SOLAR CORRECTIONS FOR THE APOLLO ORBITAL X-RAY FLUORESCENCE DATA.
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Theoretical calculations made prior to the Apollo missions show that the relative intensities of AlKα, MgKα, and SiKα emitted from the Moon should depend upon the energy spectrum of the fluorescing solar X-ray flux, as well as the content of Al, Si, and Mg in the lunar surface (1). It was also expected that the energy spectrum of the solar X-ray flux would harden (increase the ratio of high to low energy X-rays) when the total intensity increases. This effect was qualitatively found by the Apollo 15 orbital X-ray experiment (2). Thorough utilization of these data requires that effects caused by changes of solar X-ray spectrum be removed. We have developed a method to measure this effect and to remove the systematic errors caused by it. This method requires only information provided by the orbital X-ray experiment, and two basic assumptions that are valid over the thousands of hectares viewed by the detectors: (1) the concentration of Si in lunar soils is nearly a constant; and (2) the lunar regolith is nearly uniform in physical state, especially particle size. Both assumptions are extensively supported by other data, especially by the lunar sample data. The requirements of this method are: (1) a description of the variation in intensity vs. longitude of the X-ray flux coming from the Moon; and (2) an area of the Moon, crossed by many orbits, that has a surface of approximately constant chemical composition. In Figure 1 we have plotted five orbits of Apollo 16 data to show the consistent manner in which the X-ray flux from the Moon can vary as the spacecraft passes from terminator to solar maximum point (SMP) to terminator. These orbits also show the lack of influence that mare/highland differences have on the SiKα data. Orbits 8 and 9 encounter eastern Mare Fecunditatis at quite different delta longitude than do orbits 55, 56, and 58. The solar maximum point (SMP) is defined as the point during an orbit when the spacecraft's ground track most closely approaches the subsolar point on the lunar surface. The SMP and subsolar points approach to within less than 10°. For our purposes, this variation is well described by the equation $I = I_0 \cos^{1.66} \theta$, where $I_0$ is the SMP intensity and $\theta$ is the difference in longitude between the SMP and any other point between the SMP and the terminators. The Apollo 15 data (Figure 2) do not show the consistent symmetrical relationship seen in the Apollo 16 data, and the maximum intensity is often some distance away from the SMP. Simple inspection of the Apollo 15 and 16 data shows that the greater variability in the Apollo 15 data is due to variability in the solar X-ray flux, and not to chemical or physical variability of the Moon or to Sun-Moon-detector geometry. Because of this variability, we have used the Apollo 15 data to derive an empirical relationship between a measured X-ray intensity ratio (e.g., Mg/Si) and the intensity of the fluorescing solar X-ray flux. To do this, we choose a 5° x 5° area in Mare Serenitatis that was covered by many Apollo 15 orbits and plot the average measured intensity ratio vs. our index of the solar X-ray intensity (SII). SII (Solar Intensity Index) is defined as the characteristic Si X-ray flux from the Moon divided by the standard intensity given by the equation in Figure 1, where the Si X-ray flux is the value calculated from the orbital X-ray measurements. Well-defined relationships of measured Al/Si, Mg/Si, and Al/Mg intensity ratio to SII are found. Figure 3 shows this relationship for Mg/Si. We note that, as
expected, the intensity ratio changes much more slowly than the absolute intensity. If this were not true, the orbital X-ray experiment could not have produced the valuable results that it has (3). From this observation, we may also conclude that known variations in Si concentrations and the physical state of the lunar regolith have little effect on the measured Si X-ray signals. Furthermore, each causes less than a ±15% error (4) in the measured Si X-ray values. The chemical mass absorption for SiKα radiation is nearly constant over a wide range of lunar compositions (4). We also conclude that variations in the chemical mass absorption coefficient for the fluorescing solar X-radiation have only a minor effect. The empirical relationships found between SII and intensity ratios are those expected from theoretical calculations (1) stating that increased intensity of solar X-rays results in decreased intensity ratios for Al/Si and Mg/Si and increased intensity ratios for Al/Mg. The data shown in Figure 3, and also the Al/Si data, suggest that the relationship of SII to the solar X-ray energy spectrum is not constant. Orbit 23 contains a period of extremely intense emission of solar X-rays and seems to separate the data shown into two groups: those before and including orbit 23, and those after orbit 23. The line shown is a least squares fit using data for orbits 27 to 42.

Using this tool, we can now remove the effects of variation in solar X-ray activity from Apollo 15 orbits 16 through 42. This empirical relationship is not known, at the time that this was written, to be valid for any other Apollo 15 data or any Apollo 16 data, although the same process can be applied to other data. This method of making solar corrections is essentially the one that will be used with the X-ray experiment on the proposed Lunar Polar Orbiter, with the important differences that the area on the lunar surface will be replaced by a ceramic target on the spacecraft (5) and no corrections for phase angle will be necessary. We routinely apply this method to all relevant orbital X-ray data from Apollo 15, and it consistently produces substantial improvements in the orbit-to-orbit reproducibility of the intensity ratios.

**FIGURE 1.**

![Data System](image)
References:
(5) Orbital X-ray Fluorescence Experiment Proposal for the Lunar Polar Orbiter P.I., Dr. Jacob Trombka.