RECENT HISTORIES OF LUNAR CORES 15009 AND 79002/1 USING COSMOGENIC RADIONUCLIDES ^{10}Be, ^{26}Al, and ^{36}Cl; K. Nishiizumi[1], R. C. Finkel[2], M. W. Caffee[2], P. Sharma[3], J. Masarik[4], R. C. Reedy[4], and J. R. Arnold[5] ; [1] Space Sciences Laboratory, University of California, Berkeley, CA 94720; [2] CAMS, Lawrence Livermore National Lab, Livermore, CA 94551; [3] NSRL, University of Rochester, Rochester, NY 14627; [4] NIS-2, Los Alamos National Lab, Los Alamos, NM 87545; [5] Department of Chemistry, University of California, San Diego, La Jolla, CA 92093.

We report here new results on the content of ^{10}Be ($t_{1/2}$ = 1.5x10^6 years), ^{26}Al (7.1x10^5 years), and ^{36}Cl (3.0x10^5 years) in bulk fines from lunar cores 15009 and 79002/1. These results allow us to deduce likely gardening and irradiation histories in the million year time scale for these two cores. The new results add to the database earlier summarized and discussed by Langevin et al [1] for lunar regolith gardening history. Although the ^{53}Mn ($t_{1/2}$ = 3.7x10^6 years) profiles for these cores have not yet been measured, we do report ^{10}Be profiles for these two cores. The ^{10}Be profile is expected to be less sensitive to surface gardening due to the lack of SCR (Solar Cosmic Ray) production of ^{10}Be as shown by measurements in lunar surface rock 68815 [2]. However, ^{10}Be is also a useful nuclide for understanding lunar surface mixing histories, as shown below.

The results reported here for ^{10}Be, ^{26}Al, and ^{36}Cl are plotted in Figure 1 and 2 along with theoretical GCR (Galactic Cosmic Ray - dashed lines in the figures) and the sum of GCR and SCR production profiles (solid lines). The GCR profiles were calculated using the Reedy-Arnold model [3] with the most recent cross section data. The SCR parameters, R_0 = 85 MV and J (>10 MeV) = 110 proton/cm^2·s·4π [2] are used for the following discussion. These theoretical profiles are based on the average chemical composition of the 13 samples in each core. All AMS measurements were performed at Lawrence Livermore National Lab except ^{36}Cl in 79002/1, which were measured at the University of Rochester. The error bars indicate only the AMS error (1σ) and do not include chemical analysis error (2-4 %). Our interpretation of the core histories is as follows:

15009: The Apollo 15 single drive core 15009 was collected from the north rim of a 12 m diameter crater at station 6. The surface into which the core was driven is littered with angular fragments on the order of 0.5 to 2 cm and smaller [4]. The bulk density of 15009 is 1.58 g/cm^3 after extrusion. The modal abundance of agglutinates in the core indicates that the core soils are submature [5]. The ^{10}Be profile is in good agreement with the Reedy-Arnold GCR profile and shows no SCR contribution, as expected. Although ^{26}Al and ^{36}Cl profiles show clear SCR effects, the activities actually decrease toward the surface above 2 cm depth. This effect, often observed in lunar cores, is not yet understood. The sum of SCR produced ^{26}Al above 5 cm (7.9 g/cm^2) is only 75 % of the predicted value from Reedy-Arnold calculation. The ^{26}Al profile is similar to that of 74002, which was collected from the rim of Shorty Crater and is reported to have lost ~2 cm from the top of the core [6]. Unfortunately, decay made it impossible to measure a ^{22}Na profile in 15009 to check for the recent loss of core-top material. It is also worth noting that a void was observed in the first dissection of core extending from the surface to nearly 9 cm (Core Synopsis-15009). Although there is legitimate concern that loss or disturbance of the upper several cm could be a problem it is nevertheless difficult to explain the detailed profiles by simple loss of surface material. The measured SCR produced ^{36}Cl is higher than the calculated profile however the Reedy-Arnold calculation underestimates production of ^{36}Cl due to the lack of low energy proton cross section data [7].

79002/1: The Apollo 17 double drive core 79002/79001 was collected at station 9, which is approximately 70 m southeast and downslope from the rim of a 90 m diameter Van Serg Crater. The upper portion of the core was predicted to represent ejecta from Van Serg Crater [8]. The bulk density of 79002 (surface - 17.4 cm depth) is 1.76 g/cm^3 and 79001 (17.4 - 46.7 cm) is 1.90 g/cm^3 after extrusion. The core has a distinct dark-light boundary inclined 25-30° from 8.5 (15) to 11 cm (19 g/cm^2) below the surface. The Is/FeO surface exposure index [9] and the agglutinate abundance [10] shows a distinct break at the light-dark boundary. The sample above the boundary (dark) indicates the most mature regolith and the sample below the boundary (light) indicates submature regolith. The upper dark sample is a mixture of highly mature soil, which is indicative of a long gardening time at the surface, and extremely coarse material which indicates a younger regolith [10]. Since ^{26}Al and ^{36}Cl profiles clearly show SCR production, the surface samples were essentially undisturbed for times on the order of a million year. Low ^{10}Be concentrations above 40 g/cm^2 are apparently due to the under saturation of this nuclide. The ^{10}Be exposure time (deposition time) is calculated to be 2.6±0.4 My for the upper dark sample and over 3.6 My for the lower light sample. If the upper sample is Van Serg Crater ejecta, the crater-forming event occurred 2.6±0.4 My ago. The ^{10}Be concentration beneath the boundary, which might be the original surface 2.6 My ago, is still under saturated compared to the Reedy-Arnold GCR profile. The soil between 20 and 50 g/cm^2 may have been deposited only a few My prior to Van Serg Crater event. However, the age estimate has a large error due to short half-life of ^{10}Be compared to the age of the event. Measurements of ^{53}Mn, in progress, will further constrain the deposition scenario. Yokoyama et al [11] estimated the Van Serg Crater event as 1.6±0.5 My based on ^{26}Al concentration in

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trench soil 79221 (130±7 dpm/kg - 0-2 cm depth) [12]. This age is an underestimate due to the surface gardening effect. SCR produced ^{26}Al above 13 g/cm^2 is ~20 % in excess over the steady state profile. If we adopted a 2.6 My deposition age, the excess is ~30 %. The excess and disturbed depth are near the average of other cores [1]. After normalizing to the average chemical composition, the ^{36}Cl profile below 30 g/cm^2 smoothly decreases with increasing depth but is ~5 % higher than the Reedy-Arnold GCR profile. Again ^{36}Cl production near surface is much higher than predicted.

References: [1] Langevin Y. *et al.* (1982) *JGR, 87*, 6681; [2] Nishiizumi K. *et al.* (1988) *Proc. LPSC, 18*, 79; [3] Reedy R.C. and Arnold J.R. (1972) *JGR, 77*, 537; [4] Swann G.A. *et al.* (1971) *US Geol. Survey Interagency Rep. 36*; [5] Basu A. *et al.* (1991) *Proc. LPSC, 21*, 221; [6] Fruchter J.S. *et al.* (1978) *Proc. LPSC, 9*, 2019; [7] Nishiizumi K. *et al.* (1991) *LPSC, XXII*, 979; [8] *Apollo 17 Prelim. Sci. Rep.* (1973); [9] Morris R.V. *et al.* (1989) *Proc. LPSC, 19*, 269; [10] McKay D.S. *et al.* (1988) *LPSC, XIX*, 758; [11] Yokoyama Y. *et al.* (1975) *Proc. LSC, 6*, 1823; [12] O'Kelley G.D. *et al.* (1974) *Proc. LSC, 5*, 2139.

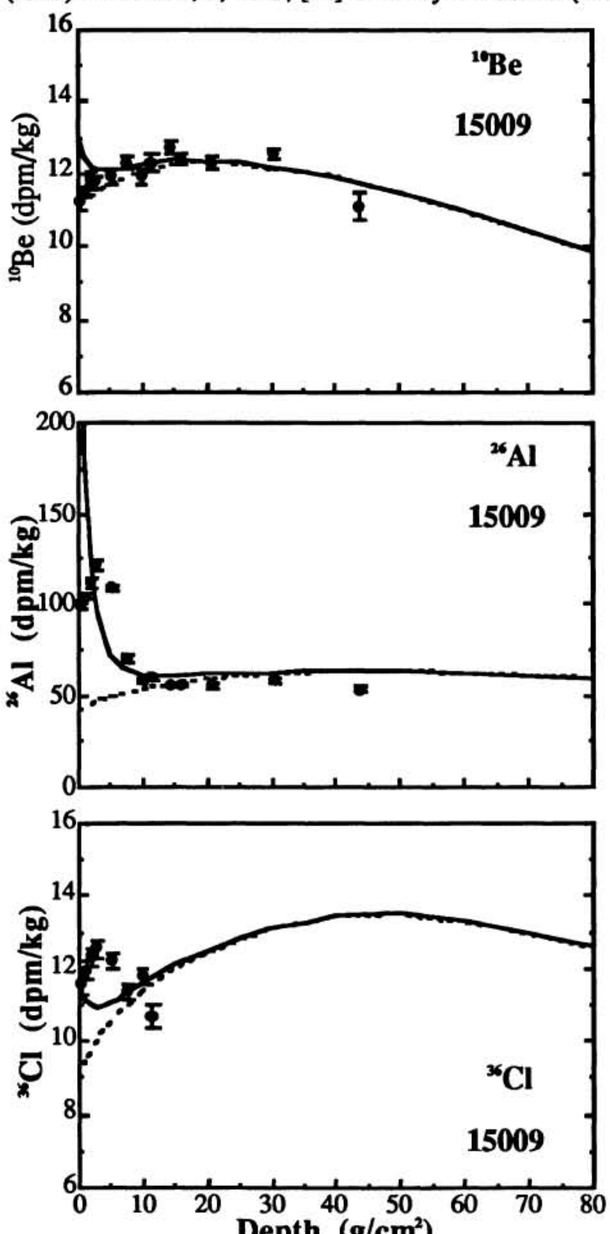

Figure 1. ^{10}Be, ^{26}Al, and ^{36}Cl in 15009

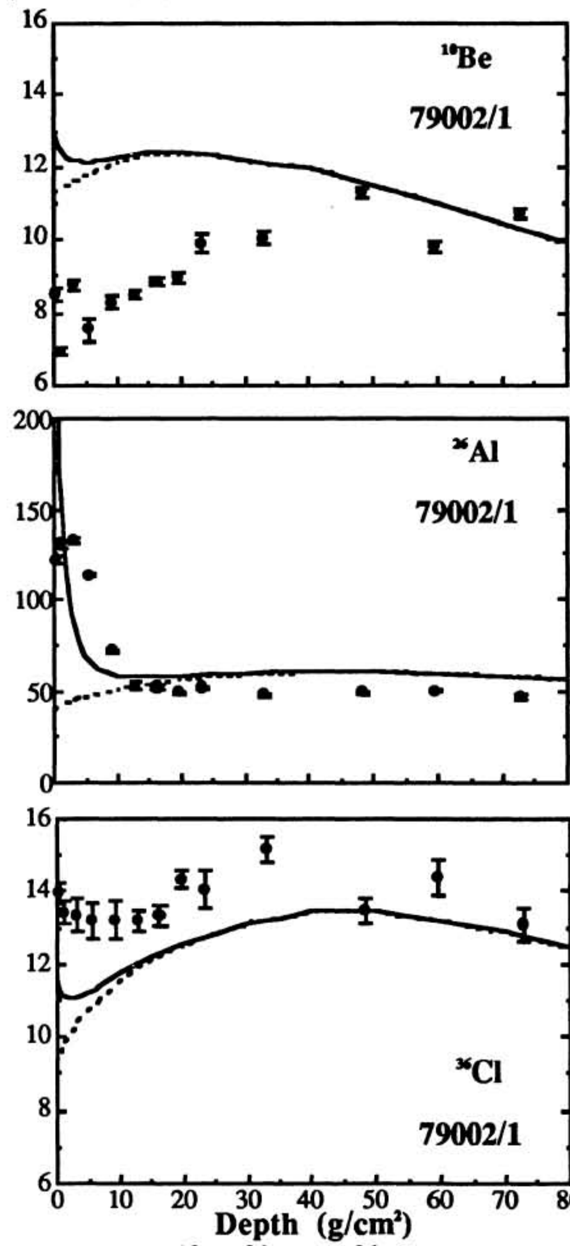

Figure 2. ^{10}Be, ^{26}Al, and ^{36}Cl in 79002/1