EVIDENCE FOR RECENT GARDENING OR DISTURBANCE IN LUNAR CORE 76001 FROM SOLAR-COSMIC-RAY RECORDS OF ^{14}C; A. J. T. Jull and S. Cloudt, NSF Arizona AMS Facility, University of Arizona, Tucson, AZ 85721.

Due to their long exposure times, lunar soils and rocks provide a continuous record of galactic (GCR) and solar-cosmic-ray (SCR) intensities. Lunar cores are very useful in studies of the production of nuclides by GCR particles in very large objects. Lunar samples also contain especially good records of SCR effects and variations of SCR fluxes in the past (1,2). Radioisotopes that have been measured and can be used to study SCR fluxes in the past range from ^{14}C, with a 5,730-yr half-life (3-5), ^{59}Ni (6), ^{41}Ca (7), ^{81}Kr (2), ^{36}Cl (8), ^{26}Al (8,9), ^{10}Be (10,11), to ^{53}Mn with a 3.7Ma half-life (8,10,11).

We used calculations of the production of ^{14}C by cosmic-ray effects on the lunar surface to Apollo 15 cores 15001-6 and 15008 using a modified Reedy-Arnold model (11). We used this model (11) for lunar GCR particle fluxes and revised cross sections for the GCR production of ^{14}C, effectively raising the GCR production rate by about 10% compared to the original paper (4,5). In order to fit the experimental data, we found that a factor of about 1.2 to 1.25 times the predicted values of the Reedy-Arnold GCR flux is required (see fig. 1). The discrepancy is almost certainly due to our lack of information on cross sections for the GCR production of ^{14}C, especially from neutrons. We found similar results in studies of lunar rock 68815 (12). In studies of rocks 12002 and 12053, Born (13) and Begemann et al (14) raised the GCR production rates of Reedy and Arnold (11) by 19% to compensate for this effect. The production rates of ^{14}C by GCR particles as a function of depth when applied to meteorites appears to agree within about 10% (10). This calculated concentration is equivalent to approx. 1.2 X 10^8 ^{14}C atoms/g sample or 30 dpm/kg, using the Reedy-Arnold model for lunar GCR particle fluxes and revised cross sections (4). The measurements of ^{14}C in the long Apollo 15 core (15001-6) indicated the expected shape of a medium-energy spallation product as a function of depth (4). The necessity to raise the GCR flux due to the apparent inability to model the ^{14}C production in lunar cores, is problematic, considering the excellent agreement to the modeling for the meteorite, Knyahinya (15).

Solar-cosmic-ray (SCR) particles are primarily protons with energies of tens to hundreds of MeV, have a range of ~1 cm in rocks. The SCR flux (J,protons/cm^2/s) can be approximated (10) as a distribution in rigidity units of the form: $dJ/dr=k \exp(-R/R_0)$, where R is the rigidity (pc/Ze) of the particles, R_o is a spectral shape parameter in MV, and k is a constant. Values of R_o in the range 70 to 100 MV are typically fitted to radioisotope data from lunar samples (2,3,5-10). Rao et al (16) have calculated values of J (for 4π irradiation and E>10MeV) of 234, 133, 102 and 84 p/cm2/s for values of Ro of 50, 70, 85 and 100MV, respectively.

Besides GCR and SCR, another possible source of ^{14}C is implanted energetic particles. Fireman et al (17) found higher than expected levels of ^{14}C in the 600-1000°C temperature fractions of the Apollo 11 soil 10084 and the Apollo 17 trench soils 73221-73261, which he interpreted as an implanted component. In a recent paper, we reported on an experiment to confirm the existence of the implanted ^{14}C component (18).

We report on new ^{14}C measurements obtained as a function of depth in the Apollo 17 drive tube core, 76001. This core was described as undisturbed by NASA documentation. The core was collected

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at a break in the slope of North Massif, on an 11° slope (19). Results are shown in the figure and compared to our earlier experimental results on the apparently undisturbed Apollo 15 cores 15001-15006 and 15008 (3). Expected SCR production rates based on best-fit values to the SCR 14C in lunar rock 68815 (12) are also shown.

The results show a disturbance of the core data in the top few g/cm^2 of this core. With one exception, samples from the top four g/cm2 show little ^{14}C above the amount expect from GCR production. Samples below about 4g/cm^2 show normal behavior. This result is similar to the observations of Nishiizumi et al. (8) of disturbances for ^{53}Mn and ^{36}Cl in core 76001. As this appears to influence several radionuclides, this is probably due to mixing of the very-surface layers of the core.

We interpret these measurements as showing that the top 2 cm of this core has been disturbed on a time scale short enough to cover the surface with soil that has <10% of the expected component of SCR ^{14}C. This event must have occurred less than 1,000 years ago, presumably from a nearby cratering event. There is some evidence of excess SCR ^{26}Al in these samples from an earlier irradiation. This argues against disturbance during collection or storage. The results from core 76001 cannot be used to estimate SCR fluxes, due to the effects observed, but show the important of an undisturbed core for such measurements.

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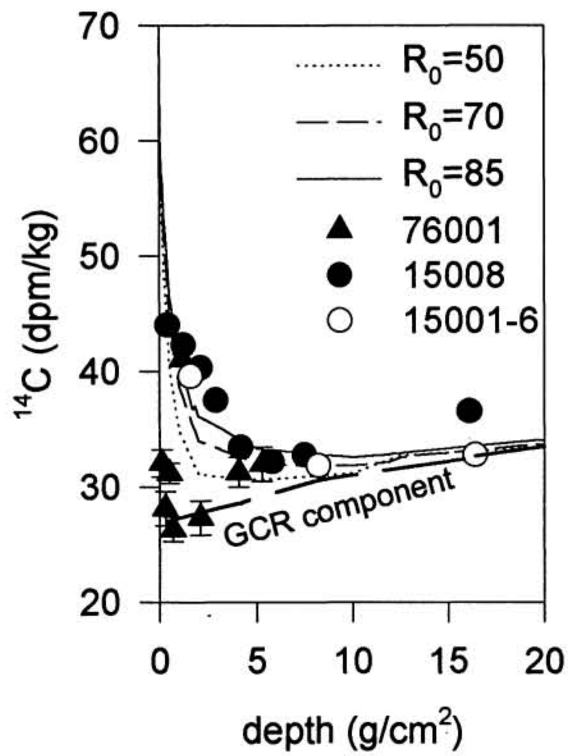

Figure 1: Depth dependence of ^{14}C in core 76001. Measurements on 76001 are shown as solid triangles. Data from Apollo 15 cores 15001-6 and 15008 [4] are shown as open and filled circles. The calculated depth dependences of SCR-produced ^{14}C for R_0=50, 70 and 85 MV are indicated as well as GCR alone.