapes determined by X-ray tomography and modes of chondrite components

*青木 錬[1]、Fagan Timothy[1]、上椙 真之[2]、土山 明[3]
*Ren Aoki[1], Timothy J. Fagan[1], Masayuki Uesugi[2], Akira Tsuchiyama[3]

1. 早稲田大学理工学術研究院創造理工学部地球環境資源工学科惑星科学研究室、2. 公益財団法人高輝度光科学研究センター、3. 京都大学大学院理学研究科地球惑星科学専攻
1. Department of Resources and Emvironmental Engineering School of Creative Science and Engineering Waseda University, 2. Japan Synchrotron Radiation Research Institute, 3. Division of Earth and Planetary Sciences, Graduate School of Science, Kyoto University

Introduction: The high abundance of Fe,Ni-metal and high Fo-contents of olivine led to the recognition that the CV3 chondrites Efremovka, Leoville and Vigarano formed at relatively low oxygen fugacities as reduced CV3s (CV3red; [1,2]). In contrast, the CVs Allende and Axtell have little to no Fe,Ni-metal and are classified as an oxidized subgroup (CV3oxA). The CV3red subgroup is characterized by lower metamorphic grades and lower porosities than CV3oxA [3,4]. It has been proposed that the lower metamorphic grade of CV3red is due to an early impact event on the CV3 parent body that lowered porosities [5] and expelled ice [6]. In this study, we test the interpretation that the CV3red subgroup was preferentially deformed by shock by comparing (1) modes of chondrite components, (2) chondrule shapes and (3) clustering of chondrule orientations in a set of CV3red and CV3oxA chondrites.
Methods: We used elemental and BSE maps and photomicrograph mosaics of polished thin sections (pts) to determine modes of chondrite components (chondrules, CAIs, AOAs, matrix) in: one pts of Leoville; two pts of Efremovka; three pts of Vigarano; two pts of Allende and one pts of Axtell. We also determined 2-D shapes and orientations of chondrules in these pts.
Three-dimensional shapes and orientations of chondrules and chondrule-like objects were determined by X-ray computed tomography (CT) in small samples of Efremovka, Vigarano and Allende. X-ray CT data were collected using X-ray CT scanner at Kyoto University (ELESCAN, NX-NCP-C80-I; Nittetsu Elex Co.) [7]. The X-ray CT data consist of a series of 2-D images, in which pixel brightness correlates with linear attenuation coefficient (LAC) [7-8]. Elliptical shapes of low-LAC chondrules and chondrule-like objects were traced on a layer overlying each X-ray CT layer. The subsets of images of traced layers were processed using SLICE software [9] to investigate their shape using tri-axial ellipsoidal approximation and orientation of each axis of chondrules and chondrule-like objects in the samples.
Results: The ratios of matrix/inclusions ("inclusions" = chondrules + CAIs + AOAs) show a trend that correlates with the porosities of [4]. Matrix/inclusions ratios are near 0.3-0.4 for Efremovka and Leoville (porosities approx., 0.6-2%), 0.6-0.7 for Vigarano (porosity, 8%), and 0.9-1.0 for Allende (porosity, 22%). Our Axtell (porosity, 23% [4]) pts has matrix/inclusions ratio = 0.7, but a large CAI probably causes the ratio of the pts to be lower than that of Axtell as a whole. Ebel et al. [10] also found matrix/inclusions lower in Leoville and Vigarano than in Allende; however, their matrix/inclusions ratio for Allende (1.3) is higher than our results.
The 2-D pts data suggest and the 3-D X-ray CT data show that Allende chondrules tend to be spherical, and that the Efremovka and Vigarano chondrules tend to be oblate. Furthermore, the Efremovka and Vigarano chondrules have short axes with well-defined preferred orientations, consistent with flattening. The chondrite component modes, and chondrule shapes and orientations support the interpretation that the CV3red chondrites were affected by an early shock event that limited fluid-rock interaction during subsequent metamorphism [5,6]. Vigarano does not appear to be as strongly shocked as Efremovka and

Leoville.

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