
Recently, we described a method (1,2) based on solar cosmic ray produced He-3 in three samples each from different depths of two lunar rocks 64435 and 61016, to deduce the SCR proton fluxes in the last few million years. The experimental data points for He-3 in these two rocks seem to fit well to the He-3 profiles generated using an average SCR proton flux of $J (\geq 10$ MeV) = $(70 + 10)$ protons cm$^{-2}$ sec$^{-1}$, with an $R = 100$ MV and a GCR flux of $J (\geq 1$ GeV) = 1.7 protons cm$^{-2}$ sec$^{-1}$, based on Reedy-Arnold model (3,4). Our results are in general agreement with the SCR proton fluxes and energy spectra, derived using Al-26 and Mn-53 measurements of several lunar rocks (5,6,7). The aim of this study is to extend the suitability of this method to lunar rocks whose surface exposure ages are greater than 4 m.y. on the lunar surface, leading to the saturation of Al-26 activity. Such studies hopefully permit the estimation of the energy spectra and the long term average SCR proton fluxes in the time periods of about 5-15 million years back.

For this purpose, we have analysed samples from 3 different depths of a well-documented anorthositic rock 79215 for elemental and isotopic composition of noble gases. Sample R1 is the surface sample (0-2 mm depth); sample R2 is of intermediate depth (2-5 mm) and R3 is the bottom sample (5-8 mm). First we discuss the results of R2 and R3 samples and then the results of R1. The He-3/He-4 ratios in R2 and R3 samples are 0.013 and 0.009 respectively. The cosmogenic He-3 in both these samples is about $5.8 \times 10^{-7}$ cc STP/g. If we adopt a He-3 production rate of $0.7 \times 10^{-8}$ cc STP/g.m.y. the GCR exposure age for 79215 is 83 m.y. The Ne-composition in both R2 and R3 samples is predominantly cosmogenic and the trapped gas content is very low. For R3 sample, the neon ratios are $20/22 = 0.75$ and $21/22 = 0.88$ and for R2 sample, they are 2.2 and 0.8 respectively. The $\text{Ne-21}_c$ content in case of both R2 and R3 samples is about $16.96 \times 10^{-8}$ cc STP/g. Using the Ne-21 production rate of $0.15 \times 10^{-8}$ cc STP/g.m.y. for this anorthositic rock, the GCR-exposure age for this rock turns out to be 110 m.y. Further the Ar-38/Ar-36 ratio in both these samples is about 1.4 indicating that the argon is mainly cosmogenic. The $\text{Ar-38}_c$ content in both these samples is about $4.79 \times 10^{-8}$ cc STP/g. The Ar-38 exposure age for this rock is estimated to be about 100 m.y.

The isotopic composition of Xe in R2 and R3 samples of this rock is predominantly cosmogenic. The Xe-126/Xe-132 ratio is 0.55 and the Xe-124/Xe-126 ratio is 0.6. Further the Xe-131/Xe-126 ratio is about 9.8, indicating the presence of large neutron-produced Xe-131 excess in 79215. This high Xe-131/Xe-126 ratio for this rock indicates that it was exposed to cosmic radiation at an average shielding depth of about 200-300 g/cm$^2$. For this
rock, La is about 2.7 ppm and in many of the Apollo 17 mare-basalts, the La/Ba ratio is about 11 \( (8,9) \). Thus we estimate the Ba-REE content of 79215 to be about 70 ppm. The \((\text{Xe-126})_c\) content is \(10.3 \times 10^{-12}\) cc STP/g in both R2 and R3 samples (average) and the Xe-126 exposure age for this rock is 110 m.y.

All these spallation produced isotopes yield a GCR exposure age of about 100 m.y. for this rock. The agreement of cosmic ray exposure ages by different indicator isotopes shows that when this rock was excavated from lunar regolith to the surface about 3.7 m.y. ago as suggested by the track-exposure age \( (6) \), no significant gas loss occurred. Alternatively, the rock 79215 might have been dislodged from a big boulder, \((of \ about \ 2-3 \ meter \ diameter)\) from the above shielding depth, where it had been residing for a period of about 100 m.y. on the lunar surface. However the second alternative seems to be less likely.

The R1 sample of 79215 yielded essentially noble gases of solar wind composition similar to other surface samples of 61016 and 64435 rocks. The He-3/He-4 ratio is about \(3.5 \times 10^{-4}\) and the Ne-20/Ne-22 ratio is about 12.8. In all the three rocks, about 80% of solar Ne was released in the 600°C temperature fractions, whereas solar Ar and Xe was released only to a small extent \((\sim 10\%)\) at this temperature. The Ne/Ar ratio is about 3 in these three rocks and this value is similar to the Ne/Ar ratio found in the soil feldspars of 14148 and 24087 analysed by us \((1,5)\). These results are being analysed by the analytical techniques \((1,5)\) described earlier, to decipher the SCR produced He-3 and Ne-21 in these samples of rock 79215, in order to estimate the SCR proton fluxes in the last 10 m.y.

Higuchi & Morgan \((10)\) determined a large excess of volatiles in this rock and suggested the possible occurrence of the ancient meteoritic component in this rock, representative of projectiles prior to the 3.9 b.y. bombardment. Similar suggestions were proposed with reference to other Apollo 17 ANT cumulates \((11)\) based on petrology. Attempts are underway to understand the composition of the ancient meteoritic component based on noble gas studies.

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References: