

The distribution and source of Na in two type B1 CAIs

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Sodium occurs as a major element in nepheline and sodalite in the "low temperature" alteration veins, and Wark-Lovering rims of type A and B CAIs. It has been suggested that these phases record the initial condensation of Na in the solar nebula (see 1 for discussion). Sodium also occurs as a trace element in the primary phases in coarse-grained CAIs and is concentrated in melilite and anorthite. The presence of Na in these higher temperature phases is not consistent with the predicted compositions of high-temperature condensates from a gas of solar composition (2). Higher concentrations (>0.1 wt%) of Na in melilite and anorthite in some inclusions has been shown to correlate with regions of isotopically "disturbed" Mg, suggesting that the introduction of Na might be part of a secondary process (3). It has also been demonstrated that Na concentrations in some, but not all, melilite crystals in type B CAI correlates with Akermanite (3). El Goresy et al., (4) suggested that Na in Allende inclusion 5241 was introduced by xenoliths that were captured while the inclusion was still a liquid droplet. This would mean that Na had condensed prior to the formation of the secondary alteration products in 5241.

In order to better understand how, and at what stage of the formation process Na entered type B CAIs it is necessary to know how the element is distributed on a large scale throughout the inclusions. This is not practical using normal microprobe point analysis techniques and requires detailed elemental mapping. Two well-characterized type B1 CAIs were used in this study: Allende 5241 (4,5) and USNM-3529Z (3). Digital elemental maps of several areas as large as 9 mm² of both inclusions were obtained by rastering the sample stage of a JEOL 8900 electron microprobe under a stationary 15keV, 20nA electron probe. The map images were collected with better than 5 μm lateral resolution using wavelength spectrometers and required approximately 9 hours to acquire. The maps clearly show the distribution of Na from the rim to the core of these inclusions. Point analyses from the regions mapped show the concentration of Na₂O to range from <0.02 to 0.2 wt% and <0.02 to 1.3 wt% for 5241 and 3529Z respectively.

Digital Na distribution maps of 5241 (Fig. 1) are typical of both inclusions and show that Na is present below the EPMA detection limit in most of the melilite in the mantle (except in and near alteration veins), but is present at concentrations up to 0.2 wt% in melilite and anorthite in the core and inner mantle. The amount of Na in melilite correlates with the Ak content as seen in Figure 2. Figure 1a shows an enhanced digital Na image of a 9 mm² region of 5241 extending from the rim (bottom right) of the inclusion into the core (upper half). The exact same region is shown in a digital backscattered electron (BSE) image in Figure 1b. The alteration veins are seen as light lines in the Na image and as dark lines in the BSE image. The most striking observation is that alteration veins in the Ak-poor melilite mantle contain substantial Na, whereas the alteration veins in the core, containing Ak-rich melilite, do not. Instead, Na in the core is concentrated in large melilite and anorthite grains. This suggests Na that entered the inclusion during the alteration process diffused into Ak-rich melilite but not into the Ak-poor melilite in the mantle. The same pattern was found in both 5241 and 3529Z.

These results strongly support speculations that at least most of the Na in melilite and anorthite in 5241 and 3529Z entered the inclusions at the time the "low temperature" (<<1000°C) alteration products formed and diffused into anorthite and Ak-rich melilite in a compositionally controlled, subsolidus process. Such a process is compatible with Mg isotopic properties of

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some CAI which show disturbed Mg in regions of higher Na concentration. It is possible that some Na was initially present in 5241 as speculated by (4) but this cannot be confirmed at present. These results do not address the environment of the process which may be nebular or planetary, but is generally considered to be nebular based on other arguments (3).

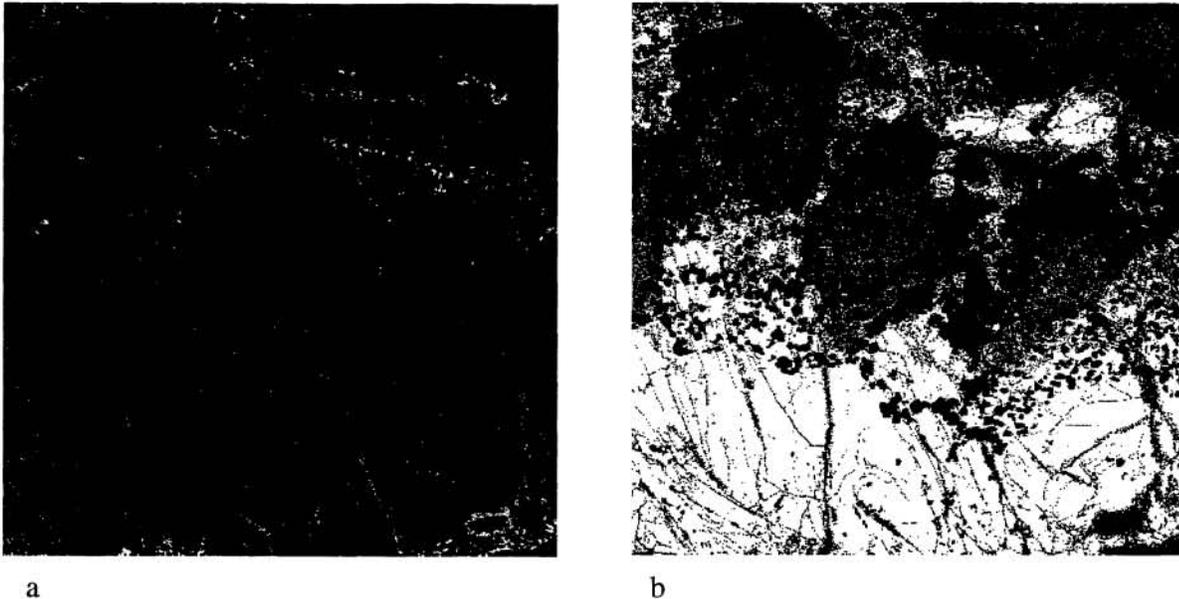


Figure 1. a) Enhanced digital Na map of a 9 mm² area of Allende 5241. The rim of the inclusion is at the far lower right. The melilite mantle is in the lower half of the image and the core is in the upper half. Note that Na (white and gray) is concentrated in the cracks and alteration areas in the melilite mantle but is concentrated in large melilite and anorthite grains in the core. b) Digital backscattered electron image of the exact same area as shown in Fig. 2a. The phases seen are melilite (white), fassaite and anorthite (gray), and spinel (black).

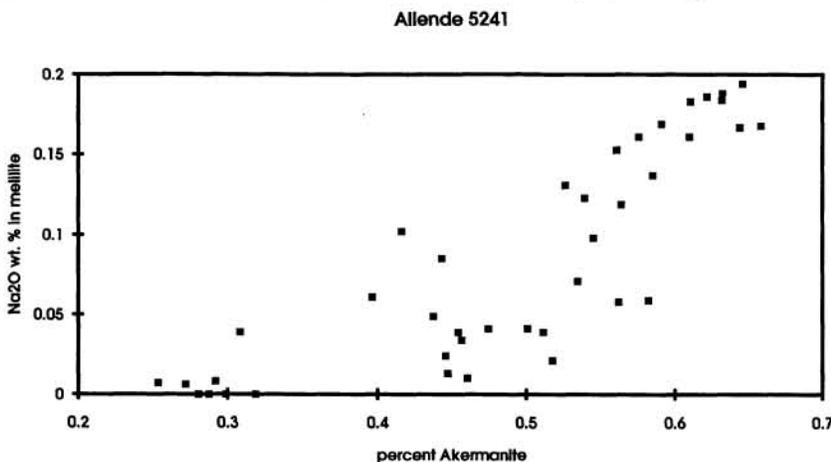


Figure 2. Na₂O concentration vs. Ak content in melilite from the mantle and core of Allende 5241. The plot shows the compositional dependence of Na concentration in type B1 melilite. The data seems to define an upper limit for Na in these melilite crystals. The lower Na concentrations in many of the analyses may reflect the distance from cracks and areas of alteration.

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