MICROSTRUCTURAL ANALYSIS OF A WARK-LOVERING RIM AROUND AN ALLENDE CAI.

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Introduction: Wark-Lovering Rims (WLRs) are tens-of-μm thick layered structures surrounding Ca-Al-rich inclusions (CAIs) [1]. The enveloping form, texture, and composition of WLRs have been ascribed to condensation, flash heating, and metasomatic exchange [1-4]. [5] initiated a coordinated structure-isotope study on WLRs and their relationship with the inclusion to gain further insight into their origins. Here we expand on those efforts and report the results of a microstructural analysis on a WLR from the Allende CV3 chondrite. This inclusion and WLR were previously characterized [6] for its Ti and V valence.

Methods: A 20 μm × 1 μm × 200 nm strap of Pt was electron-beam deposited across part of a WLR surrounding TS24, a Fluffy Type A CAI from Allende (CV3). The strap was coated with a 20 μm × 1 μm × 1.5 μm strap of ion-beam-deposited C. We used an FEI Nova 600 focused-ion-beam scanning-electron microscope (FIB-SEM) microscope to create and extract an electron-transparent cross section of the WLR for transmission electron microscope (TEM) analysis. The FIB section was examined with a 200 keV JEOL 2200FS TEM equipped with an energy-dispersive X-ray spectrometer and scanning-based TEM bright- and high-angle annular-dark-field (HAADF) detectors.

Results and Discussion: The WLR consists of spinel, grossular + anorthite, and pyroxene layers grading outward from the inclusion to the accretionary rim. The spinel is nearly pure Mg-Al spinel with minor Fe, Ti, and Cr. The grossular crystal (1.2 × 2.8 μm) has minor Mg and Fe. Beneath the grossular are two larger (2.3 × 3.4 and 2.8 × 3.9 μm), nearly pure anorthite grains. Bright-field imaging reveals lamellar features in the anorthite grains, which contain high Z-contrast in the HAADF image, similar to previously observed WLR anorthite [5]. The lamellae are either due to twinning or exsolution, if they are a different phase from their host crystal. The pyroxene layer is polycrystalline with grains ranging in size from hundreds of nm to several μm. Most pyroxene crystals are well ordered but stacking disorder occurs in an augite grain adjacent to grossular. The Ti and Al contents of the pyroxenes decrease outward from the inclusion to the rim in augite, diopside, and hedenbergite. EDS shows the V content varies among the pyroxenes.

The WLR in TS24 experienced a complex history. Although previous measurements indicate that it formed under highly reducing conditions [6], the observed variation in V content along the surface pyroxenes may indicate localized heterogeneities in the nebular gas. It has been suggested that anorthite and grossular form through metasomatic alteration involving aqueous fluids on a parent body [7] or nebular metasomatism between a Si-rich gas and the primary CAI phases [2]. It is not yet clear which of these mechanisms are responsible, but additional measurements will help to clarify the nature of these features.

References: [1] Wark D. A. & Lovering J. F. 1977. *Proc Lunar Planet. Sci. Conf. 8th:* 95. [2] MacPherson et al. 1981 *Proc. Lunar Planet. Sci. Conf. 12th*: 1079. [3] Simon J. I. et al. 2005. *EPSL* 238: 272. [4] Wark D. A. & Boynton W. V. 2001. *MAPS* 36: 1135. [5] Zega T. J. et al. 2007. *MAPS* 42: A169. [6] Simon S. et al 2007. *GCA* 71: 3098. [7] Krot A. et al. 1995. Meteoritics 30: 748.