DEFORMATION IN CV CHONDRITES: DUCTILE IN LEOVILLE, BRITTLE IN VIGARANO

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Introduction: Variations in shock deformation of the CV3 chondrites were identified by [1] using optical extinction in olivine. Subsequently, the CV3s were divided into three subgroups—oxidized Allende-like ($CV3_{oxA}$); oxidized Bali-like ($CV3_{oxB}$) and reduced ($CV3_{red}$) [2,3,4]—and differences in shock deformation have been used to explain different properties and metamorphic histories of the subgroups. Higher shock levels of the $CV3_{red}$ group may account for relatively low porosities [5] and low matrix/inclusions ratios ("inclusions" = chondrules + CAIs + AOAs) in the reduced CVs [6]. Low porosities induced by shock may have limited limited flow of aqueous fluid during metamorphism of $CV3_{red}$, limiting the extent of metamorphic recrystallization in the reduced subgroup [7,8].

In this study, we compare deformation in the $CV3_{red}$ chondrites Leoville and Vigarano. Previous studies have shown that chondrules in Leoville have undergone flattening due to shock compression [9,10]. Vigarano is considered a breccia rich in $CV3_{red}$ components, but also containing fragments of $CV3_{oxB}$ lithologies, implying regolith gardening near the surface of its parent body [11]. In this study, we characterize a clastic zone in Vigarano that we interpret as a fault breccia, consistent with brittle deformation in a near-surface setting, compared with more ductile deformation of Leoville.

Analytical Methods: One polished thin section (pts) of Vigarano and one pts of Leoville were examined in detail. Mosaics of the thin sections were prepared in plane polarized and cross-polarized light. Elemental X-ray and back-scattered electron (BSE) maps of the pts were collected using a JEOL JXA 8900 electron probe micro-analyzer (EPMA) at Waseda University. Thin sections were mapped at pixel densities of 7 µm per step for Leoville, 6 µm for Vigarano and 2 µm for the clastic zone within Vigarano. Image maps were imported as layers into a vector graphics program. Chondrules and other chondrite components were outlined in overlying layers. Modes of chondrite components were determined manually using a grid overlain on the pts images.

Results: Our thin section of Leoville exhibits elongate chondrules (presumably from flattening in 3D) with a well-defined preferred orientation as described in previous studies [9,10]. We determined a matrix/inclusions ratio of 0.40, close to the 0.42 ratio for Leoville obtained by [6].

Two distinct textural domains occur in our thin section of Vigarano: (1) a host domain with large chondrules separated by wide swaths of matrix; and (2) a clastic zone rich in small chondrule fragments separated by thin seams of matrix (Fig. 1). Chondrules in the Vigarano host domain appear more equant than those of Leoville and many have irregular outlines. In fact, we did not attempt to draw long and short axes on the Vigarano chondrules for this study. The matrix/inclusions ratio of Vigarano host is 0.56, comparable to the ratio of 0.63 determined by [6].

The clastic zone has a sharp lower boundary and more diffuse upper boundary as shown in Fig. 1. Some round clasts—evidently, whole chondrules—occur in the clastic zone, but the zone is dominated by pieces of fragmented chondrules that are much smaller than chondrules of the host domain. A chondrule, a CAI and a troilite-rich clast all in the host domain appear to be truncated at the lower boundary of the clastic zone.

From the truncation of chondrite components along the clastic zone/host boundary and the fragmentation of chondrules in the clastic zone, we infer that the boundary is a fault and that the clastic zone can be considered a fault breccia. Brittle deformation in Vigarano suggests a relatively cool setting near the parent body surface, whereas the ductile deformation of Leoville implies a higher-temperature setting in the interior of the parent body.

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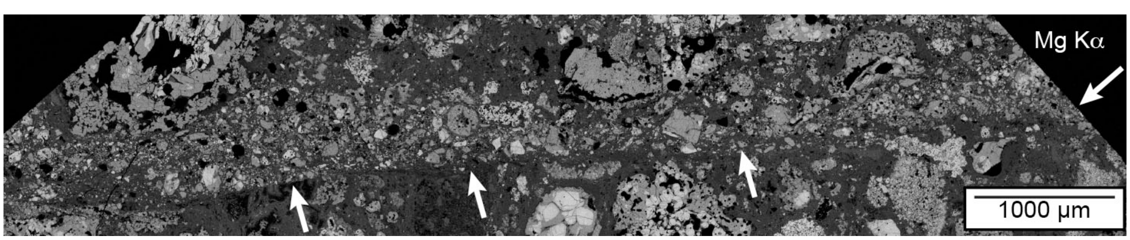

Figure 1. Mg Kα map of clastic zone in Vigarano. Arrows highlight the lower boundary of the clastic zone as shown in this image. The upper boundary is more diffuse.