TIME AVERAGED FLUX OF VERY VERY HEAVY NUCLEI IN SOLAR AND GALACTIC COSMIC RAYS,

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Results of measurements of long fossil tracks (>20 micron), ascribed due to VVH group of nuclei ($Z > 30$) in lunar and meteoritic samples are reported. The observations have been made at effective shielding depths of 10^{-3} to 10 cms equivalent of typical stony or stony-iron materials corresponding to kinetic energy interval, 6-1500 MeV/n and relate to exposure times of 10^{-3}-10^{8} years. The earlier observations (1-4) of VVH nuclei are confined to energy range (250-1500) MeV/n. We have now obtained this information down to 6 MeV/n basing on analysis of rocks (using thick section technique (5)) and grains exposed to low energy cosmic rays on the lunar surface. Patwar meteorite samples were analysed for data in the energy interval 0.4 - 1.5 BeV/n. Rather than determine absolute flux, in the present work, we estimate the flux ratio of $Z>30$ and $Z>20$ nuclei based on ratios of track densities due to tracks of lengths, $\ell>20$ microns and $\ell>1$ micron; this ratio is not very sensitive to assumptions of irradiation geometries.

Our observations are confined to olivine crystals which were etched following the recipe (6) of Krishnaswami et al (1971). Olivines, by virtue of their higher registration threshold, offer a particular advantage over pyroxenes and feldspars since the background tracks due to iron group nuclei are lower, by about a factory of 2 to 2.5. The experimental procedures are given in details elsewhere (7). The etching efficiency for VVH tracks in olivines in the various energy intervals, was determined experimentally. The possible effects on the measured values of VVH/VH track density ratios due to annealing and erosion on the lunar surface has also been investigated, based on a range of possible conditions prevailing on the moon. The results indicate that the effects of erosion (for a range of 10^{-9} to 10^{-7} cm/yr) can in no way alter the conclusions given below. Also, based on the recent work of Price et al (8), we estimate that annealing of tracks is not significant for olivines, certainly not for exposure times of the order of 1 m.y.

The results are summarised in Tables 1 and 2 for lunar samples only. All results, including Patwar data are summarised in Fig. 1; the results refer to normal etching time. Patwar data are based on a total of 417 long tracks, 243 from depths of 1.7 - 1.8 cms and 174 from 14-16 cms depth.

The observation indicates that the relative abundance of the $(Z>30/(Z>20)$ nuclei is almost constant in the kinetic energy interval $(50\text{-}10^3)$ MeV/n: these nuclei must be identified with the galactic cosmic rays. At lower energies, the heavier nuclei progressively become important, the ratio of abundance $(Z>30)/(Z>20)$ increases by more than a factor of 5 in going down from (50-6) MeV/n. Considering the features of the energy spectra of the iron group nuclei, we identify the VVH nuclei having kinetic energy <10 MeV/n entirely due to the solar origin. The implications of a energy dependant ratio for solar cosmic rays are discussed elsewhere.

References:

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TABLE 1 VH/VVH track densities in olivine grains from Apollo rock 12020*

Code number crystal mount(s)	Effective depth from irradiated surface (cm)	Total areal track density ρ_{VH}, of tracks of $l \geqslant 1$ micron (cm^{-2})	Observed number of tracks of $l > 20$ microns	Ratio $\rho(l > 20\mu)/\rho(l > 1\mu)$
KA-3; K-1-5-1	0.011 - 0.017	$(16\text{-}23) \times 10^6$	71	$(1.8 \pm 0.21) \times 10^{-3}$
K-1-14-2; K-1-14-3 and K-1-14-4	0.027 - 0.033	$(12\text{-}13) \times 10^6$	85	$(1.9 \pm 0.20) \times 10^{-3}$
K-1-1	0.092 - 0.108	$(10\text{-}12) \times 10^6$	33	$(2.8 \pm 0.5) \times 10^{-3}$
KT-1-6-3	0.25 - 0.30	7.0×10^6	18	$(2.5 \pm 0.6) \times 10^{-3}$
K-3	7 ± 1	6.65×10^6	109	$(1.94 \pm 0.2) \times 10^{-3}$

* Surface (sun-tan) exposure age ~ 2.6 m.y. (Bhandari et al, Geochim. Cosmochim. Acta, 1971, Vol. 3, pp 2611-2019).

TABLE 2 VH/VVH track densities in olivine grains from lunar fines*

Code No. of crystal mount	NASA Code for sample of fines	Effective* depth from irradiated surface (cm)	Total areal density of tracks of $l > 1$ micron (cm^{-2})	Observed number of tracks of $l > 20$ microns	Ratio $\rho(l > 20\mu)/\rho(l > 1\mu)$
D 193 - 9	12028, 27, 193	0.004 - 0.007	46.5×10^6	91	$(11.6 \pm 1.2) \times 10^{-3}$
AD 201 - 14	14163, 121	0.006 - 0.008	54×10^6	107	$(7.1 \pm 0.7) \times 10^{-3}$
D 204-13	12028, 31, 204	0.007 - 0.011	32×10^6	85	$(6 \pm 0.65) \times 10^{-3}$
D 118-8	12028, 35, 118	a) 0.005 - 0.008	65×10^6	124	$(8.6 \pm 0.9) \times 10^{-3}$
		b) 0.011 - 0.015	51×10^6	88	$(3.0 \pm 0.3) \times 10^{-3}$

* All results in this table are for grains in which track density gradients are observed. Depth is computed from the irradiated surface.

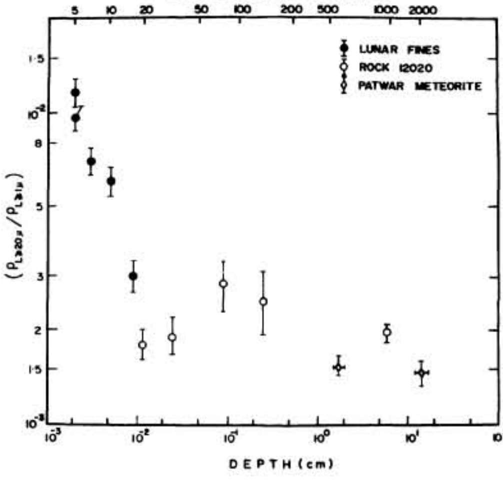

Fig. 1: The observed variation in ratio of track densities due to tracks of length, $\ell > 20$ and $\ell > 1$ microns, as a function of effective shielding (cm) during irradiation.