PREDOMINANT TRAPPING OF SOLAR-FLARE GASES IN LUNAR SOILS
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Assuming crystals and lithic fragments (grain-size: 100-600 μ) having high cosmic-ray track densities in their centers (>10^8 cm^-2) are solar-flare irradiated fragments (Track-Rich Fragments = TRF), then there is a correlation between the percentages of TRF and Ar^36 content for bulk soils. For each soil sample reported here, 80 to 140 fragments have been counted. Our data (underlined), and data from the literature, are shown in Fig. 1. A distinct correlation is also reported for gas-rich achondrites (straight line on the left side of Fig. 1). If one considers that the light rare gases in Pesyanoe aubrite are almost purely of solar-wind origin, it is of some interest, after appropriate corrections (median grain size, % TRF), to normalize the solar gas content of lunar soils to the maximum meteoritic values. The following ratios are obtained for a grain size of 100 μ using the data of Eberhardt et al. (1):

<table>
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<tr>
<th></th>
<th>Ne^20</th>
<th>Ar^36</th>
<th>Ar^38</th>
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<tr>
<td>10084 ilmenite/Pesyanoe</td>
<td>~21</td>
<td>~ 7</td>
<td>~ 8</td>
</tr>
<tr>
<td>10084 bulk soil/Pesyanoe</td>
<td>~23</td>
<td>~58</td>
<td>~56</td>
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We believe the largest fraction of these "excess" gases was solar-flare implanted. However, this does not explain the large Ar^36 and Ar^38 "excesses" observed in the bulk soil as compared to the ilmenite. Another process therefore must be considered in order to explain these "excess" amounts of Ar isotopes. We suggest spallation reactions with calcium as the main target by solar-flare particles and high-energy neutrons emitted by the Sun 4.0-4.6 AE ago. According to this hypothesis, the Ca-rich material of the lunar highlands was strongly irradiated. Thus a soil containing a larger fraction of highlands material shows larger "excesses" of Ar isotopes. To check this working hypothesis, we have computed the Ar^40 "excess" for a number of soils, taking into account the weighted average of their different components (2,3,4,5,6). Our own data are reported in Fig. 2, along with other data from the literature (7,8).

In the 114 fragments studied, we have been unable to find even one fragment of Luna 16 (C-119, 20-22 cm depth in the core) which was not TRF. Correspondingly, Luna 16 soil shows the largest Ar^40 "excess", although it has the lowest K content of all the soils studied to date. Conversely, 12032 and 12033 show...
the smallest fraction of TRF (3 and 17%, respectively) and the smallest amount of trapped solar gases. If it is assumed that soil 12032 has been essentially irradiated by galactic cosmic rays, then an "exposure age" of 700-800 Myr is found. For the same soil, assuming that all the Ar$^{40}$ is radiogenic in K-REEP, a bulk K-Ar age of 1.5 AE is found, whereas Pepin and Nyquist (9) have computed an age of 0.95±0.05 AE for K-REEP in 12033. Thus the lower limit (exposure age) and the highest limit (all Ar$^{40}$ is radiogenic) bracket an age of 1.2±0.4 for the impact event which formed the K-REEP fragments. This latter value (within the error limits stated) is the same as that obtained by Hartmann (10) using lunar cratering chronology for Copernicus. For Apollo 14 and 15 soils we have no rare gas data yet, except 14259 (11). In Fig. 2, we have thus assumed that the Imbrian impact (3.9 AE) governs the age of the noritic component. In such a case, our data (in Fig. 2) have to be considered as "predicted values" for the Ar$^{40}$ "excess".

It is of interest to note that Funkhouser et al. (12) in their study of Apollo 11 and 12 soils and breccias have shown that the Ar$^{40}$ "excess" follows the trend: Apollo 11 breccia (Luna 16 soil) > Apollo 11 soils > Apollo 12 soils > Apollo 12 breccia and 12033 and 12032 soils. Summarizing this sequence reflects: 1) the early intense cratering rate which produced the Apollo 11 breccia; 2) the early intense flux of solar particles (protons, neutrons) which irradiated the highlands material in which strong turnover and stirring processes must have acted; 3) the large fractions of highly irradiated highlands material contained in Luna 16 and Apollo 11 breccia and soils due to their proximity to nearby highlands.

If our hypothesis is correct, then differences in isotopic K-ratios produced by bombarding solar particles should be found in Apollo 11 breccias or in the finest grain size of Luna 16 soil. If these differences are found, then the strange mechanisms proposed to explain the so-called "excess" Ar$^{40}$ in lunar soils (1,13,14) would have to be rejected.

3) Apollo Soil Survey (1971), ibid. 12, 49.
5) Jakes et al. (1972), Earth Planet. Sci. Lett. 12, 257.
6) Wood et al. (1971), Meteoritics 6, 181.
12) Funkhouser et al. (1971), preprint.
14) Manka and Mitchel (1970), Science 169, 278.
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Fig. 1 $\text{Ar}^{36} \times 10^{-4}$ cc STP/g

Fig. 2 LUNAR SOILS (grain-size < 1mm)

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