

ANALYSIS OF PHOBOS MISSION GAMMA-RAY SPECTRA FROM MARS:TWO APPROACHES J.I. Trombka, L.G. Evans*, R. Starr**, S.R. Floyd; NASA Goddard Space Flight Center, Greenbelt, MD, USA; S.W. Squyres, J.T. Whelan; Cornell University, Ithaca, NY, USA; G.J. Bamford, R.L. Coldwell, A.C. Rester; University of Florida, Gainesville, FL, USA; Yu.A. Surkov, L.P. Moskaleva, V.P. Kharyukova, O.S. Manvelyan, S. Ye. Zaitseva, G.G. Smirnov; Vernadsky Institute of Geochemistry and Analytical Chemistry; Moscow, USSR

An important aspect of the investigation of planetary evolution is the determination of the chemical composition of the surface of planets, comets and asteroids. Remote sensing gamma-ray spectrometers can be used to obtain information on the global elemental composition of condensed matter in the solar system. Significant results have already been obtained with such instruments flown on a number of spaceflight missions of the USSR and the USA. These missions include the Luna 10, Mars 5, and Phobos 2 of the USSR and the Apollo 15 and 16 missions of the USA. The present study is focused on data acquired with the CsI gamma-ray spectrometer on the Phobos 2 mission and analyzed with independent methods by groups in the USSR and USA. Preliminary results are in general agreement on the percentage contribution of five key elements to the composition of the Martian surface. The elements are associated with the most intense gamma-ray emissions expected from the Martian surface.

The analytical method used by the Soviet group can be described briefly as follows. Gamma-ray pulse height spectra obtained at large distances from Mars are used as the background spectrum, including such effects as natural and induced radioactivity in the spacecraft and the spectrometer, the diffuse cosmic-ray background and the cosmic-ray proton interactions in the detector. The gamma-ray spectrum near the planetary surface includes the spectrum from the Martian surface and the background. The difference between spectra near Mars and far from Mars is taken to be the spectrum from the planetary surface. The planetary emission spectrum consists of two components, a discrete line component and a continuum. To convert the measured spectrum to elemental composition, one constructs "elemental response functions" for all the major elements expected to appear in the spectrum. Each monoelemental response function includes such factors as all expected line emissions for the element, the detector efficiency including photopeak, Compton and pair production contributions, and a conversion factor which relates gamma-ray flux to percentage of elemental composition. The continuum is assumed to have a power law shape. It is determined and then subtracted from the planetary spectrum, yielding the discrete line spectrum. The monoelemental response functions are then used to convert the discrete line pulse height spectrum to estimated elemental composition.

Working independently, the US group defined an "off Mars" background spectrum and an "on Mars" background-plus-signal spectrum in the same manner as above. The code ROBFIT was used to fit both the continuum and the discrete lines simultaneously. The differences between the discrete line intensities in the "on Mars" and "off Mars" spectra were then converted into gamma-ray line fluxes emitted from the Martian surface. Theoretical factors (assuming 0% H content) for the conversion of fluxes of dominant lines characteristic of O, Si, K, Fe and Th were then used to infer the relative contribution of each element to the surface composition of the planet.

Preliminary results obtained with the two methods are presented in the table. Results are shown for two sets of spectral accumulation intervals: orbit 4 (PC4), spectra 2-3, and orbit 3 (PC3), spectra 11-14. The accumulation intervals chosen are those closest to the planet, where the ratio of martian signal to the spacecraft background is maximized.

The accumulation from PC4 are centered over the central Valles Marineris, while those from PC3 are centered slightly further to the east, but cover a broader range of longitudes and hence include a greater proportion of Tharsis volcanics. We have convolved footprint maps of the gamma-ray response with a digital geologic map of Mars to determine the percentage contribution of each major geologic unit on the planet to the spectra. In PC4, the major contributors are ancient highlands 53%, Hesperian plains 27%, channel and canyon materials 17%, Tharsis volcanics 2%, and others 1%. In PC3, the breakdown is ancient highlands 44%, Hesperian plains 25%, channel and canyon materials 9%, Tharsis volcanics 21%, and others 1%.

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The chemical compositions found in the table are plausible in some regards, but also hold some surprises. For O, Fe, and K the results from the two techniques are effectively the same within the statistical error limits. Si and Th results are less clearly consistent, though the error limits still overlap. The compositions obtained are generally reasonable for a geologic material: They are highest in O and Si, with significant Fe, a small amount of K, and trace Th. The reasonable nature of the numbers and the similarity of the values obtained by the two very different data analysis techniques give us hope that we may be obtaining some meaningful results.

The concentrations of O are consistent with expectations for silicate materials, but otherwise provide no particularly useful geochemical information. Si concentrations are rather different for the two techniques. The Soviet Si concentrations agree well with the Viking result of 21.5%, while the US values are lower. In fact, while the US 1-sigma maxima for Si are reasonable, the nominal values of 11% and 15% are too low for any plausible silicate material. The Si results therefore are also of somewhat questionable geochemical usefulness.

Fe concentration, as obtained using both techniques, are lower than the Viking value of 13.5%. They are also substantially lower than the Fe concentration in SNC meteorites, but are closer to what is more typically found for terrestrial mafic rocks. In fact, the Fe concentration would be lower if the H₂O concentration in the soil was not so low. This could imply that the martian surface materials in this region are comparatively dry. Neither technique allowed detection of H from the surface, but the absence of a net H signal places an upper limit on H₂O concentration (<4.5% H₂O) that is not useful in this regard.

Viking only put an upper limit of about 0.25% on the K concentration in martian soil. Our values are close to that limit, and substantially exceed values typical for SNC meteorites. Low-temperature weathering reactions on Mars might be expected to fractionate K from other lithophiles and concentrate it in the soil, however, so an enhancement over SNC rock values is not necessarily unexpected. The biggest surprise is Th, which at several ppm would exceed typical values for SNC meteorites by more than an order of magnitude. Our ratio of the incompatible elements K/Th is approximately 1000, which is (within our large error limits) comparable to values for the lunar crust and several times smaller than those typical for SNC's. Such a low K/Th value, if it were shown to be correct, might imply that Mars is a more volatile-poor body than is generally believed.

Finally, there are no clearly significant differences between the compositions obtained for PC3 and PC4. The strongest candidate for a difference is Fe, which in the US data appears higher in concentration in PC3 than in PC4. The primary geologic difference between PC3 and PC4 is that PC3 contains a greater proportion of Tharsis materials. Tharsis is probably a region of mafic volcanism, and an enhanced Fe concentration there would be consistent with a more mafic composition. Alternatively, Viking thermal inertia data suggest that Tharsis has a comparatively high concentration of wind-blown dust, which Viking results have shown to be Fe rich.

TABLE - PERCENT COMPOSITION by MASS

Element	PC3		PC4	
	USSR ¹	USA ²	USSR ¹	USA ²
O	48 (5)	40 (18)	46 (4)	54 (27)
Si	19 (4)	11 (6)	20 (3)	15 (7)
Fe	9 (3)	10 (4)	8 (4)	4 (7)
K	0.3 (.1)	0.2 (0.15)	0.4 (0.1)	0.3 (.2)
Th	1.9 (.6)ppm	3.1 (1.3)ppm	2.0 (0.4) ppm	2.2 (1.0)ppm

1. Since the response function for the total gamma-ray emission is used for the calculation of statistical errors, the USSR statistical errors should be smaller than those of the US analysis.

2. Based on single photopeaks

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