ELEMENT EXCHANGE BETWEEN MATRIX AND CAIS IN THE ALLENDE METEORITE. R. L. Ford and A. J. Brearley, Dept. of Earth and Planetary Sciences, MSC03-2040, 1University of New Mexico, Albuquerque, NM 87131 (rford@unm.edu).

Introduction: CAIs are the oldest surviving solid material in our solar system. They provide a unique opportunity to glimpse the earliest moments of solar nebular evolution. However, essentially all CAIs are complex objects whose petrographic, chemical and isotopic characteristics are the end result of a variety of different processes that occurred both in the solar nebula and on asteroidal parent bodies. Secondary alteration of CAIs is particularly evident in members of the Allende subgroup of the CV carbonaceous chondrites. Many CAIs from Allende have experienced alteration, but the timing and location of that alteration is unclear and controversial. Previously the controversy around the alteration of CAIs was primarily concerned with whether that alteration occurred on the parent body or in the solar nebula. More recently mounting evidence suggests that the parent body maybe the location of alteration for CAIs.

There are numerous pieces of evidence that indicate Allende experienced alteration. These include iron-alkali-halogen metasomatism of CAIs, chondrules and matrix, formation of the formation of fayalitic olivine rims on chondrule olivines and the oxidiation and sulfidization of opaque assemblages. [1-5] In type A CAIs, the more common alteration style involves the replacement of primary minerals by nepheline, grossular, anorthite, and more rarely, phyllosilicates [6]. In general, the altered CAIs in Allende show an overall loss of Ca and a gain in Si, Na, and to a much lesser extent, Fe. The location of formation of these minerals is controversial. For instance, the formation of phyllosilicates in Allende CAIs is attributed to nebular processes due to the high temperatures needed to produce the phyllosilicates [7]. However, more recent studies have indicated that the metamorphic temperatures reached by Allende may have been significantly higher than previously believed [4,5] allowing for phyllosilicate formation on the Allende parent body.

Phyllosilicates were previously thought to have a nebular origin, because of the lack of evidence for the presence of hydrous alteration on the CV3 parent body. However, a mounting body of data exists that suggests aqueous fluids may have had a significant role in the alteration of the Allende-like CV3 chondrites. [3,5]. Some workers have suggested that the loss of Ca from altered CAIs also occurred in the solar nebular as a result of interaction with a nebular gas. The CAIs behaved as , repre open systems whereby Ca is lost and Si, Na, and Fe are gained [8,9]. In this model, the loss of Ca occurred under high temperature conditions (in the range of partial melting) and Na was incorporated easily into the melt. The addition of Si and Fe to the CAI is also attributed to the nebular gas [8-10].

To address the issue of where and how CAIs in Allende have been altered, we have examined the alteration of CAIs in Allende, focusing specifically on the behavior of Ca. Our data provide useful constraints on the location of alteration as well as elemental mass transfer between between chondrules and matrix.

Methods: We examined a type A CAI from the Allende meteorite. Polished thin sections were studied initially using a JEOL JSM-5800 Scanning Electron Microscope. WDS X-ray maps of Ca, Na, Al and Mg and quantitative mineral analysis of individual phases were obtaining using a JEOL JXA-8200 Superprobe electron microprobe. The WDS X-ray maps of the CAI were processed using Adobe Photoshop software to determine modal abundances of the phases. **Results:** The type A CAI reported here is highly altered. As previously reported [11], the primary mineralogy of the CAI consists of melilite, Ca-pyroxene, perovskite, and spinel. The melilite crystals are large (30-150 μm) and poikilitically enclose spinel. Melilite edges show embayment and a reaction rim. The aureole around the CAI consist almost completely of andradite and Ca-pyroxene. The CAI and the surrounding aureole are shown in Figure 1. Secondary alteration has mainly resulted in the replacement of the primary melilite by nepheline, sodalite and to a lesser extent anorthite, grossular and possibly phyllosilicates. Calculated modal abundances of different mineral phases, both primary and secondary, in the CAI are as follows: 34% melilite, 22% spinel, 11% anorthite, 12% nepheline, and 19% fine-grained alteration material that includes grossular, anorthite, nepheline, sodalite, and phyllosilicates.

In order to assess whether the Ca-rich aureole around the inclusion could have been produced by Ca loss from the CAI alone, we also calculated the modal abundances for the entire CAI-aureole system. Here we define the CAI-aureole system as all the material in the CAI and matrix out to the edge of the Ca-rich aureole in the matrix ~200μm away from the edge of the CAI. For simplicity, we assumed that all of the Ca was coming solely from the alteration of gehlenitic melilite. Modal abundances for the CAI-aureole system are given in Table 1, and these are the abundances used to determine the release of Ca from the CAI.

The modal abundances from Table 1 were used to calculate the amount of Ca released through melilite alteration, by converting the volumes into mass percents. This was compared to the amount of Ca consumed in the production of alteration products, assuming that all of the Ca comes from the alteration of melilite. Our calculations show that the ratio of CaO released by melilite alteration to CaO consumed by the formation of andradite and Ca-pyroxenes was 8:7, or within the errors of this study, approximately the same amount of Ca was released as was consumed by alteration products.

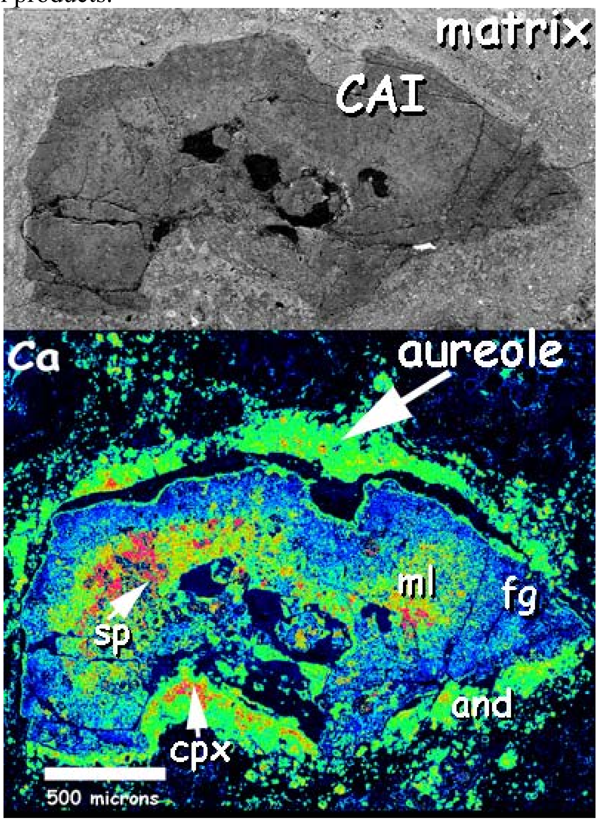

Figure 1. A backscattered electron image (top) and a Ca WDS X-ray map of the CAI examined in this study. The X-ray map shows a Ca-rich aureole around the highly altered CAI. The large black regions in the CAI are voids resulting from plucking during thin section preparation. The low Ca region just outside the CAI is the accretionary matrix. The Ca-rich aureole lies outside the accretionary matrix , and adjacent to typical Allende matrix. (abr. Sp=spinel, ml=melilite, and=andradite, fg= fine-grained alteration, cpx= Ca pyroxene)

Discussion: The calculated amount of Ca that was lost by melilite alteration in the CAI (8:7) is very similar to the amount needed to produce the aureole around the CAI. This is consistent with our earlier suggestion that the Ca in the aureole is derived from the adjacent CAI. It seems highly improbable that nebular alteration could produce such a correlation and therefore , we consider the open system models inferred in [8,9] implausible. Instead, we suggest that during alteration of the CAI resulted in transport of Ca into the matrix, and Na, Si and Cl entered the CAI in an exchange reaction with the host chondrite.

Basic reactions for the breakdown of melilite and the production of alteration materials do not offer an immediate solution for the sources of Na and Si. However, there is abundant Na and Si in chondrule mesostasis, [12] and both Na and Si are highly mobile elements. The breakdown of enstatite into fayalitic olivine is also an additional potential source of SiO_2 [3].

Table 1. Modal abundance of Aureole-CAI system

melilite	27.8 %
spinel	17.6 %
fine grained alteration	15.3 %
pyroxene/olivine	10.6 %
nepheline	10.1 %
anorthite	9.3 %
andradite	7.4 %
cpx	1.9 %

Conclusions: From our preliminary data, we have determined that enough Ca is released from the alteration of this CAI to produce the associated Ca-rich aureole. Further work is in progress to determine whether Ca released in this process is enough to account for most of the Ca-rich regions that surround many CAIs in Allende matrix. We suggest that the Ca loss from CAIs is not an open system process, but instead represents exchange of Ca, Na, Si, and Cl between the CAI and the surrounding matrix, aided by fluid transport.

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