METAMORPHISM OF AN EFREMOVKA TYPE B CAI AND COMPARISON WITH OTHER SETTINGS OF ALTERATION

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Introduction: Ca-Al-rich inclusions (CAIs) formed at early stages of the solar nebula and underwent variable alteration during subsequent parent body metamorphism. In the oxidized CV3 ($CV3_{ox}$) Allende, individual CAIs have been metamorphosed to the extent that up to, and even exceeding, 50% by mode of the original primary minerals have been recrystallizaed to form secondary minerals [1,2]. The reduced CVs ($CV3_{red}$) are less metamorphosed than Allende [3,4], thus CAIs from $CV3_{red}$ are more likely to preserve a record of nebular processes unsullied by parent body metamorphism. However, the $CV3_{red}$ have undergone some metamorphism. In this study, we characterize secondary minerals in a type B CAI from the $CV3_{red}$ Efremovka and compare alteration effects with Allende CAIs and with a terrestrial gabbro.

Methods: CGI-10 is a type B CAI in Efremovka [5]. To identify minerals, textures and mode, we examined CGI-10 using petrographic microscope, X-ray elemental maps, back-scattered electron (BSE) imaging, cathodoluminescence (CL), quantitative electron microprobe analyses (EPMA), and transmission electron microscope (TEM) observations of a focussed ion beam (FIB) section. Micro-raman analyses were attempted but were masked by fluorescence. Results were compared with similar observations from Allende CAIs [1,2,6] and from a terrestrial gabbro altered by quartz veins in Murotomisaki, Japan [7].

Results: In terms of modal abundances, CGI-10 is much less altered than type B CAIs from Allende. The grossular-rich veins characteristic of Allende CAIs [1] are not present in CGI-10. However, similar to Allende CAIs, some of the melilite near the rim of CGI-10 has been replaced by feldspathoids, FeO-bearing spinel and an elongate secondary mineral (ESM) with composition ~ $CaAl_2Si_2O_8$. In fact, the bulk Na_2O content of CGI-10 (0.3 wt% based on modal recombination) is comparable to that of a type B CAI (4022-1, see [1]) from Allende. ESM in CGI-10 is rare and appears to consist of anorthite, whereas ESM is abundant and consists mostly of dmisteinbergite in the $CV3_{ox}$ CAIs studied to date [6,8].

Primary feldspar occurs in type B CAIs (as anorthite) and in the Murotomisaki gabbro (MG, as normally zoned crystals, e.g., An_{70} to An_{40}). Adjacent to a quartz vein, the MG feldspar has been albitized. In contrast, even though Na was available during alteration of CAIs, no evidence of albitization of primary CAI anorthite has been detected. Na-rich melilite has been identified adjacent to grossular-rich veins in Allende CAIs studied by [9].

References: [1] Fagan T.J. et al., 2007, *MaPS* 42:1221-1240. [2] Enokido Y. et al., 2014, *NIPR* 37:13-14. [3] Bonal L. et al., 2006, GCA 70:1849-1863. [4] MacPherson G.J. and Krot A.N., 2014, MaPS 49:1250-1270. [5] Fagan T.J. et al., 2004, MaPS 39:1257-1272. [6] Brearley A.J. et al., 2014, LPSC 45: #2287. [7] Hoshide T. et al., 2006, Jour. Mineral. Petrol. Sci. 101:223-239. [8] Fintor K. et al., 2014, MaPS 49:812-823. [9] Krot A.N. et al., 2010, LPSC 41: #1406.