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 $\approx 1$ 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 $Z > 60$, 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 $Z > 32$
particles which is intermediate between the very steep spectrum
postulated for $Z > 60$ and the Fe group spectrum.

Since heavy nuclei of energy $\approx 1$ GeV/nucleon are stopped at
depths of a few cm in meteorites or lunar rocks then a study of
the depth variation of VVH ($Z > 30$) track densities at such
depths should be of considerable interest. The depth dependen-
ce 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 Qhandari 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 different source for
these particles than those producing the cosmic rays of higher
energy.

We have measured VVH ($Z > 30$) track densities, $\Phi_{VVH}$, 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 ($28 > Z > 20$).

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. $>13.4 \mu m$) were measured; those with total lengths $>15 \mu m$
were assigned to the VH 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 VH
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 ~2 μm 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 > 15 μm
(and therefore with mean etch rates > 0.5 μm/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 VH 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 (VH/VH)O of 1 x 10^{-3} in
order to scale them to the experimental data. The curve has
also been corrected for the efficiency of VH track revelation.

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

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

References:
260.
Vol.3, 2577.
1, 75.
Sci.Lett. 32, 35.
VWH Energy Spectrum

Bull, R.K. et al.

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).