(iv) lag gravel, and (v) bare rock. Viking 1 successfully landed at a place that has all of these models—a credit to the engineers who designed and built the spacecraft. These materials combine to produce a scientifically interesting site.

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3. "Soil," as used in this report, refers to the relatively fine-grained near-surface materials of Mars that have been deformed as a result of the landing of the spacecraft and which have been acquired by the collector head. Large objects about 2 cm and larger that obviously have large cohesion are termed rocks, fragments, and blocks. The word "sample" usually indicates that which was analyzed by the three active soil analysis experiments: biology, GCMS, and XRFS. Note that GCMS-2 was not analyzed, so that GCMS-3 was the second sample analyzed by the GCMS experiment. The word "acquisition" usually refers to the process of obtaining soil.
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17. We acknowledge the continued aid and support given to the physical properties team by the surface sampler team. The lander imaging team kindly furnished the images used in this report. The wind velocity and direction were kindly provided by the meteorology team. The help of Drs. H. Zimmer and G. Neukum during the acquisition of data is appreciated. We also thank I. M. Mack for her assistance as the physical properties intern during the month of August. We thank Dr. E. C. Morris for his continuing assistance during the Viking 1 mission and for review of the manuscript. We also thank A. Castro and V. Gillespie for their additional support. We acknowledge the help and assistance of S. Dwornik, particularly at the beginning of the project when the physical properties investigation first started. Supported by the National Aeronautics and Space Administration.

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Viking Orbital Colorimetric Images of Mars: Preliminary Results

Abstract. *Color reconstruction and ratios of orbital images of Mars confirm Earth-based measurements showing red/violet ratios for bright areas to be roughly 1.5 times greater than dark areas. The new results show complex variation among dark materials; dark streaks emanating from craters in southern cratered terrains are much bluer than dark materials of the north equatorial plains on which Viking 1 landed.*

The use of color in distinguishing geologic materials is applied universally at various levels. Methods vary from visual inspection, the most common, to precise measurements of spectral reflectance. During the last several years, multispectral digital imaging systems have been developed and used both in Earth-based and spacecraft programs to study and map spectral reflectivity variations on Earth, the moon, and Mercury (*1*). These systems, far more sensitive to color variation than the human eye, provide images in which the subtle color variations are related in spatial context to the regional geologic patterns and morphology. In the case of the moon, they have proved precise indicators of surface mineralogy (*2*). The Viking orbiter imaging systems have provided, for the first time, data of this nature for Mars, the most colorful of our neighboring terrestrial planets.

Spectrophotometric measurements of the reflectivity of Mars (0.3 to 2.5 μm) made from ground-based telescopes (*3*) have shown that the spectral reflectance curves of bright and dark areas are broadly separable into two types, showing different form and absorption features. Both bright and dark areas are extremely red, showing an abrupt rise in geometric albedo from 5 percent in the blue-ultraviolet to 15 to 30 percent in the red, with bright areas showing the higher red reflectance. The strong ultraviolet-blue absorption has been attributed to several percent ferric oxide in the soils (*4*). In contrast to bright areas, the dark regions display a broad absorption feature between 0.7 and 1.1 μm (*3*), which has been suggested as Fe^{2+} absorption (*5*). The mutual occurrence of Fe^{2+} and Fe^{3+} features are indicative of a thin alteration zone (< 1 μm). Further, aeolian abrasion is probably removed and disperses these thin alteration layers, exposing fresh ferrosilicate in the dark areas and depositing the fine altered material elsewhere (*4*). Although the Viking orbiter cameras have lower spectral coverage and resolution, their much higher spatial resolution allows an examination of the local geologic setting for each of the spectral types (*6*). In addition, from orbital resolution it has proved possible to recognize a greater diversity of spectral types, occurring as units too small to resolve from the earth. Finally, by comparison with surface geochemical measurements at the landing site, the orbital data provide a regional context for materials that occur there.

The Viking orbiter vidicon cameras are equipped with an array of filters covering the visible spectrum from 0.35 to 0.65 μm. Three-color images are acquired using the violet, green, and red filters (0.45 ± 0.02 μm, 0.53 ± 0.04 μm, and 0.59 ± 0.03 μm). Color scenes can be reconstructed by photometrically correcting and balancing such images to synthesize blue, green, and red components. By acquiring multiple arrays of frames in each filter, three-color mosaics are built up covering large regions. The cover illustration (this issue) is an example in which 15 frames were shuttered (five in each of the three colors). The frames were acquired over a period of about 5 minutes near apoapsis at a range of about 32,500 km to minimize variations in viewing and lighting angles < 1° among the color components.

Digital processing involved (i) removing variations in sensitivity across the fields of view to generate linear intensity scales for each frame, (ii) balancing spectral response variations between the two cameras aboard the Viking I orbiter spacecraft, (iii) dividing each frame by a model photometric function to suppress the enormous brightness variations across and between frames due to differences in solar illumination angle, and (iv) computer mosaicking each of the three sets of five images. Figure 1 shows the result of this process for the five red frames. Knowledge of the spectral reflectance curve for Mars (3) was then used to balance the three color components. These were then composited to generate the natural color version displayed on the cover of this issue.

Figure 1 has been processed to preserve as precisely as possible the relative albedo or spectral reflectance in the red band. Additional techniques can be used to bring out the rich detail contained in

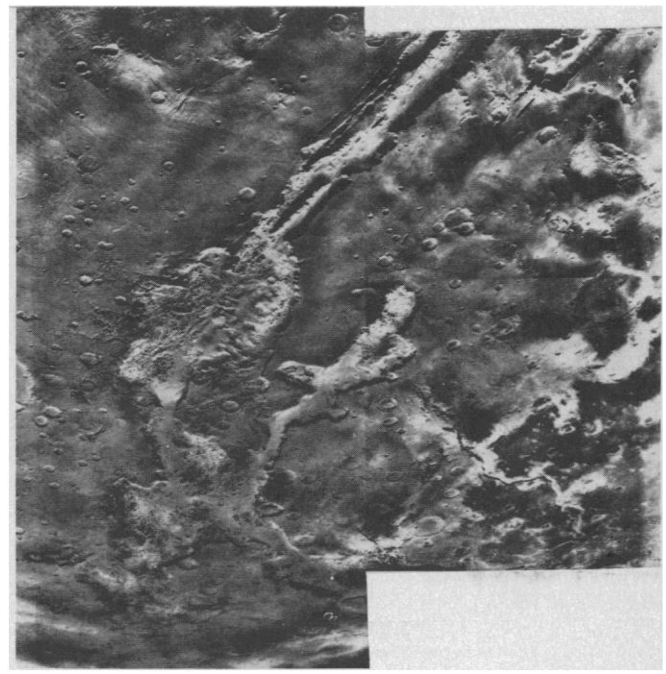
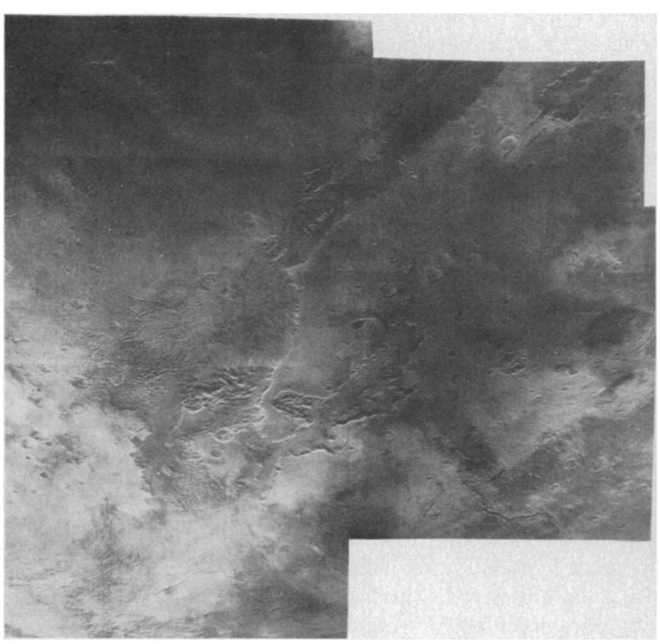


Fig. 1 (left). Computerized mosaic of five red frames. These frames have been corrected for variations in camera sensitivity and solar illumination angle and mosaicked by computer. This version, which best represents the relative albedo variations on the planet, was used as the red component in the color composite (see cover). Fig. 2 (right). Detail enhancement of mosaic of the green frames. In this version regional variations in albedo have been suppressed, resulting in exaggeration of local details of the surface morphology. Notice in particular the flows, ridges, and channel features near the terminator in the upper left corner.



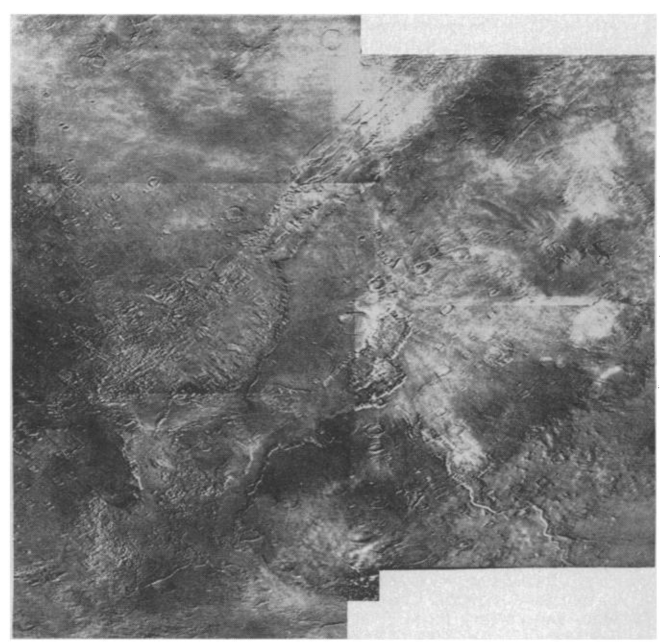


Fig. 3 (left). Color ratio 0.59 μm/0.45 μm. This image displays the color ratios between the red and violet mosaics. The darkest areas are approximately 25 percent more violet than average, the brightest areas about 25 percent redder. Atmospheric effects dominate this version. The dark area in the top third of the scene is near the terminator ($\sim$ 10°) and probably represents high-altitude water clouds which become pronounced as the surface brightness falls toward the terminator. The lower part of the scene shows pronounced color variations among surface materials. Fig. 4 (right). Color ratio 0.53 μm/0.59 μm. This color ratio of the green to red mosaics best displays color variations within surface materials. Comparison with Fig. 3 illustrates that atmospheric effects (near the terminator at the top of the scene) are less dominant in this ratio. This version confirms Earth-based observations (3) that brighter materials on Mars are redder (compare with Fig. 1). Dark areas are generally about 10 percent redder than average, bright areas about 10 percent greener. However, a number of anomalies do appear, including redder dark areas near the canyons and bluer dark wind streaks cast off large craters.

the mosaicked data bases; such a version of the green mosaic is shown in Fig. 2. Here the image has been filtered to remove or suppress local variations in albedo patterns and to enhance the finer detail associated, primarily, with surface topographic forms.

Figures 3 and 4 demonstrate the potential of such multispectral images for delineating the varieties of soils and rocks and for establishing relationships of these materials to local geomorphology and surface processes. These figures display color variations in the form of ratios between the red, green, and blue mosaics. To first order, topography and albedo variations are removed in ratio images. This arises because the albedo and topographic effects occur as the same multiplicative component in each of the three spectral bands.

The red/violet ratio (Fig. 3) is extremely sensitive to atmospheric hazes and clouds, particularly near the terminator. By contrast the green/red ratio displays primarily variations in surface materials. Comparison of these two versions, then, allows discrimination between surface and atmospheric effects. The color ratio results support Earth-based telescopic observations (*3*) showing the bright regions on Mars to be much redder (approximately 60 percent higher in red and violet). A number of interesting anomalies are observed. Dark materials are separable into at least two classes, one slightly (~ 10 percent) higher in violet than the other. This bluer unit (that is, less red) is associated with dark streaks emanating from large craters in the southern highlands. The redder dark occurs in the younger north equatorial plains. These tentative results await verification and further analysis of additional frames. A noteworthy point is that the distribution of materials seen in the orbital images may occur at the Viking 1 landing site; in which at least two classes of dark rocks (one substantially bluer) (*7*) and bright ocher fines are seen.

In summary, the two global spectral types established by telescopic observations are confirmed in the new data. Additionally, the subdivision seen here of dark regions into several types may be indicative of primary chemistry or localized effects of surface weathering. For instance, the less red character of the "wind streaks" may indicate increased aeolian erosion exposing fresh, less-oxidized ferrosilicates.

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The Viking Biological Investigation: Preliminary Results

Abstract. *Three different types of biological experiments on samples of martian surface material ("soil") were conducted inside the Viking lander. In the carbon assimilation or pyrolytic release experiment,* $^{14}CO_2$ and ^{14}CO *were exposed to soil in the presence of light. A small amount of gas was found to be converted into organic material. Heat treatment of a duplicate sample prevented such conversion. In the gas exchange experiment, soil was first humidified (exposed to water vapor) for 6 sols and then wet with a complex aqueous solution of metabolites. The gas above the soil was monitored by gas chromatography. A substantial amount of* O_2 *was detected in the first chromatogram taken 2.8 hours after humidification. Subsequent analyses revealed that significant increases in* CO_2 *and only small changes in* N_2 *had also occurred. In the labeled release experiment, soil was moistened with a solution containing several* ^{14}C*-labeled organic compounds. A substantial evolution of radioactive gas was registered, but did not occur with a duplicate heat-treated sample. Alternative chemical and biological interpretations are possible for these preliminary data. The experiments are still in process, and these results so far do not allow a decision regarding the existence of life on the planet Mars.*

We present here a preliminary progress report on the Viking biological investigation, through its first month. Details of the scientific concepts behind each of the experiments, as well as examples of the kinds of results that are obtained when these concepts are tested with the use of terrestrial samples, have been described (*1–3*). The actual flight instrumentation and the tests to which the flight instruments were subjected have also been described (*4*).

During the manufacture of the flight instruments for the biology experiments, rigorous clean-room techniques were employed to minimize airborne contamination (*5*), after which the fully assembled flight hardware was heated at 120° ± 1.7°C for 54 hours in an atmosphere of dry 100 percent nitrogen prior to shipment to the Kennedy Space Center. Here the instruments were installed in the landers under clean-room conditions and heated once more when the encapsulated landers were subjected to terminal sterilization. This time the heating regime was 112° ± 1.8°C for periods sufficient to reduce the spacecraft biological contamination loads to acceptable limits (*6*).

About a month after Viking 1 went into orbit around Mars, the biology instrument was turned on briefly for the first time since launch. At this time, 39 hours before separation, selected valves within the instrument were automatically closed to prevent exhaust products from entering the instrument during the descent phase when the instrument was powered down. On 22 July 1976, 2 days after landing, the instrument was again turned on. With activation of both radioactivity detectors, background counts were taken in dual- and single-channel counting modes. A chromatogram was also taken, and the appropriate incubation cells were rotated into position to receive surface samples. The sample for the biology investigation reported here was acquired in the morning of sol 8 (a Mars day is called a sol and equals 24 hours 39 minutes) from the surface at a depth of 0 to 4 cm in an area consisting chiefly of fine-grained material. The sample was introduced into the instrument via a soil processor on top of the lander, which screened out coarse material, larger than 1.5 mm; 7 cm^3 of the resulting smaller-grained material was metered down into the biology instrument. Samples for the individual biology experiments were metered and dis-