COSMOGENIC RECORDS IN EFREMOVKA CV3 METEORITE, S. V. S. Murty¹, K. Nishizumiu², and J. N. Goswami³, ¹Physical Research Laboratory, Ahmedabad 380009, India, ²University of California, Berkeley, Berkeley, California 94720, USA.

Cosmic ray produced noble gas, radionuclide and nuclear track records have been studied in the CV3 meteorite Efremovka. A ²¹Ne exposure age of 11.4±1.7 Ma and a pre-atmospheric radius of 20 cm are obtained. Saturation activities of ¹⁰Be, ²⁶Al and ³⁶Cl are similar to chondritic values and consistent with the deduced size and a simple cosmic ray exposure of Efremovka meteorite. The measured ³⁶Cl activity of 11.5 dpm/kg can at best have ~20% contribution from in situ neutron produced ³⁶Cl and suggest that the neutron fluence experienced by Efremovka is almost an order of magnitude less than that by Allende.

Introduction. The CV3 meteorite Efremovka is a find with a recovered mass of 21 kg. Petrologic and chemical studies suggest Efremovka to be the most pristine member of CV3 class, with very little secondary alteration of its matrix and CAIs [1]. Signatures of the short-lived isotopes ²⁶Al, ⁴¹Ca and ³⁶Cl [2-4] found in this meteorite clearly attest to its pristine nature. The objective of the present study is to decipher the cosmogenic records in Efremovka and derive its exposure age, pre-atmospheric radius and the neutron fluence experienced by it.

Experimental. Separate samples of bulk Efremovka (adjacent to the CAIs studied for ⁴¹Ca) have been used for nuclear track, noble gas and cosmogenic nuclide studies. Olivine grains, hand picked from a disaggregated bulk piece, were used for nuclear track studies following standard procedures [5]. Accelerator mass spectrometry has been employed for the determination of the activities of ¹⁰Be, ²⁶Al and ³⁶Cl [6]. Standard noble gas mass spectrometric procedures have been employed in the study of Ne, Kr, Xe, as detailed in [7].

Results: Noble gases: Two bulk samples and fragments of two CAIs (E40, E42) have been studied for noble gases. A trapped Ne composition of 20/22=10.1±0.1 can be derived from the Ne three isotope plot of the data for the different temperature fractions of these four samples. Data for both the bulk samples yield (22/21)=1.11±0.01 and exposure ages of 12.7 and 10.1 Ma, respectively using production rates from [8]. We adopt an average exposure age $T_{21}=11.4±1.7$ Ma, which includes uncertainties in concentration of Ne as well in the production rate. This value is better than the previously reported value of 9Ma [4] which was based on a assumed value of 8.4 for trapped 20/22. Independent calculation of cosmogenic ³⁶Ar is not possible due to the presence of excess ³⁶Ar [4], while large amounts of trapped gases make cosmogenic effects barely detectable in Kr and Xe isotope data.

Nuclear Tracks: The measured track density of ~3x10⁵/cm² in olivine grains correspond to a track production rate of ~2.6x10⁴ tracks/cm²/Ma for an exposure age of 11.4Ma. A maximum shielding depth of 9 cm for the analysed sample can be deduced from the track data. Considering the recovered mass of 21Kg, we can
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estimate a preatmospheric radius of ≤20 cm for the Efremovka meteorite. The small size of Efremovka meteorite is also supported by the radionuclide data.

Radionuclides: The activities of $^{36}\text{Cl}$, $^{26}\text{Al}$ and $^{10}\text{Be}$ in bulk samples of Efremovka are $11.52±0.28$, $59.9±0.28$ and $18.47±0.23$ dpm/kg, respectively and are similar to saturation activity level seen in samples of normal-sized chondritic meteorites. The radionuclide data and the cosmogenic neon (22/21) ratio, both support the small shielding depth of the analysed sample deduced from the track data. The radionuclide data are also consistent with the small preatmospheric size of Efremovka and suggest a simple cosmic ray exposure history for this meteorite. The $^{36}\text{Cl}$ activity of Efremovka is much less than the maximum value of $54±2$ dpm/kg found in Allende [9] for which the presence of a significant contribution from neutron induced production has been well established. If we use a spallation production ratio of $\text{P}_{36}(\text{Ca})/\text{P}_{36}(\text{Fe})=8$, and appropriate chemical composition, the expected spallation $^{36}\text{Cl}$ in Efremovka turns out to be $9.6±1.3$ dpm/kg. This suggests that we can attribute at the most ~2 dpm/kg of $^{36}\text{Cl}$ activity in Efremovka as due to secondary neutron induced production. If we consider the Cl concentration in Efremovka and Allende to be similar and take into account the lower cosmic ray exposure age of 5Ma for Allende [10], the neutron fluence experienced by Efremovka during its cosmic ray exposure turns out to be almost ten times lower than by Allende. This is in agreement with the results reported by us earlier based on the data for neutron produced $^{80}\text{Kr}$ and $^{132}\text{Xe}$ in Efremovka samples [4]. These results also show that the neutron produced component cannot account for more than a few percent of the observed excess of $^{41}\text{K}$ in Efremovka CAIs [3].