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PLANETARY RESEARCH CENTER
LOWELL OBSERVATORY
FLAGSTAFF, ARIZONA 86002

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POST-MISSION VIKING DATA ANALYSIS

FINAL REPORT

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PERSONNEL

Averaged over the time interval (3.7 years) that funds were expended under this grant, the following staff devoted the indicated percentages of their time to it:

W. A. Baum, Principal Investigator, 18% time
L. J. Martin, Co-Investigator, 52%
K. Lumme, Co-Investigator, 19%
L. H. Wasserman, Co-Investigator, 9%
T. J. Kreidl, Computer Programmer, 5%
Others (combined), Research Assistants, 7%

"Others" include H. S. Horstman, M. L. Kantz, and S. E. Jones. In addition, there are several Observatory employees paid through overhead who provide services such as library, bookkeeping, and maintenance.

BACKGROUND

Work under this grant was a continuation of our participation in the Viking Mission. That participation commenced in 1970 with Baum's membership on the Viking Orbiter Imaging Team and continued through the end of team operations in 1978. This grant then commenced in 1979 at the start of the Mars Data Analysis Program (MDAP). MDAP was planned by NASA as a 5-year program, and our initial MDAP proposal was scaled to that expectation and to a funding level consistent with the Mars research projects in which we were already engaged. As it turned out, there were subsequent reductions in MDAP funds, and we (like many of our colleagues at other institutions) had to adjust the scope of our Mars research projects accordingly. Even so, we have been able to produce at least some results under all projects. Moreover, a low-level effort is continuing under private Lowell Observatory funds.

Three Mars data analysis projects were identified in our initial proposal, and three more came into being as the work proceeded. All together, these six pertained to: (A) the vertical distribution of scattering particles in the Martian atmosphere at various locations in various seasons, (B) the physical parameters that define photometric properties of the Martian surface and atmosphere, (C) patterns of dust-cloud and global dust-storm development, (D) a direct comparison of near-simultaneous Viking and ground-based observations, (E) the annual formation and dissipation of polar frost caps, and (F) evidence concerning possible present-day volcanism or venting.

MAIN ACCOMPLISHMENTS

Work on the six Mars projects listed above led to the accomplishments outlined in the correspondingly lettered paragraphs (A through F) below. Publications resulting from that work are listed in another section of this report, where a letter (A through F) identifies each with the project to which it relates.

(A) Whenever Viking Orbiter images included the limb of Mars, they recorded one or more layers of clouds above the limb. The height above the limb and the brightness (reflectivity) of these limb clouds have been determined in 57 selected images sampling various Martian seasons, latitudes, longitudes, and phase angles. In order to assign heights to limb cloud layers, we had to determine where the surface limb was. Since the surface limb was generally obscured by clouds, its locus had to be calculated from cartographic data for craters visible in the foregrounds of the same images. The most notable finding is that some of the limb clouds are surprisingly high, reaching 60 or 70 km above the surface. Statistically, the reflectivity of the clouds increases with phase angle but appears to be uncorrelated with latitude. Heights seem to have some dependence on season. One paper presenting a radiative transfer interpretation of two sample limb brightness profiles was presented at the 1981 DPS meeting, another concerning observational material was presented at the 1983 DPS meeting, and a manuscript incorporating reduced observational data from all 57 images is now in draft form.

(B) All photometric observations of Mars contain a blend of light from the surface and light from scattering particles in the atmosphere. Utilizing Viking orbiter image data, Mariner 9 image data, ground-based UBV photometry, and ground-based Patrol photographs, we derived photometric properties of the Martian surface, of the "clear" atmosphere, and of the dust-laden atmosphere. We published our radiative transfer model, together with fits to the observational data, in a 1981 Icarus paper and also presented the results at the 1980 DPS meeting. Specifically, we found that the dust particles of the 1971 storm had a single scattering albedo of 0.84 and an asymmetry factor of 0.35 in green light. The geometric albedo of Mars was 0.15 and the phase integral was 1.83, yielding a Bond albedo of 0.27. The mean optical thickness of the "clear" atmosphere averaged over the whole planet was 0.15 and was not detectably dependent on wavelength. Geometric albedos for the Martian surface are 0.25 (light areas) and 0.17 (dark areas) in V, 0.095 in B (both areas), and 0.060 in U (both areas). The soil particles are moderately backward scattering.

(C) In earlier work we had investigated the pattern of development of pre-Viking dust storms using Earth-based observations, and during the Viking Mission we collaborated with G. A. Briggs, P. James, J. Barnes, N. Evans, and others in assembling the dust-cloud/dust-storm record from Viking Orbiter imaging observations. Selected material was published in 1980 as a chapter (Baum and James) in NASA SP-441. Related work under the MDAP grant included publication (with Briggs and Barnes) of a 1979 wrap-up paper in JGR, as well as a review presented at the Second International Mars Colloquium. A paper on the 1977 global dust storm was presented at the 1981 DPS meeting. In a much more recent (1984) Icarus paper, we have further clarified the historical record concerning the pattern of global dust storm development. Most of the dust activity seen by Viking occurred during southern hemisphere spring and early summer, when Mars was near perihelion and insolation was near maximum. About half the observed local clouds occurred near the edge of the southern polar cap, where winds are presumably enhanced by a strong temperature gradient. The other half occurred mainly in the southern hemisphere near regions where circulation models incorporating topography predict positive vertical velocities. Although the onsets of major dust storms observed from the Earth show a similar partial correlation with models, some ambiguity exists concerning interpretation of regions near Hellespontus that have spawned the most spectacular Martian dust storms on record.

(D) Viking "global" sequences obtained by Orbiter I on two dates in early 1978 and four in early 1980 fell within broader time intervals of Earth-based Patrol photography. Clouds, haze, and albedo features are present in both kinds of observation, but each contains information lacking in the other. Viking provided six high-resolution "snapshots" of 1/3 of the planet, whereas Earth-based Patrol photography provided low-resolution monitoring of all sides of the planet in four colors for several weeks in each of the two years. These 1978 and 1980 time intervals were the only two during the entire Viking Mission that Mars could be observed simultaneously with useful resolution from the Earth. Results of our analysis were presented at the 1980 DPS meeting, and a related note appeared in Sky and Telescope in 1983.

(E) In earlier studies, we had measured the annual formation and dissipation of polar frost caps and polar hood clouds on pre-Viking Earth-based photographs. During MDAP, additional work was done in collaboration with P. B. James and was reported at the 1980 DPS meeting. The polar-cap project is now continuing under a new grant entitled "Synoptic Monitoring of Martian Atmospheric Phenomena," starting 1 April 1984, with James (University of Missouri) as P.I. As this work proceeds, we are learning the degree to which the annual pattern of cap and hood formation repeats itself.

(F) During MDAP, L. J. Martin of our staff discovered evidence for present-day volcanism or venting on Mars. The earliest clue came from Viking Orbiter image sequences taken at our request around the time of the 1980 Mars opposition. A tiny bright cloud, unlike other atmospheric features, was found at the base of a mountain north of Solis Planum. The triangular shadow of this unique cloud indicated it to be of conical form with its base at the surface, as might occur if there were a steam vent due to rapid volatilization of subsurface water or permafrost. Soon afterward, another small "vertical" cloud was discovered on a particularly fortuitous overlapping sequence of frames. It rose directly out of a crater chain in the south rift zone of Arsia Mons. Within 30 minutes the cloud dissipated. Papers were presented at the 1980 DPS meeting, at the December 1980 AGU meeting, and in 1981 at the Third International Colloquium on Mars.

FINANCIAL STATUS

All funding of this grant was spent out by the end of 1982, and a final financial report has been submitted separately. Work since then has been carried on with limited private funds of the Observatory.

PUBLICATIONS

Letters A through F in the left margin identify the project to which each paper is related.

(C) Baum, W. A., and James, P. B. (1980). The atmosphere. Chapter in Viking Orbiter Views of Mars, NASA SP-441, pp. 138-159. U. S. Government Printing Office, Washington, D. C.

(C) Baum, W. A., Martin, L. J., Briggs, G. A., and Barnes, J. (1979). A review of Martian dust clouds and storms. NASA Conference Publication 2072, p. 6.

(C) Briggs, G. A., Baum, W. A., and Barnes, J. (1979). Viking orbiter imaging observations of dust in the Martian atmosphere. J. Geophys. Res. 84, 2795-2820.

(E) James, P. B., and Lumme, K. (1980). Martian south polar cap boundary: 1971 and 1973 terrestrial observations. Bull. Amer. Astron. Soc. 12, 722.

(B) Lumme, K., Martin, L. J., and Baum, W. A. (1980). Theoretical interpretation of photometric properties of the Martian surface and atmosphere. Bull. Amer. Astron. Soc. 12, 727.

(B) Lumme, K., Martin, L. J., and Baum, W. A. (1981). Theoretical interpretation of photometric properties of the Martian surface and atmosphere. Icarus 45, 379-397.

(A) Lumme, K., Martin, L. J., Wasserman, L. H., and Baum, W. A. (1981). Theoretical interpretation of the Martian limb brightness profile. Bull. Amer. Astron. Soc. 13, 712.

(F) Martin, L. J. (1980). A possible triggering mechanism for Solis Lacus dust storms. Bull. Amer. Astron. Soc. 12, 724.

(F) Martin, L. J. (1980). Evidence for volcanic origins for some Martian clouds. EOS 61, 1021.

(F) Martin, L. J. (1981). Possible volcanic activity on Mars during the Viking mission. Lunar and Planetary Inst. Contribution 441,145.

(C) Martin, L. J. (1981). A closer look at a developing Martian dust storm: Analysis of Viking images. Bull. Amer. Astron. Soc. 13, 708.

(D) Martin, L. J., and Baum, W. A. (1980). Near-simultaneous Viking and Earth-based observations of Mars in 1978. Bull. Amer. Astron. Soc. 12, 726.

(A) Martin, L. J., and Baum, W. A. (1983). Clouds above the Martian limb. Bull. Amer. Astron. Soc. 15, 847.

(D) Martin, L. J. (1983). Mars from Earth and space. Sky and Telescope 65, 559.

(C) Martin, L. J. (1984). Clearing the Martian air: The troubled history of dust storms. Icarus, in press.

(A) Martin, L. J., Baum, W. A., Wasserman, L. H., and Kreidl, T. J. (1984). Clouds above the Martian limb: Viking observations. In preparation.