I-Xe AGES AND THE THERMAL HISTORY OF THE TOLUCA IAB METEORITE.

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Introduction: The IAB iron meteorites have complicated textures and chemical-mineralogical features that indicate a complex history for the parent body. These meteorites commonly contain abundant silicate inclusions embedded in the metal phase. In an attempt to develop the least complicated formation scenario, Benedix et al. [1] explored a hypothesis in which the differentiation process on the parent body is interrupted by a catastrophic impact. The subsequent gravitational reassembly mixes together lithologies from different formation regions of the parent body. Although this hypothesis does not completely explain all properties of these meteorites, it does explain the emplacement of solid silicates within molten metal as well as slow cooling rates (< 700 K/Ma) of the reassembled debris.

To explore if the I-Xe system in IAB silicates can provide information on the complex history of the IAB parent body, we studied the USNM 931 specimen of the Toluca meteorite [1]. The specimen still contains remnants of three troilite inclusions, with one of them including abundant silicate grains of different habits. Our previous work showed that the ^{129}Xe in chlorapatite, pyroxene, and perryite grains from this nodule was dominated by radiogenic ^{129}Xe (^{129*}Xe from ^{129}I decay) [2]. Pyroxenes also exhibit a clear correlation between the Mg/(Fe+Mg) ratio and ^{129*}Xe concentration, being highest in the high-Mg grains.

To investigate this correlation, we separated 63 pyroxene grains from the same troilite nodule of Toluca. The concentrations of Fe, Mg, Si, and Al were determined by the EDAX which also revealed small amounts of Ni and Cr in some grains (< 1% atom.). To monitor possible troilite intergrowths S concentrations were also measured. Although the Mg-rich pyroxene grains were more abundant, for our study we selected 32 grains which exhibit a continuous trend of Mg/(Fe+Mg) ratios.

The selected grains, along with the Shallowater enstatite irradiation standards, were weighed, sealed under vacuum in fused-quartz ampoules and irradiated in the pool area of the University of Missouri Research Reactor in a continuously rotating water-flooded capsule. The grains were then placed in the extraction system of the mass-spectrometer and melted individually with a focused Nd-YAG (1.06 μm) CW laser. The laser power was increased until melting by a pair of water-cooled glan-thompson polarizers with continuously variable orientations). Total degassing and melting of an average-sized (~ 20 μg) grain took about 5 seconds. Xenon isotopic composition was measured in each grain by ion counting mass-spectrometry [3]. "Hot blanks", typically ~ 2×10^{-15} cm^3 STP ^{132}Xe, were measured by similar laser power levels directed for 5 seconds into the empty holes in the grain holder stub of the laser cell and were always completely negligible.

Concentrations of ^{132}Xe ranged from 35.6×10^{-12} to 357.8×10^{-12} cm^3 STP/g, with average value of 184.5×10^{-12} cm^3 STP/g, in agreement with the previously reported data for Mundrabilla (IAB) silicates and etched Pitts (IAB) silicates [4]. Radiogenic ^{129*}Xe remained loosely correlated with the Mg/(Fe+Mg) ratio, and as we previously found also consistent with [4].

Final experimental points fill a triangular area on three isotope plot *(a)* and represent the total xenon released from each of the Toluca grains. The grains were sorted according their Mg/(Mg+Fe) ratios, with 9 grains having troilite content higher than 10% (marked by their numbers on plot *a*) being eliminated.

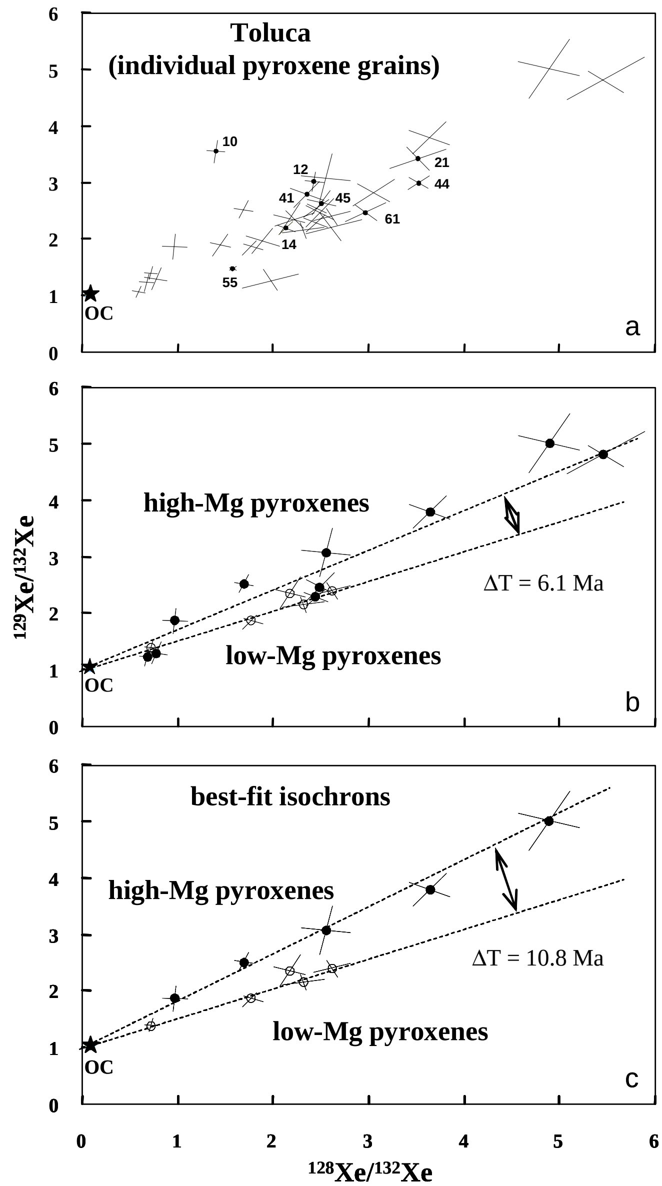
We considered the suite of 10 grains with the highest Mg/(Mg+Fe) ratios, which gradually decreased by 8%, to be the Mg-rich subset (solid points, plot *b*). Using a similar 8% increase in Mg/(Mg+Fe) ratios, starting from the lowest value, we selected 6 grains (open points, plot *b*) for the low-Mg subset. Different formation times could then yield different isochrons for these two groups but, unlike stepwise heating, total melting does not allow to identify the uncorrelated ^{128*}Xe.

If the iodine-xenon system in a suite of grains would have closed at the same time, then the Xe released from these grains would form a pseudo isochron on a three isotope I-Xe plot. Additions of uncorrelated ^{128*}Xe (varying from grain-to-grain) would then move experimental points to the right. However, since most ^{128*}Xe (> 80%) is associated with ^{129*}Xe, the scattering of points to the right of the isochron will be slight and its slope, perhaps determined with less precision, should not be seriously affected. Based on different computational procedures, the I-Xe system in high-Mg pyroxenes closed 0.3 – 4.9 Ma after Shallowater, but most probably 2.6 Ma after Shallowater (free fit correlation lines). With the absolute age of Shallowater determined to be 4562.3 ± 0.3 Ma [5], this sets the closure time of the I-Xe system in high-Mg pyroxenes at 4559.7 Ma, in agreement with the previously reported range of I-Xe ages for silicates from IAB iron meteorites [4, 6].

The Toluca graphite-troilite nodules are almost certainly formed by liquid immiscibility in the still molten Fe-Ni-S-C system, trapping solid pyroxene grains. The troilite shows twinning and/or undulatory extinction from plastic deformation, but it apparently did not experience shock melting [7]. It led to the conclusion that some metallic melts formed by the time of catastrophic breakup of the IAB parent body could have remain intact [1]. Then, the I-Xe age of high-Mg Toluca pyroxenes, separated from one of such graphite-troilite nodules, most probably reflects the time of the metal/silicate mixing after the disruption and reassembly of the IAB parent body about 7 Ma after the formation of CAI's [8].

The age difference between the high- and low-Mg isochrons (10.8 - 6.1 Ma) forms a basis for cooling rate calculations. The difference in melting temperatures of 411 K between the high- and low-Mg pyroxenes (1830 K and 1419 K, respectively [9]) can be used as a first order estimate of the difference in the Xe closure temperatures. Alternatively, difference in *tammann* temperatures for enstatite and ferrosilite of 214 K gives a lower limit of the difference in closure temperatures between the high- and low-Mg pyroxenes. Then a cooling rate for the temperature range of Xe closure in Toluca pyroxenes can be calculated in a straight forward manner. It is ~ 40 ± 20 K/Ma, in a good agreement with the metallographic values reported for 7 IAB meteorites [10].

I-Xe system in Toluca silicates seems to survive catastrophic impact and breakup of IAB parent body. It supports a suggestion that accretion and melting of the IAB parent occurred within a few Ma after the initial formation of solid objects in the Solar System [6]. As a result of subsequent cooling at about 40 ± 20 K/Ma, I-Xe system in the high-Mg pyroxenes in Toluca nodules closed at about 4559.7 Ma, while in low-Mg pyroxenes at 4553.6 – 4548.9 Ma.



Supported by NASA grant #NNG06GE84G.

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