# 14C STUDIES OF SHADOWED LUNAR SOIL AT APOLLO 17.

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**Introduction:** During the Apollo 17 mission, astronauts sampled a series of soil samples adjacent to a large boulder (5x4x3m, boulder no.4). One soil sample (76240) was sampled as it was thought to be permanently shadowed location, so the sample should be shielded from direct solar radiation [1,2]. Two samples from soils outside the permanently-shaded area were also collected (76260 and 76280). These were skim samples from a depth of up to ~2cm. A further soil 76320 was collected from the top of an adjacent boulder. These samples have recently become of renewed interest since they are in the suite of samples, indeed some small portions of 76240 were stored frozen by NASA. Our measurements were made some considerable time ago, but this is our first report of these results. We also review some related $^{14}$C results from other Apollo 17 samples.

**Permanently-shadowed soil:** Keith et al. [3] and Yokoyama et al. [4] measured $^{22}$Na in sample 76240 and found it to be apparently low in $^{22}$Na (41±3 dpm/kg) suggesting shielding by the adjacent boulder and similarly, and $^{26}$Al at 156±14 dpm/kg was less than full exposure to solar (SCR) and galactic cosmic rays (GCR). Similarly, Rancitelli et al. [5] measured a similar level of $^{26}$Al (151±6 dpm/kg), but below the expected value for a 2π exposure on the Moon if there was no shielding. However, sample 76261, which is outside the shaded area showed higher levels of $^{22}$Na but similar levels of $^{26}$Al, still below expected levels for a 2π flat surface [5]. This is due to partial shielding of the sky to GCR as well as SCR. Rancitelli et al. [5] estimated the exposure age of soil 76240 as ~0.5Ma, although measurements of the cosmogenic and track exposure ages of sample (76315) removed the boulder gave ages of ~22Ma [6,7,8].

**$^{14}$C Measurements:** We extracted the samples for cosmogenic $^{14}$C at the University of Arizona using previously reported procedures [9,10]. Briefly, samples were preheated to 500°C in air for one hour (to remove any terrestrial sources) and then placed in an alumina crucible with Fe chips as a combustion accelerant. The sample is heated in a RF furnace to melting in a flow of oxygen. The $CO_2$ is collected from the gas stream, measured volumetrically and reduced to graphite for $^{14}$C measurement by accelerator mass spectrometry (AMS). Results obtained were 14.7±0.5 dpmkg (76241,6), 22.8±0.9 dpm/kg (76261,1) and 17.4±0.5 dpmkg (76281,1). Soil 76321,105 which was taken from the top of an adjacent boulder gave 26.0±0.5 dpm/kg and soil 10084,60 for comparison was 30.1±0.7 dpm/kg.

**Discussion:** We can compare the results to the expected GCR and SCR concentrations in lunar rocks and soils [9]. An average value of about 32-33 dpm/kg $^{14}$C is expected for a soil averaging over 0-2cm (the depth of collection of these samples) and ~29 dpm/kg from GCR alone, based on scaling from levels in lunar cores, meteorites and soil 10084 [9,10]. We conclude from our results that all the three samples at station 6 are undersaturated for $^{14}$C. A simple geometric model suggests that these samples should be exposed to about 1.55 steradians (78%) of the sky. If we take a baseline of 30 dpm/kg, this would be ~49%, 76% and 58% for samples, 76241, 76261 and 76281 respectively. Our estimate for 76241 may underestimate the amount of shielding.

*Is the shaded area stable?* We also undertook a simple geometric calculation of the stability of the "shaded area". We determined that the shadowed area should not move by than about 17cm over the time of precession of the lunar orbit, so the shaded area shouldn't reach 76261 (see picture in [1]). Hence, the area should be extremely stable as a recorder of lunar shaded temperatures as proposed by Durrani et al. [2]. Further studies on other cosmogenic nuclides will be useful to better understand the exposure history of these and other similar samples.

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**References:** [1] Meyer C. (2009) 76240 Shadowed Soil. Lunar Sample Compendium. http://curator.jsc.nasa.gov/lunar/lsc/76240.pdf. [2] Durrani S. A. et al. (1976) Proc. Lunar Sci. Conf. 7th. 1157-1172. [3] Keith J.E. et al. (1974) Proc. Lunar Sci. Conf. 5th p.2121-2138. [4] Yokyoyama Y. et al. (1974) Proc. Lunar Planet. Sci. Conf 4th. p. 2209-2227. [5] Rancitelli L. A. et al. (1974) Proc. Lunar Sci. Conf. 5th. p. 2185-2203. [6] Meyer C. (2008) Impact Melt Breccia 76315. Lunar Sample Compendium. http://curator.jsc.nasa.gov/lunar/lsc/76315.pdf. [7] Crozaz G. et al. 1974. Proc. Lunar Sci. Conf. 5th. p. 2475-2499. [8] Arvidson R. et al. (1975) The Moon 13: 259-276. [9] Jull A. J. T. et al. (1998) Geochim. Cosmochim. Acta 62, 3025-3036. [10] Jull A. J. T. et al. (2010) Meteorit. Planet. Sci. 45, 1271-1283.