

OXYGEN ISOTOPIC COMPOSITIONS OF THE ALLENDE FoB CAI SJ101. M. I. Petaev^{1,2}, K. Nagashima³, A. N. Krot³, and S. B. Jacobsen². ¹Harvard-Smithsonian Center for Astrophysics, Cambridge, MA 02138, USA; ²Department of Earth and Planetary Sciences, Harvard University, Cambridge, MA 02138, USA; ³Hawai'i Institute of Geophysics and Planetology, University of Hawai'i at Manoa, Honolulu, HI 96822, USA; mpetaev@cfa.harvard.edu.

Introduction: The forsterite-bearing Type B CAIs (FoBs) are rare but important members of the CV chondrite CAI's suite because of (1) their intermediate chemistry and mineralogy between the 'classic' CAIs and amoeboid olivine aggregates and (2) high proportion of FUN CAIs among them [1]. The characteristic feature of most FoBs is the pronounced enrichment of melilite (Mel) mantles in heavy Si and Mg isotopes compared to the forsterite (Fo) – spinel (Sp) – clinopyroxene (Cpx) – Mel \pm anorthite (An) interiors that is typically attributed to the evaporative loss of Si and Mg from molten CAIs [1]. FoBs also show pronounced mass-dependent fractionations of O isotopes among different minerals [e.g., 2,3].

Recently we [4] described a new FoB from Allende, SJ101, which, being a rather typical FoB CAI mineralogically and chemically, texturally differs from other FoBs in displaying (1) the nearly complete segregation of Fo from Sp and (2) neither petrographic nor isotopic [5–7] evidence for Si and Mg evaporation. The mineralogy, petrography and isotopic compositions of SJ101 provide crucial information for understanding the origin of FoB CAIs, which appear to have formed by melting of CAIs surrounded by thick Fo-rich accretionary rims.

SJ101 consists of three major structural units (Fig. 1): (1) large patches of sector-zoned, poikilitic Al-rich Cpx with numerous inclusions of small Sp grains and aggregates and subordinate amounts of Åk-rich Mel and An (Sp-Cpx lithology – green and purple patches in Fig. 1), (2) narrow sinuous bands of Al-rich Cpx with large (up to $\sim 300 \times 60 \mu\text{m}$) poikilitically enclosed euhedral Fo crystals (Fo-Cpx lithology – red bands in Fig. 1), and (3) the external Cpx-Sp-An rim overlying the entire inclusion. The two major lithologies are always separated by a transition zone of Cpx poikilitically enclosing both Fo and Sp. The patches of the Sp-Cpx lithology exhibit significant textural and mineralogical variability that is size-dependent. Small patches (purple in Fig. 1) typically consist of Cpx and abundant Sp with minor remnants of Mel and/or its alteration products (mainly grossular and monticellite). Large patches (green/blue in Fig. 1) contain Mel-An-rich cores with either equigranularophitic-subophitic or 'lacy' textures reminiscent of those in Type B or C CAIs, respectively. All silicates poikilitically enclose numerous Sp grains of identical habit. The complex, convoluted internal structure of SJ101 suggests that the coarse-grained Sp-An-Mel-Cpx cores and Fo-Cpx lithology represent the precursor materials of FoBs, proto-CAIs and Fo-rich accretionary rims, respec-

tively, which avoided homogenization during last melting event. The inferred nebular history of SJ101 [4] includes condensation of its precursors in a closed system interrupted by at least two distinct melting episodes. To further test the formation history of SJ101 and its proto-CAI(s) we measured O-isotopic compositions of individual mineral grains from different lithologies.

Sample and Analytical Technique: O-isotopic measurements were carried out on a thick polished section of SJ101 embedded into epoxy resin. Fig. 1 shows the areas representing different SJ101 lithologies where one or more mineral grains were analyzed. The examples of different lithologies and analytical spots are shown in Fig. 2. The mineral grains analyzed include 3 Fo (areas 9, H01, H05), 8 An (areas 2, 16, 23, H02), 2 Sp (area H05), 8 Mel (areas 2, 3, 020, H02), and 4 Cpx (areas 2, 9, 16, 020). The analytical procedure was the same as in [8]. Most analyses were done on large $\sim 10 \times 10 \mu\text{m}$ spots, with a few smaller spots employed for Sp-saturated Mel.

Results and Implications: The O-isotopic compositions of SJ101 minerals (Fig. 3) are typical of Allende CAIs. Sp, Fo, and Cpx appear to retain their primary ^{16}O -rich compositions with $\Delta^{17}\text{O} \sim -24\text{‰}$ and $\delta^{18}\text{O} \sim -48\text{‰}$, consistent with O-isotopic compositions of these minerals in other CV CAIs, including FoB and FUN [2,3], and CR CAIs [8]. On the other hand, Mel and An are ^{16}O -depleted to varying degrees, suggesting isotopic exchange with an external ^{16}O -poor reservoir, either nebular gas or high-temperature fluid on the Allende parent asteroid. The degree of O-isotopic exchange in Mel and An of SJ101 is smaller than in other FoB CAIs from Allende [3]. The very small spread in O-isotopic compositions of Fo, Sp, and Cpx in SJ101 along a mass-dependent fractionation line implies that the degree of mass fractionation due to an evaporative loss of oxygen during the last melting episode was insignificant. O-isotopic data confirm that the origin of precursors of SJ101 and their melting occurred in a relatively closed system in an ^{16}O -rich region of the solar nebula.

References: [1] MacPherson G.J. (2004) *Treatise on Geochemistry*, vol. 1, 201–246. [2] Krot A.N. et al. (2008) *Lunar Planet. Sci.* 39, #2162. [3] MacPherson G.J. et al. (2008) *Lunar Planet. Sci.* 39, #2039. [4] Petaev M.I. & Jacobsen S.B. (2009) *GCA* 73, 5100–5114. [5] Jacobsen S.B. et al. (2007) *CMES workshop*, 82–83. [6] Jacobsen S.B. et al. (2008) *Lunar Planet. Sci.* 39, #1999. [7] Farkas J. et al. (2009) *Lunar Planet. Sci.* 40, 20. [8] Makide K. et al. (2009) *GCA*, 73, 5018–5050.

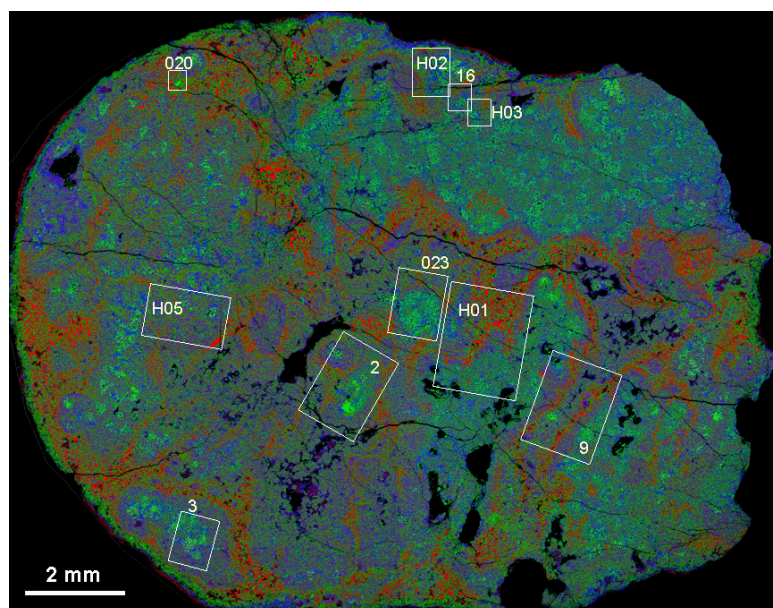


Fig. 1. Combined elemental map of SJ101 in Mg (red), Ca (green), and Al (blue) K α X-rays. The CAI is composed of Al-rich clinopyroxene (dark green), Mg-rich melilite (bright green), anorthite (blue), spinel (purple), and forsterite (red). 'Lacy' melilite and clinopyroxene grains are very similar in color due to the presence of variable amounts of small anorthite and spinel inclusions. Many melilite grains are almost completely pseudomorphed by grossular and monticellite. In general, the red sinuous bands represent the Fo-Cpx lithology, the purple domains are the 'ordinary' Sp-Cpx lithology, and the green/blue patches are the Mel-An-Cpx coarse cores. Numbered boxes outline areas selected for O isotope studies.

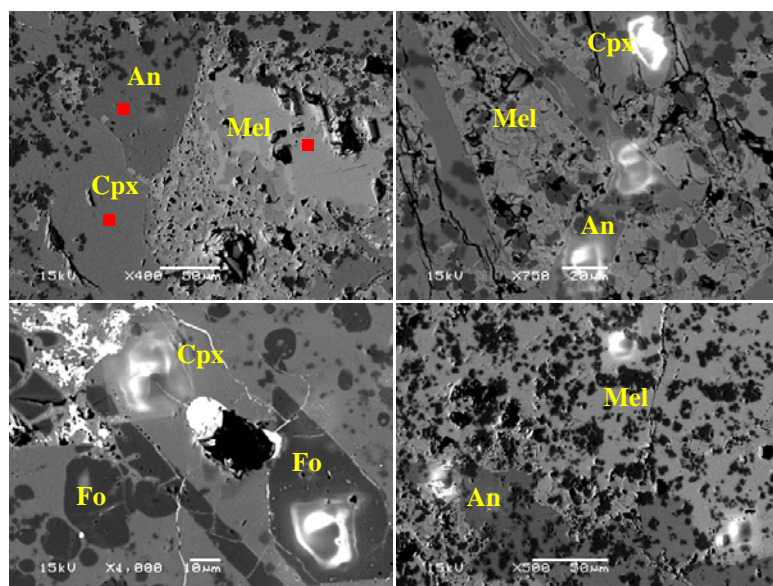


Fig. 2. BSE images of areas outlined in Fig. 1: top left panel – a fragment of proto-CAI with equigranular texture in area 2, top right – a fragment of proto-CAI with subophitic texture in area 16, bottom left – poikilitic texture of Fo-Cpx lithology in area 9, bottom right – a fragment of proto-CAI with equigranular texture in area 3. Labeled minerals are anorthite (An), clinopyroxene (Cpx), melilite or its alteration products (Mel), and forsterite (Fo). Spinel forms widespread clusters of small dark gray grains. White specs are Fe,Ni metal and/or Fe oxides. The red squares in the top left panel show analytical spots. In other panels the analytical spots look like squared pits. Note large and small analytical spots next to one another in the lower corner of the bottom right panel.

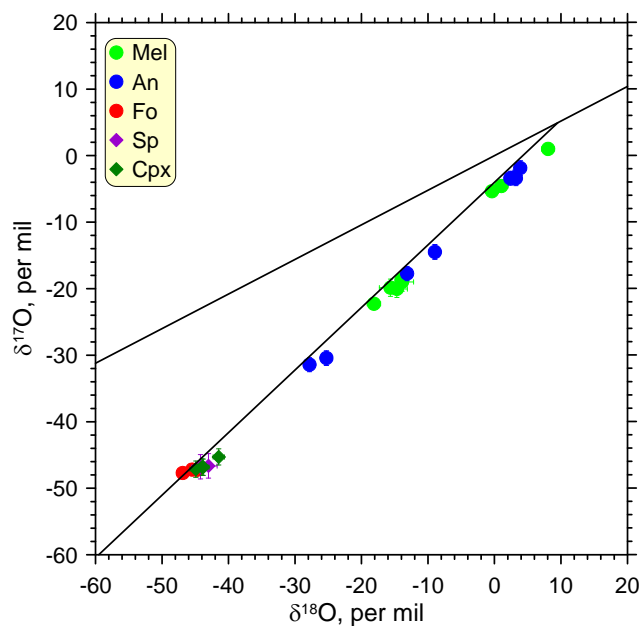


Fig. 3. Oxygen isotopic compositions of SJ101 minerals. 2 σ error bars are typically smaller than the symbol size.