NEUTRON-CAPTURE ^{128}Xe IN THE SAN JUAN MASS OF THE CAMPO DEL CIELO IAB IRON METEORITE: EVIDENCE FOR A HIGH FLUENCE OF THERMALIZED NEUTRONS. [1]O. Pravdivtseva, [1]A. Meshik, [1]C. Hohenberg, [2]M. E. Varela, [2]M. F. Gerarduzzi. [1]Laboratory for Space Sciences and Physics Department, Washington University, CB1105, One Brookings Drive, Saint Louis, MO 63130 (olga@physics.wustl.edu), [2]ICATE- CONICET, Avenida España 1512 sur, J5402DSP, San Juan, Argentina.

Introduction: Galactic Cosmic Rays (GCR)- induced effects provide a means to study the history of meteorites as small objects in space or in the top few meters of their parent body. Most important are cosmogenic nuclides, produced by interactions of primary and secondary cosmic ray particles with target atoms. Interactions with high-energy neutrons and protons usually result in spallogenic nuclides of a lower mass than the original target. Neutron capture of thermal (<0.6 eV) or epithermal (up to hundreds of eV) secondary neutrons produces heavier nuclides. Cosmogenic ^{128}Xe produced by capture of low-energy neutrons on ^{127}I has been previously observed in Allende CAIs [1], lunar dust [2], and the El Taco fragment of Campo del Cielo [3]. Here we report cosmogenic ^{128}Xe from neutron capture on ^{127}I in the San Juan fragment of Campo del Cielo and its correlation with ^{129}Xe from extinct ^{129}I, a natural I-Xe study.

Sample and Methods: San Juan A2 is a sample of the San Juan mass of Campo del Cielo (IAB) iron [4] with an angular silicate inclusion of up to about 1 cm^2 in size. The texture is coarse-granular consisting of magnesian olivine and orthopyroxene (Fo_{95}, $En_{91.3}$; $Fs_{7.4}$, $Wo_{1.2}$, respectively), albitic plagioclase (An_{20}), clinopyroxene and graphite. The latter is filling intergranular and interaggregate space and covering the inclusion surface. Cliftonite is present in kamacite (6.3 wt% Ni) of the octahedrite metal (Figure 1).

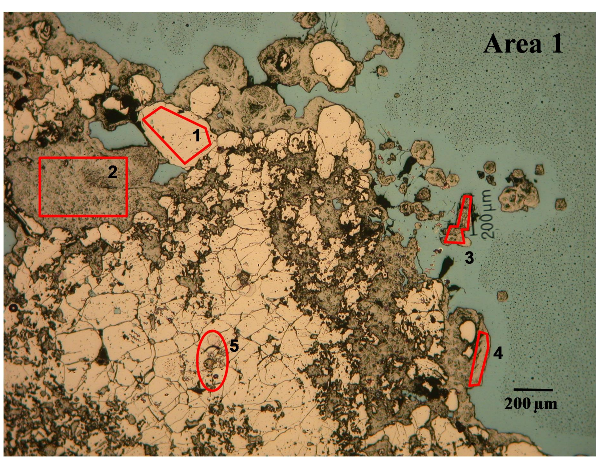

Figure 1. Area 1 (one of seven studied areas) of the San Juan A2 polished section. Outlined are rastered areas of silicate (1), massive graphite (2), cliftonite (3), rim (4) and platy graphite (5).

Xe and Ne isotopic compositions have been measured in radial graphite rims surrounding silicates, massive graphite inclusions, fine-grained graphite aggregates, cliftonite inclusions, and platy graphite. Two silicate inclusions were also analyzed, as well as 3 different areas of metal. Gases were extracted by *in situ* rastering using an acoustically Q-switched Nd-YAG laser (1064 nm) with an average laser spot size of 15 µm and power of 6W.

Released gases were cleaned sequentially by first exposing them to SAES St707 getter pellets, maintained at 275°C, and then to freshly deposited Ti-film getters. The heavy noble gases were separated from He, Ne, and Ar using activated charcoal at a temperature of –90°C for the adsorption of Xe and +165°C for Xe desorption. The Ne isotopic composition was measured by high-transmition mass-spectrometer SuperGnome-S. Xe was analyzed subsequently using detection parameters optimized for heavy noble gases. Sensitivity was 7×10^{-15} cm^3 STP/Hz for Ne and 7×10^{-16} cm^3 STP/Hz for Xe.

Results: The Xe isotopic composition in San Juan A2 silicates and graphite inclusions is consistent with a mixture of two major components – air (introduced by cutting and polishing) and iodine-derived Xe (Figure 2). The Xe contribution from U-fission was negligible. None of the samples showed excesses due to spallation on Ba/REE.

When plotted as ^{129}Xe/^{132}Xe versus ^{128}Xe/^{132}Xe, data points representing silicates, fine-grained graphites and cliftonites (solid symbols, Figure 2) form a well-defined correlation line with the slope of 16.3 ± 0.8. Fine-grained graphite in San Juan A2 is intermixed with silicates, thus Xe isotopic composition in these samples could have contribution from both, graphite and silicates. Analyzed areas of cliftonite (solid squares) are surrounded by metal, making contribution from silicates unlikely. Data points for other graphite areas (open symbols) cluster above the correlation line.

This correlation is essentially the I-Xe isochron, indicating that the I-Xe system in silicates, cliftonites and fine-grained graphites in San Juan A2 closed within 2 Ma. The unknown neutron fluence and spectrum, of course, prevent the time of closure from being obtained. However, we can estimate the thermal neutron equivalent fluence received by this sample from the slope of the correlation line.

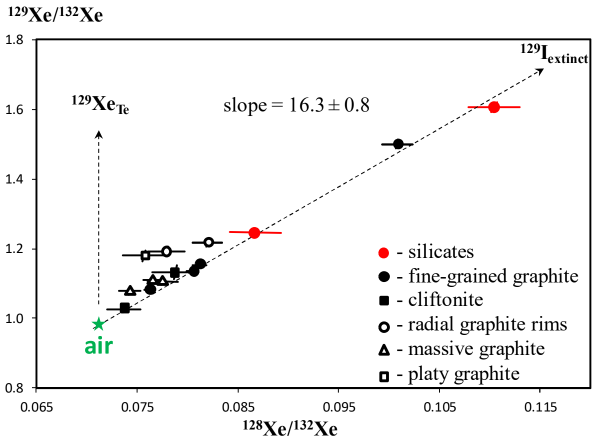

Figure 2. Xenon three-isotope correlation plot for silicates and graphites from the San Juan A2 polished section. I-Xe isochron is defined by solid symbols.

In our previous studies of Campo del Cielo silicates [5] we determined closure times of I-Xe system in two individual grains, diopside and oligoclase, extracted from the metal. To convert ^{127}I into ^{128}Xe, both grains were irradiated with thermal neutrons at the University of Missouri Research Reactor (MURR) to the fluence of 2×10^{19} neutrons/cm^2. Xe isotopic compositions were measured in step-wise heating experiments. The ratios of the excess amounts ^{129*}Xe/^{128*}Xe were constant for both grains from ~ 1300 °C up to melting. Plotted as ^{129}Xe/^{132}Xe versus ^{128}Xe/^{132}Xe, these ratios define correlations with the slopes of 0.5173 ± 0.0038 for diopside and 0.5547 ± 0.0153 for oligoclase, corresponding to an age difference of 1.6 Ma [5]. Assuming the I-Xe system in all silicates in Campo del Cielo and its fragments closed within this 1.6 Ma interval, the difference in thermal neutron fluences (GCR exposure versus reactor irradiation) can be derived from the difference in the slopes of the San Juan and Campo del Cielo silicates correlation lines. Based on this estimation, the San Juan inclusions studied here experienced 29 - 31 times lower fluence than Campo del Cielo silicates, or about 6.6×10^{17} thermal equivalent neutrons/cm^2. Campo del Cielo apparently experienced a simple single stage irradiation history, without any mechanical damage (constant exposure geometry) for more than 1.8×10^{8} years [6]. Assuming the neutron flux spectra are identical for MURR and Campo del Cielo (certainly not true but good for an estimate), the average thermal equivalent neutron flux for these fragments is about 1.2×10^{2} n/cm^{2}s.

Radial rims and platy graphite have higher ^{129*}Xe/^{128*}Xe ratios with corresponding data points falling above the isochron. Rims and platy graphite are closely associated with silicates, while massive graphite with lower ^{129*}Xe/^{128*}Xe values is less so (all shown as open symbols). Nevertheless, the apparent extra ^{129*}Xe in rims, platy and massive graphites cannot be explained by preferential accumulation of iodine in silicates at the time of silicate and graphite exsolution from metal or by later migration of iodine from graphite into silicates. The same ^{129*}Xe/^{128*}Xe ratio in cliftonites and silicates indicates that the I-Xe system in these samples closed within 2 Ma and was not subsequently disturbed. An alternative explanation for the ^{129*}Xe/^{128*}Xe ratios in rims, massive and platy graphites is the addition of ^{129}Xe from low-energy neutron capture by ^{128}Te and ^{130}Te [7], although the carrier of Te is unclear. The Xe isotopic composition of platy graphite may have some contribution from the surrounding silicates, similar to what is observed for fine-grained graphites, yet their Xe isotopic compositions are different. Detailed mineralogical studies of the analyzed areas may help to identify Te-rich phases, if neutron reactions on Te are responsible for higher ^{129*}Xe/^{128*}Xe ratios in rims, platy and massive graphites.

The ^{22}Ne/^{21}Ne values in San Juan A2 silicates and graphites studied here range from 0.96 to 1.07, with an average value of 1.04, consistent with irradiation in a large body at a large shielding depth. The preatmospheric size of Campo del Cielo was estimated from concentration of long-lived cosmogenic ^{36}Cl [8]. With a radius larger than 3 m, it might be one of the largest iron meteorites to have been recovered. Based on the Xe isotopic composition of its components, and the observed correlation line between ^{128}Xe and ^{129}Xe, the San Juan fragment of Campo del Cielo was well shielded from primary cosmic ray high-energy irradiation. Its size allowed the secondary neutrons to be fairly well thermalized, receiving an equivalent (normalized to the MURR spectrum) fluence of thermal and epi-thermal neutrons of 6.6×10^{17} n/cm^2.

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