SOLAR COSMIC RAY PRODUCED NEON AND ARGON ISOTOPES AND
PARTICLE TRACKS IN APOLLO 16 SOILS AND ROCKS AND THEIR SOLAR
FLARE EXPOSURE AGES. M.N. Rao, T.R. Venkatesan, J.N. Goswami
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380009, India.

Last year, we have demonstrated in case of Apollo 14 and
Luna 24 soils that the neon isotopic compositions obtained in
step-wise heating analysis of selectively etched feldspar size
separates could be quantitatively decomposed into trapped,
galactic and solar cosmic ray (GCR and SCB) produced components
using detailed analytical procedures developed in our laboratory
(Bhai et al., 1978). At present, we extend these studies to
three other soil samples 69921, 69941 and 61221 from Apollo 16
mission. Further we describe a new technique for delineating
the SCB produced Ne and Ar components in lunar rocks, using an
anorthositic rock 61016. As a result, these studies provide for the first time, quantitative procedures for deducing
the solar flare exposure ages of these soils and rocks on lunar
surface.

The soil sample 69921 (skim soil) is sieved into several
size fractions and the resulting material was subjected to
magnetic and density separations to obtain pure feldspars. These
feldspar size separates were selectively etched to remove the
surficial solar wind (Bhai et al., 1978) and then they were
subjected to step-wise heating mass spectrometric investigations.
In case of rock 61016, three samples were obtained representing
shielding depths between about 100 microns to 2 mm (R-1 sample)
2 to 5 mm (R-2 sample) and at about 2.2 cm (R-3 sample) with
reference to the exposed (zero depth) surface.

One of the aims of this work is to provide a method for
calculating the SCR exposure ages for lunar rocks based on neon
and argon isotope systematics. Using well documented rocks
first we determine the Ne-21 and Ar-38 excesses in the surface
samples where both SCR and GCR contribute to the production of
these isotopic excesses (at depths around 0.5 g/cm² with reference
to the top exposed surface of the rock, as revealed by
particle track studies). The GCR produced Ne-21 and Ar-38 con-
centrations, measured in the deep interior samples in the same
rock (with proper depth corrections for GCR) are then subtracted
from the sum of SCR and GCR contents determined in the above
surface sample. From the residual Ne-21 and Ar-38 excesses,
the solar flare exposure ages are calculated using proper
production rates.

In case of 61016, the Ar-38 excess due to GCR production
in the R-3 sample (about 7 g/cm²) is determined and the GCR
exposure age of this rock is estimated to be (4.6 ± 0.6) m.y.
(using composition and depth corrected Ar-38 production rate of
0.77 x 10^-8 cc STP/g m.y.) Reedy (person comm.) and Hohenberg
et al. (1978). The GCR exposure age given by Stettler et al.
(1973) for this rock is <7 m.y. and they attribute this high age

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due to the difficulty in resolving the small amount of GCR produced Ar-38 from the enormous amount of Ar-38 from Cl-37 (n, γ) reaction due to reactor thermal neutron irradiation of this rock. It is possible that in our case also small contribution of Ar-38 from Cl-37 (n, γ) reaction due to natural thermal neutron irradiation during the subsurface residence of this rock in lunar regolith may be present but the anomalous Ar-38 cannot be accounted by this process.

The solar flare exposure age of 61016 is deduced by comparing the trapped and cosmogenic gas contents in 61016 - R1 sample with those of R-3 sample, after applying depth-dependant production corrections. The resulting Ar-38 excess in R-1 is attributed to SCR-production. Using an Ar-38 SCR-production rate at 0.5 g/cm², the solar flare exposure age of 61016 is calculated to be (2.3 ± 0.4) m.y. which could be considered to be in rough agreement with the solar flare track exposure age of 1.5 m.y. (Bhandari et al., 1976).

In case of Ne data for 61016, the procedures employed for resolving the multicomponent noble gas mixtures are similar to those of Ar, discussed above. The GCR produced Ne-21 in case of 61016 - R3 sample is 0.342 x 10⁻⁶ cc STP/g and this yields a GCR age of (3.4 ± 0.8) m.y. using Ne-21 production rate given by Reedy's systematics (person. comm.) and Hohenberg et al. (1978) at 7 g/cm². Similarly the Ne-21 based SCR exposure age for 61016 rock is found to be (1.3 ± 0.6) m.y.

Skim soil 69921 collected at station 9 represents the top 5 mm of lunar regolith. The Ne isotopic compositions, determined for etched feldspar size-separates are decomposed into trapped, GCR and SCR components using the procedures described by Bhai et al. (1978). For this soil, based on Ne-21, the SCR exposure age is calculated to be about 120 m.y. and the GCR exposure age is found to be about 300 m.y.


This work is carried out under proposal Nos. S 8172 and S 8113.
Table 1: Particle track data for Apollo 16 soil samples

<table>
<thead>
<tr>
<th>Sample no.</th>
<th>Grain-size (microns)</th>
<th>( N_H/N )</th>
<th>( \rho_0 )</th>
<th>( \rho_{\text{min}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>69921</td>
<td>40-90</td>
<td>0.83</td>
<td>100</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>90-200</td>
<td>0.8</td>
<td>100</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>200-750</td>
<td>0.9</td>
<td>100</td>
<td>16</td>
</tr>
<tr>
<td>69941</td>
<td>Bulk</td>
<td>0.77</td>
<td>75</td>
<td>2</td>
</tr>
<tr>
<td>61221</td>
<td>Bulk</td>
<td>0.12</td>
<td>6</td>
<td>1.4</td>
</tr>
</tbody>
</table>

Table 2: Elemental and isotopic composition of neon and argon in Apollo 16 soils and rocks.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Temp.</th>
<th>Neon</th>
<th>Argon</th>
<th>( 10^{-8} ) cc STP/gm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>20/22</td>
<td>21/22</td>
<td>40/36 36 36/36</td>
</tr>
<tr>
<td>69921,9</td>
<td>500°C</td>
<td>11.196</td>
<td>0.087</td>
<td>0.90 0.216 88.58 81.99</td>
</tr>
<tr>
<td>fines</td>
<td>1000°C</td>
<td>9.192</td>
<td>0.135</td>
<td>4.68 0.253 153.49 430.99</td>
</tr>
<tr>
<td>(&gt;200 micron)</td>
<td>1600°C</td>
<td>3.787</td>
<td>0.562</td>
<td>9.75 0.349 6.35 145.85</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>9.768</td>
<td>0.129</td>
<td>5.33 0.270 248.42 658.63</td>
</tr>
<tr>
<td>61016-R1</td>
<td>500°C</td>
<td>11.618</td>
<td>0.039</td>
<td>6.47 0.188 17.87 3.86</td>
</tr>
<tr>
<td>(rock)</td>
<td>1600°C</td>
<td>11.460</td>
<td>0.139</td>
<td>5.22 0.199 2.58 69.26</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>11.598</td>
<td>0.052</td>
<td>5.29 0.198 20.45 73.12</td>
</tr>
<tr>
<td>61016-R3</td>
<td>1600°C</td>
<td>3.413</td>
<td>0.647</td>
<td>526.19 0.847 0.54 0.52</td>
</tr>
<tr>
<td>(rock)</td>
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<td></td>
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