er-Tropsch (*17*) or Miller-Urey (*18*) processes, H_2S photolysis was not the initial step. We have produced in other experiments a brownish polymer from sulfur-free reducing atmospheres; this result demonstrates that sulfur compounds are not essential for the optical absorption in such products.

Some of the compounds found in our ultraviolet syntheses are coal tar derivatives. Many have impressive thermal stabilities (for example, thiophene can be maintained at 850°C for substantial periods without decomposition). We stress that in our analysis we have not necessarily identified the organics in the brown solid but only some of the pyrolysis products of this solid. However, because of the deep circulation in Jupiter and Saturn, pyrolysis must occur there at depth. Our pyrolysis temperature of 450°C is achieved at a pressure of about 100 bars on Jupiter (*8*) at high H_2 dilutions. Pyrolysis products are probably circulated to high altitudes on Jupiter where they may be observed and identified. As analytical techniques improve, those products (Table 1) which may form and persist at high H_2 abundances should be sought in investigations of the atmospheres in the outer solar system. The promising candidates for this search would be aliphatic and aromatic hydrocarbons, thiophenes, and to a lesser degree organic sulfides.

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9. In a typical experiment, a spherical reaction vessel (12.7 liters) is filled with 3350 cm^3 of CH_4, 3437 cm^3 of NH_3, and 2862 cm^3 of H_2S; the gases are irradiated with the resonance emission lines of mercury from a 450-W high-pressure quartz (Hanovia) lamp radiating 5.8 W at 2537 Å. The gases, along with the photolytic products, are recycled by a greaseless solenoid pump [J. S. Watson, *Can. J. Technol.* **34**, 373 (1956)] out from and back into the reaction vessel. As the photolysis continues, the interior wall of the reaction vessel accumulates an orange-brown solid. After 12 hours and 40 minutes of photolysis, 3521 cm^3 of C_2H_6 and an additional 850 cm^3 of H_2S are introduced. After 29 hours of further photolysis, a seal is magnetically broken on a tube containing 50 ml of distilled water; thereupon, the pump can circulate gases and reaction products over an NH_4OH bath. After another 6 days and 19 hours, 1150 cm^3 of H_2S are introduced. The experiment is terminated after an additional 8 days and 22 hours. The visual appearance of the brownish solid did not change after the first few hours of photolysis. The NH_4OH bath, which was not exposed to ultraviolet radiation, also acquired a distinct brownish coloration after the reaction products acquired access to it. Gases were transferred to the reaction vessel through a coiled glass diffusion trap maintained at −78°C, as a precaution against the introduction of mercury vapor and other impurities into the reaction vessel.
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11. The pyrolysis products were analyzed with a GC (Perkin-Elmer model 226) equipped with an OS 138 (polyphenylether) SCOT capillary column (45 m long and 0.05 cm in inside diameter). The GC was programmed from 40° to 190°C at 2.5°C min^{-1} after an initial 10-minute period at 40°C. The GC was interfaced to a medium-resolution MS (Hitachi RMU-6E) through a Watson-Biemann molecular separator. Mass scans, each 5 seconds, were taken of each peak as it emerged from the GC. Further details of the pyrolysis apparatus can be found in E. L. Bandurski and B. Nagy, *Geochim. Cosmochim. Acta* **40**, 1397 (1976).
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19. We are grateful to Prof. F. McLafferty and his research group for assistance with the PBM and STIRS computer systems at Cornell, and to Dr. J. E. Zumberge of the University of Arizona for assistance during the mass spectrometric scans. This research was supported by NASA grants NGR 33-010-101 and NGR 03-002-171.
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Phobos Transit of Mars as Viewed by the Viking Cameras

Abstract. *A Viking orbiting spacecraft successfully obtained pictures of the martian satellite Phobos with Mars in the background. This is the first time that a single picture was obtained from a spacecraft which contained both a planet and a moon and had significant surface detail visible on both. The region of Mars below Phobos included volcanoes in the Tharsis Montes region. These pictures showed Phobos to be smaller than previously thought. The image of Phobos can be used as a control point to determine the map coordinates of surface features on Mars.*

On 23 June 1977, the Viking Orbiter 2 (VO-2) spacecraft imaged Phobos as the martian satellite was in transit across Mars. The spacecraft camera viewed Phobos against the volcanoes in the Tharsis Montes region. Four television sequences were designed to obtain a photomosaic covering Olympus Mons, Ascraeus Mons, and Pavonis Mons as background to three separate views of Phobos. Olympus Mons was beyond the pointing limits of the camera when the

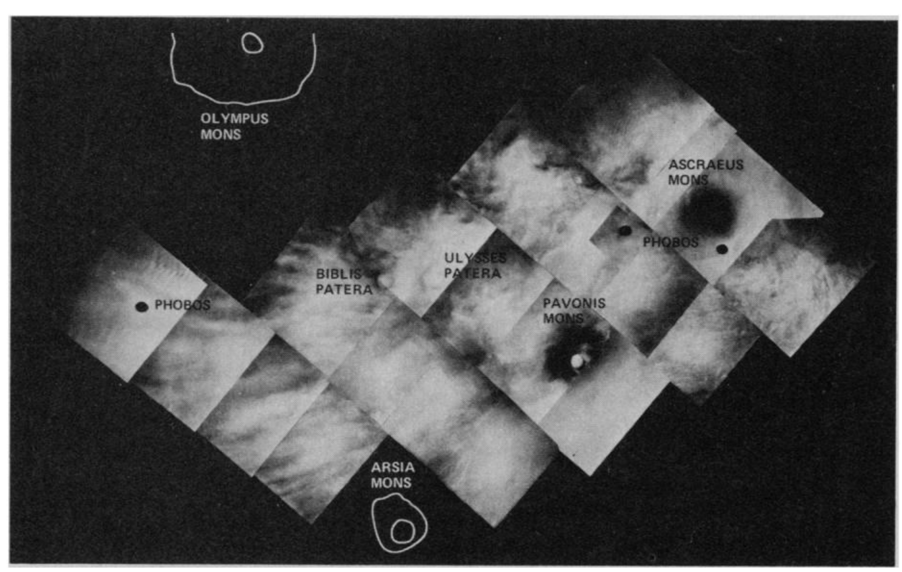

Fig. 1. A mosaic of 20 VO-2 television pictures (pictures 304B51–89) taken within a 5-minute period showing the Tharsis Montes region of Mars with Phobos in transit across Mars. The exposures of these pictures were set for the brightness of Mars, making the much darker Phobos appear as dark areas in the mosaic. This is the first time that a picture of any moon against its primary planet has been obtained where the surfaces of both bodies were readily visible.

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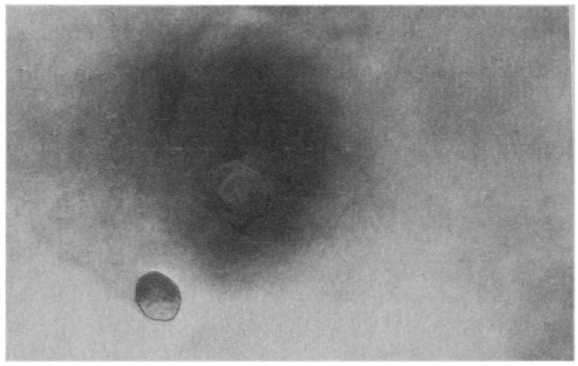

Fig. 2. Phobos is seen above Ascraeus Mons, one of the largest volcanoes on Mars. This VO-2 picture (picture 304B88) is the first ever taken showing such detail on both a satellite and primary planet. Phobos is about 22 km in diameter, whereas Ascraeus Mons is more than 300 km in diameter at the base of its cone. The complete outline of Phobos is seen from direct and reflected sunlight.

pictures were actually taken; therefore, one sequence was moved from Olympus Mons to give additional coverage of the other two volcanoes.

A similar view of Phobos was obtained by the Mariner 7 spacecraft 1 day before it flew by Mars (*1*). However, Phobos appeared as a dark dot covering only a few picture elements (pixels) in a picture that contained the complete image of the illuminated side of Mars facing Mariner 7. In recent VO-2 close-up pictures, Phobos covers an area of over 10,000 pixels with significant surface detail visible on both Phobos and Mars. These types of pictures are valuable for determining the cross-sectional area of Phobos since the complete outline of the satellite is seen. Moreover, the image of Phobos can be used to give a tie point between inertial coordinates and surface feature on Mars surrounding the Phobos image.

The transit of Phobos was viewed by VO-2 at about 2 hours and 20 minutes after periapsis of revolution 304 about Mars. At this time, the region of Mars below VO-2 was illuminated and was within the pointing limits of the television cameras. This region of Mars included Tharsis Montes, an area dominated by the largest known volcanoes in our solar system. The spacecraft was about 13,000 km above the surface of Mars and about 8000 km above Phobos, which enlarges the apparent size of Phobos relative to the surface features. The phase angles of Mars and Phobos were about 60°, with Phobos moving from the morning terminator to the illuminated portion of Mars.

A mosaic of the raw pictures is shown in Fig. 1. Phobos, which has an albedo of ~ 0.05 (*2*) as compared to a martian albedo of ~ 0.2, appears very dark in these pictures whose exposures were set for the brightness of Mars. The surface of Mars is obscured by dust and clouds associated with the seasonal dust storm that was in progress. Calderas of two volcanoes, which reach ~ 27 km above the local surface, are higher than the dust and clouds and reveal surface detail.

Figure 2 was enhanced to bring out surface detail on Mars and Phobos. The entire outline of Phobos is seen because of the bright Mars background; this photograph is in contrast to pictures showing only a partially illuminated Phobos against dark space. With Phobos in synchronous rotation about Mars, the anti-Mars side of Phobos is facing us. The longest axis of Phobos is toward Mars; therefore, we are seeing the smallest cross-sectional area of Phobos in these views.

A comparison was made between the predicted and observed cross-sectional area of Phobos. The predicted area was computed with Phobos modeled as an ellipsoid in synchronous rotation; the axes of the ellipsoid (Table 1) were determined from Mariner 9 imaging data. Observed radii were determined from the outline of Phobos, with corrections made for the electronic response of the camera and scattered light (< 3 percent). The observed values of the two shorter radii of Phobos were less than the predicted values. Using the smaller radii values observed here, I obtained a volume of 5344 km^3 for Phobos as compared to the volume of 5000 km^3 proposed by Tolson *et al.* (*3*), which they used to obtain a mean density of ~ 1.9 g/cm^3.

Table 1. Ellipsoidal radii of Phobos; *a*, toward Mars; *b*, in the orbit plane; and *c*, normal to the orbit plane.

Source	*a* (km)	*b* (km)	*c* (km)	Volume (km^3)
Mariner 9	13.5	10.8	9.4	5741
Transit pictures (VO-2)	13.5	10.5	9.0	5344

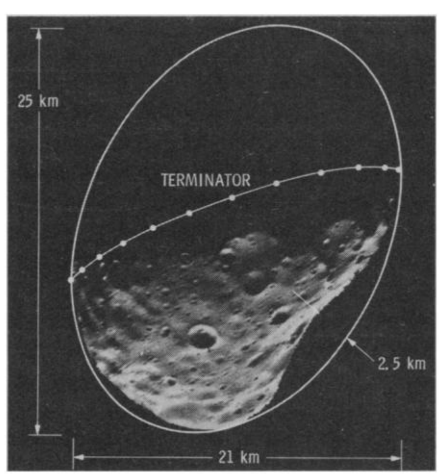

Fig. 3. Picture 372A03 showing a large depression on the illuminated limb of Phobos. The VO-1 spacecraft viewed Phobos at a phase angle of 85° and a range of 2900 km. This is the first picture in which a major variation of the surface of Phobos is seen on the limb.

The actual volume of Phobos may well differ significantly from either of these values. Mariner and Viking imaging have shown that the actual topography of Phobos varies markedly from the simple ellipsoidal model of the surface. A recent picture taken by VO-1 (Fig. 3) shows a local depression which deviates about 2.5 km (over 20 percent) from the nominal ellipsoidal surface. A precise value for the volume (and density) of Phobos will need to take into account the size of the mean surface as well as topographic variations, regolith thickness, and crater depressions.

These pictures of a satellite against the primary planet are thus useful for geodetic studies of both the satellite and planet. The size and shape of the satellite can be determined from the satellite outline. The inertial position of the satellite can be used to determine the map coordinates of surface features of the primary planet surrounding the satellite image. Phobos was observed to be smaller than predicted on the basis of Mariner 9 data but not as small as proposed on the basis of other Viking data. Additional processing of Viking imaging data will be needed to accurately determine the volume of Phobos and to determine the mean density to an accuracy of better than 10 percent.

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