COSMOGENIC RADIONUCLIDES IN CHELYABINSK METEORITE (UPDATE).

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Introduction: The Chelyabinsk LL5 chondrite fell in Russia on February 15, 2013. Thus far, ~1,000 kg has been recovered including a main mass of 540 kg. Based on observations of the fireball the pre-atmospheric radius was estimated to be >5 m. We measured cosmogenic radionuclides in this meteorite to investigate its cosmic ray exposure (CRE) age and preatmospheric shielding conditions [1]. CRE age determinations were performed by other methods using both radionuclides and noble gas measurements [e.g., 2-6]. In this study, we provide new measurements and discuss exposure conditions and preatmospheric size of Chelyabinsk.

Samples and Experiments: We received three fragments of the Chelyabinsk meteorite; #6-21, 4-63, and 10-116 from the Vernadsky Institute, Moscow and four fragments of #02, 05, 07, and 10 from Natural History Museum, Vienna (NHMW). The later samples are same fragments that were studied by [5]. In addition, a surface fragment of Chelyabinsk main mass (CMM) [7] was provided by the Vernadsky Institute. After separation of metal and stony fractions from each fragment, concentrations of cosmogenic ^{10}Be ($t_{1/2}$ = 1.36 Myr), ^{26}Al (0.705 Myr), and ^{36}Cl (0.301 Myr) in each fraction were measured by accelerator mass spectrometry (AMS) at Purdue University.

Cosmic Ray Exposure Age: Several different methods were applied to calculate the CRE age of Chelyabinsk because of the large recovered mass and unknown shielding conditions of the recovered fragments. A reliable CRE age could not be obtained based on noble gas concentrations alone [2, 3, 6]. The shielding condition can only be obtained by comparision of cosmogenic radionuclide concentrations with model production rates. In this study, we applied model independent exposure age calculations. We previously found that ^{10}Be and ^{36}Cl concentrations, [^{10}Be] and [^{36}Cl] in iron meteorites or metallic phase of meteorites with exposure ages >10 Ma are related as an equation: $[^{36}Cl]/[^{10}Be] = 6.17 - 0.28x[^{10}Be] - 0.012x[^{10}Be]^2$. Measured ^{36}Cl/^{10}Be ratios in all Chelyabinsk samples are higher than calculated from this relationship because of shorter exposure age that leads to under-saturation of ^{10}Be. We obtained an average CRE age of 1.8±0.4 Myr, with some scatter, based on measurements in 9 samples using this relationship. The production rate ratio of ^{26}Al to ^{10}Be in the metal phase is constant at any shielding condition. We obtained a ratio of 0.72±0.06 based on over 200 measurements of iron meteorites and metallic phase of meteorites. We calculate a CRE age of 1.2±0.5 Myr based on the observed ratio of 1.10±0.04 in 7 metal fragments of Chelyabinsk. Our measurements do not indicate a complex exposure history. However, some published results, such as sample HR-5 [2, 4], could only be explained by a complex exposure history. We have no good explanation to reconcile the two different findings.

Preatmospheric Size and Depths: Chlorine-36 were measured in both metal and stony phases of Chelyabinsk. In addition to ^{36}Cl produced by spallation reaction in both metal and stony phases, ^{36}Cl is also produced by thermal neutron capture on ^{35}Cl in heavily shielded samples of a larger stony meteorite object. The thermal neutron capture produced ^{36}Cl in the stony phase was calculated by subtracting spallation component of ^{36}Cl using that in metal phase at the same shielding condition. The thermal neutron capture ^{36}Cl contributions was found to vary from 0.27 to 7.5 dpm/kg. The concentrations of neutron capture ^{36}Cl are well correlated with those of neutron-capture produced ^{60}Co in the same fragment. The shielding depths derived from this neutron capture ^{36}Cl (assuming Cl concentration of 100 ppm in stony phase) range from ~10 to 260 cm. The shielding depth of one fragment from CMM is ~80 cm based on ^{36}Cl and ^{10}Be concentrations, so that the maximum shielding depth of any sample from CMM is 150 cm based on recovered size [7] of CMM. We thus conclude that the CMM was not close to the center of the Chelyabinsk meteoroid if we assume a preatmospheric radius is >5 m.

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