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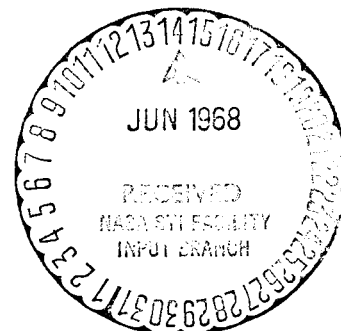
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Mars Mariner IV: Identification of Some Martian Surface Features

Abstract. Several frames of the Mariner-IV picture series show one or more features of sufficient size to be recorded on telescopic photographs taken from the earth during 1965 and 1967. The variability of certain martian surface markings has hindered earlier efforts to identify the Mariner features with those on published maps of Mars. Recognition here includes features in the Propontis-Hades-Phlegra complex, a small oasis, and the border between Zephyria and Mare Sirenum.

On 14 July 1965 Mariner IV recorded its historic series of photographs of the planet Mars, and shortly thereafter transmitted 21 frames back to earth to give man his first close-up view of this enigmatic planet.(1) In nearly all of these high-resolution photographs it is possible to distinguish certain geological features such as craters in various states of preservation, faults, and other formations as yet unidentified (2).

One unhappy consequence of this relatively high resolution, however, is the magnitude of the gap in our familiarity and recognition between the Mariner pictures and the best telescopic photographs taken from the earth. When one considers that a typical Mariner-IV frame with a width of 250 km has a characteristic dimension which is only twice as large as a single resolution element on the best photographs taken from earth, it is possible to appreciate the difficulty in identifying any features common to both Mariner and ground-based photographs. Indeed, were it not for the fortuitous recording of several characteristic objects in the Mariner photographic series, it is probable that no conclusive identifications would have been made.

One of the more fortunate occurrences in the Mariner-IV sequence was the recording of the limb of Mars on frame 1. By knowing even the approximate coordinates of this horizon, we are in a favorable position to start a search for features that resemble those in frame 1. Moreover, frames 1 and 2 were taken at a highly oblique angle with respect to the surface and at a relatively large slant range. These factors combine to provide surface areas in frames 1 and 2 which are several times larger than in the other frames, and this improves our chances for finding specific features that we can recognize. We were also most fortunate in having frame 8 cover an area containing the boundary between a bright "desert" region and one of the dark areas called "maria."

Earlier attempts by others to locate familiar features on the Mariner-IV photographs have been frustrated by inadequacies in the maps of Mars which show the relatively low-resolution detail as it is seen from the earth. We want to state clearly that the term "inadequate" in no way reflects incompetence on the part of the compilers of these maps. In fact, some of these maps are the product of many careful measures of telescopic photographs accumulated over intervals of up to 60 years. Therefore, they tend to represent long-term average conditions, and in this we find the source of their weakness, for these "errors" which appear in all of the accepted maps of Mars can be traced to the variable nature of many of the planet's surface features.

It is a well-known fact that certain features on Mars undergo both seasonal and secular changes in their appearance, occasionally to such a degree as to be hardly recognizable from one apparition to the next. In some cases the boundaries of dark areas have been observed to migrate, and this is particularly true of an active region which includes Mariner frames

1 and 2. We therefore felt it necessary to disregard all of the existing published maps of Mars and work only with photographs collected during the Mars apparitions of 1965 and 1967. Images of higher quality are usually obtained when Mars is near opposition, in this case March 1965 and April 1967, and these dates permit us to bracket the conditions existing on Mars at the time of Mariner IV encounter in July 1965 (3). Photographic coverage of Mars in 1965 and 1967 was both thorough and of good quality at the New Mexico State University Observatory. The NMSU plate collection, therefore, provided all of the material necessary to conduct our investigation.

Recognition of features on the Mariner photographs must obviously be limited to those markings having sufficient size and contrast to be recordable on the better telescopic photographs. Both 1965 and 1967 were unfavorable opposition years for Mars, with the planet's maximum angular size reaching only 14.0 and 15.6 seconds, respectively. Consequently, we could not expect our photographs to show dark areas with diameters much smaller than 200 km. On the other hand, the inclination of the martian equator was such that the northern hemisphere was tipped toward the earth, and this gave us a definite advantage in studying the region covered by frames 1 and 2. We proceed now with an evaluation of the Mariner-IV frames, and examine each for the possibility of its containing objects recognizable from the earth.

Both frames 1 and 2, reproduced here as Fig. 1, show features or parts of features with dimensions exceeding 200 km. Frames 3 and 4 do not contain any markings large enough to be seen on photographs taken from the earth. Frames 5 and 6 share part of a dark area which could possibly have a diameter as large as 250 km and might, therefore, be just visible from earth. Frame 7 shows many craters, but none are of sufficient size for our purposes. Frame 8, reproduced here with frame 6 as Fig. 2, contains the boundary

between a bright and a dark region, as mentioned earlier. Frames 9 through 12 boast many interesting objects, but none of them are of sufficient size and contrast to be recorded on our plates. All frames following 12 include regions too far to the martian south to be well observed on the 1965 and 1967 photographs. Only frames 1,2,5,6 and 8, then, could provide any hope for identification.

As a preliminary step, we prepared a contemporary map of the Mariner-IV region on Mars from the NMSU photographic plates. With reasonably good accuracy, this map presents the appearance and location of all martian features visible in this region during 1965 and 1967. Coordinates were determined by placing appropriate grids over enlarged composite transparencies produced from the better images on our original photographic plates. Repeated measures indicate that it is possible to map a given point with an error of only one degree of areocentric angle, i.e., about 60 km on the surface of Mars. This map, which appears here as Fig. 3, should be compared with Fig. 4, which is adapted from a map (Mars Chart MEC-2) prepared by the USAF Aeronautical Chart and Information Center. We wish to call special attention to the region surrounding the area covered by frames 1 and 2. The remarkable new development of this region has been in progress for at least the past four years and perhaps longer. To a lesser extent, differences may also be noted in other areas on the maps. Many of these are real, although some variation must certainly be attributed to the individual "artistic style" of the compilers. With a contemporary map and the approximate frame coordinates (4) now at our disposal, the actual positioning of the frames through identification of the surface features was comparatively trivial.

Frame 1: The dark area, above center and at the far right side of the frame, is actually part of a larger feature, approximately 500 km in diameter and centered at longitude 184° and latitude 36° north. We have been unable to locate any object of similar size and contrast at this position on any of the previously published maps of Mars. However, a dark area rather similar to this, called Propontis I and located at (180° , 45°N) can be found on nearly all other maps, although it is conspicuously absent in our 1965-67 representation. At this time we are unable to suggest whether or not this new feature, which we have tentatively designated as Propontis 0, is in any way related to Propontis I. The answer must await further examination of photographs of this region which cover an interval extending over the past 10 or 20 years. Through this continued study we hope to ascertain whether Propontis I faded out and was later replaced by Propontis 0, some 750 km away, or whether Propontis I has actually migrated slowly to this new position.

Covering most of the lower half and left side of frame 1 is another dark feature, smaller than Propontis 0 and also absent as a well-defined dark area on earlier maps. It is in a rather loosely defined complex sometimes called Hades-Phlegra. Both of these dark areas can be seen within the outline of frame 1 in Fig. 3.

The dark streak near the horizon in the Mariner photograph is probably the beginning of the Diacria-Boreas region (5). An interesting dark spot can be seen near the middle of this streak, but its diameter is only 20 km and therefore could not possibly be seen from the earth. We remind the reader that frame 1 was taken at an oblique angle and that all of these features, therefore, appear very much foreshortened.

Frame 2: This view overlaps part of frame 1 and shows portions of the first two of the features discussed above. Whatever may be the true nature

of this dark mottled area covering hundreds of thousands of square kilometers, it did not exist thirty years ago as we now see it.

Frame 6: The dark area at the upper right of this frame coincides with an "oasis" which is just visible on the higher quality 1967 photographs at (176°, 4°S). We tentatively identify it as Aquae Apolinales, a small oasis shown near this position on Antoniadi's map (6). The irregular outline of this object is worth noting. Its appearance does not resemble that of an impact crater as has been suggested for martian oases by Tombaugh (7).

Running northwest from Aquae Apolinales in Fig. 3 is the Tartarus "canal", which also was recorded on the 1967 photographs. Although not reproduced here, Mariner frame 5 contains an irregular dark spot at the upper left, which would be just a little too small to be seen as an individual feature from the earth. This suggests that Tartarus, and perhaps other canals as well, are formed by discontinuous dark patches, but appear through imperfect resolution as continuous linear features. Visual observations at Pic-du-Midi have led French astronomers to this same conclusion (8). With admittedly less supporting evidence, we might go on to suggest that the features which form both canals and oases are geologically identical, differing only in size and, therefore, conspicuousness. The true nature of these irregular dark patches, and why they are arranged in a more or less linear manner, remains unanswered.

Frame 8: Here we see the boundary between the bright "desert" region, Zephyria and the darker Mare Sirenum. Within the resolution limitations of the Mariner photograph, there appears to be no physical difference, other than albedo, between desert and mare.

In conclusion, we are reasonably confident that we have identified certain objects in the photographs taken by Mariner IV in July 1965. Features of

sufficient extent and contrast to be seen from the earth have been individually recognized. Those in the very active Propontis-Hades-Phlegra region are not to be found on the published maps of Mars, thus precluding any possibility of identification through the use of such maps. Our comparisons, therefore, were made with a special map prepared from contemporary photographs. We have identified the oasis, Aquae Apolinales, and noted that it does not have the appearance of an impact crater. Traces of the Tartarus canal seem to be present and suggest that martian canals are perhaps a linear arrangement of discontinuous irregular patches. The border between the desert area, Zephyria and Mare Sirenum is clearly indicated, but we observe no interesting differences between desert and mare.

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References and Notes

1. A complete description of the Mariner IV television experiment has recently been released by the investigators (Mariner IV Pictures of Mars; by R. B. Leighton, B. C. Murray, R. P. Sharp, J. D. Allen, and R. K. Sloan; JPL Technical Report 32-884, December 1967). Although we disagree with the identification of some of the features described by authors Leighton, Murray and Sharp, the source of disagreement is generally traceable to those maps available to them at the time of preparation of their report.
2. See, for example, R. B. Leighton et.al., Science 149, 627 (1965) and G. Fielder, Nature, 5004, 1381 (1965).
3. The equivalent terrestrial seasonal date on Mars at the time of Mariner IV encounter was August 12. Photographs taken during late May 1967 match this seasonal date very well. Those photographs taken during 1965, on the other hand, provide a more favorable comparison with regard to possible secular changes.
4. Frame coordinates computed from orbital and attitude data were kindly provided by Alan Herriman of the Jet Propulsion Laboratory.
5. The entire region surrounding frames 1 and 2 has undergone such extreme change since the maps of Fournier, Lowell, and Antoniadi were prepared, that we have found it quite impossible to assign the appropriate names to these features with any real feeling of confidence.
6. E.-M. Antoniadi, La Planète Mars, Librairie Scientifique Hermann, Paris, (1930).
7. C. W. Tombaugh, Astron J. 55, 184 (1950). Tombaugh has since suggested collapsed caldera as a possible origin for some of the oases, (private communication).

8. See A. Dollfus, Chapter 15, page 556 of Planets and Satellites, Edited by G. P. Kuiper and B. M. Middlehurst, Univ. of Chicago Press, Chicago (1961).
9. We thank Drs. R. B. Leighton, B. C. Murray and C. W. Tombaugh for their comments, and Dr. Leighton for making available the sharpened and enhanced Mariner IV photographs prior to their publication. Supported in part by NASA grants NsG-142-61 and NGR-32-003-027.

FIGURE LEGENDS

- Figure 1. Mariner IV frames 1 (left) and 2 (right). Frame 1 contains the limb of Mars, and a part of Propontis 0 at the far right center. See text.
- Figure 2. Mariner IV frames 6 (left) and 8 (right). The irregular dark feature at the upper right of frame 6 is probably the "oasis", *Aquae Apolinales*. The boundary between the "desert" region *Zephyria* and the darker *Mare Sirenum* is seen running across the middle of frame 8.
- Figure 3. The Mariner IV region of Mars prepared from photographs taken during the 1965 and 1967 apparitions, showing the proposed locations of Mariner frames 1 (at top) through 13.
- Figure 4. A part of the ACIC Mars Chart MEC-2 showing the same region as Fig. 3. Note the differences between this long-term "average" appearance and the recent 1965-67 appearance established by photography.