LETTERS TO THE EDITOR

SOLAR FLARE PROTON FLUXES IN THE LAST FEW MILLION YEARS

LAST year we reported results of the quantitative studies, aimed at isolating the Ne and Ar isotopes produced by solar cosmic rays (SCR) and galactic cosmic rays (GCR), in lunar soils and rocks[1]. In this report, for the first time, using ^3He in samples from three different depths of lunar rocks, we describe a method for deducing the absolute SCR (flare) proton fluxes in the last few million years.

When a big crater is formed on the surface of the moon, deeply buried rocks are excavated to the surface. During such shock events, the rocks lose their noble gases either completely or partially. The helium, in a shocked rock, is considered to be completely degassed. If $m(^3He)$ is the measured spallogenic, ^3He content per gm of the rock with a simple history, we have

$$m(^3He) = (P_g + P_s)\,T$$

where P_g and P_s are the GCR and SCR ^3He production rates respectively. If one chooses a deep interior sample (R3) from a rock, such that $P_s = 0$, then $m(^3He) = P_g T$. Since P_g is known, T for R3 is calculated. Using the calculated T, we compute the total SCR + GCR production rates, $[P_s + P_g = m(^3He)/T]$ for other samples (R1 and R2) at lower depths from top and plot these values against depth as shown in Fig. 1. The SCR parameters of the production profile that fit best to the data points, describe quantitatively the SCR flux.

We measured He, Ne, Ar contents in six samples from known depths of two well-documented shocked rocks 61016 and 64435, in which He clock is reset. Since we do not have the deepest samples where P_s is almost zero, we adopt the following procedure to find the SCR proton fluxes from our studies. We calculate the ^3He production profile as a function of depth for combined SCR + GCR production per m.y., using Reedy–Arnold model and a SCR proton flux of $J(E \geqslant 10\,MeV) = 70\,p.cm^{-2}sec^{-1}$ and $R_0 = 100\,MV^2$ and a GCR flux of $1{\cdot}7\,p.cm^{-2}\,sec^{-1}$. Using the SCR + GCR production rate for 61016–R3 sample at a depth of $5{\cdot}1\,g.cm^{-2}$, we calculate T (GCR) for 61016. Then we use this T (GCR) to find the $m(^3He)/T$ for R1 sample of 61016 and plot these values in Fig. 1. Similar procedure is adopted in the case of 64435 samples. Within the error limits, the points of rocks 61016 and 64435 seem to fit the curve B in Fig. 1.

We check next how these data points fit to a different SCR proton flux of $J(E \geqslant 10\,MeV) = 140\,p.cm^{-2}\,sec^{-1}$ and $R_0 = 150\,MV$, deduced by Bhandari *et al.*[3] for the same rocks based on ^{26}Al studies. The combined SCR + GCR ^3He production profile calculated for this SCR flux is shown by curve A in Fig. 1. Using the normalization procedure, mentioned earlier, for R3 points of rock 61016 and 64435, we calculate the other R1 and R2 points by the new ^3He SCR + GCR production rates and plot the points in Fig. 1. As one could see, the fit of the data points to curve A is less satisfactory than in the case of curve B. This shows that the ^3He production profile, generated using a SCR proton flux of J (E 10 MeV) = $70\,p.cm^{-2}sec^{-1}$ and $R_0 = 100\,MV^2$, seems to fit the data points better.

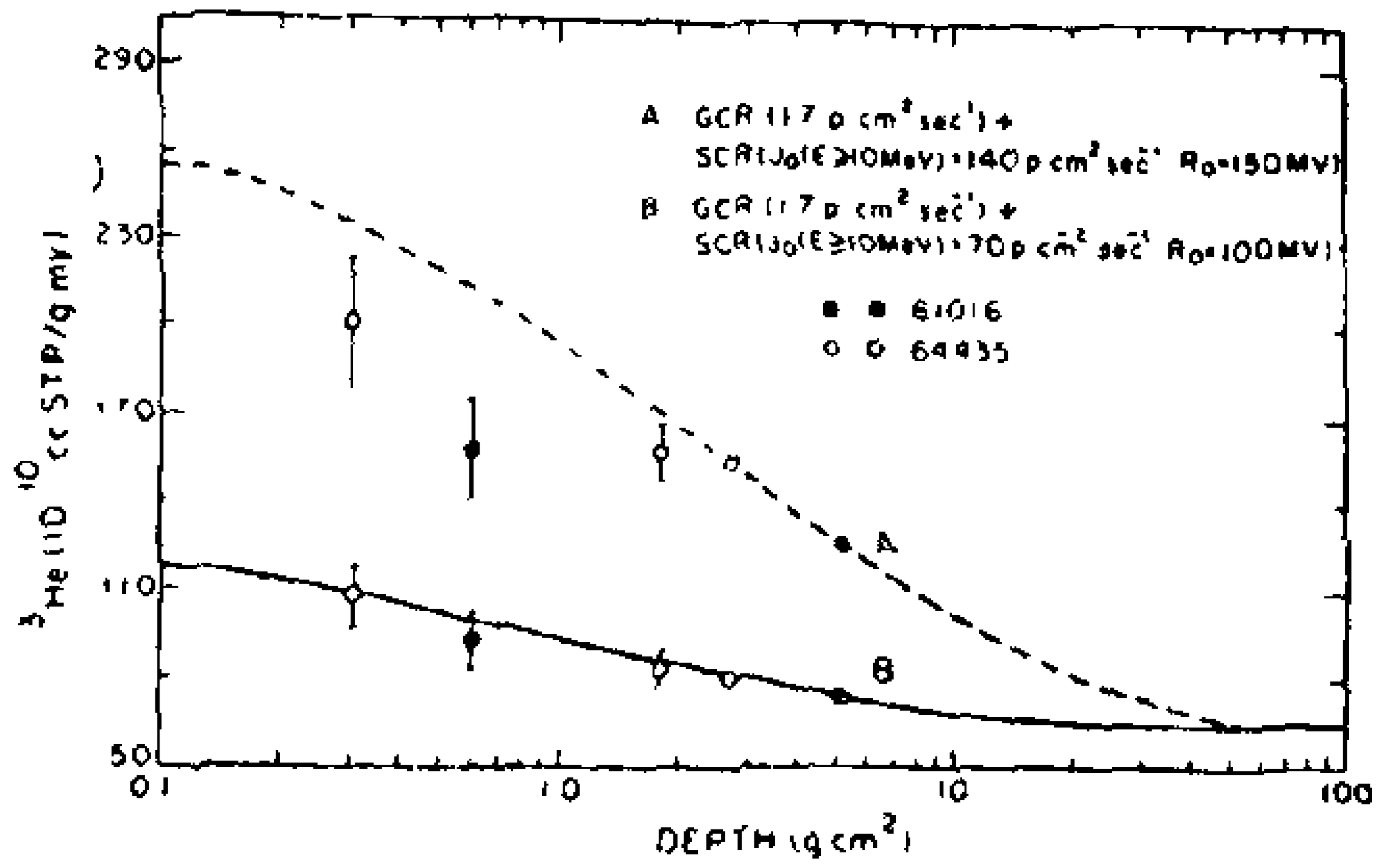

FIG. 1. Concentration profiles of ^3He as a function of depth in lunar rocks 64435 and 61016. The data points in the case of 64435 are normalized to the R3 points at $2{\cdot}7\,g.cm^{-2}$ and in the case of 61016, at $5{\cdot}1\,g.cm^{-2}$. The error bars are not shown for the normalizing points. The solid curve B is generated from the SCR proton flux given by Kohl *et al*[2] and the dashed curve A is generated from the SCR flux given by Bhandari *et al.*[3].

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