INTERNAL Rb-Sr AGE AND INITIAL $^{87}$Sr/$^{86}$Sr OF A SILICATE INCLUSION FROM THE CAMPO DEL CIELO IRON METEORITE. Y. Liu1, L. Nyquist1, H. Wiesmann2, C. Shih3, C. Schwandt2, and H. Takeda2

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Introduction: The largest group of iron meteorites, IAB, is distinguished by the presence of diverse silicate inclusions. In principle, Rb-Sr and Sm-Nd radiometric dating of these silicate inclusions by internal isochron techniques can determine both the times of melting and parent/daughter ratios in the precursor materials via initial $^{87}$Sr/$^{86}$Sr and $^{143}$Nd/$^{144}$Nd ratios. The $^{87}$Sr/$^{86}$Sr and $^{143}$Nd/$^{144}$Nd ratios could distinguish chondritic precursors from already differentiated silicates. We reported Rb-Sr and Sm-Nd internal isochron ages of 4.52 ± 0.03 Ga and 4.50 ± 0.04 Ga, respectively, for plagioclase-diopside-rich material in the Caddo County IAB iron meteorite [1,2]. These results are essentially identical to literature values of its Ar-Ar age of 4.520 ± 0.005 Ga and its Sm-Nd age of 4.53 ± 0.02 Ga [3,4].

The Campo del Cielo IAB iron meteorite contains angular silicate inclusions that are roughly chondritic both in mineral composition and bulk chemistry [5,6]. Campo del Cielo silicate seems have been more strongly heated than Caddo County and other IAB silicates [7]. Also, there is evidence for partial melting and removal of diopside and plagioclase [5]. A Rb-Sr age of ~4.7 ± 0.1 Ga for Campo del Cielo silicate was reported in pioneering work [8,9]. Also, the I-Xe age of Campo del Cielo silicate work shows it cooled enough to retain 129Xe only 3.8 Ma after cooling of the L4 chondrite Bjurböle [10].

The purpose of this study is to evaluate the formation and evolution of silicate inclusions in IAB iron meteorites by determination of their initial $^{87}$Sr/$^{86}$Sr ratios combined with higher-resolution chronology and mineralogical and geochemical studies.

Sample and analytical details: The mineralogical and chemical compositions of silicate inclusions in Campo del Cielo were described by Wlotzka and Jarosewich [5]. Bild [7] reported additional mineralogy and abundances of major and trace elements shortly thereafter. Differences in both mineralogy and chemical composition have been observed among the silicate inclusions in Campo del Cielo. The ~2.15 g sample of USNM 5615 used in this study was provided by the National Museum of Natural History, Smithsonian Institution, and is from Campo del Cielo Inclusion #2, the same inclusion studied by Bild [7]. A 0.263 g slice was cut from the total to make a polished thin section (PTS). The remaining sample was crushed in a cleaned stainless steel mortar to pass 75 and 250 µm sieves. The sample fraction <75 µm was used for the whole rock analysis. Sample fractions of 75-250 µm were prepared for mineral separation. Plagioclase-, Opx-, and olivine-enriched samples were obtained first by magnetic separation, followed by heavy liquid separation and handpicking. The mineral separates were cleaned in 2N HCl at room temperature for 20 min. Graphite powder in the mineral separates was removed by ultrasonic and centrifugation.

Mineralogy: The PTS prepared from USNM 5615 has dimensions of 6.0×12 mm. Elemental distribution maps of Na, Al, Mg, Si, Fe, Ca, P, K, Cr, Ni and S were determined using the Cameca SX100 Electron Probe Micro Analyser (EPMA) at JSC. The maps were 500×500 pixels and were obtained with 50 msec counting time for 10 µm beam size. The modal abundance of minerals determined by point counting is 45% Opx, 24% olivine, 21% plagioclase, 2% chromian diopside and 1.5% metal.

Rb-Sr chronology: Data for the whole rock (WR) and mineral separates of plagioclase (PL), and orthopyroxene (Opx) define an internal isochron as shown in Fig. 1. Unfortunately, the Rb analysis of the olivine (Ol) separate failed. A high measured $^{87}$Sr/$^{86}$Sr ratio suggests $^{87}$Rb/$^{86}$Sr ~0.5 in Ol and offers the prospect of refining the age. Nevertheless, the slope of the isochron in Fig.1 is relatively precisely defined, and corresponds to an age of 4.54 ± 0.08 Ga for $\lambda(^{87}$Rb) = 0.01402 Ga⁻¹. This result is in adequate agreement with the previously determined Rb-Sr age of ~4.7 ± 0.1 Ga [8,9] for bulk silicate inclusions and ages of ~4.56 Ga [10,11] calculated from I-Xe and K-Kr ages of Campo del Cielo silicate inclusions. The Rb-Sr age of the Campo del Cielo inclusion studied here is indistinguishable from all the radiometric ages of the plagioclase-diopside-rich silicate material in Caddo County. The initial $^{87}$Sr/$^{86}$Sr ratio of 0.69926 ± 0.00027 is also consistent with initial $^{87}$Sr/$^{86}$Sr ratios of 0.69915 ± 0.00005 for Caddo County and 0.69990 ± 0.00039 for a group of five IAB irons [2,8].

The $^{87}$Sr/$^{86}$Sr evolution paths for silicate inclusions in Caddo County and Campo del Cielo (CdC) are shown in Fig. 2. The $^{87}$Rb/$^{86}$Sr ratios in H-chondrites vary from 0.33 to 0.80 with average of ~0.63 [12],...
while carbonaceous chondrites range from 0.26 (CV) to 0.87 (CI). It can be seen from Fig.2 that both C- and H-chondrite parent bodies could be precursor materials involved in the $^{87}\text{Sr}/^{86}\text{Sr}$ evolution for the silicate inclusions in Caddo and CdC. However, the short I-Xe formation interval of 3.8 Ma for Campo del Cielo silicate combined with a relatively high initial $^{87}\text{Sr}/^{86}\text{Sr}$ suggests evolution in the higher-μ environment estimated for the Solar Nebula (SN).

Mineralogy/petrogenesis: The modal abundances of minerals observed in the Campo del Cielo PTS (opx 45%, olivine 24%, plagioclase 21%, chromian diopside 2%) differs somewhat from those reported by Wlotzka and Jarosewich [5]. This can be explained as heterogeneity due to addition or subtraction of various amounts of diopside and/or plagioclase during partial melting. Some regions of the PTS enriched in sodic plagioclase, chromian diopside, and chromite have been identified.

Fig. 3 shows the abundance ratios of Rb, Sr and 6 REE in inclusions of Caddo County and Campo del Cielo relative to CI chondrites. In contrast to the Caddo plagioclase-diopside, the silicate inclusion of Campo del Cielo has depletions of La, Nd and Sm [1,3,7]. Because diopside and plagioclase are major carriers of REE, their addition and subtraction during partial melting may account for variation of some REE. The enrichment in Sr-Lu (Fig.3) for Caddo could be produced by ~15-20% partial melting of a chondritic precursor. Depletion of light REE in Campo del Cielo silicate suggests that its precursor could have been a residue after extraction of a partial melt. Also, Campo del Cielo silicates may have been strongly heated [7] accounting for low abundances of volatile Cd and In [7], and possibly Rb.