# THE Fe-Al RELATION OF LUNAR SOILS AND ORBITAL CHEMICAL DATA: IMPLICATIONS FOR Al ABUNDANCES ESTIMATED FROM APOLLO ORBITAL GAMMA-RAY DATA.

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Several studies have noted that there is an almost perfect, linear inverse correlation between the Al and Fe concentrations in lunar samples [1,2]. This relation has been informally used by workers attempting to estimate regional Al concentrations from orbital gamma-ray Fe data for areas of the Moon where no X-ray Al coverage exists [e.g., 3]. In this study, we systematically examine both lunar samples and orbital data (where X-ray and gamma-ray coverage overlap) to quantitatively evaluate the Fe-Al relation and apply these results to the complete Apollo Fe gamma-ray dataset. Our aims are both to produce a "synthetic" Al concentration map of the lunar surface from the gamma-ray Fe data and to refine the estimate of global crustal Al abundance as a possible test of crustal origin mechanisms [e.g., 4].

The Fe-Al relation of lunar samples. Because the orbital sensors flown on the Apollo 15 and 16 spacecraft analyzed regolith, we have restricted our sample dataset to lunar soils (all published data, partly summarized in [5]) and two lunar meteorites ALHA 81005 and Y 791197 (both regolith breccias, included because they appear to represent portions of the Moon chemically different from the Apollo and Luna sites [6]). The Fe-Al relation for lunar soils is shown in Fig. 1; the near-perfect inverse relation is readily apparent. A linear least-squares fit to the data of Fig. 1 gives the following result:

$$\text{Al (wt.\%)} = -0.850\ \text{Fe (wt.\%)} + 17.4$$
$$r^2 = 0.960$$

Transformation of the data into semi-log space only slightly improves the correlation ($r^2$ = 0.979) and for this effort, we prefer to use a simple linear fit. This result may be compared with the previous result of [2], where Al = -0.746 Fe + 16.0; that study not only was based primarily on rock data (n=69 for regression analysis), but it also deliberately excluded Apollo 16 samples that fell well above the regression line [2]. Our analysis is restricted to materials representative of those analyzed from orbit, includes a larger database (n=148), and the regression line is derived from all samples analyzed to date.

Fe-Al relation for orbital X-ray and gamma-ray data. We have analyzed the available Apollo orbital chemical data [7] to determine the Fe-Al relation. This analysis is based on the 9% of the lunar surface covered by both X-ray (Al/Si ratio) and gamma-ray (Fe) data. The Al/Si image was first filtered to an effective surface resolution of about 100 km, comparable to the Fe data. We converted the Al/Si data into Al concentrations by assuming a constant Si value of 21 wt.% [8] (the average Si content of lunar soils (mean ± one sigma) in our database is 21.052 ± 1.008 wt.%). Each pixel value in the resulting Al (from X-ray) and Fe (from gamma-ray) images are plotted in Fig. 2. The inverse correlation appears to be not as "clean" as that for the sample data; however, the broad trend mimics a linear inverse correlation. The best-fit line for these data is as follows:

$$\text{Al (wt.\%)} = -0.711\ \text{Fe (wt.\%)} + 15.7$$
$$r^2 = 0.555$$

Numerous subtrends are evident in this plot (Fig. 2), similar to those found in our previous efforts to produce petrologic maps of the Moon [9,10]; we believe this reflects at least in part the presence of unsampled lunar compositions that contribute to mixing relations on the lunar surface. We applied the best-fit lines derived from both sample and orbital data analysis to make synthetic maps of Al concentrations for areas of the Moon represented by the Apollo gamma-ray groundtracks. These results were then compared with the original Al X-ray map both to estimate the magnitude of errors and to determine where the best-fit relations do not hold up.

Al concentrations estimated from Apollo orbital Fe data. Using the best-fit line determined from sample data, the range of Al concentrations on the Moon is 4.7 to 17.3 wt.% with a global mean of 12.1 ± 2.6 wt.%. Comparable results using the best-fit equation from the orbital data are a range of 5.1 to 15.6 wt.% and a global mean of 11.3 ± 2.2 wt.%. Comparison of the two synthetic Al maps with the X-ray Al map of the eastern limb area shows that mare regions display the least difference between the two datasets (values agree within 2 wt.%); greatest differences occur in some highlands regions, particularly the areas around the Crisium and Smythii basin rims. We attribute this effect as largely reflecting the fact that errors associated with the orbital Fe data are lowest where Fe concentrations are highest; thus, in the synthetic Al map, values are most accurate in the maria and less so in highlands regions. We have used these synthetic Al maps to estimate the average Al concentration of only highlands areas; results indicate average Al values of 12.3 ± 1.6 wt.% (determined from orbital data) to 13.3 ± 1.9 wt.% (determined from the sample best-fit). Our previous estimate of Al in the highlands [4], based on petrologic mapping from orbital chemical data [9,10], is 14.3 ± 1.0 wt.%. As previously discussed [4], we believe these values suggest that the lunar crust is too aluminous to have originated purely by a "serial magmatism" mechanism [e.g., 11] and they tend to support models calling for global plagioclase fractionation early in lunar history (recently summarized in [12]).

References. [1] Janghorbani, M., et al. (1973) PLSC 4, 1115. [2] Miller, M., et al. (1974) PLSC 5, 1079. [3] Spudis, P. et al. (1984) PLPSC 15, JGR 89, C197. [4] Spudis, P. and Davis, P. (1986) PLPSC 17, JGR 91, E84. [5] Morris, R. et al. (1983) NASA JSC 19069. [6] GRL Special issue (1983) 10, 773. [7] La Jolla Consortium (1977) PLSC 8, frontispiece. [8] Bielefeld, M. (1977) PLSC 8, 1131. [9] Davis, P. and Spudis P. (1985) PLPSC 15, JGR 90, D61. [10] Davis P. and Spudis, P. (1987) PLPSC 17, JGR 92, E387. [11] Walker, D. (1983) PLPSC 14, JGR 88, B17. [12] Warren P. (1985) Ann. Rev. Earth Planet. Sci. 13, 201.

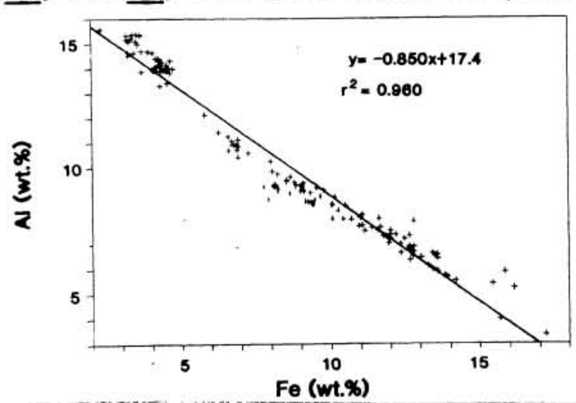


Figure 1. Fe-Al relation of lunar soils. Results of regression analysis shown. Source: all published chemical data.

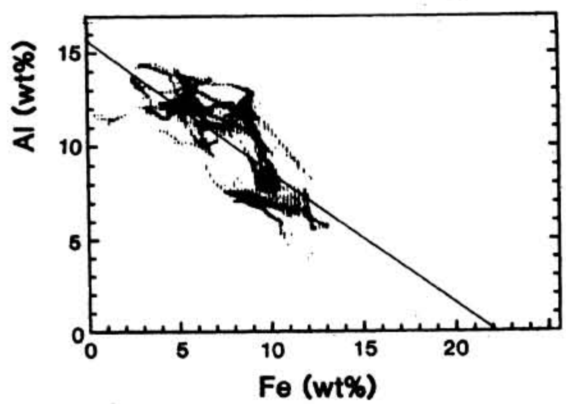


Figure 2. Pixel plot (1/4 degree) of orbital X-ray (Al) and gamma-ray (Fe) data on the lunar eastern limb. Results of regression analysis shown.