

## CONSTRAINTS ON THE COOLING RATE FROM $^{16}\text{O}$ -RICH PEROVSKITE IN A COMPACT TYPE A CAI FROM ALLENDE.

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**Introduction:** Coarse-grained type A Ca-Al-rich inclusions (CAIs) in CV3 chondrites consist of mostly melilite and minor amount of spinel, perovskite, Al-Ti-diopside, and hibonite. Oxygen isotopes of the CAI minerals except perovskite have been extensively studied; those of spinel and hibonite are uniformly  $^{16}\text{O}$ -enriched ( $\sim -24\%$  in  $\Delta^{17}\text{O}$ ), whereas those of melilite and Al-Ti-diopside are relatively  $^{16}\text{O}$ -depleted [1]. Only few studies reported  $^{16}\text{O}$ -depleted compositions for perovskite grains in compact type A CAIs from CV chondrites [2-4]. Several mechanisms have been proposed to explain O-isotopic variation among and within the individual minerals: 1) gas-melt interaction in the  $^{16}\text{O}$ -depleted nebula gas [e.g., 5, 6], 2) diffusive exchange between CAI minerals and  $^{16}\text{O}$ -poor nebular gas by multiple reheating events [7], postcrystallization O-isotope exchange during fluid-rock interaction on the parent body [8, 9]. Since perovskite is a common primary phase in most CAI varieties, further investigation on O-isotopic compositions for perovskite may shed a light on the O-isotope evolution of CAI minerals.

**Experimental:** A compact type A CAI (*ON01*) from Allende was studied for mineral chemistry and oxygen isotopes. Spot analyses and quantitative imaging for oxygen isotopes of perovskite and enclosing melilite carried out with the Hokudai isotope microscope system consisted of the Cameca ims-1270 and a stacked CMOS-type active pixel sensor (SCAPS) ion imager. The analytical procedure is described in the previous study [10].

**Results and Discussion:** Perovskite are small (generally  $<20\ \mu\text{m}$  in diameter) and enclosed by large (mostly  $300 - 500\ \mu\text{m}$ ) melilite. Quantitative O-isotope imaging and spot analyses on the individual perovskite inclusions clearly shows that O-isotopes become heavier from the crystal core towards rim. The O-isotopic compositions of perovskite vary from  $-22\%$  to  $-1\%$  in  $\Delta^{17}\text{O}$ , whereas those of enclosing melilite are homogeneously  $^{16}\text{O}$ -depleted ( $\Delta^{17}\text{O} \geq -5\%$ ). The O-isotope dichotomy between perovskite and melilite can constrain their origin. If fluid-assisted thermal metamorphism on the CV parent body resulted in almost complete O-isotope exchange of melilite with  $^{16}\text{O}$ -depleted fluid [9], O-isotopes of perovskite is also expected to have changed to  $^{16}\text{O}$ -depleted, based on its much smaller grain size and much faster O-isotope diffusivity relative to melilite [11-14]; thus it may not be the case in spite of the lack of experimental data on O-isotope diffusion under wet condition. If multiple reheating events in the  $^{16}\text{O}$ -depleted gaseous reservoir [7] changed O-isotopes of entire melilite crystals, O-isotopic compositions of perovskite enclosed by the melilite should have also become  $^{16}\text{O}$ -depleted; thus it is also not the case. The most plausible scenario to explain the  $^{16}\text{O}$ -enriched perovskite enclosed by  $^{16}\text{O}$ -depleted melilite is that the perovskite is relic as already mentioned by previous study [15] and the melilite has crystallized from the melt that exchanged its O-isotopes with surrounding  $^{16}\text{O}$ -depleted gas. O-isotope diffusive exchange between melilite and relic perovskite likely resulted in O-isotope variation within the perovskite, and thus can constrain the cooling rate of the CAI. The estimated cooling rate of the CAI by numerical modeling is  $1000 - 5000\ \text{K/hr}$  at peak temperature of  $\sim 1600\text{K}$ , the melting temperature of perovskite in compact type A CAI composition [15]. Such fast cooling rate of the CAI is comparable with  $<3000\ \text{K/hr}$  estimated by the cooling experiment on perovskite reproducing (101) twins that is commonly observed in type A CAIs from CV chondrites [16, 17]. It is worthy to note that relatively slow cooling rate for type B CAI melts ( $0.5 - 50\ \text{K/hr}$  [18]) mostly relied on the crystallization of euhedral anorthite.

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