THE ENERGY SPECTRUM OF THE VVH COSMIC RAYS AVERAGED OVER THE LAST 19 MYr. R.K. Bull, P.F. Green and S.A. Durrani, Department of Physics, University of Birmingham, Birmingham B15 2TT, England.

The nature of the energy spectrum of the VVH cosmic rays in the region of ∿1 GeV/nucleon has recently been the issue of some controversy. Shirk et al. (1) have reported results which suggest a very steep spectrum for particles with $Z \geqslant 60$, whereas recent work by Fowler et al. (2) indicates that the spectrum for particles of $Z > 65$ is similar to that for Fe group nuclei. Binns et al. (3) have reported an energy spectrum for $Z \geqslant 32$ particles which is intermediate between the very steep spectrum postulated for $Z \geqslant 60$ and the Fe group spectrum.

Since heavy nuclei of energy ∿1 GeV/nucleon are stopped at depths of a few cm in meteorites or lunar rocks then a study of the depth variation of VVH ($Z \gtrsim 30$) track densities at such depths should be of considerable interest. The depth dependence of the VVH track density will allow constraints to be placed upon the energy spectrum of the particles. A few measurements in this region have been made by Bhandari et al. (4) using lunar rocks and the Patwar meteorite. No evidence for a steep energy spectrum for VVH galactic cosmic rays was found by these authors.

If confirmed, a steep VVH spectrum could have considerable astrophysical significance. For example an overabundance of VVH nuclei at low energies could indicate a sifferent source for these particles than those producing the cosmic rays of higher energy.

We have measured VVH ($Z \gtrsim 30$) track densities, ρ_{VVH}, in hyperstene crystals from a number of depths within the Shalka meteorite and also from one sample of Patwar. On the basis of extensive calibration experiments, a cut-off value in the track etch rate V_T has been used to separate tracks due to WH ions from those due to VH ions ($28 \geqslant Z \geqslant 20$).

Shalka hypersthene crystals have been irradiated with Ca, Ti, Fe, Ni, Cu, Kr, Xe and U ions. By measuring V_T as a function of residual range a calibration curve of V_T versus primary ionisation J, has been constructed and used to compute V_T versus residual range profiles which are shown in fig.1. More details of our calibration experiments are given in ref.5.

From fig.1, it may be seen that an etch-rate cut-off at $0.5\mu m.min.^{-1}$ effectively excludes all ions with $Z < 30$. After etching the crystals for 30 min. the surfaces were scanned and all tracks with projected lengths ≥100 eyepiece micrometer units (i.e. ≥13.4μm) were measured; those with total lengths ≥15μm

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were assigned to the VVH group. After further etching intervals the tracks were re-measured. Tracks identified as being due to stopping particles were assigned a charge. These events are plotted on fig.1.

We have neglected possible annealing effects for the VVH tracks on the basis of the following evidence: (i) the main peak in the fossil track-in-track length distributions for Shalka is shifted to shorter lengths by only ∿2μm with respect to fresh Fe ion track lengths (6), (ii) annealing experiments have shown that heating events which produce significant healing of Fe ion tracks result in no measurable effects in Kr tracks.

The areal densities of all tracks with total lengths ⩾15μm (and therefore with mean etch rates ⩾0.5μm.min^{-1}) are shown in fig.2 as a function of pre-atmospheric sample depth. These depths have been deduced from VH track densities. One datum point for the Patwar meteorite is shown, but it is important to note that the Patwar hypersthene has not been as thoroughly calibrated as that from Shalka.

The solid line shown on fig.2 is a VVH track-production rate versus depth profile taken from Fleischer et al. (7). These production rates were originally given in arbitrary units, so we have multiplied them by a ratio $(VVH/VH)_0$ of 1×10^{-3} in order to scale them to the experimental data. The curve has also been corrected for the efficiency of VVH track revelation.

The data shown in fig.2, whilst slightly suggestive of a ρ_{VVH} versus depth profile which is steeper than the calculated one (assuming the same exponent for both the VVH and the VH energy spectra) do not provide compelling evidence for a very steep VVH energy spectrum. It should be realised, however, that these data are dominated by particles of Z∿30-40.

Improved statistics should allow more definitive conclusions on the VVH energy spectrum to be drawn.

References:

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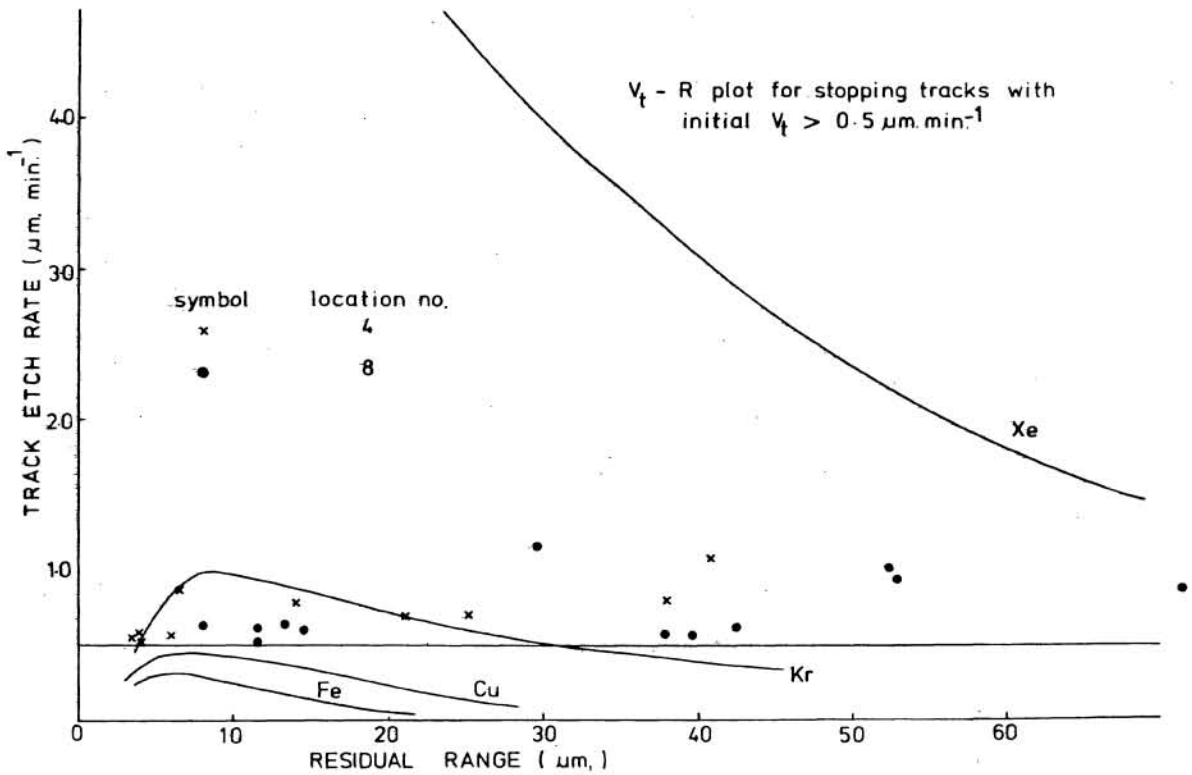

Fig. 1. V_T-R profiles obtained from calibration data. Also shown are some points for fossil tracks from two locations in Shalka.

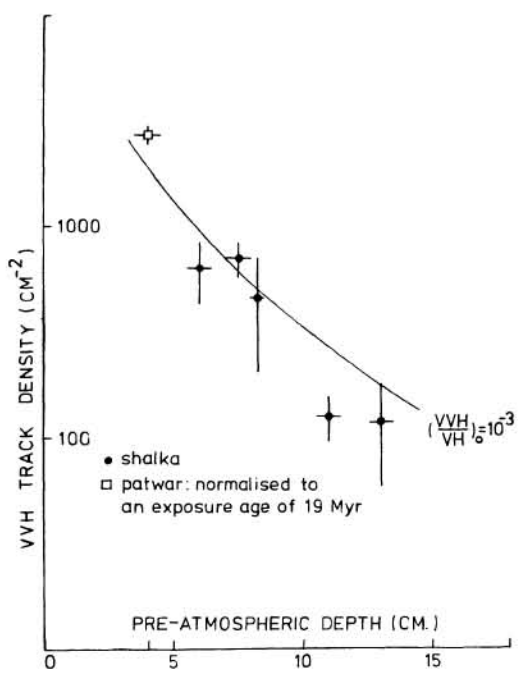

Fig. 2. Track density vs. depth profile for tracks > 15μm long in Shalka and Patwar. The solid line is a calculated profile adapted from Fleischer et al (1967).