Microstructural and Isotopic Constraints on WL Rim Formation

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Coordinated microanalyses of Wark-Lovering (WL) rims are needed to best understand their origin and to decipher their subsequent evolution both in the nebular and parent body settings. Here we present the mineralogy, petrology, microstructures, O isotopic compositions, and Al-Mg systematics of a WL rim on a Type B CAI, ''Big Guy", from the reduced CV3 chondrite Vigarano [1].

Our SEM and TEM study reveals seven distinct mineral layers in the WL rim that include: (1) gehlenite with rare grossite, (2) hibonite, (3) spinel with minor hibonite and perovskite, (4) zoned melilite ($Åk_{\sim 0\text{-}10}$), (5) anorthite, (6) zoned diopside grading outwards from Al,Ti-rich to Al,Ti-poor, and (7) forsterite intergrown with diopside. We infer a two-stage history in which WL rim formation was initiated by flash melting and extensive evaporation of the original inclusion edge, followed by subsequent condensation under highly dynamic conditions.

The outermost edge of the CAI mantle is mineralogically and texturally distinct compared to the underlying mantle that is composed of coarse, zoned melilite ($Åk_{\sim 10\text{-}60}$) grains. The mantle edge contains fine-grained gehlenite with hibonite and rare grossite that likely formed by rapid crystallization from a Ca,Al-rich melt produced during a flash vaporization event [2]. These gehlenite and hibonite layers are surrounded by successive layers of spinel, melilite, diopside, and forsterite, indicating their sequential gas-solid reactions onto hibonite. Anorthite occurs as a discontinuous layer that corrodes adjacent melilite and Al-diopside, and appears to have replaced them [3,4], probably even later than the forsterite layer formation.

All the WL rim minerals analyzed using the JSC NanoSIMS 50L are ^{16}O-rich ($\Delta^{17}O \approx -23$‰), indicating their formation in an ^{16}O-rich gas reservoir. Our data are in contrast with many CV CAIs that show heterogeneous $\Delta^{17}O$ values across their WL rims [5]. Our Al-Mg data obtained using the UCLA ims-1290 ion microprobe of the CAI interior and the WL rim define a well-correlated isochron with $(^{26}Al/^{27}Al)_0 = 4.94 \times 10^{-5}$, indicating their synchronous formation $\leq 5 \times 10^4$ years after the canonical CAI value. In contrast, no ^{26}Mg excesses are observed in the WL rim anorthite, which suggests its later formation or later isotopic resetting in an ^{16}O-rich gas reservoir, after ^{26}Al had decayed.

References: [1] Han J. et al. (2020) GCA 269, 639-660. [2] Beckett J. R. and Stolper E. (1994) Meteoritics 29, 41-65. [3] Han J. and Brearley A. J. (2016) GCA 183, 176-197. [4] Krot A. N. et al. (2017) GCA 201, 155-184. [5] Simon J. I. et al. (2016) GCA 186, 242-276.