Reports

Mariner IV Photography of Mars: Initial Results

Abstract. *The 22 photographs of Mars taken by Mariner IV have been successfully received on earth. The Martian surface photographed is rather densely populated with impact craters whose sizes range up to at least 120 kilometers in diameter. We infer that the visible Martian surface is extremely old and that neither a dense atmosphere nor oceans have been present on the planet since the cratered surface was formed.*

The Mariner IV spacecraft successfully acquired and transmitted to earth 22 pictures of the planet Mars taken from a distance of 17,000 to 12,000 km just before its closest approach to Mars at approximately 00:30 UT on 15 July 1965. This first report describes the performance of the television camera system, the resultant picture quality, and the more prominent surface features present in the picture. We feel that some of these features are so striking that certain physical and geological inferences can be drawn even at this early date.

The complete set of pictures in their current state of processing was released to the scientific community and the public on 29 July 1965. The completely processed pictures, the relevant calibration data, and a more detailed analysis of surface features will be presented later.

In regard to the design and performance of the TV system, one of the most difficult problems associated with the Mariner photographic mission to Mars was the wide illumination range and the low surface contrast to be expected. Since the camera would be viewing the surface from the bright limb to, and beyond, the evening terminator, the camera was called upon to respond to brightness ranging from full solar illumination near the subsolar point to near total darkness as the terminator was crossed. The slow-scan vidicon chosen was capable of handling a 30-to-1 range of illumination with fixed operating voltages. The low communications rate from the planet required a digital transmission system. In order to effectively utilize a high signal-to-noise ratio the video signal was divided into 64 equal increments. Since the video signal level would decrease as the photo path approached the terminator, automatic video gain control was incorporated. The control was designed to maintain a video level which would contain at least 15 of 64 increments. The camera telescope was of the Cassegrain type with 12-inch (30-cm) focal length, *f*/8 focal ratio, and 0.2-second shutter time.

The camera operated at the mini-

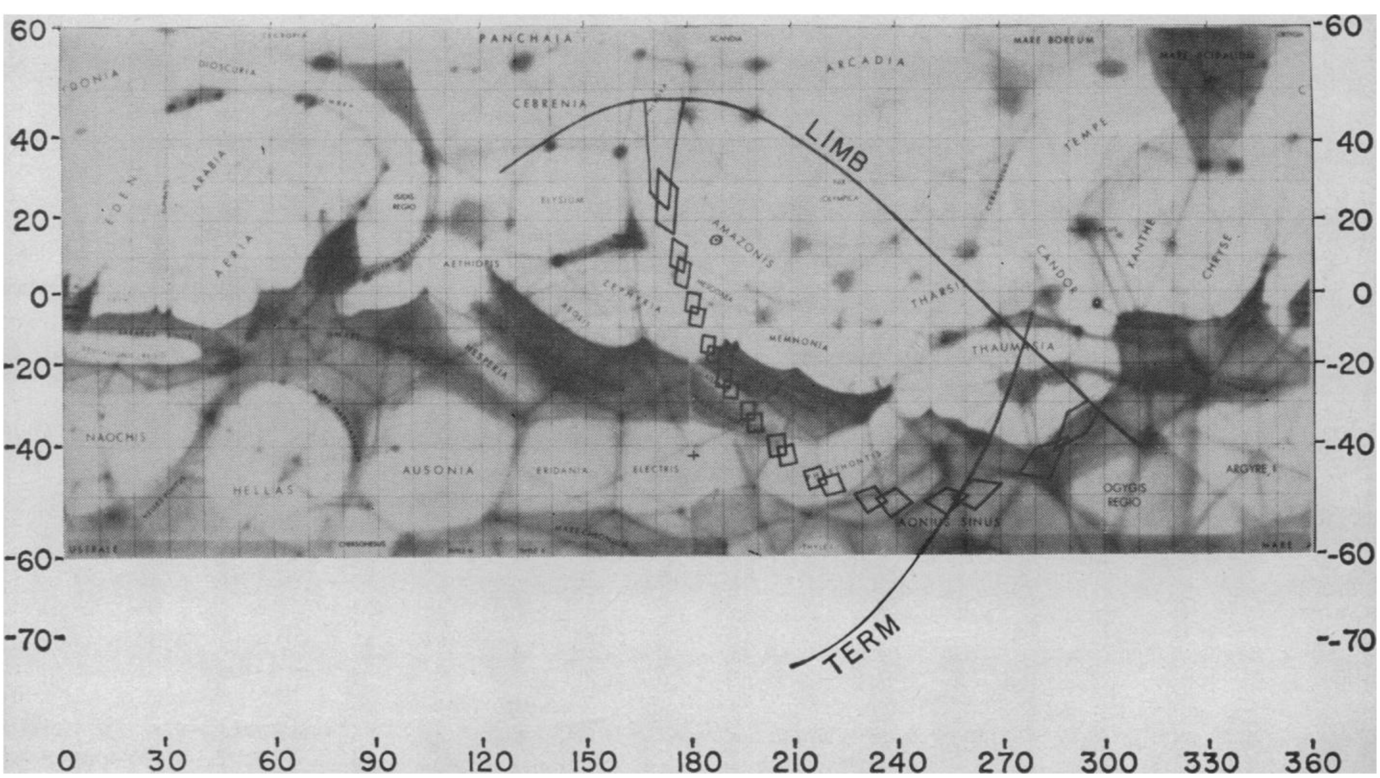


Fig. 1. Diagram of locations on the planet of the Mariner IV photographs. The pictures were taken in overlapping pairs, an orange filter being used for one member of a pair and a green filter for the other. *TERM*, terminator.

mum gain until picture No. 18, in which the video level fell below the minimum allowed (Fig. 1). The system then increased gain for picture No. 19 which was taken 96 seconds later. As the terminator was approached, the gain increased a second time for picture No. 20 and reached its maximum for pictures No. 21 and No. 22. The automatic adjustment of video signal level was not able to fully cope with the unexpectedly low light intensity, and pictures No. 15 through 20 show decreasing signal-to-noise ratios. In addition, a spurious background brightness was detected on picture No. 1 apparently at a distance of more than 100 km from the limb of the planet. Preliminary analysis has indicated this spurious background to be approximately one-fourth the brightness of the planet itself. Similar analysis of pictures Nos. 21 and 22, which were taken on the dark side of the terminator, reveals considerably lower levels of brightness, about 1/8th and 1/25th that of picture No. 1, respectively. This background is tentatively attributed to an instrumental defect of an optical nature which developed during the 7½-month

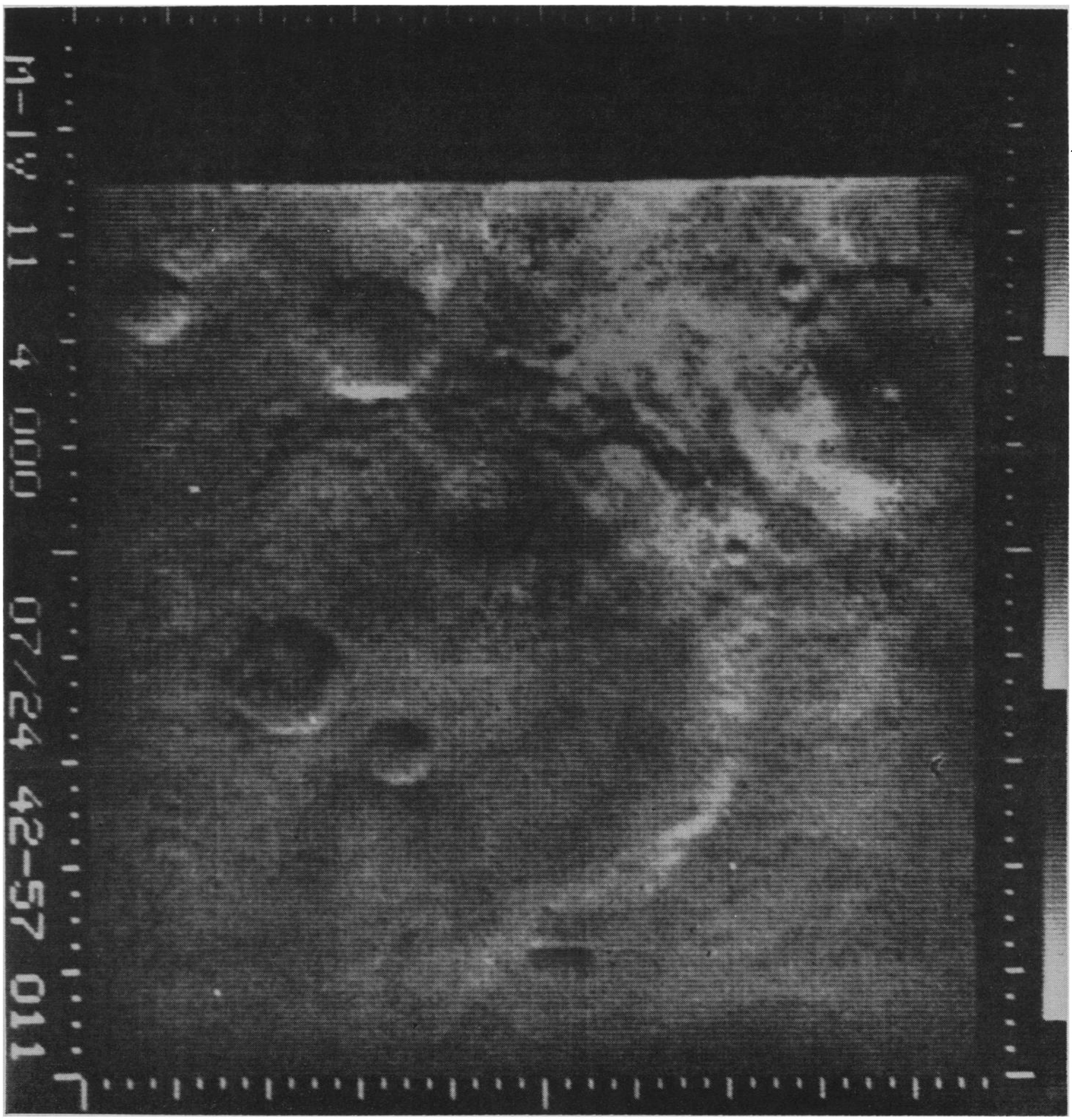


Fig. 2. Picture No. 11 of the Mariner IV sequence. This picture shows twelve craters ranging from five to about 120 km in diameter. The area of Mars covered by the picture is about 238 by 275 km.

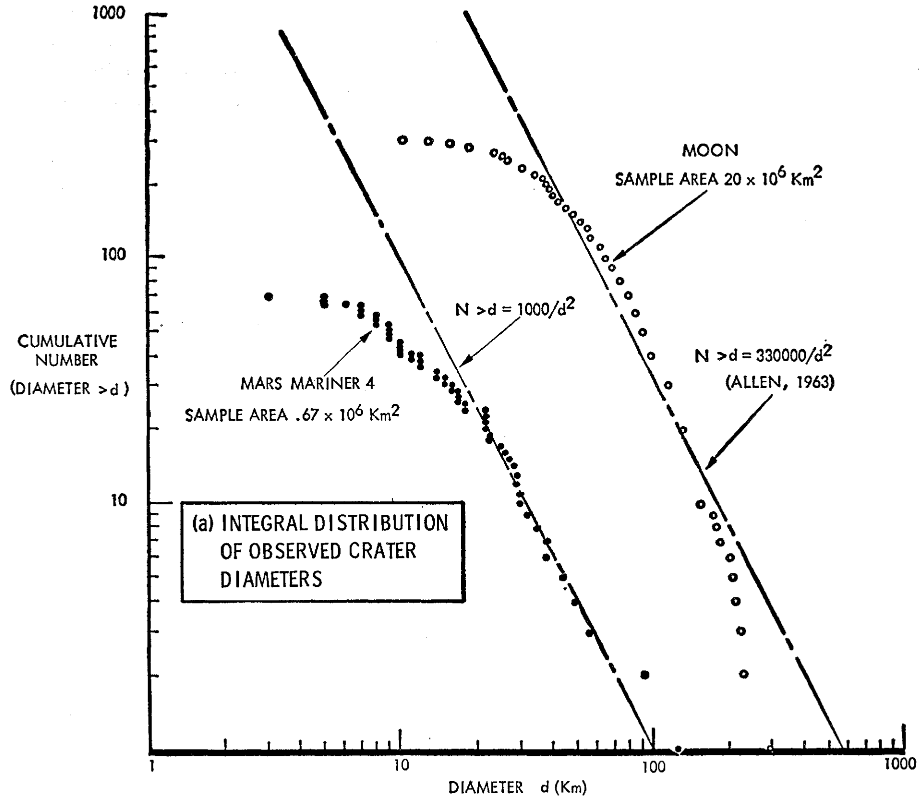
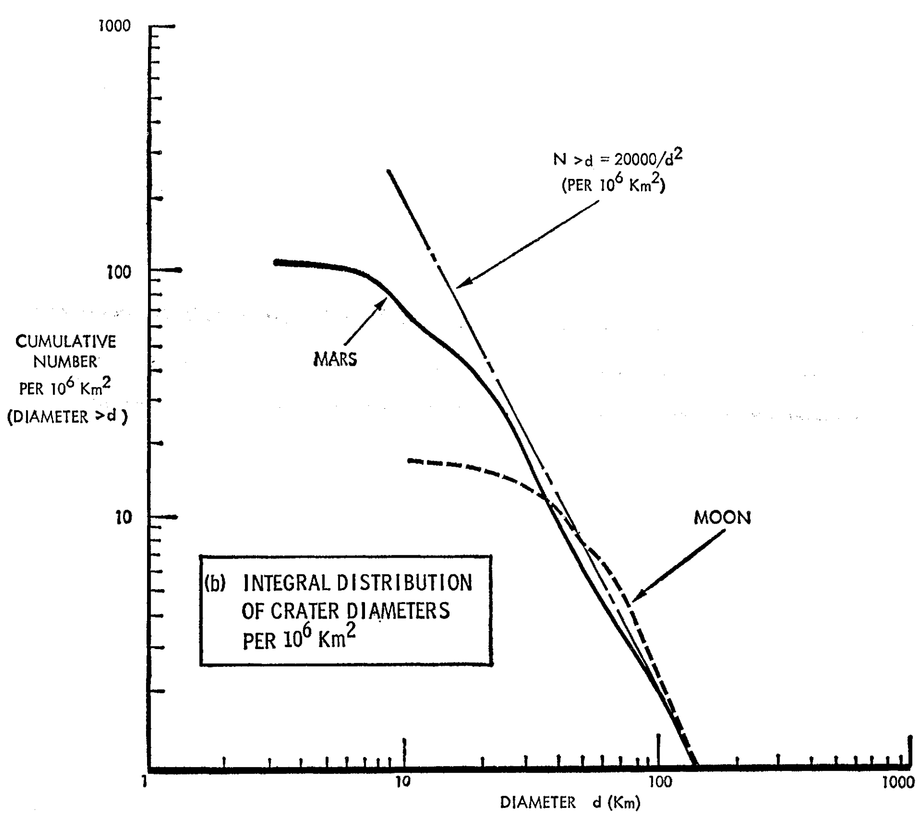


Fig. 3. Integral size distribution of crater diameters on Mars and the Moon: (*a*) as observed; (*b*) the same data, normalized to an area of 10^6 km^2; the lunar crater diameters were taken from Baldwin (*2*); the maria and uplands were not differentiated in the analysis.



space flight. All other camera characteristics such as resolution and geometrical fidelity appear normal. Results of the first tape playback have indicated that the tape machine and communications equipment operated as designed.

In pictures No. 1 through No. 4, the very high solar illumination of the terrain viewed by the camera significantly reduced the visibility of surface features, as had been anticipated. Pictures No. 5 through No. 14, however, present a view of a densely cratered surface, closely comparable to bright upland areas of the Moon (Fig. 2).

We have observed more than 70 clearly distinguishable craters ranging in diameter from 4 to 120 km. It seems likely that smaller craters exist; there also may be still larger craters than those photographed, since Mariner IV photographed, in all, only about 1 percent of the Martian surface.

The observed craters have rims rising to about 100 m above the surrounding surface and depths of many hundred meters below the rims. Crater walls so far measured seem to slope at angles up to about 10°. The number of large craters present per unit area on the Martian surface and the size distribution of those craters resemble remarkably closely the lunar uplands, as illustrated in Fig. 3.

If the Mariner sample is representative of the Martian surface, the total number of craters of the sizes so far observed is more than 10,000 compared to a mere handful on Earth. In appearance, the Martian craters closely resemble impact craters on Earth, both artificial and natural, and the craters of the Moon. Craters of widely different degree of preservation and, presumably, age are distinguished. A few elongate markings of diffuse nature are present on the Mariner photos but at this early stage of analysis no conclusions can be offered concerning them. On frame No. 13, one such feature looks like a part of the edge of a very large crater and, perhaps significantly, lies near the border of a Martian dark area. In southern subpolar latitudes, where the season is now late midwinter, some craters appear to be rimmed with frost, particularly those in frame No. 14.

Some mention must be made of features looked for, but not seen, on the Mariner photos. Although the line of flight crossed several "canals" sketched from time to time on maps of Mars, no trace of these features was discernible. It should be remembered in this respect that the visibility of many Martian surface features, including the "canals," is variable with time. No Earth-like features, such as mountain chains, great valleys, ocean basins, or continental plates were recognized. Clouds were not identified, and the flight path did not cross either polar cap.

Although it may be difficult to ever arrive at an unambiguous identification and interpretation of all the features recorded on the Mariner photographs, we feel that the existence of a lunar-type cratered surface, even in only a 1-percent sample, has profound implications about the origin and evolution of Mars and further enhances the uniqueness of Earth within the solar system. By analogy with the Moon, much of the heavily cratered surface of Mars must be very ancient—perhaps 2 to 5×10^9 years old (*1*). The remarkable state of preservation of such an ancient surface leads us to the inference that no atmosphere significantly denser than the present very thin one has characterized the planet since that surface was formed. Similarly, it is difficult to believe that free water in quantities sufficient to form streams or to fill oceans could have existed anywhere on Mars since that time. The presence of such amounts of water (and consequent atmosphere) would have caused severe erosion over the entire surface.

The principal topographic features of Mars in the areas photographed by Mariner have not been produced by stress and deformation originating within the planet, in distinction to the case of Earth. Earth, of course, is internally dynamic, giving rise to mountains, continents, and other such features, whereas Mars has evidently long been inactive. The lack of internal activity is also consistent with the absence of a significant magnetic field on Mars, as determined by the Mariner magnetometer experiment.

As we had anticipated, Mariner photos neither demonstrate nor preclude the possible existence of life on Mars. Terrestrial geological experience would suggest that the search for a fossil record appears less promising if Martian oceans never existed. On the other hand, if the Martian surface is truly "near pristine," that surface may prove to be the best—perhaps the only—place in the solar system still preserving clues to primitive organic development, traces of which have long since disappeared from Earth.

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Rock Degradation by Alkali Metals: A Possible Lunar Erosion Mechanism

Abstract. *When rocks melt under ultrahigh-vacuum conditions, their alkali components volatilize as metals. These metal vapors act to comminute polycrystalline rocks to their component minerals. The resultant powder is porous and loosely packed and its characteristics may be compatible with the lunar surface as revealed by the Ranger photographs. If meteorite impact or lunar volcanism has produced vaporization or areas of molten lava, alkali erosion may have given dust of this character in adjacent solid areas.*

The unusual phenomena which might attend the melting of lunar rocks under high-vacuum conditions due to volcanism or meteoric impact have received some attention (*1*). In addition to observing the usual rock gases, we have noted the evolution of vapors of alkali metals from rocks melted in the laboratory under ultrahigh vacuum conditions. Polycrystalline rock materials were rapidly eroded by these metal vapors at moderate temperatures. It is possible that this erosion phenomenon may have contributed to the production of a lunar dust layer. That such a dust layer exists on the lunar surface is supported by the recent Ranger photographs (*2*), although the depth and bearing quality of the layer are still matters of some controversy. Previously, this dust has been attributed variously to cosmic material swept up by the moon, to volcanic ash eruptions, or to the erosion of the lunar surface by various agents such as solar radiation, meteoritic impacts, and the rock-fracturing effects of rapid changes in temperature (*3*).

Dissociation of the common alkali oxides on vaporization under laboratory conditions is known to occur (*4*) and similar dissociation of silicates might be anticipated. When we made a rough calculation of equilibrium vapor pressures, using available thermodynamic data for silicates and making estimates for unavailable figures, we found that a partial pressure of approximately 10^{-5} mm would be expected for potassium at 1500°K above the surface of a potassium-aluminum silicate (kaliophilite) of about the acidity of basalt. This vapor pressure can be used to estimate the maximum evaporation rate of the potassium from such a silicate (*5*), which, for a reasonable eruptive period of about a month, would amount to 0.25 g/cm^2. In actual rock melts maintained at a temperature of 1500° to 1900°K for periods as long as 1 hour, visible alkali vaporization occurs which is independent of the material of which the crucible containing the melt is constructed (molybdenum, platinum, and alumina). A basalt with a Na/K ratio of about 7 gives a vaporized film with a Na/K ratio of approximately 3, this ratio reflecting the higher dissociation vapor pressure of the potassium compound (*4*).

Of particular interest is the eroding behavior of metallic sodium and potassium in contact with rock materials. The disintegration of ceramic bodies by grain-boundary attack by liquid sodium was noted previously (*6*), but the effect on rock materials as described below seems not to have been observed.

When the alkali metals were deposited under vacuum conditions on pieces of broken rock, or on polished sections of rock, and the glass or quartz containers sealed off under vacuum and exposed at 100°C, disintegration of the rock to a powder became evident after about 2 weeks. Exposure to the vapor of the metal at 350°C or higher produced evident erosive effects within an hour, and complete disintegration of the rock was accomplished by exposure for 12 hours. For convenience, most of our experi-