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還元タイプCV3コンドライトであるエフレモフカ隕石中のタイプB CAIにおける変成作用
Metamorphism of a type B CAI from the reduced CV3 chondrite Efremovka.

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Calcium-aluminium-rich inclusions (CAIs) are among the first rocks to form in the solar nebula and are abundant in CV chondrites [1,2]. Most CAIs have been altered and the understanding of metamorphic effects is essential for interpreting the metamorphic conditions of parent bodies and formation conditions in the solar nebula. Especially, the CV3 chondrite Allende has undergone relatively strong metamorphism, and previous studies have addressed effects of metamorphism on Allende CAIs [3,4]. On the other hand, the CV3 chondrite Efremovka has undergone less metamorphism than Allende [5]. Therefore study of Efremovka is useful for understanding more primitive conditions. In this study, we describe secondary minerals, their textures and modal abundances in a type B CAI from Efremovka (CGI-10), using elemental mapping, quantitative EPMA, cathodoluminescence, and Raman spectroscopy. We compare secondary features of CGI-10 with Allende CAIs, particularly with the Allende type B CAI 4022 (see [3]).

CGI-10 is a type B CAI with primary spinel, anorthite and fassaite, all with 16O-rich compositions, and melilite that is 16O-poor [6]. The main secondary minerals in CGI-10 are sodalite, nepheline, Fe-bearing spinel and an elongate secondary mineral (ESM) with composition CaAl2Si2O8. These secondary minerals are concentrated in FeO-alkali-rich domains near the CAI rim. Similar minerals and textures are observed in Allende CAIs [3]; however, FeO-alkali-rich domains are more abundant in Allende CAIs than in CGI-10 (approx. 1.5 mode% in CGI-10 vs. 8% in CAI 4022) and ESM is more abundant in the FeO-alkali-rich domains of Allende CAIs than in CGI-10 (trace in CGI-10 vs. 2.5 mode% in 4022). Furthermore, the main ESM in Allende appears to be dmisteinbergite [7,8], whereas the main ESM in Efremovka CGI-10 appears to be anorthite, based on the similarity of its cathodoluminescence (CL) to the CL of primary anorthite. Dmisteinbergite occurs in coal heaps in Chelyabinsk, Russia that underwent pyrometamorphism at low pressure (Earth surface), over a short time (10 to 15 years), at temperatures ranging up to 1200C and in the presence of gases of varying compositions and variable f(O2) [9]. Some crystallization in the coal heaps apparently occurred during annealing while the heaps cooled from peak temperatures [9]. Although peak metamorphic temperatures were lower in Allende than in the Chelyabinsk coal heaps, it is possible that Allende shared some similarities in metamorphic conditions (low pressure, variable gas compositions, short heating & cooling times) that favored the formation of dmisteinbergite instead of anorthite.

In contrast with Allende CAIs [4], no grossular-rich veins were identified in CGI-10, and the mode of secondary minerals in CGI-10 (˜2%) is much less than in Allende type B CAIs (˜30%), consistent with the interpretation that Allende was metamorphosed at higher temperature than Efremovka [5]. On the other hand, the concentration of Na2O in CGI-10 is similar to that of a similar Allende CAI (both approx. 0.3 wt%). The similarity in Na2O-abundances suggests that infiltration of Na into CAIs during metamorphism is not due completely to metamorphic temperature, but is related to other factors (for example, composition and abundance of fluid available during metamorphism). In any case, CGI-10 has undergone some metamorphic recrystallization. Thus, when Efremovka CAIs are used to interpret conditions from the solar nebula, metamorphic effects should also be considered.

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