DEPOSITIONAL AND IRRADIATIONAL HISTORY OF 15010-15011 CORE SOILS: NOBLE GASES AND FMR. D. D. Bogard,1 R. V. Morris,1 W. C. Hirsch,2 and H. V. Lauer, Jr.3 (1) NASA, Johnson Space Center, Houston, TX 77058; (2) Northrop Services, Inc., JSC, Houston, TX 77058; (3) LEMSCO, JSC, Houston, TX 77058.

The 15010-15011 double drive tube is an \( \sim \) 56 cm section of lunar regolith collected from the edge of Hadley Rill (1). An \( \text{I}_\text{g}/\text{FeO} \) profile of the first dissection level of the entire core showed that the soil varies from submature in the upper half to immature toward the bottom (2), which makes the soil in this core among the least mature of soils returned from the Apollo 15 site. The soils are primarily composed of fragments, minerals, and glasses derived from local basalts, but grain-size data, mineralogy, and chemical composition suggest that an additional, probable highland component has been admixed (3,4). Earlier interpretations of the core site suggested rapid erosion into the rill (5), from which one might expect a relatively simple irradiation history.

Twelve soil samples from various depths along the 15010/11 core were seived into various grain sizes (3) and have been analyzed by our consortium for grain size distribution and mineralogy (3), chemical composition (4), particle tracks (6), FMR, and noble gases. Here we summarize the noble gas results for these 12 samples and present \( \text{FeO} \) and \( \text{I}_\text{g}/\text{FeO} \) data obtained for soils from the core.

Figure 1 presents the depth profiles of \( \text{FeO} \) and \( \text{I}_\text{g}/\text{FeO} \) for the 15010/11 core. The large and small data points denote, respectively, the first and third dissection levels of 15011. As each dissection level is 1 cm thick, any differences in \( \text{FeO} \) and \( \text{I}_\text{g}/\text{FeO} \) presumably reflect variations in these parameters over 1-3 cm lateral distances at the core site. Comparison of concentrations of \( \text{FeO} \) between the two dissection levels shows no differences, within uncertainties. The core shows an average \( \text{FeO} \) of \( \sim \) 17.5% down to \( \sim \) 48 cm, and a value of \( \sim \) 16.5% below that depth. Values of \( \text{I}_\text{g}/\text{FeO} \) between dissection levels 1 and 3 are also similar and generally agree to within 5 units for a given depth.

Noble gas isotopic measurements were made of \(< 20, 75-90, \) and 150-250 \( \mu \)m size separates of all 12 core soils. Data for the three grain sizes of each soil were analyzed by ordinate-intercept techniques to determine the isotopic composition of the trapped solar gases and the concentrations of the cosmic ray-produced nuclides. The measured abundance of \( ^{36}\text{Ar} \) in the 75-90 \( \mu \)m fraction, the trapped \( ^{40}\text{Ar}/^{36}\text{Ar} \) ratio, and the concentrations of cosmogenic \( ^3\text{He}, \) \( ^{21}\text{Ne}, \) and \( ^{38}\text{Ar} \) are plotted in Figure 2 as a function of core depth. Abundances of solar gases in these core soils are typical of mare soils and, as expected, show a good correlation with the \( \text{I}_\text{g}/\text{FeO} \) maturity parameter. The isotopic compositions of the derived trapped component generally fall within narrow intervals which are typical of other mare soils, e.g., \( ^4\text{He}/^{3}\text{He}, \) 2510-2660; \( ^{20}\text{Ne}/^{22}\text{Ne}, \) 12.58-12.75; \( ^{36}\text{Ar}/^{38}\text{Ar}, \) 5.20-5.24. The derived trapped \( ^{40}\text{Ar}/^{36}\text{Ar} \) ratios show differences outside analytical uncertainty. The relatively smooth variation of this ratio with core depth does not conform with the variation in \( \text{I}_\text{g}/\text{FeO} \) with depth, which suggests that mixing of soil components with different \( ^{40}\text{Ar}/^{36}\text{Ar} \) rather than regolith reworking is responsible for the observed \( ^{40}\text{Ar}/^{36}\text{Ar} \) profile.

The uncertainties assigned to cosmogenic gases (Fig. 2) vary considerably and reflect the degree of nonlinearity of the ordinate-intercept plots. Cosmogenic \( ^{21}\text{Ne} \) was separately calculated for the 150-250 and 75-90 \( \mu \)m size fractions to analyze this nonlinearity. There is a tendency for \( ^{21}\text{Ne} \) to be smaller in the coarser grain sizes, which suggests that the coarser grains may have had an overall shorter irradiation time. Concentrations of cosmogenic gases show moderate but apparently erratic variations with core depth. The dotted line, which gives the approximate production profile of \( ^{21}\text{Ne} \) with depth (arbitrarily normalized to \( ^{21}\text{Ne} = 50 \times 10^{-8} \text{ cm}^3/\text{g} \) at 0 cm depth), demonstrates that the core
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has not had a simple irradiation history in its present configuration. This production profile could be made to approximately fit data for soils between \( \approx 12 \) cm and \( \approx 44 \) cm depths which were unirradiated at the time of deposition. For this irradiation model soils at \( \leq 12 \) cm and at \( \geq 44 \) cm would have been pre-irradiated before deposition. However, cosmogenic \(^{21}\)Ne for the 150-250 size separates at 22 cm depth suggests that all soils received substantial pre-irradiation before deposition and that a simple irradiation model for even the soils between \( \approx 12 \) cm and 44 cm depths is unlikely. Core lithology (1), \(^{40}\)Ar/\(^{36}\)Ar ratios, and mineralogy and chemistry (3,4) are consistent with a separate origin and history for at least a portion of the soil below 48 cm. However, the \( I_{\gamma}/FeO \) and available track data (6) do not suggest any fossil lunar surfaces in the core.

The Apollo 15 deep drill core has apparently had a long post-depositional history and has been subjected to in situ reworking by meteorite bombardment down to a depth of \( \approx 50 \) cm. This reworking can be seen as an increase in the amounts of \( I_{\gamma}/FeO \), agglutinates, solar gases, etc., nearer the surface but an apparent loss of cosmogenic \(^{21}\)Ne near the surface due to reworking (7,8). The 15010/11 core, by contrast, does not show these effects. The \( I_{\gamma}/FeO \) profile of the 15010/11 core resembles that of the deep drill below 100 cm depth. However, cosmogenic \(^{21}\)Ne in 15010/11 is substantially less than in the deep drill core and could represent a total irradiation time by cosmic rays as short as \( \approx 3 \times 10^8 \) years, depending upon irradiation depth. The available data suggest that most likely the 15010/11 core represents two or more pre-irradiated soils which were reasonably well mixed and deposited at the core site over a relatively short time interval. Either this deposition occurred a relatively short time ago, or many cm of soil have recently been stripped away from the core surface. The lack of an obvious \( I_{\gamma}/FeO \) reworking profile near the core surface would restrict either of the above events to \( \leq 10^7 \) years ago.

Fig. 2: Concentrations of cosmogenic \(^3\)He, \(^{21}\)Ne, and \(^{38}\)Ar as a function of core depth.
(units, \( 10^{-8} \) cm\(^3\)/g)
Fig. 1 (left): FeO concentrations and I_s/FeO as a function of core depth.

Fig. 2 (right): Concentrations of trapped $^{36}$Ar ($10^{-4}$ cm$^3$/g) in the 75-90 μm size fraction and trapped $^{40}$Ar/$^{36}$Ar as a function of core depth.