TEMPORAL AND SPATIAL HETEROGENEITIES IN THE SOLAR NEBULA REFLECTED IN RB-SR AND SM-ND SYSTEMATICS OF AL3S4, AN ALLENDE TYPE B CAI. N.E. Marks[1], L.E. Borg[1], I.D. Hutcheon[1], B. Jacobsen[1], R.N. Clayton[2], T.K. Mayeda. [1]Institute of Geophysics & Planetary Physics, Lawrence Livermore National Laboratory, 7000 East Ave. L-231 Livermore CA 94550 (marks23@llnl.gov), [2]Department of Chemistry, The University of Chicago, 5640 S Ellis Ave, Chicago, IL 60637, USA.

Introduction: The Rb-Sr and Sm-Nd geochronometers are each valuable for investigating different aspects of meteorite evolution. The Rb-Sr and ^{147}Sm-^{143}Nd isotopic systems can provide valuable information about the complex formation history of CAIs. Although a number of studies [1-3] have demonstrated the extreme primitive (unradiogenic) ^{87}Sr/^{86}Sr ratio of some Allende CAIs, they have not defined internal mineral isochron ages for the inclusions because their Rb-Sr systematics appear to be disturbed. Likewise attempts to determine the ^{147}Sm–^{143}Nd isotopic systematics using mineral separates from the Allende CAIs Egg-2, Egg-6 and Big Al yielded inconsistent ages ranging between 4.53 and 4.80 Ga [4-6]. The ^{146}Sm-^{142}Nd system is potentially more useful for dating CAI formation because it has a shorter half-life than either the Rb-Sr or ^{147}Sm-^{143}Nd systems. In addition, recent studies have demonstrated a clear difference in ^{142}Nd/^{144}Nd in chondrites and bulk Earth, suggesting the nebula is slightly heterogeneous in terms of ^{142}Nd/^{144}Nd or that the Earth has a hidden reservoir of low Sm/Nd (i.e. characterized by low ^{142}Nd/^{144}Nd [7-8]). Thus, analysis of this isotopic system in CAIs facilitates the assessment of isotopic heterogeneities in the early solar nebula. Isotopically heterogeneous Sm and Nd are not unlikely in the solar nebula because the parent isotope (^{146}Sm; *p*-process) and daughter isotope (^{142}Nd; *s*-process) are produced in different stellar environments. In this study we have measured the Rb-Sr and Sm-Nd isotope compositions of a type B CAI. The results of high precision Sm-Nd and Rb-Sr measurements are presented below.

Sm-Nd Systematics of Al3S4: Results of ^{147}Sm-^{143}Nd isotopic analyses for the Al3S4 CAI are presented in an isochron plot in Figure 1A. A linear regression fitted through five points yields an apparent age of 4575 ± 34 Ma and an initial εNd of -0.48 ± 0.09. This isochron excludes the whole rock point, and uses the isotope dilution (ID) Nd isotopic composition for the pyroxene fraction. The regression is a very good fit of the data as indicated by a MSWD of 1.7. The ancient age recorded in this isochron is interpreted to represent the crystallization age of the CAI. The initial epsilon ^{143}Nd value (ε^{143}Nd) is slightly lower than the chondritic value calculated using ^{143}Nd/^{144}Nd = 0.512638 and ^{147}Sm/^{144}Nd = 0.1966, suggesting CAIs have less radiogenic ^{143}Nd than do chondrites. Results of ^{147}Sm-^{142}Nd isotopic analyses for the Al3S4 CAI are presented in an isochron plot in Figure 1B.

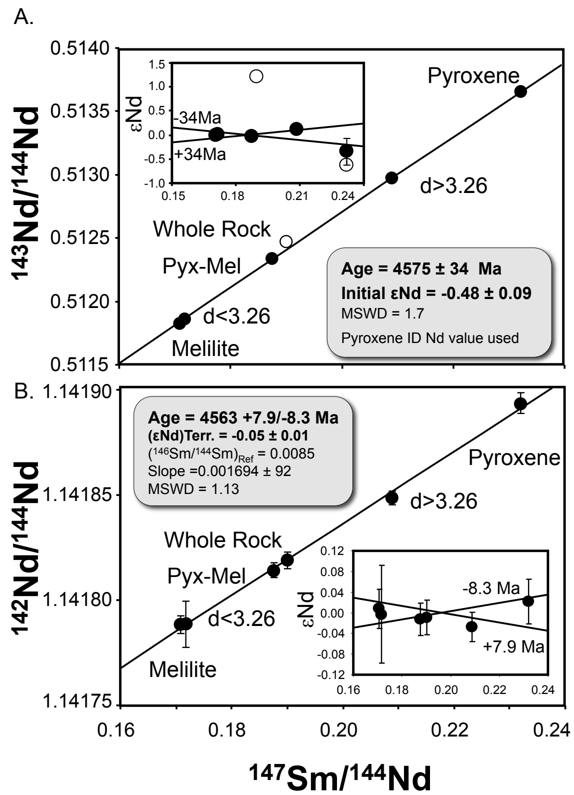

Figure 1 A.) ^{147}Sm/^{143}Nd isochron for mineral separates from Al3S4 yielding an age of 4575 + 35 Ma with an initial e143Nd of -0.48 + 09. The age was determined using the pyroxene ID value for Nd as this resulted in smaller error. B.) ^{147}Sm/^{142}Nd isochron yielding an age of 4563 +7.9/-8.3 Ma with an initial ε^{142}Nd of -0.05 + 0.01.

A linear regression fitted through six points yields an apparent age of 4563 ± 8 Ma with an ε^{142}Nd of -0.05 ± 0.01 calculated using ^{146}Sm/^{144}Sm = 0.0085. The MSWD for this isochron is 1.1, indicating a good fit of the data. This isochron is also interpreted to date the crystallization of the CAI, and is concordant with the ^{147}Sm-^{143}Nd isochron.

Rb-Sr Systematics of A13S4: Results of Rb-Sr isotopic analyses for the A13S4 CAI are presented in an isochron plot in Figure 2. A linear regression fitted through five mineral fractions yields an apparent age of 4246 ± 110 Ma and an initial ^{87}Sr/^{86}Sr of 0.6989419 ± 0.0000076. Despite the relatively large uncertainty associated with the Rb-Sr age, the regression is a very good fit of the data, as indicated by a MSWD of 1.3. The large uncertainty in this age does not reflect a lack of linearity, rather it reflects our inability to measure $^{87}Sr/^{86}Sr$ to better than ~10 ppm (2 sigma) and the limited spread in $^{87}Rb/^{86}Sr$ ratios resulting from very low Rb abundances in the CAI minerals. Similar ages have been observed in bulk rock measurements of CAIs and chondritic meteorites ranging from 3481-4287 Ma with initial $^{87}Sr/^{86}Sr$ values ranging from 0.698371 to 0.699087 [1-3]. Note that all Sr isotopic data are renormalized to our NBS-987 value of 0.710246 ± 8 (2 stdev; N=46). Regressions for data from [1] and [3] pass through the isochron data generated in this study, indicating the Rb-Sr system has been similarly disturbed in a variety of primitive meteorite samples.

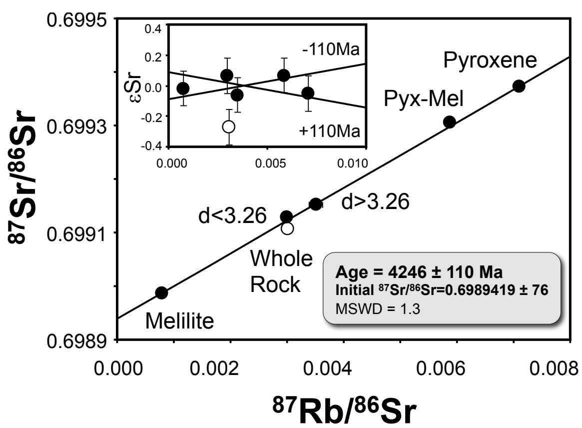

Figure 2. Rb-Sr isochron plot for Allende CAI A13S4 yielding an age of 4246 + 110 Ma (λ =1.402x10^{-11}yr^{-1}).

Discussion: The type B CAI Al3S4 mineral separates yield two Sm-Nd internal isochrons with concordant ages; these ages are also concordant with Pb-Pb and Al-Mg ages of 4567+0.93 Ma measured in Allende CAIs [e.g., 9-10]. The concordance of these isochrons suggests that the Sm-Nd system has not been disturbed since crystallization of the minerals in CAIs. The apparent age of 4246 ± 110 Ma calculated from Rb-Sr isotopic measurements on these same mineral separates is interpreted to reflect a late addition of Rb following crystallization. As such, this age records the time of an alteration event on the CV3 parent body [11].

The measured $\varepsilon^{142}Nd$ initial is essentially identical to the $\varepsilon^{142}Nd$ initial calculated using the terrestrial value at 4.567 Ga, using $^{147}Sm/^{144}Nd$ = 0.1966. These data indicate that CAIs and the Earth have the same $^{142}Nd/^{144}Nd$ isotopic composition and that bulk carbonaceous chondrites are distinct from both Earth and CAIs. This difference is illustrated in Fig. 3, where chondrite data and bulk Earth are plotted with our CAI isochron. The fact that the CAI isochron does not intersect carbonaceous chondritic Nd isotopic compositions implies that chrondritic meteorites formed in a reservoir distinct from Earth and CAIs.

The ~20 ppm range in $^{142}Nd/^{144}Nd$ observed among chondrites has been ascribed to incomplete mixing of stellar debris containing non-solar abundances of parent (^{146}Sm) and/or daughter (^{142}Nd) isotopes [7-8]. This phenomenon is supported by observations of variable Ba, Cr, Mo, Nd, and Sm isotopic compositions of primitive meteorites and Earth [e.g., 12-16]. Different $^{142}Nd/^{144}Nd$ ratios of Earth and carbonaceous chondrites could therefore also reflect nebular heterogeneity. The ~20 ppm difference in $^{142}Nd/^{144}Nd$ between bulk Earth and chondrites has also been attributed to global chemical differentiation during the lifetime of ^{146}Sm, producing complementary high and low Sm/Nd reservoirs that remained separate throughout Earth's history [8]. Our data demonstrate that CAI and Earth have similar ^{146}Sm-^{142}Nd isotopic systematics and that these systematics differ from those of carbonaceous chondrites. Thus, our data suggest that heterogeneous distribution of ^{142}Nd and/or ^{146}Sm is a more likely explanation for the different $^{142}Nd/^{144}Nd$ of bulk Earth and carbonaceous chondrites than a hidden terrestrial reservoir.

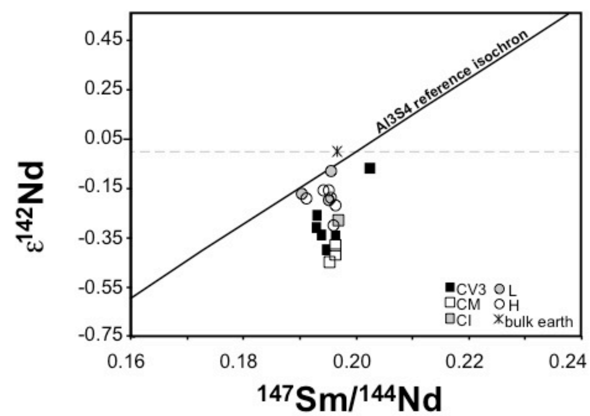

Figure 3. ^{147}Sm-^{142}Nd diagram with carbonaceous chondrites (squares), ordinary chondrites (circles), and the accepted bulk earth value of $^{147}Sm/^{144}Nd$ = 0.1966. Data is from [1,2]. The regression is from the mineral separates of CAI Al3S4.

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