NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Technical Report 32-1492

Observational Patrol of Mars in Support of Mariners VI and VII

C. F. Capen

JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
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Preface

The work described in this report was performed by the Space Sciences Division of the Jet Propulsion Laboratory.

Acknowledgment

Detailed planetary aspects of the Martian disk during the periods of *Mariner* encounters would not be possible without the assistance and perseverance of the observers: R. A. Schorn, J. W. Young, and V. W. Capen of the Jet Propulsion Laboratory, and E. S. Barker and S. J. Little of the McDonald Observatory, University of Texas, Austin. Grateful appreciation goes to Dr. A. Dollfus and the members of his staff for presenting, for comparison, Pic du Midi observations of Mars, which increased the Martian longitude coverage over that possible from the western part of the United States.

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Abstract

A summary of the physical appearance of Mars during the 1969 apparition is presented for use in planetary research and in support of the *Mariner VI* and *VII* missions. An account is given of the seasonal meteorological activity and surface conditions before and during the *Mariner* encounters. Diameter measurements of the regressing south polar cap are tabulated. For comparison with *Mariner* pictures, a current Regional Mars Map 1969 of longitudes 240° to 100°, inclusive, was prepared from high-resolution observations (0.1 to 0.2 arc seconds) acquired during late Martian summer. Selected photographs and drawings are reproduced for reference with the text.

Observational Patrol of Mars in Support of *Mariners VI* and *VII*

I. Introduction

The programs for the photographic and visual patrol of Mars have been designed to explore the physical condition of the Martian polar and equatorial regions and to collect statistical data on the visible meteorology occurring over these regions. The patrols have necessarily been planned to give as much heliocentric orbital coverage as practical in order to collect physical data during several Martian seasons. It has been found possible to observe Mars from the earth for periods of 18 to 20 terrestrial months, or about 9 to 10 Martian months.

Nightly observations of Mars were begun on August 31, 1968 with the 16- and 24-inch Cassegrainian reflectors operated by the Jet Propulsion Laboratory (JPL) and located at the Table Mountain Observatory (Ref. 1). The 30-inch Cassegrainian reflector of the Gilbert Observatory at Flagstaff, Arizona was used for three months during this apparition with the kind permission of Dr. H. Masursky and Mr. H. Pohn of the U.S. Geological Survey astrogeological survey. The 82-inch Struve reflector of the McDonald Observatory at Fort Davis, Texas was also made available for the observational patrol for several weeks—for some part of each month from March through August 1969—with the permission of Dr. H. Smith, Director, and Dr. R. Schorn, of JPL. Astronomical teams made direct observations of the physical aspects of the planet from these three observatories during the period of encounter of the *Mariner* spacecraft with Mars. The optical characteristics and the highest possible resolution of features on Mars during its closest approach to earth are given in Table 1 for each telescope.

Telescopic observations were secured each night, visually in seven spectral passbands from deep violet through red, and photographically in five separate spectral passbands and in integrated light by using color film (Ref. 2). Two new magenta filters, having an entirely new colorimetry concept for visual and photographic observations of Mars, were tested. These filters are regarded as minus-green filters because they absorb green light but transmit the blue and red ends of the spectrum. In practice, at the telescope they affected the appearance of the Martian disk in the following manner: dark features that were bluish lost contrast, light regions that were ocher-colored were brightened, and dark features that were intrinsically green exhibited an increase in contrast. Furthermore, the magenta filters recorded the positions of bright aerosols and limb brightenings relative to surface features, records which are of considerable impor-

Table 1. Telescope characteristics

Telescope	Focal length	Focal ratio	Resolution		Image scale	
			arc s	km	arc s	Barlow
16-in. (40 cm) Cassegrainian-type, Table Mountain Observatory	800 in.	f/50	0.29	101	10.2/mm	5.1/mm
24-in. (60 cm) Cassegrainian-type, Table Mountain Observatory	389 in.	f/16	0.19	66	21.1/mm	5.3/mm
30-in. (76 cm) Cassegrainian-type, USGS–astrogeology	450 in.	f/15	0.15	51.5	18.1/mm	4.5/mm
82-in. (208 cm) coudé-type, McDonald Observatory	1900 in.	f/23	0.055	19.1	4.3/mm	2.21/mm

tance. The results of the observational technique are shown in the drawings and photographs of Figs. 1, 2, and 3. Given on each image are the terrestrial date in universal time, the time of the observation (UT), the longitude of the local central meridian (CM), the telescope used, the Martian date (MD), and the initials of the responsible observer when observations were made by someone other than the author. The physical aspects of the planet in 1969 are described in Ref. 3.

II. Summary of Patrol: August 1968 to June 1969

The North Pole of Mars was tilted toward the earth before and during the opposition period, thus allowing accurate micrometer measurements of the spring–summer regression phase of the north polar cap. A graph made of the retreating cap showed a normal regression curve. Temporary hazes were sometimes observed in the arctic region. The north polar hood suddenly reappeared as a large and dense entity about June 4, terrestrial date. (The terrestrial date is given in universal time, or UT.) The dull, gray-white north hood had a poorly defined periphery, and it appeared at times to be larger than the south polar cap. The reformation of the north cap was irregular beneath the variable density of the hood. The south cap became clear of its polar hood about the last week of May, but became covered again for most of June 1969.

Morning frosts, or bright fogs, were prevalent over the Elysium, Neith Regio, Meroe Insulae, Nymphaeum, Edom, Aram, Eos, and Nix Olympica, and along the northern border of the Sabaeus–Meridiani Sinus on the Deucalionis Regio this apparition. The Hellas plateau, in the south, was only partly covered with a white extension from the south cap, while its north two-thirds was a dark ocher hue. The usual seasonal cloud activity was present over the Libya–Crocea region on the southern border of the Syrtis Major. White "W-cloud" formations, recurring in the afternoon, were again recorded in blue and violet light over the Great Martian Desert region. Up to this time, it seemed that fewer equatorial cloud bands were photographed in this apparition. Weak-to-moderate periods of atmospheric "blue-clearing" were recorded in violet light as far away as 247 days from opposition, and a strong-to-moderate period was observed around the time of opposition of May 31 (refer to photographs of Figs. 2 and 3).

Martian seasonal and secular changes of dark features in the vicinity of Syrtis Major, Sabaeus Sinus, and Margaritifer Sinus were noted from photographic and visual observations with the McDonald Observatory 82-inch reflector from May 27 through June 2, 1969. The good seeing averaged 0.1 to 0.2 arc seconds. In the Aeria desert at aerographic longitude 295° to 340°, latitude +49° to −02°, along the west side of the Syrtis, a linear feature, probably new, was observed contiguous to the Nymphaeum area connecting Antigones Fons (298° longitude; +20° latitude) to Typhonii Sinus (315°; −02°). A medium-contrast, triangular oasis was located about center of this new feature. Two connecting canal lineaments were also noted in this area, which have not previously been mapped. The Antigones Fons and the Coloe Palus (303°; +42°) appeared dark gray, and enlarged, with definite geometric structure (Fig. 1).

The Aethiopis–Laocoontis region (235° − 250°; +35°–0°) has been active, and has been observed with interest, since 1965. Spectroscopic multicolor photographs showed the Laocoontis to be one of the most color-saturated structures on the Martian disk in 1967. The large, dark area reported at longitude 245° by Dr. G. de Vaucouleurs (Ref. 4) was verified as a vague feature on 82-inch-reflector photographs and drawings obtained during the 1969 opposition (Ref. 5). An enlarged, dark structure was

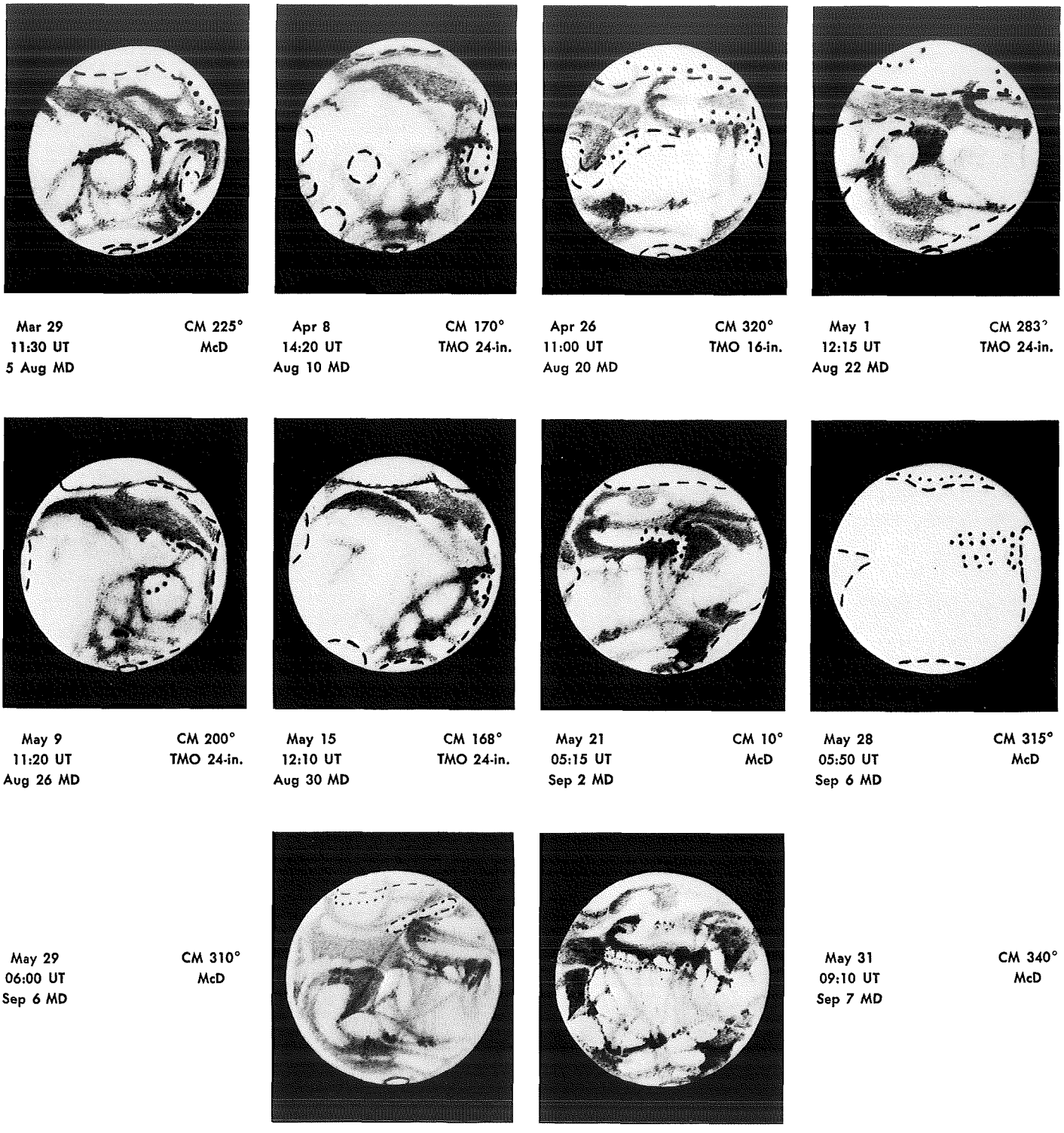

Fig. 1. Drawings of the Martian disk as it appeared from March 29 to May 31, 1969. The axial tilt D_e, as viewed from the earth, ranged from +18° to +06°, and the apparent diameter of the disk increased from 11 to 19 arc seconds. Ill-defined aerosol regions are indicated by dashed lines, and bright white areas by dotted lines. Information on each photograph shows the date in universal time, initial letter of the color used, the universal time of the exposure (UT), the areographic longitude on the central meridian during the exposure (CM), the telescope used, and the Martian date (MD).

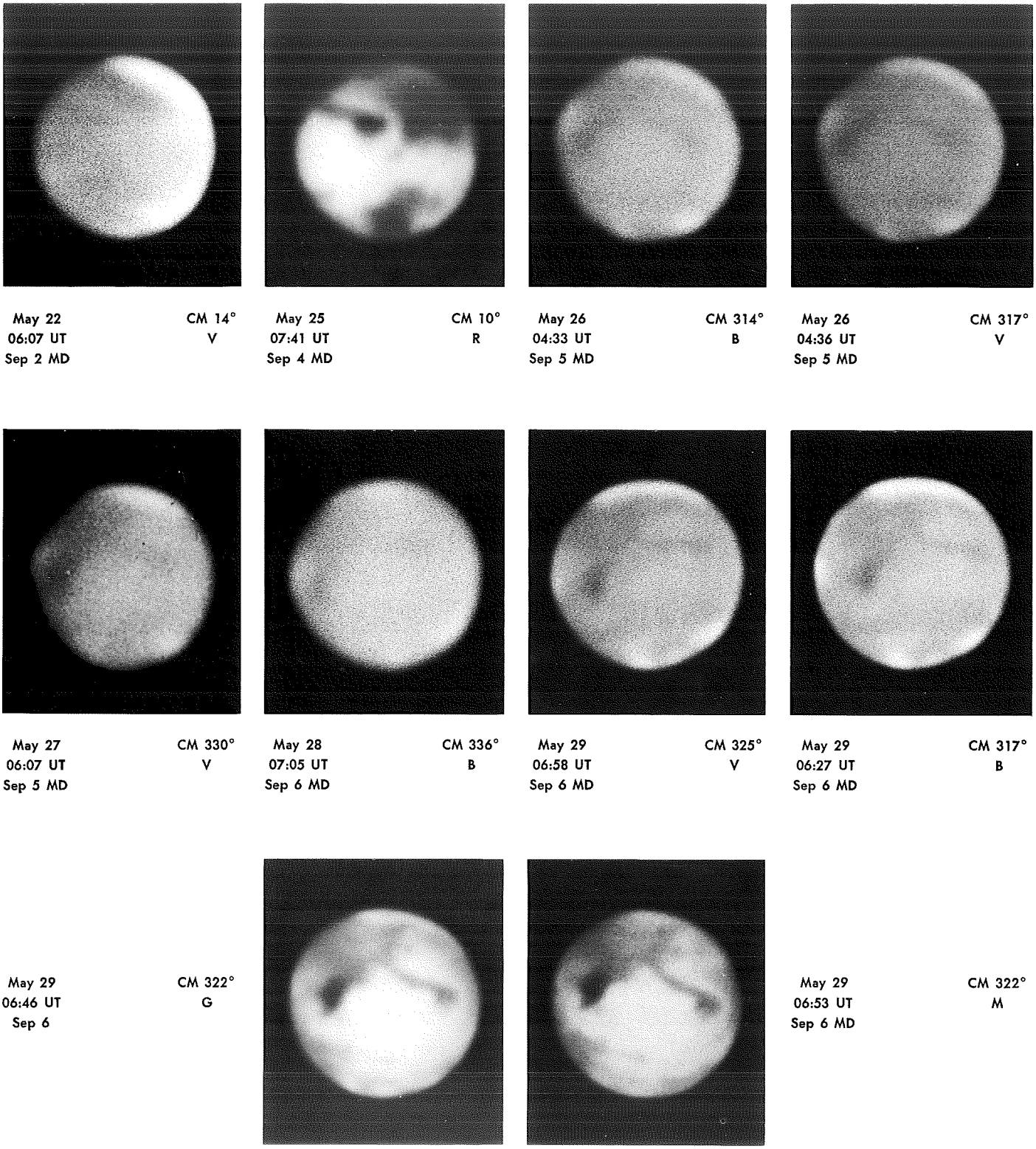

Fig. 2. Photographs of Mars in violet, blue, green, magenta, and red light made with the McDonald 82-in. reflector at the coudé focus by the author before the period of opposition from May 22 to May 29, 1969. The axial tilt D_e of the planet, as viewed from the earth, averaged +06°, the apparent diameter of the disk was 18.9 arc seconds, and the apparent declination was −23°9

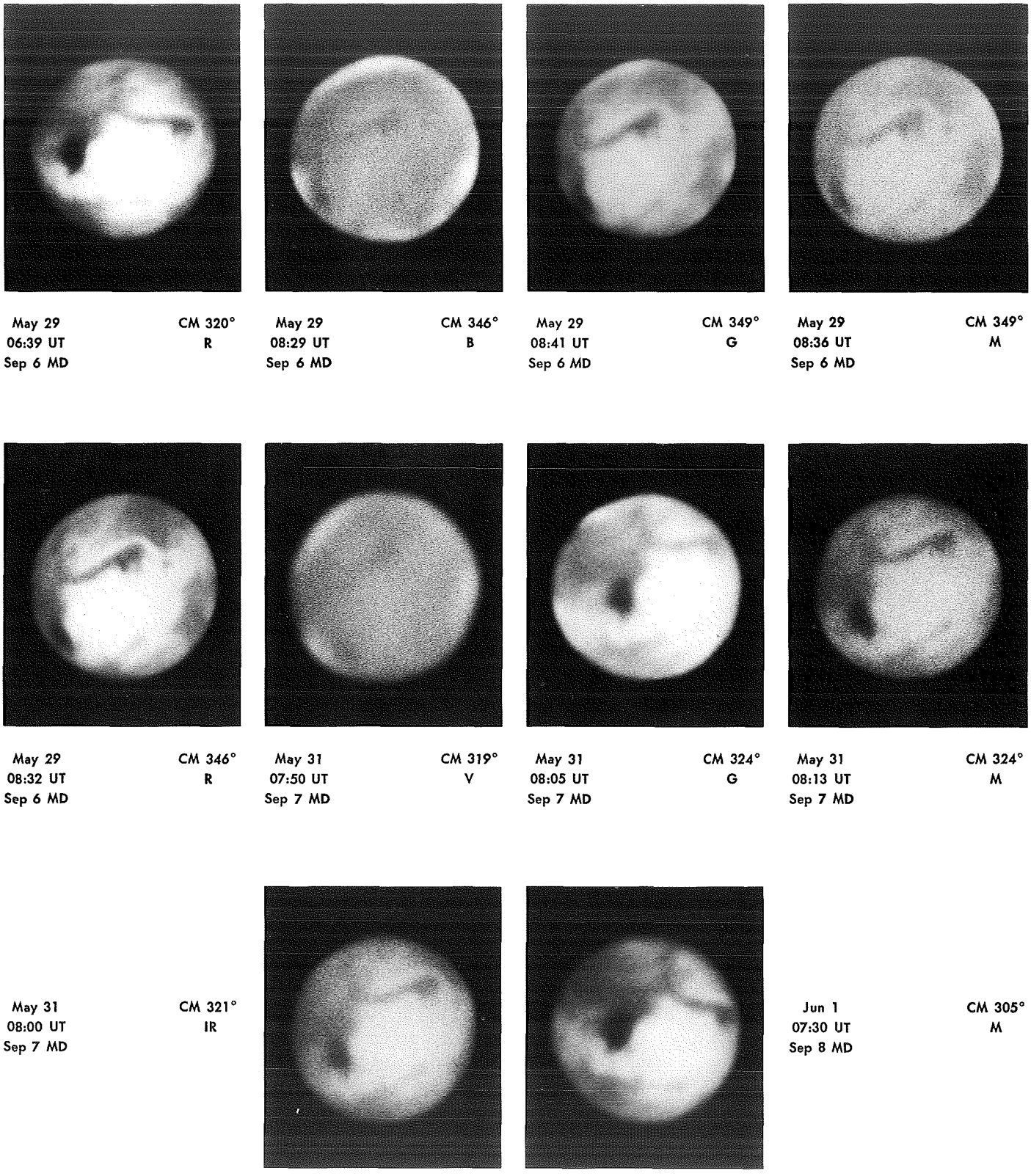

Fig. 3. Photographs of Mars in violet, blue, green, magenta, red, and infrared light made with the McDonald 82-inch reflector at the coudé focus during the period of opposition from May 29 to June 1, 1969. The axial tilt D_e averaged +07° and the apparent diameter was 19.2 arc seconds

photographed in the Fastigium Aryn (0°; +05°) connecting the two promontories of the Meridiani Sinus.

High resolution of surface detail, less than 20 miles, was achieved on the nights of May 29 and 30 with the 82-inch McDonald reflector, when seeing was about 0.1 arc second. The oases appeared to be composed of small triangular and circular objects, the maria were composed of various geometric structures, and some of the canal-lineaments broke up into dark gray, irregular, circular, and parallel filaments that were aligned approximately lengthwise with the axes of the canal features. Several new surface features, mention of which has not been found to date in the literature, were noted on the following side of the Syrtis Major. During the moments of excellent seeing, more fine surface detail was seen than could be recorded (Ref. 6). The high-resolution visual and photographic observations produced the current photovisual Regional Mars Map 1969 shown in Fig. 4.

III. South Polar Region: May to August, 1969

The south polar hood first became tenuous about May 16 UT and again on May 25 and 26, when a bright compass of the south cap was observed through the haze hood. Evidence of the south cap was missing from the disk on the night of May 27 because the polar hood once again temporarily increased in density until the evening of May 29, when visual and photographic observations with excellent seeing conditions revealed a well-defined edge of the cap (Table 2). The hood returned from time to time to cover the south polar region, and the presence of antarctic hazes and the northward planetary tilt contributed to make measurements of the diameter of the south cap difficult and inaccurate. Extensive antarctic haze was recorded as far north as −36° to −30° latitude from July 1 to July 16 UT.

Early micrometric and photographic measurements close to the spring equinox in the southern hemisphere showed the edge of the south cap to be at an average −46° to −48° latitude, or a cap diameter of about 86°, which is slightly larger than the average diameter of 80° (−50° latitude) found by E. Slipher (Ref. 7). Cap extensions were observed and measured as far north (toward the equator) as −35° to −34° latitude over the southern light areas:

May 31. The Hellas was covered white to 290° and 300° longitude, −35° latitude. When the Hellas was last observed on July 16, it was completely covered by a bright, white cloud and probable surface whitening. The white covering was expected to continue over the Hellas during this Martian season.

June 30. The Noachis covered white to 0° longitude, −37° latitude; and 20°, −36°.

July 2. The Noachis: 0°, −35°; 10°, −34°; and 20°, −37°.

June 30. The Argyre I: 30°, −37°; and 40°, −40°.

June 19–24. The Phaethontis 100°, −39° or −40°.

Color photographs were measured on the Lowell Observatory IAU Planetary Research Center image projector. The telescopic micrometer readings used a yellow–orange filter to control irradiation and to penetrate possible antarctic haze.

Table 2. South cap measurements and Martian atmospheric conditions at observation

1969 date, UT	South cap edge, deg	CM, deg	Type of observation	Remarks
May 29	−44 to −48	340	Photographic	Tenuous hood
May 31	−44 to −48	330	↓	Tenuous hood
June 1	−45 to −48	330	↓	Polar hazes
June 2	−45 to −49	330	↓	Polar hazes
June 12	−33 to −49	170	↓	Extensive haze
June 19	−46 to −48	100	Photographic	
June 21	−46 to −48	100	Micrometric	
June 23	−47 to −49	120	Photographic	
June 29	−50	60	Photographic	
July 2	−55	05	Micrometric	Extensive haze
July 9	−52	320	↓	Extensive haze
July 25	−58	170	↓	
July 28	−57	110	↓	
July 29	−60	110	Micrometric	

IV. Observations Made Before *Mariner VI* and *VII* Encounters: June to August, 1969

An equatorial cloud band was present from 20° through 240° longitude during most of June UT. In the northern hemisphere, evening limb haze from the equator to the North Pole was prevalent most of June. The Libya–Crocea region (260°–300° longitude; 0° latitude) appeared light at times, possibly because of the large, bright, seasonal cloud that comes through this region each Martian July and August. Dense, bright, morning

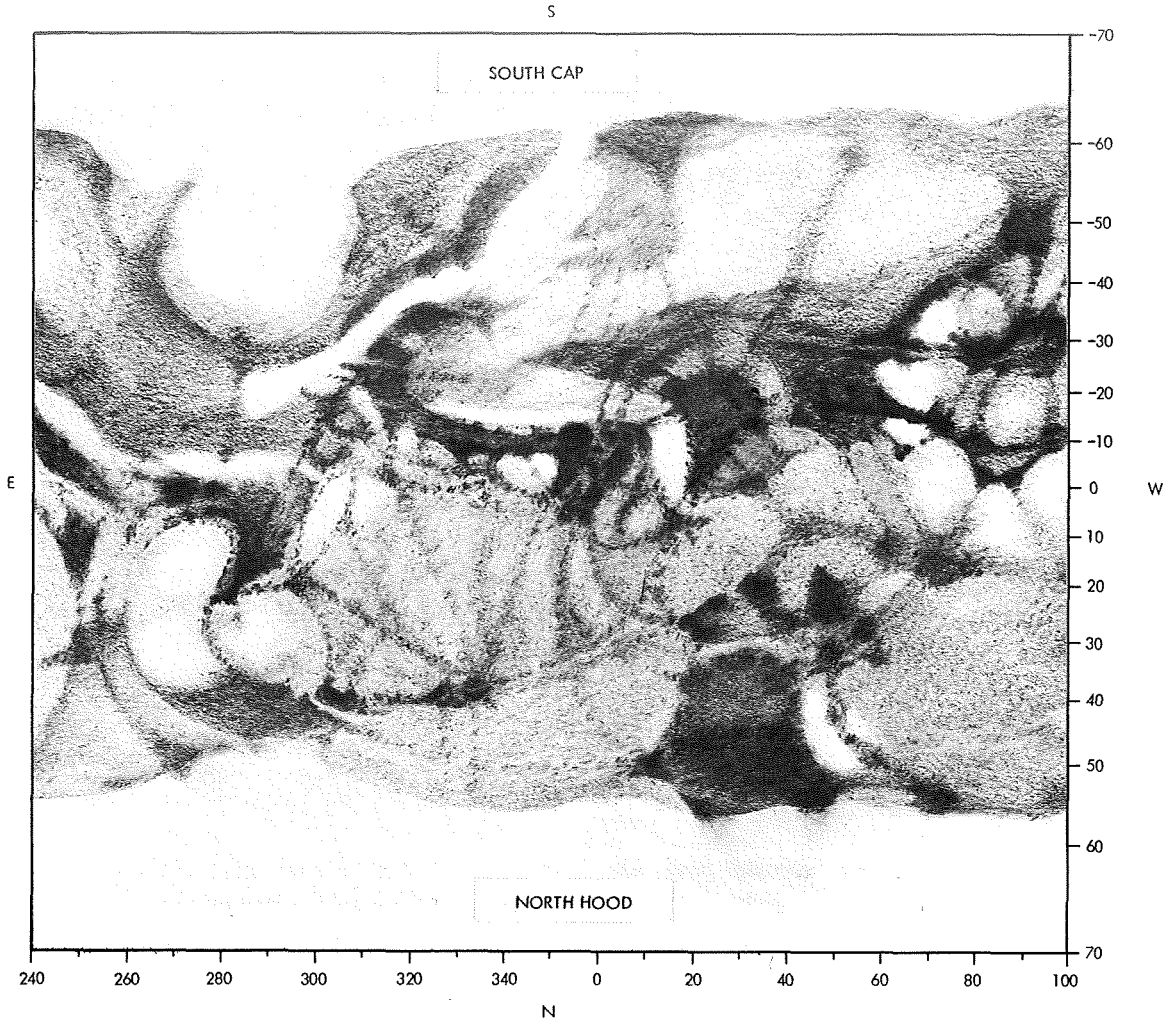

Fig. 4. High-resolution photovisual Regional Mars Map 1969 showing the seasonal and secular surface aspects of late *Martian summer* of the 240° through 100° *longitudes during the 1969 apparition*. The excellent seeing quality of 0.2 to 0.1 arc second resolved surface detail to less than 20 miles during the period of opposition. The map was produced from measurements of 20 photographs, 13 drawings, and 15 telescopic micrometer observations

aerosols and possible surface frost were present over the Isidis Regio–Neith Regio–Meroe Insulae region during early June UT. This meteorological condition dissipated during July UT. A large, dense, wedge-shaped cloud was noted over the Mare Umbra–Dioscuria–Cydonia region (285°; 20°). It was curiously contained by the Protonilus–Deuteronilus canal on the south and the Pierius canal to the north from July 1 to 16 UT. At times it was contiguous to, or joined with, the arctic hood. This interesting cloud was dense and bright from Martian 6 to 9 o'clock; then dissipated, in temperate latitudes, by 10:30 to 11 o'clock, while in the arctic region close to the north polar cap where the climate of the day was cooler, it remained. A dense, bright cloud was also present during this period along the eastern border of the Mare Acidalium from the north polar cap to Novem Viae (20°; +49°). The Mare Acidalium was covered with dense, morning, limb mists during July—a condition that persisted after *Mariner* encounter. From July 25 to 26 UT a morning cloud was present over the Elysium plateau, and weak arctic morning terminator haze and evening limb haze was present in the northern hemisphere.

The Hellas was covered with white cloud, and possibly frost, during July UT, a condition that appeared and disappeared unpredictably throughout the Martian spring–summer season of the southern hemisphere. The whitening (frost or low cloud) that was observed during May and June UT on the Deucalionis Regio, backed up along the south border of the Sabaeus–Meridiani Sinus, disappeared

during July UT. Likewise, the white on the Edom (350°; 0°) was gone. However, the Aram (08°; 0°) was still covered in white when last observed on July 6 and 9 UT. A white patch of frost or fog was observed contiguous to the Niliacus Lacus and Nilokeras II canal centered about 38°; +22° the last of June UT. The Candor–Tharsis region below the Eye-of-Mars (65°–115°; +05°) exhibited surface whitening during mid-June. This region had numerous afternoon clouds and diurnal whitening throughout the period of this report. On July 28 and 29 UT the white shade and light ocher hue of the Candor–Tharsis denoted meteorological activity in this region. A bright, white streak of fog, or frost, in the southern hemisphere was photographed in infrared, red, and green light, but was not recorded in blue or violet light. This cloud streak can be seen on the current Regional Mars Map 1969 of Fig. 4 extending from the edge of the south cap and winding northward through the east side of the Noachis, cutting across the Charis, and ending below the Hellas in the Iapygia area. Martian atmospheric blue-clearing was recorded as a weak phenomenon twice during July UT.

The Sabaeus Sinus south border appeared photographically to be composed of multiple, parallel, medium-dark structures. The Fastigium Aryn (0°; +05°), or Dawes' Forked Bay, was still seasonally filled in with dark contrast. The third fork of the Meridiani Sinus and its connecting Cantabras canal exhibited good contrast. The Typhon–Orontes canal lineament was easily observed from the earth during June and July UT. The Oxia Palus (15°; +15°) was dark and composed of several geometrical structures. An interesting surface darkening was photographed in the Chryse desert contiguous to the following west border of the Margaritifer Sinus. Whether this was a seasonal change or will prove to be a secular change is to be determined during the next several apparitions, but this area as viewed at close range by *Mariner VI* should be most interesting. The Juventae Fons (66°; −08°) remained small and dark, without enlarging during this apparition. The Pandorae Fretum exhibited good contrast except for its east end. Photographs of the southern maria show these areas to be composed of irregular geometric shapes.

V. Physical Aspects Observed During Mariner Flybys: July 29 to August 7, 1969

The disk of Mars exhibited moderate meteorological activity during the encounter periods of the *Mariners VI* and *VII* according to visual and photographic observations. Violet light photographs disclosed a possible local blue-clearing confined to the northern hemisphere on August 5 and 6. This blue-clearing was not noted visually. The northern morning terminator and evening limb showed brightening over the Mare Boreum–Tempe region and the Eden–Cydonia region. A classical evening mist, or cloud, was confined chiefly over the Deucalionis–Pandorae region.

A slightly lighter-than-normal appearance of the Deucalionis Regio and the Aram (10°; 0°) indicated the possible presence of scattered surface frost patches. The Candor–Tharsis was definitely covered by frost or aerosols throughout most of the Martian day during the encounter period. The Amazonis exhibited some patchy whitening. A light pink hue (white and ocher) to weak white was present on the NE border of the Elysium on July 25 UT. A morning aerosol or frost was easily observed until about Martian 8 or 9 o'clock over the Thaumasia–Solis Lacus region. The Hellas was completely covered with bright white on July 16 UT, and this condition persisted in varying degrees during the *Mariner* encounters. Extensive and tenuous polar mists and frosts covered most of the arctic region from the 5th to the 7th of August UT. The arctic whitening expanded and joined with the northern terminator whitening during this period. On the night of July 31 and through August 1 a bright oval patch was noted on the Abalos just south of the Hyperboreus Lacus and located about 80°; +73°; the patch was joined with the morning terminator aerosol, or frost, from the 3rd through the 6th of August.

The gross, dark, surface features appeared approximately the same as had been observed during June and early July UT. The darkening on the Fastigium Aryn (Dawes' Forked Bay) between the two main promontories of Meridiani Sinus was vague, but still present. The extensive surface darkening (20° to 40°; −8° to +10°) in the Chryse Desert contiguous to the following west border of the Margaritifer Sinus still exhibited good contrast. The two or three dark spots which compose the Juventae Fons appeared to be connected, which gave the general appearance of enlarging the oasis. The Mare Erythraeum appeared composed of dark, mottled spots and arcs.

The physical aspects of Mars during the period of spacecraft encounters are shown in the photographs and drawings of Figs. 5, 6, and 7. The photographs were exposed in violet, blue, and red light. The drawings show the dark surface features relative to the lighter areas of meteorological activity.

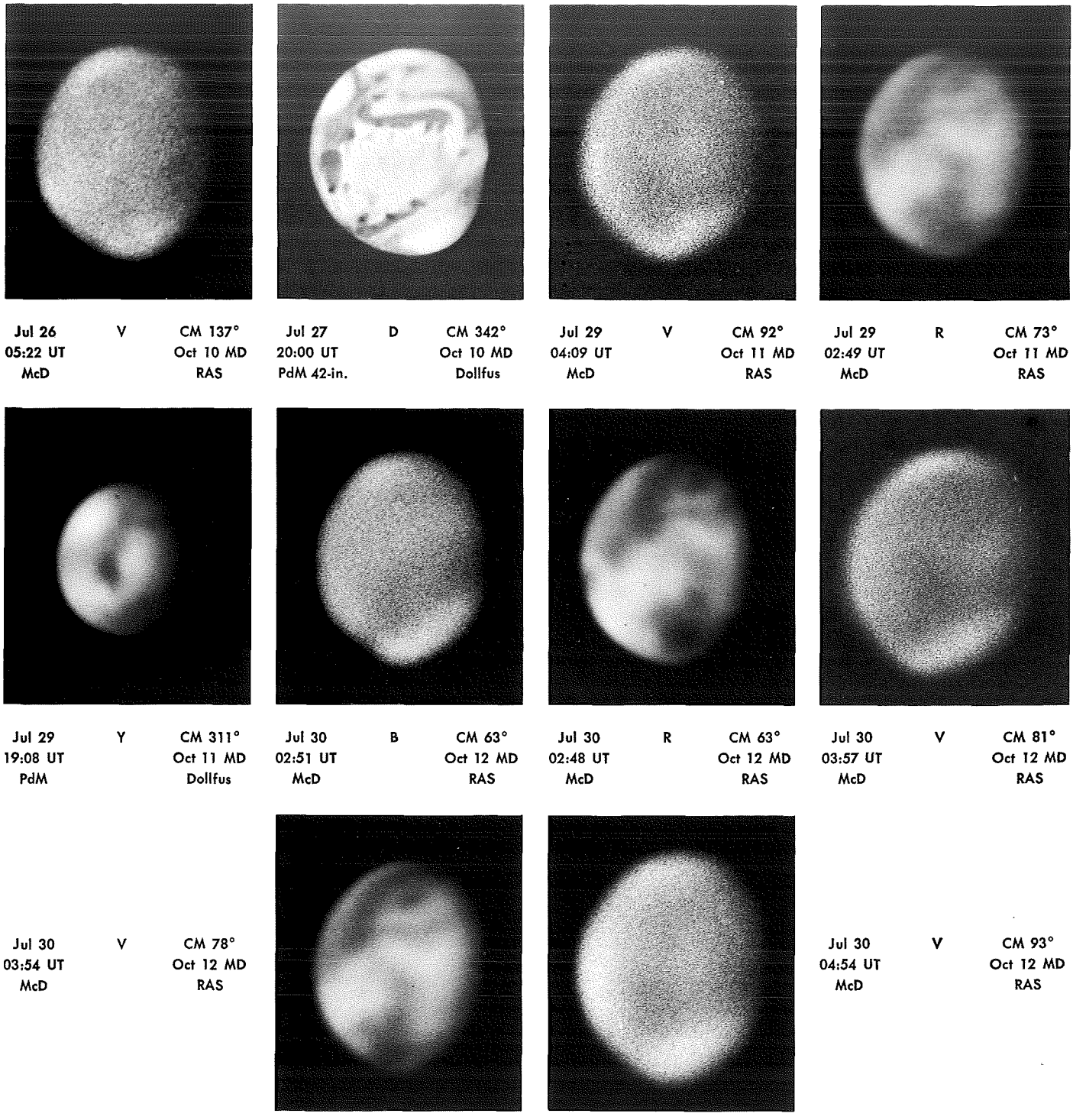

Fig. 5. Drawings and photographs in violet, blue, and red light of the Martian disk through the encounter periods of *Mariners VI* and *VII*. The axial tilt D_e, as viewed from the earth, was approximately $+10°$, the apparent disk diameter was 14.5 arc seconds, and the apparent declination was $-24°$. The observations were made with the McDonald 82-inch and the Pic du Midi 42-inch reflectors. Information on each photograph shows the date in universal time, initial letter of the color employed, the universal time of the exposure (UT), the areographic longitude on the central meridian during the exposure (CM), the telescope used, the Martian date (MD), and the initials of the responsible observer when observations were made by someone other than the author

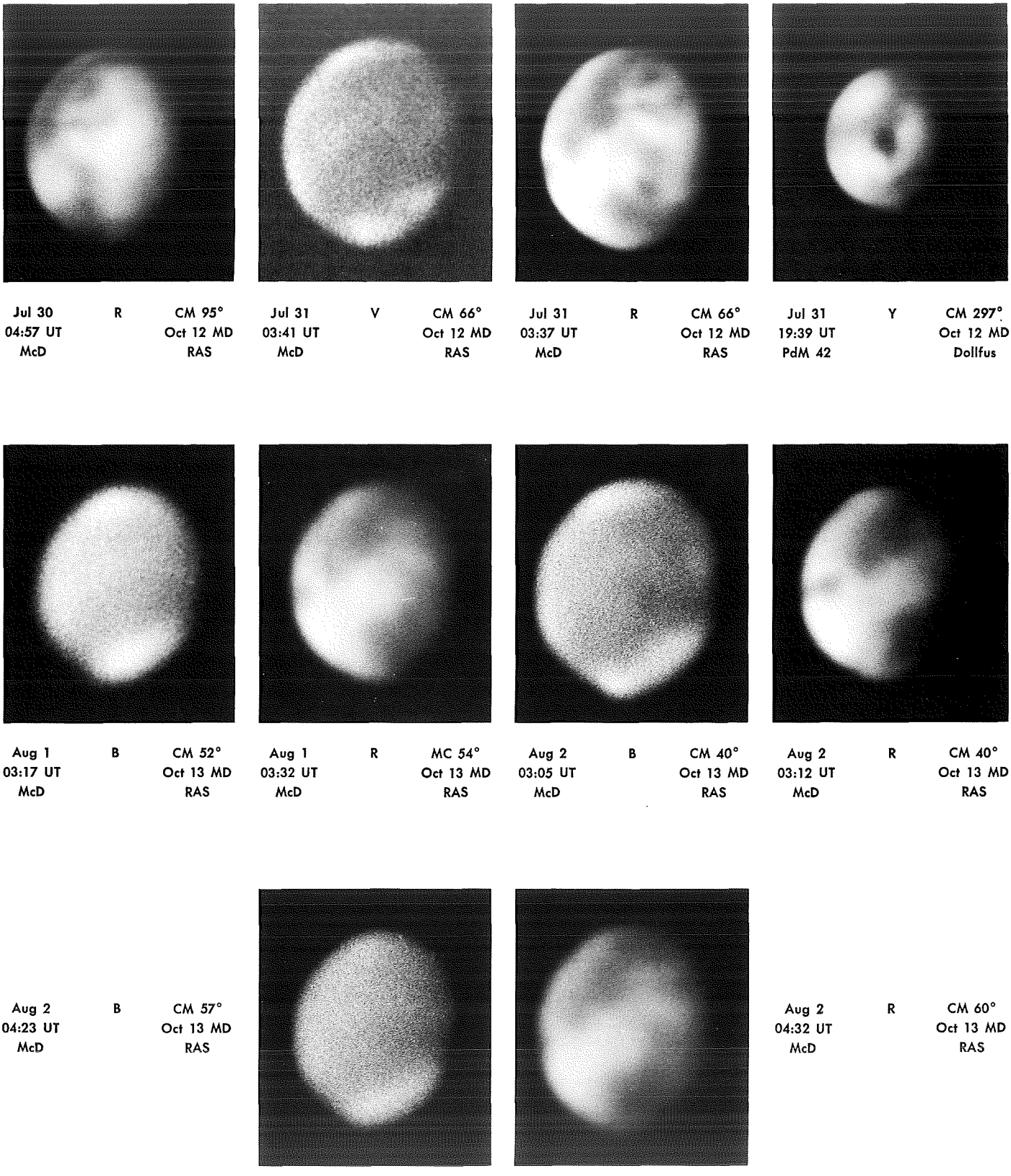

Fig. 6. Photographs of Mars in violet, blue, yellow, and red light made with the McDonald 82-inch and Pic du Midi 42-inch reflectors during the encounter period of *Mariner VI*

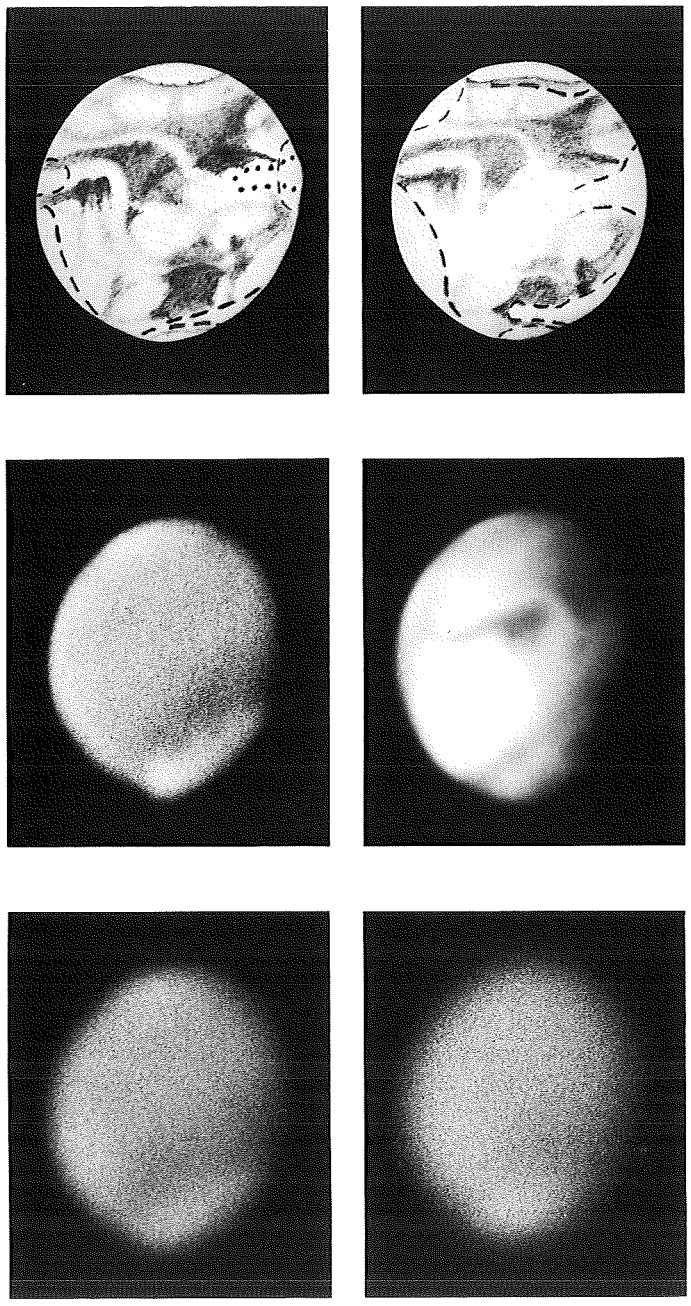

Fig. 7. Drawings and photographs in violet, blue, and red light of the Martian disk during the encounter period of *Mariner VII*. The observations were made with the USGS astrogeological 30-inch and the McDonald 82-inch reflectors

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15. Supplementary Notes

16. Abstract

A summary of the physical appearance of Mars during the 1969 apparition is presented for use in planetary research and in support of the Mariner VI and VII missions. An account is given of the seasonal meteorological activity and surface conditions before and during the Mariner encounters. Diameter measurements of the regressing south polar cap are tabulated. For comparison with Mariner pictures, a current Regional Mars Map 1969 of longitudes 240° to 100°, inclusive, was prepared from high-resolution observations (0.1 to 0.2 arc seconds) acquired during late Martian summer. Selected photographs and drawings are reproduced for reference with the text.

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