Setting of Na-alteration in a type B2 Ca-Al-rich inclusion from the Allende CV3 chondrite

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Ca-Al-rich inclusions (CAIs) in chondritic meteorites are recognized as primitive rocks with petrologic and isotopic records of high-temperature interactions between gas and condensed phases in the solar nebula. Many CAIs have also undergone low-temperature alteration, which may have occurred in their asteroidal parent bodies, or during earlier thermal events in the solar nebula, or in both nebular and parent-body settings. Determining the settings of alteration and thermal histories of CAIs remain major goals for understanding the formation and re-processing of rocks in the solar nebula and parent bodies.

This study focuses on the Na-alteration of melilite in a type B2 CAI (4022-1) from the CV3 chondrite Allende. Melilite with high Na_2O (0.28 wt%) and FeO (0.32 wt%) contents was discovered near the margin of this CAI. Yet, within 30 micrometers, both Na_2O and FeO are below electron microprobe analysis (EPMA) detection limits (0.03 wt% for Na_2O and 0.08 wt% for FeO). This discovery prompted a search for correlations between Na_2O, FeO and akermanite (Ak) content and location within this CAI.

Methods: Three sets of melilite analyses were collected: (1) near the rim of CAI 4022-1, where the secondary minerals grossular, secondary anorthite, FeO-bearing spinel and feldspathoids are abundant; (2) at randomly selected sites throughout the CAI; (3) at sites throughout the core and rim of a type B1 CAI (CGI-10, see [1]) from Efremovka. Back-scattered electron (BSE) images and quantitative EPMA were collected using the JEOL JXA-8900 electron microprobe at Waseda University. Analyses were conducted by WDS using a 15 kV focused beam with currents of 10 nA or 20 nA, and counting times of 10 s on peak and background. Oxides and silicates were used as standards.

Results and Discussion: Melilite with elevated Na_2O (0.15 wt%) and FeO (0.2 wt%) occur throughout the Allende type B2 CAI (4022-1), though the highest Na_2O- and FeO-contents (0.40 and 0.36 wt%, respectively) occur near the CAI margin. Comparable compositions are present near the rim of the Efremovka type B1 CAI (CGI-10), but melilite in the interior of CGI-10 is relatively depleted in Na2O and FeO. Most analyses show a correlation between Na2O and Ak-content; however, several exceptions to this trend occur near the margin of CAI 4022-1. Iron and Na_2O concentrations show a positive correlation for the CGI-10 and 4022-1 near-rim analyses, but no correlation between Na_2O and FeO was detected for the analyses collected throughout 4022-1.

The two Na_2O vs. FeO trends indicate two mechanisms for alteration of CAI 4022-1 melilite. The positive correlation between Na_2O and FeO in melilite near the CAI rim suggests that this alteration was coincident with formation of feldspathoids and FeO-bearing secondary minerals along the margin of the CAI. Sodium and Fe may have been incorporated into melilite by a combination of fluid-assisted diffusion and local recrystallization. Exceptions to the Na_2O-Ak correlation are gehelenitic melilites that occur near the CAI rim and incorporated Na_2O during this alteration event. A similar event affected melilite in Efremovka CGI-10.

Sodium and FeO are uncorrelated in melilite in the interior of CAI 4022-1. Our favored hypothesis for alteration of this melilite depends on an early Na-alteration event in the solar nebula followed by incomplete melilite melting, recrystallization and diffusive relaxation [2-4]. This model accounts for the efficient dispersal of Na to melilite throughout the CAI.

References: [1] Fagan T.J. et al. 2004 Meteorit. Planet. Sci. 39: 1257-1272. [2] MacPherson G.J. and Davis A.M. 1993 Geochim. Cosmochim. Acta 57: 231-243. [3] Beckett J.R. et al. 2000 Geochim. Cosmochim. Acta 64: 2519-2534. [4] Simon S.B. and Grossman L. 2006 Meteorit. Planet. Sci. 39: 1257-1272.