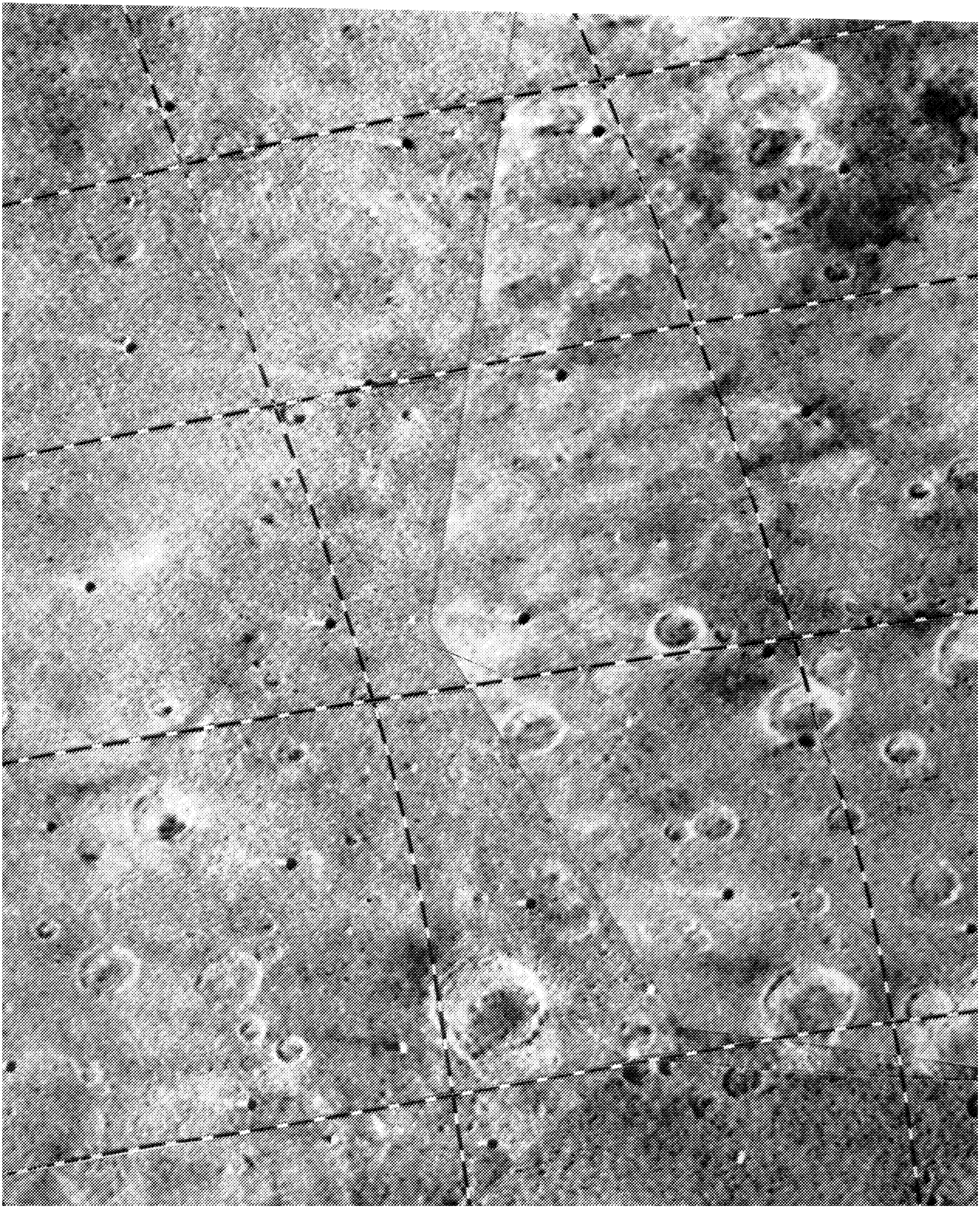
NASA SP-263

THE MARINER 6 AND 7 PICTURES OF MARS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION



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This color picture of Mars shows greater detail than any Earth-based photographs could provide. It was made by combining three black-and-white frames that were taken by Mariner 7 through color filters.

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THE MARINER 6 AND 7 PICTURES OF MARS

By

Stewart A. Collins

Prepared at Jet Propulsion Laboratory
Pasadena, California

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Foreword

Mars, the fourth planet, is a subject of romance and mystery in human culture. Astronomers, over the past century, have revealed that this close neighbor of Earth is in many respects its twin among the satellites of the Sun. Its transparent atmosphere permits observation of the seasonal variation of its surface markings that long ago gave rise to speculations that Mars also harbors life as does Earth. The meager information we have had about Mars has stimulated a whole literature of imaginative conjecture about the planet, which engendered and sustained the wide public interest in the scientific exploration of Mars by astronomical observation and space flight.

Mars is the planet most accessible for study from Earth, and most amenable for research by modern space-flight techniques. It also poses scientific questions most likely to better our understanding of our home planet's origin, evolution, and fundamental processes, and thus to provide knowledge potentially as beneficial to human affairs as it is interesting in an absolute sense. For these reasons the study of Mars has been ranked top priority by the scientific community, as for instance in the recommendations of the Space Science Board of the National Academy of Sciences. The National Aeronautics and Space Administration early in its history embarked on a progressive series of missions to enlarge our knowledge of Mars. The initial reconnaissance of Mars was carried out in 1964 by the Mariner IV spacecraft, which transmitted to Earth close-up television pictures of the lunarlike, cratered, mountainous surface, and reported on the condition of the planet's atmosphere and space environment. Mariner VI and VII in 1969 extended this reconnaissance in both detail and diversity of observations. The planned succeeding phases of investigating Mars will continue with Mariner Mars Orbiter missions, to be launched in 1971, whose task is to lay the groundwork for atmospheric entry and soft landers on the surface by the Viking program in 1976. The present volume presents the results of the Mariner VI and VII missions, in a more finished form that has been issued hitherto. Greatest interest attaches to the 200-odd television images which the world first viewed in their crude form as they were received on Earth. This book tells the story of the teamwork that produced this splendid result, and provides to the reading public the fruits of a venture that well characterizes the age of space exploration.

HENRY J. SMITH
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Preface

This book presents a comprehensive set of the television pictures taken of Mars by the Mariner 6 and 7 spacecraft. These pictures are the final results from the ambitious and complex television experiment of the Mariner Mars 1969 Project, a project managed by the Jet Propulsion Laboratory (JPL) of the California Institute of Technology for the National Aeronautics and Space Administration. To most fully utilize this television data, NASA has sponsored extensive post-flyby computer processing and analysis of these pictures.

The purpose of this book is to make available high-quality reproductions of the final, computer-processed pictures. The text serves only to explain the genesis and unique characteristics of the pictures, to point out interesting features in them, and to provide some indication of their significance in the history of Mars investigations.

Detailed analysis has been avoided in this volume. Such interpretation is the subject of the special supplement "The Mariner 6 and 7 Pictures of Mars" in the January 1971 issue of the *Journal of Geophysical Research*, a supplement which presents the observations and conclusions of the Television Experiment Team under the leadership of Dr. Robert B. Leighton. The television team has not participated directly in writing this book.

The Mariner pictures are not copyrighted and may be obtained through the National Space Science Data Center, Goddard Space Flight Center, Greenbelt, Maryland 20771.

The author is indebted to the JPL Image Processing Laboratory, which prepared all the Mariner pictures used in this book, and to James K. Campbell, who provided the trajectory and viewing data. The valuable assistance of Mary Fran Buehler, Patricia B. Conklin, Patricia Shutts, David Thiessen, and James H. Wilson is gratefully acknowledged. The administrative and scientific judgment of Dr. A. Bruce Whitehead has also been essential to the preparation of this volume. Chapters 1, 3, and 4 are based in part on material prepared by Claude M. Michaux, who also made the drawings. Finally, Drs. Robert B. Leighton, Bruce C. Murray, and Robert P. Sharp, all of the Television Experiment Team, and G. Edward Danielson, Television Experiment Representative, have been very helpful in reviewing portions of this manuscript, correcting misstatements, and helping the author clarify the expression of many ideas.

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Jet Propulsion Laboratory
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Pasadena, California

Stewart A. Collins

Contents

CHAPTER 1

Previous Investigations

For thousands of years, Mars has intrigued man, for it has stood apart as an unusual heavenly body. The ancients identified it as a "star" which wandered about the sky and periodically varied in brightness. The early Greeks recognized that Mars was a "neighbor" of the Earth and first called it a planet.

Modern Martian exploration began during the seventeenth century when Francesco Fontana first studied Mars with a telescope, identified its gibbous phase, and thus found that Mars shone by light reflected from the Sun. Fontana also saw on Mars a marking which he believed to be permanent, probably the dark, triangular Syrtis Major. In 1659, Christian Huygens sketched this feature and, by timing its passage across the Martian disk, concluded: ". . . . the rotation of Mars seems to take place like that of Earth in 24 of our hours." In 1672, Huygens and J. D. Cassini observed the white area known as the South Polar Cap. In the early eighteenth century, Giacomo Maraldi noted that the polar caps changed size with seasons and that the small summertime southern cap was slightly offset from the South Pole, a fact not then known to be true of the Earth's polar caps. He was also the first to observe changes in the location and size of surface markings and remarked that some of these changes might be due to clouds.

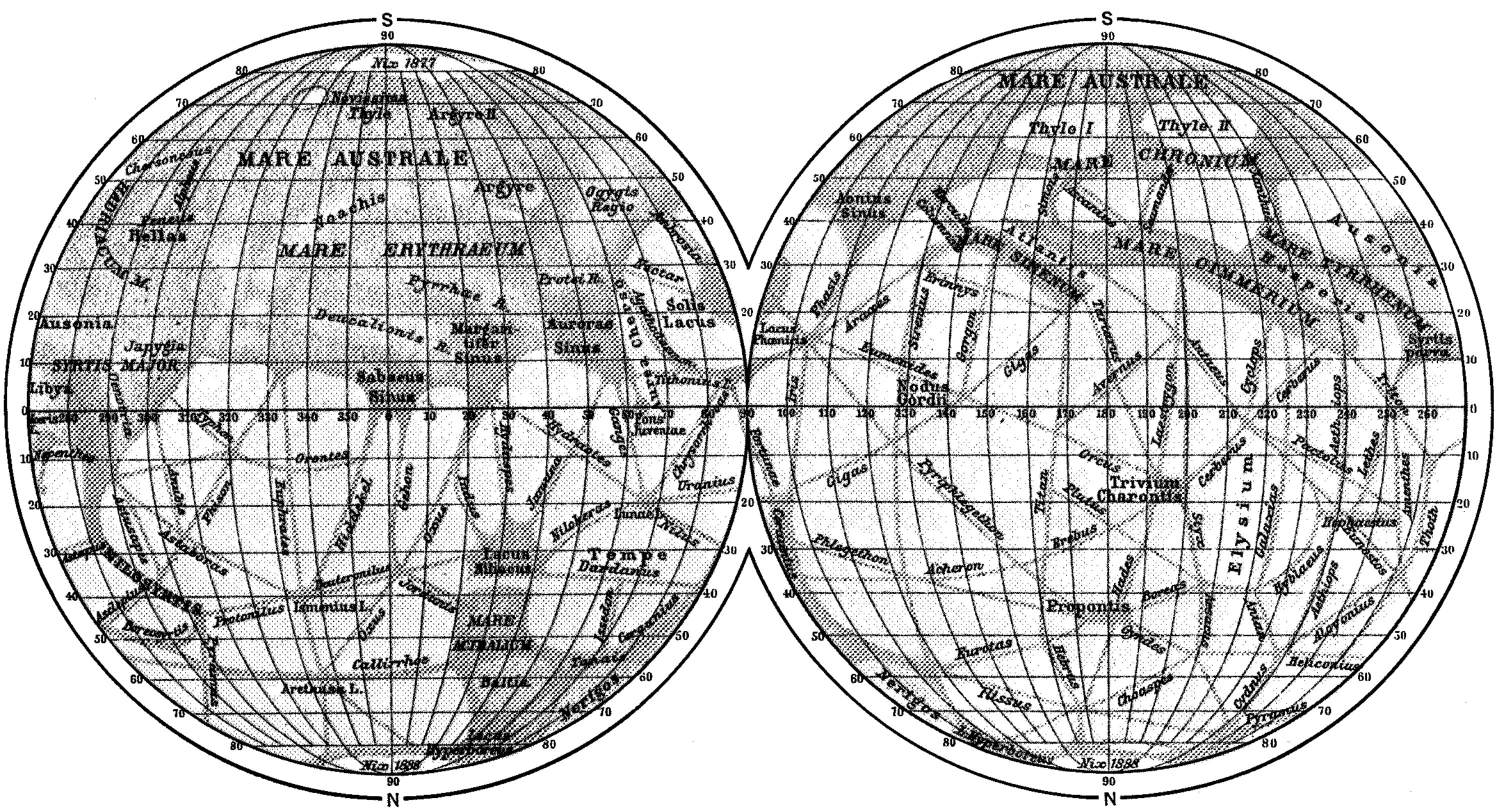
About 1780, Sir William Herschel, continuing the work of Maraldi, sought to correlate the color and size changes of features with the Martian seasons. In doing so, he located the Martian spring in the planet's solar orbit. Herschel concluded that the polar white areas were ice caps, the dark areas were oceans, the light areas were continents, and that Mars had an atmosphere "so that its inhabitants probably enjoy conditions analogous to ours in several respects." These statements, from such a respected authority, influenced subsequent investigators for over one hundred years.

The nineteenth century brought a host of Martian map makers. Two of these men, Wilhelm Beer and Johann von Mädler, established a

Martian longitude–latitude system much like that accepted today and more accurately defined the Martian rotation period to be 24 hours, 37 minutes, 23.7 seconds. Giovanni Schiaparelli, starting in 1878, published a series of maps identifying features with Latin names, most of which are still in use today. His maps' greatest significance, however, was not the settlement of international naming feuds. Rather, his maps showed many dark lines—he called them "canali" (channels)—interconnecting the dark areas in a strange-looking network. "Canali" was soon mis-translated into "canals," and intelligent life on Mars was suddenly an intriguing popular concept.

As the idea of Martian life took firm root in public thought, another astronomer, Asaph Hall, discovered two small moons of Mars and named them Phobos and Deimos. Phobos was found to revolve around Mars three times faster than the planet rotates and would, therefore,

The maps of Giovanni Schiaparelli were the first to use Latin nomenclature for Martian features. This map, drawn in 1888, was made from visual, not photographic, observations. It shows many features visible in the Mariner pictures and also many "canali" (channels), which later caused excitement about the possibility of Martian life.



appear to rise in the west and set in the east twice daily. Deimos, with a period slightly longer than the rotation of Mars, would rise in the east and travel slowly across the sky before setting in the west three days later.

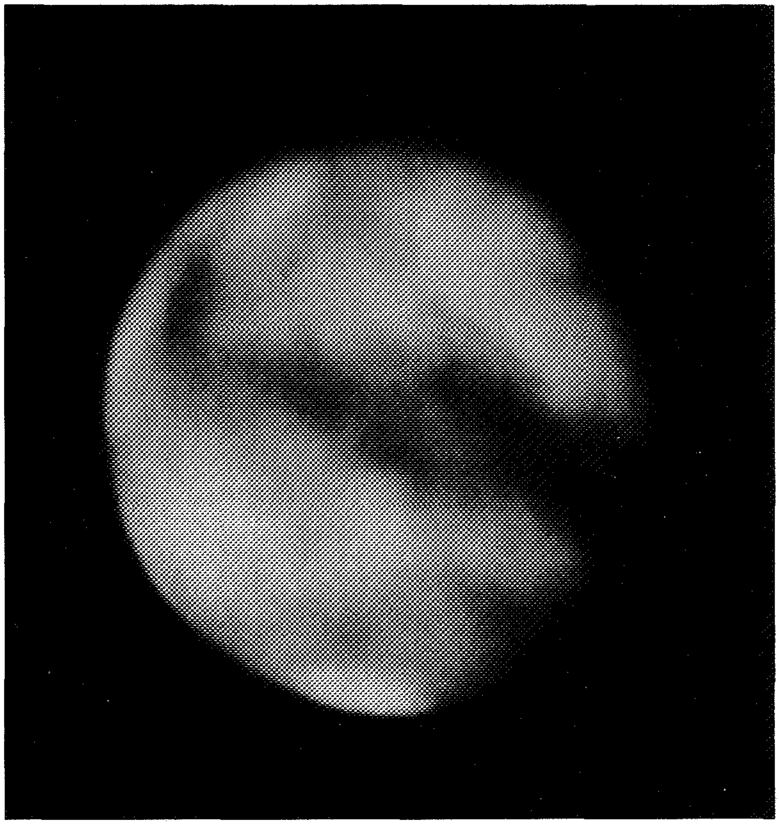
In 1892, as astronomers began to study canals more carefully, William Pickering discovered a canal crossing the dark area of Mare Erythraeum. This finding refuted the theory, surviving from Herschel one hundred years earlier, that the dark areas were oceans.

A new explanation of the changing sizes and colors of the dark areas was then proposed: that these were land areas covered with a vegetation that flourished in the spring and dried in the autumn. This theory remained popular through the 1950's.

As Martian exploration entered the twentieth century, Martian life found its most ardent defender, Percival Lowell. Enthusiastic over Schiaparelli's canali, Lowell devoted his life and a fully staffed observatory to the study of Mars. The canals, he proposed, were constructed by intelligent Mars inhabitants seeking to survive on a dry and forbidding planet. As the polar caps melted during their summer seasons, the canals carried the melt-water away to the drier equatorial regions to irrigate the life-sustaining crops there. Canals sketched by Lowell were thin, straight lines so precisely arranged as to require an intelligent origin. During the ensuing debate, E. M. Antoniadi announced he had identified canals as an alignment of spots or ragged edges, not straight, continuous lines. While many of Lowell's canals disappeared from later maps, they were erased much more slowly from the minds of observers and the public. By 1930, Mars had been fastidiously mapped within the limitations of visual observation.

The improvement of photography at the turn of the century introduced a new capability with which astronomers could compare observations made many years apart. Thus began a systematic study of seasonal variations, like the "wave of darkening"—a progressive darkening from pole to equator of the dark areas in the hemisphere of the melting polar cap, and daily variations, such as the reported appearance of blue, white, and yellow clouds.

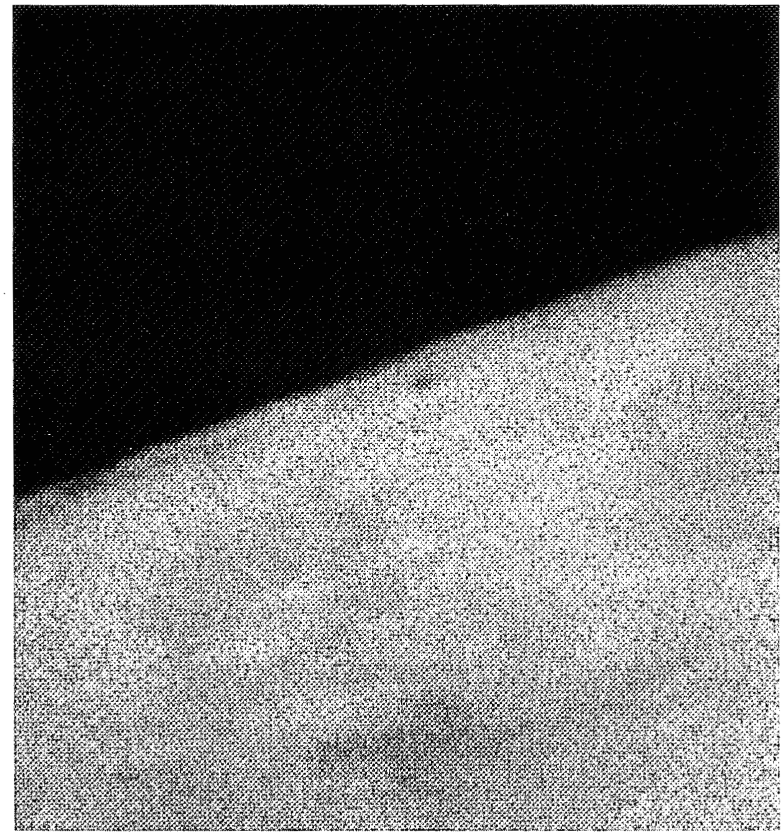
This century also introduced the use of new analysis instruments, such as spectroscopes, thermocouples (infrared radiometers), polarimeters, and photometers, to planetary study.



This Earth-based photograph was taken in 1956 by Dr. Robert B. Leighton at the Mount Wilson Observatory. Just appearing near the western limb is Syrtis Major, and just disappearing at the eastern terminator is Cerberus. Bordering the South Polar Cap is the light area Ausonia. North is at the top.

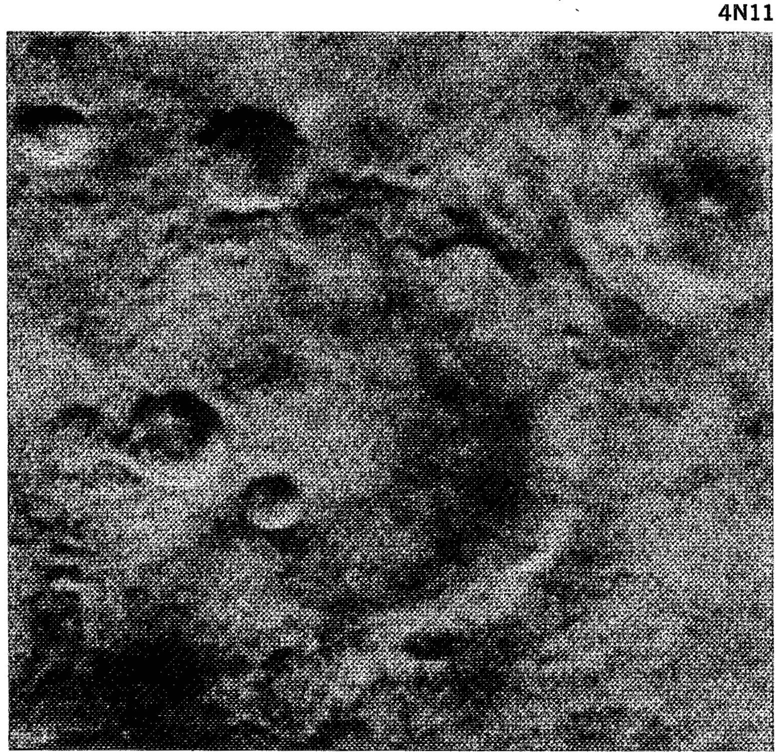
Using a spectrometer, G. P. Kuiper discovered carbon dioxide in the Martian atmosphere in 1947. Similar ground-based studies later disclosed small amounts of water and carbon monoxide and indicated that the Martian atmospheric pressure might be as low as 10–15 millibars, roughly 1% of that on Earth. With a thermocouple it was determined that the surface of Mars was very cold, with temperatures above freezing only during summer days in the tropical latitudes. Polarimeters, measuring polarization, and photometers, measuring brightness, suggested the bright areas included finely divided material containing at least some ferric iron.

In 1965, more than 350 years after Galileo sought the first close-up view of Mars, the Mariner 4 spacecraft flew close enough to the planet to make a number of new measurements and acquire 22 television pictures. Mariner 4 found an extremely thin (5–10 millibars) carbon dioxide atmosphere and sent pictures revealing Mars to be extensively cratered.



4N1

4N11

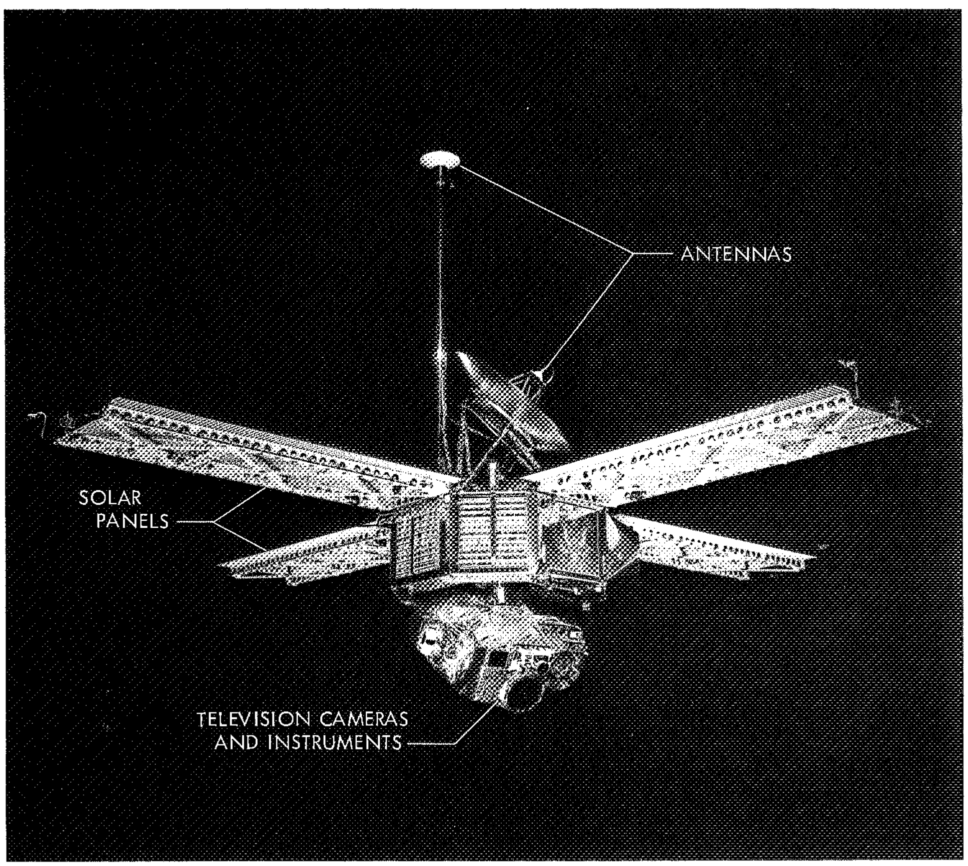


Mariner 4 provided man's first close-up pictures of Mars. Frame 4N1 showed the Martian limb and the area Phlegra. Frame 4N11, taken farther south, presented a crater 175 kilometers in diameter.

CHAPTER 2

The Spacecraft and the Mission

Shortly after the successful Mariner 4 mission, NASA authorized the Mariner Mars 1969 Project. Mariners 6 and 7, launched by the more powerful Atlas–Centaur rocket, were to greatly increase and improve the observations made by Mariner 4 and by Earth-based investigators. Thus scientists and engineers began to design a more ambitious exploratory mission and to build larger, more sophisticated spacecraft to complete this mission.



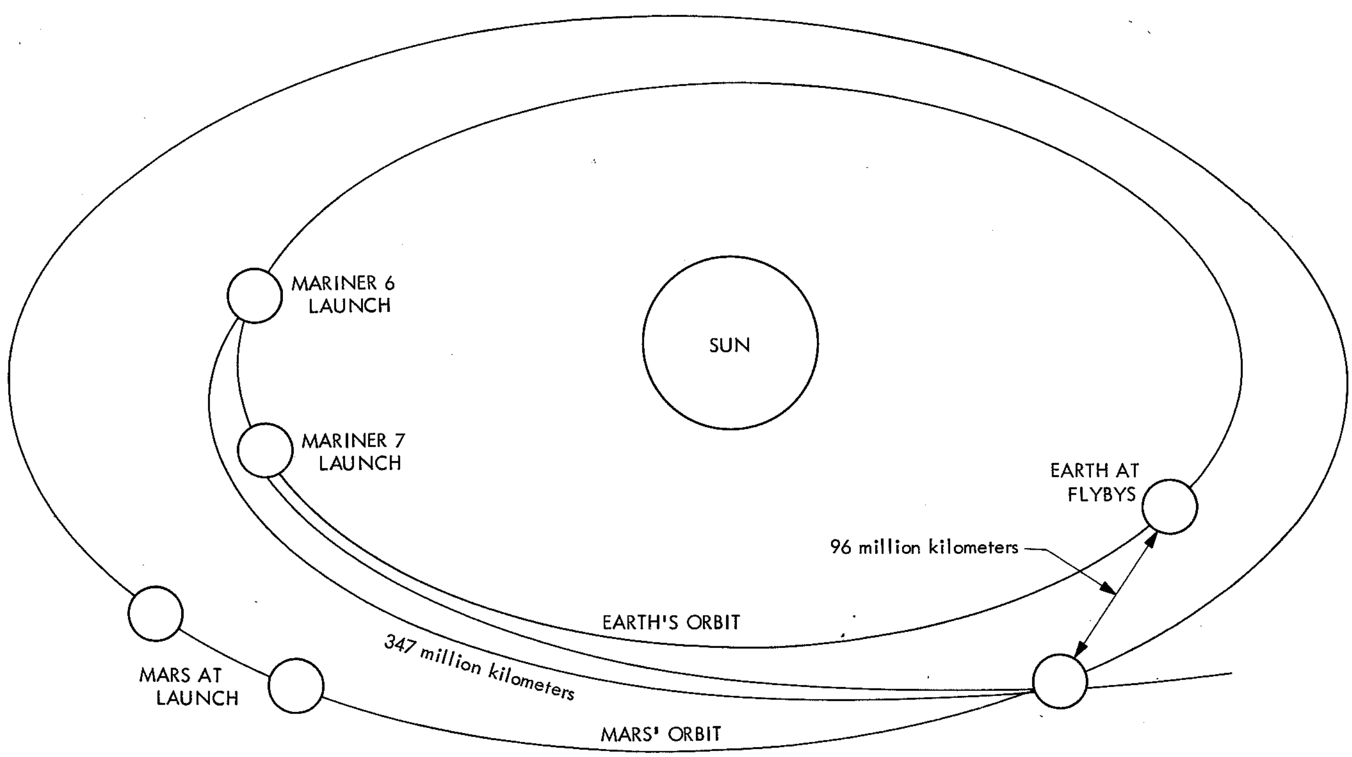
The Mariner 1969 spacecraft were larger (5.8 meters or 19 feet) across the solar panels and heavier (380 kilograms or 840 pounds) than any previous NASA planetary spacecraft.

This Atlas–Centaur, a massive vehicle of 145 metric tons, successfully launched Mariner 7 on March 27, 1969. Mariner 6 had been launched by a similar vehicle a month earlier, on February 24, 1969.

After more than 3 years of preparation, Mariner 6 was perched atop its Atlas–Centaur rocket 10 days before its scheduled launch toward Mars. Unexpectedly, a faulty switch opened the main valves on the Atlas stage, and the rocket, as tall as a 12-story building, began to collapse like a punctured tire. As the air roared out, two ground crewmen ran into the vehicle, started the pressurizing pumps, and thus prevented further "deflation" of the launch vehicle. While NASA prepared Exceptional Bravery Medals for these two crewmen, engineers began a thorough inspection of the complex Mariner 6 spacecraft and determined that it had sustained no damage during the mishap. The spacecraft was removed from the wrinkled rocket and was placed upon another Atlas–Centaur. So successful was this switch that Mariner 6 was launched, on schedule, 10 days later toward its Mars encounter.

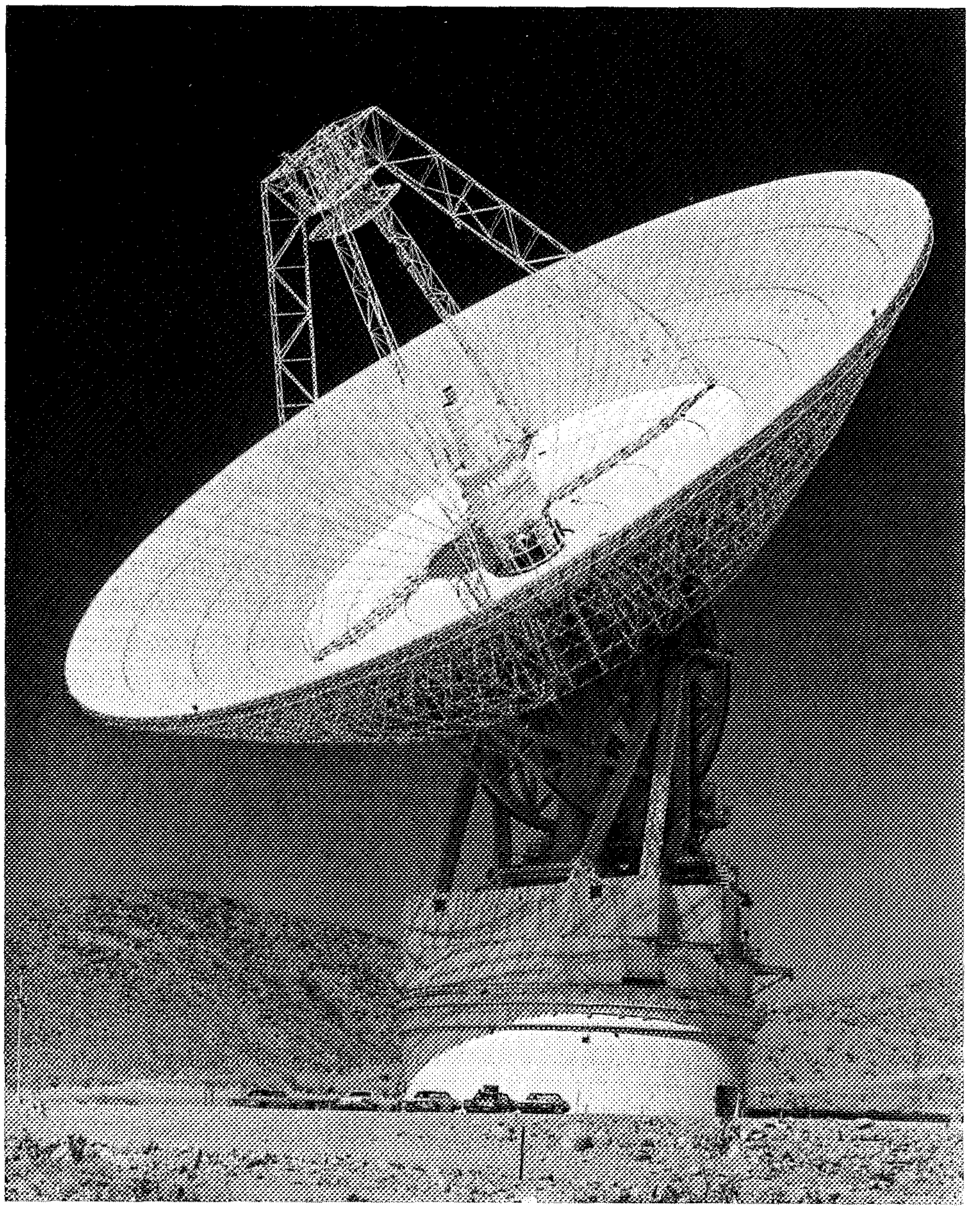
This ingenuity and flexibility of operation typified the entire Mariner Mars 1969 Project. The two spacecraft, Mariners 6 and 7, incorporated two major improvements over previous planetary probes, improvements that encouraged adaptive operation. The first was the use of programmable computers aboard the craft. In previous planetary missions, most of the sequences and other spacecraft instructions had been read into the on-board computer prior to launch, and it was difficult or impossible to modify these instructions after launch. The Mariner 6 and 7 computers could be reprogrammed from the ground at any time during the mission. The second advance was the experimental high-rate telemetry system. This system, due in part to the new 64-meter-diameter receiving antenna at Goldstone, California, enabled

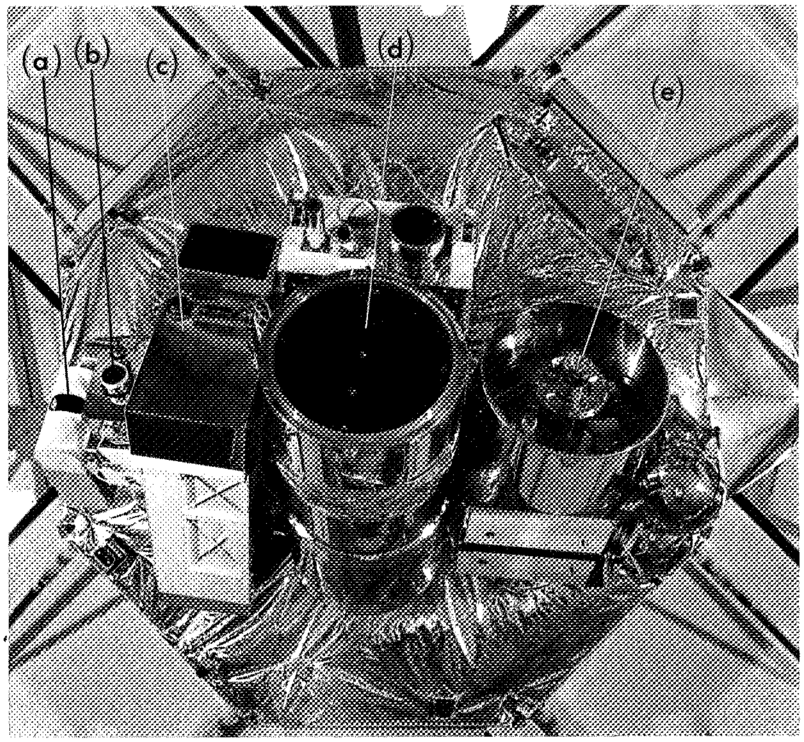
Mariners 6 and 7 both followed a long solar orbit that carried them gradually out to Mars. Mariner 7 was launched a month later than Mariner 6 but arrived only 5 days later because of the "inside track" taken by Mariner 7. At the time of encounter, Mars was 96 million kilometers (60 million miles) from Earth, and radio signals, traveling at the speed of light, from the spacecraft were received at Earth 5 minutes later.



the Mariners to communicate 2000 times faster than Mariner 4. These two advances figured prominently in many after-launch decisions aimed at increasing the quality or quantity of data or at correcting problems that had arisen on the spacecraft.

The giant antenna, 64 meters (210 feet) in diameter, at the Deep Space Network's Goldstone, California, station was an essential element of the high-rate telemetry system. Other stations located around the world used antennas 26 meters (85 feet) in diameter.





The science instrument scan platform was mounted beneath the spacecraft, as shown in the photograph. The platform was movable so that the instruments could be pointed at different regions on Mars. Unlike previous Mariners, these spacecraft carried no instruments to gather interplanetary data during the Earth–Mars cruise. The entire mission was focused on obtaining information about the Martian surface and atmosphere. Instruments are: (a) infrared radiometer, (b) wide-angle television, (c) ultraviolet spectrometer, (d) narrow-angle television, and (e) infrared spectrometer.

Picture-taking activities for both Mariners were divided into two sequences: far encounter sequence and near encounter sequence. The far encounter sequence took place during several days prior to flyby when all of Mars appeared as a disk in the television pictures. Near encounter included the 30 minutes during flyby when detailed pictures were taken of small areas on Mars. The pictures are identified by spacecraft, sequence, and picture number within that sequence. Thus 6F38 is the thirty-eighth picture taken by Mariner 6 during its far encounter, while 7N13 is the thirteenth Mariner 7 near encounter picture. An abbreviated account of operations during encounter week is given below.

Encounter Events

Tuesday, July 29. Throughout Tuesday, Mariner 6 records 33 far encounter pictures on its tape recorder. The tape is played back and the pictures are transmitted to Earth that evening. Originally, Mariner 6 was to take only eight far encounter pictures, but the experimental high-rate telemetry system has proved so successful that 50 such pictures will be returned by this spacecraft.

Wednesday, July 30. Mariner 6 records an additional 16-1/5 pictures and transmits them back late in the afternoon. As flight controllers prepare for the complex Mariner 6 near encounter sequence, to occur Wednesday night, contact is suddenly lost with Mariner 7. Most personnel continue to prepare Mariner 6 while a smaller team concentrates on solving the Mariner 7 problems. Both efforts climax at the same time. While Mariner 6 begins recording its 25 near encounter pictures, a cheer goes up at the announcement that Mariner 7 communication has been re-established after a 7-hour silence. The day ends as Mariner 6 passes behind Mars.

Thursday, July 31. Spacecraft engineers analyze the data now being received from Mariner 7 and determine that several problems still exist. Post-encounter study will reveal that the Mariner 7 battery probably ruptured and vented its contents into the spacecraft. This in turn caused electrical transients that induced the spacecraft to spin like a pinwheel and to lose contact with Earth. Now, however, the most serious consequence appears to be damage to the equipment that reports the pointing direction of the television cameras. Since the Mariner 7 cameras cannot be pointed properly without this information, work is begun tc find a solution. On Thursday night, the 25 Mariner 6 near encounter pictures, recorded a day earlier, are played back.

Friday, August 1. A scheme has been devised to calibrate the pointing indicator for the Mariner 7 cameras. The cameras are turned on and begin transmitting pictures of black space. They are then moved around in a search which climaxes when Mars appears in the corner of one frame. Several additional corrections center Mars in the frame and provide the needed calibration. This operation, essential before any television pictures can be acquired by Mariner 7, is possible because of the high-rate telemetry system which sends an entire picture in 42 seconds instead of the 35 minutes required by the standard system.

Saturday, August 2. Properly oriented once again, Mariner 7 records 33 far encounter pictures and plays them back during the evening.

Sunday, August 3. Mariner 7 records and transmits an additional 33 far encounter pictures. Analysis of the Mariner 6 data continues in an effort to determine whether Mariner 7's plan should be altered in any way to study interesting features seen by Mariner 6.

Monday, August 4. Mariner 7 records its final 25 far encounter pictures and plays them back. Mariner 7 now has taken a total of 91 far encounter pictures, quite a contrast to the eight originally planned. Mission planners have completed their study of Mariner 6 data and have decided to assign to the still-limping Mariner 7 a more ambitious job than that performed by its sister craft. Far encounter data will be sent back until one hour before near encounter—Mariner 6 stopped 6 hours prior to encounter. Also, Mariner 7's near encounter coverage is increased to 33 pictures. This aggressive, last-minute plan is executed perfectly; and Mariner 7, following its sister's path, passes behind Mars.

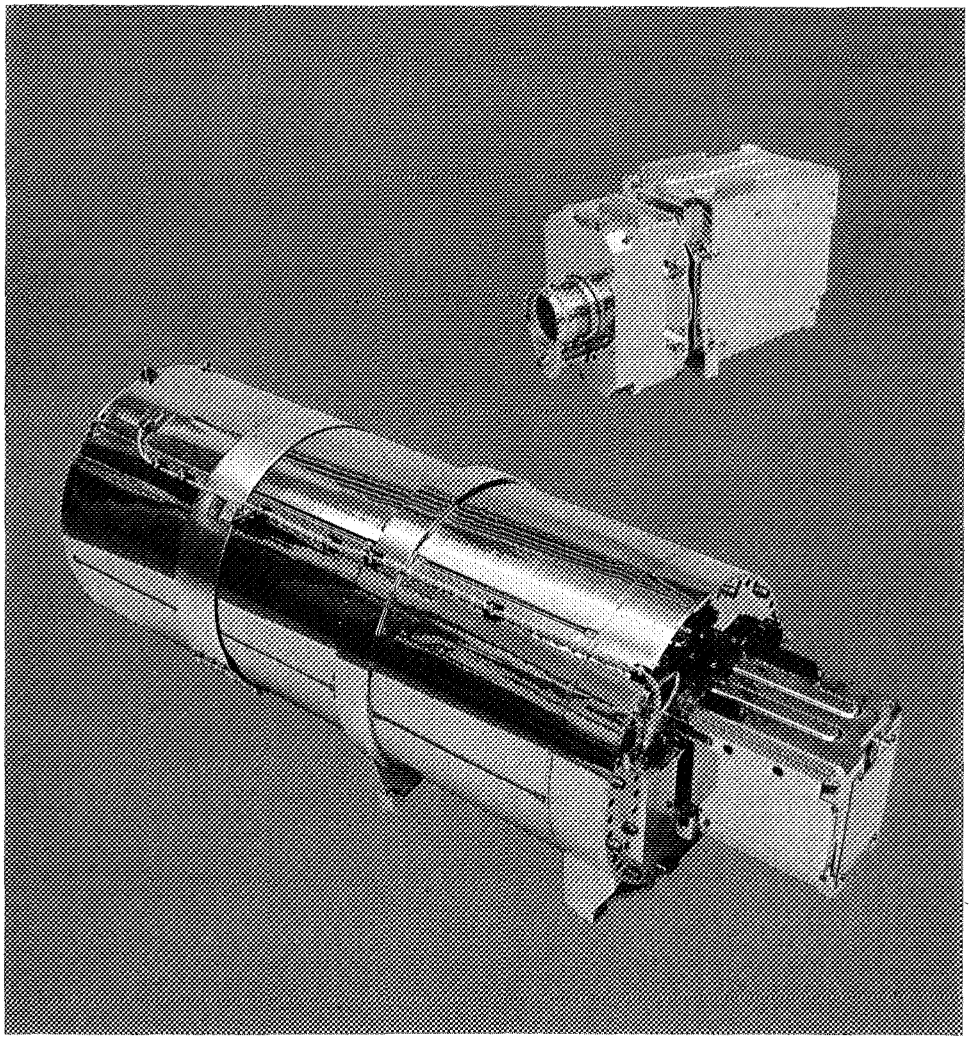
Tuesday, August 5. Mariner 7 plays back its 33 near encounter pictures, and both spacecraft continue in orbit around the Sun.

Postscript. At this writing 16 months later, both spacecraft are operational and in regular radio contact with NASA's ground stations. As the spacecraft passed behind the Sun, the radio signal was used in the most sensitive test yet made of Einstein's General Theory of Relativity.

The Television System

Mariners 6 and 7 each carried two television cameras to photograph Mars. At the near encounter distances from Mars, Camera A, with a wide-angle lens, showed large areas of the planet (approximately 1000 × 1000 kilometers, about the size of Alaska) and details as small as 3 kilometers (2 miles). Camera B, using a telephoto lens, at the same distance from Mars, showed smaller areas (100 × 100 kilometers, about the size of the Los Angeles basin) and details as small as 300 meters (300 yards). The fields of view and shutter sequence were planned so that the A frames, taken sequentially through blue, green, and red filters, would overlap, and the B frames, taken through a minus-blue filter, would be located in the overlap area of two A frames. Most far encounter pictures were taken using the B camera.

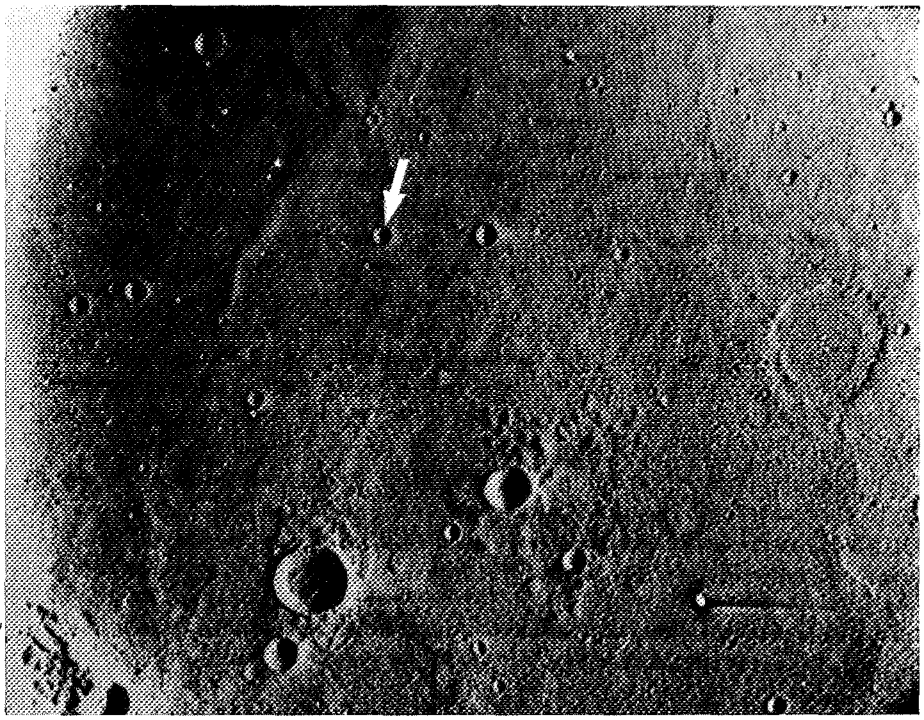
A television picture taken by Mariners 6 and 7 is actually an array of points, each of which has a numerical value from zero to 255, representing the brightness at that point. Zero represents black, 255 indicates white, and the 254 intermediate numbers correspond to the intermediate shades of grey. Each picture is composed of 704 lines

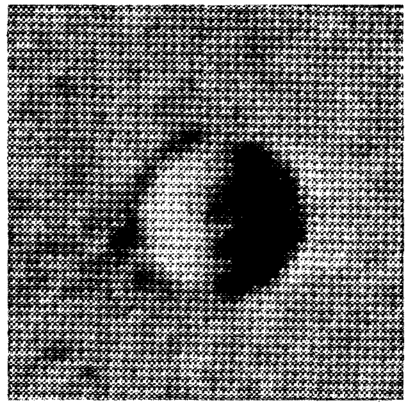


The two cameras carried by each spacecraft differed only in their optical systems. The wide-angle Camera A (top) used a 50-millimeter focal length Zeiss planar lens with blue, green, and red filters, while the high-resolution Camera B (bottom) used a large (508-millimeter focal length) Cassegrain telephoto lens.

with 945 points, or pixels (picture elements) per line (665,280 pixels per picture).

This numerical information was received in the telemetry from the spacecraft, stored on magnetic tape, and readily processed as numerical data by computers. Through the use of a system roughly similar to a home television set, pictures were read off these tapes and were photographed as they appeared on an electronic display screen.





Shown here are the actual numerical values of the points in a small portion of this picture. In this large array of numbers, it is possible to identify a crater by the low data numbers of its dark slopes and the high data numbers of the bright, sunlit slopes.

153	160	135	126	110	102	113	118	125	135	140	143	130	120	122	120	113	115	135	142	112	108	112	109	99	108	127	132	133	127
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109	103	106	95	89	133	208	255	255	246	180	146	129	65	61	67	1	0	18	14	0	0	10	78	126	160	153	159	159	144
103	101	108	103	71	127	214	254	255	255	217	169	127	76	74	81	18	10	40	23	0	0	7	74	130	173	164	160	161	156
98	115	103	92	54	95	177	231	255	255	232	184	147	119	109	95	45	31	31	18	0	0	6	71	142	181	171	170	178	171
108	123	72	45	50	88	156	221	255	229	218	197	177	133	92	59	33	28	10	0	0	0	0	69	150	169	152	157	177	176
154	133	65	35	62	93	135	205	245	224	244	214	153	96	64	45	38	42	27	6	0	0	28	116	183	169	149	156	170	164
144	109	85	72	102	132	146	201	248	229	252	225	156	101	68	57	42	41	34	3	0	0	85	186	221	195	188	186	177	154
101	84	95	82	103	120	123	167	215	205	214	205	163	122	92	84	62	59	47	0	0	45	152	215	214	193	193	181	160	149
93	106	110	103	120	98	93	127	164	204	207	195	154	122	95	75	47	40	13	0	18	118	190	195	170	150	146	144	140	152
105	115	112	122	109	57	75	98	102	171	191	173	142	110	65	35	16	20	13	23	89	161	181	167	146	130	132	130	133	143
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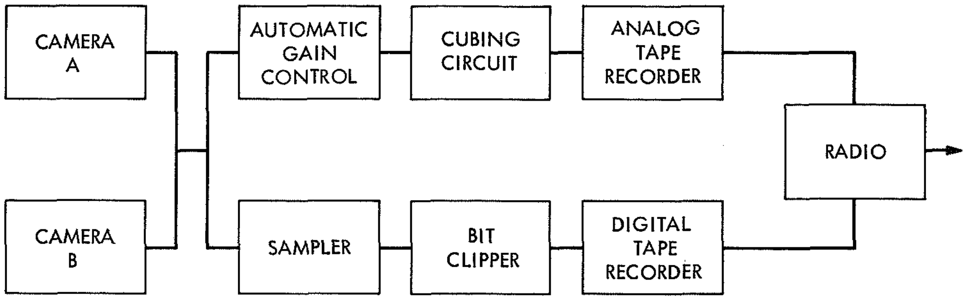
139	112	109	122	112	115	118	119	115	105	125	122	116	123	113	115	140	157	176	173	157	143	120	125	127	122	126	146	144	125
126	113	102	103	130	130	110	113	112	116	125	133	136	123	120	119	132	146	166	173	164	147	122	130	137	129	112	137	137	122
118	125	132	126	149	140	110	115	125	127	115	126	140	133	142	132	132	143	156	163	143	135	125	132	139	147	133	143	130	127
127	116	130	137	127	115	113	135	150	136	118	127	153	154	147	123	125	139	139	152	136	122	126	144	140	149	136	129	113	122



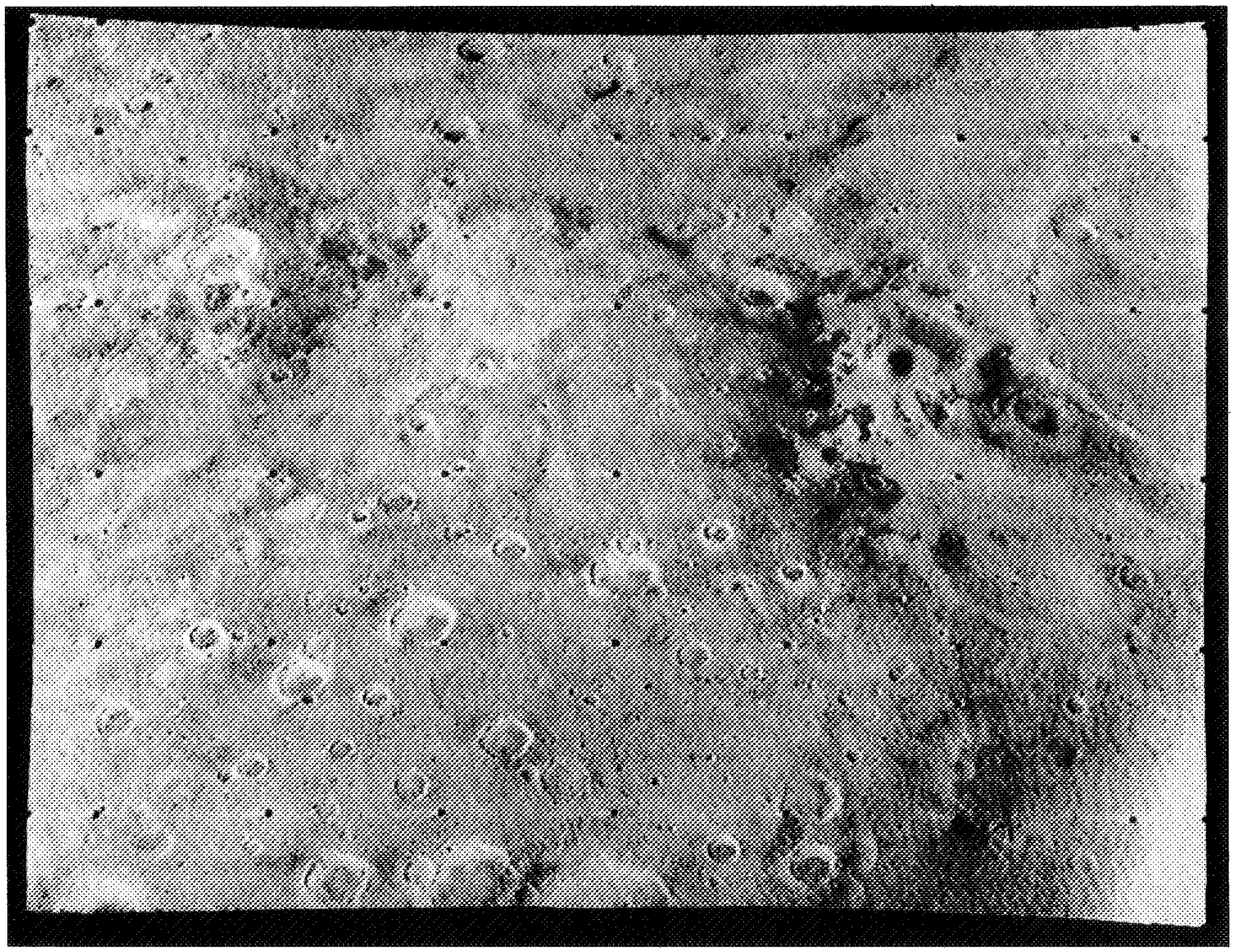
This block diagram shows the television system in its near encounter mode and indicates the on-board processing of the television signal.

The Mariner 4 television experiment had shown Mars to have a very low-contrast surface with only subtle detail. For this reason, during near encounter the electronic television signal was processed on the spacecraft into two forms of data: analog video and digital video.

The primary data form, the analog video, was processed (high-pass filtered) to emphasize small-scale details. This signal was nonlinearly amplified to enhance high-frequency detail while sacrificing the fidelity of large-scale brightness variations. If such pictures had been taken of Earth, small detail such as mountains, valleys, rivers, and coastlines would have been enhanced, but differences between large deserts, oceans, and forests, for instance, would have been minimized.

The secondary data form, the digital video, was not enhanced and therefore accurately preserved the large light-to-dark variations. Digital video, however, was taken for only selected picture elements and required extensive computer processing before it could be used. In the far encounter sequence, there was only one data type, a form of analog video to which the enhancement technique had not been applied and which therefore more accurately represented the actual scene.

Obtaining and transmitting the pictures to Earth was only half the job. Remaining was the task of computer processing the pictures so that they most accurately represented Mars. Eventually two versions of pictures were produced—a maximum-definition version using only the analog video and a photometric version combining the analog and digital video. The maximum-definition pictures showed maximum fine surface detail and the photometric version portrayed Mars as it actually appeared, revealing fewer details but better showing the large-scale variations.

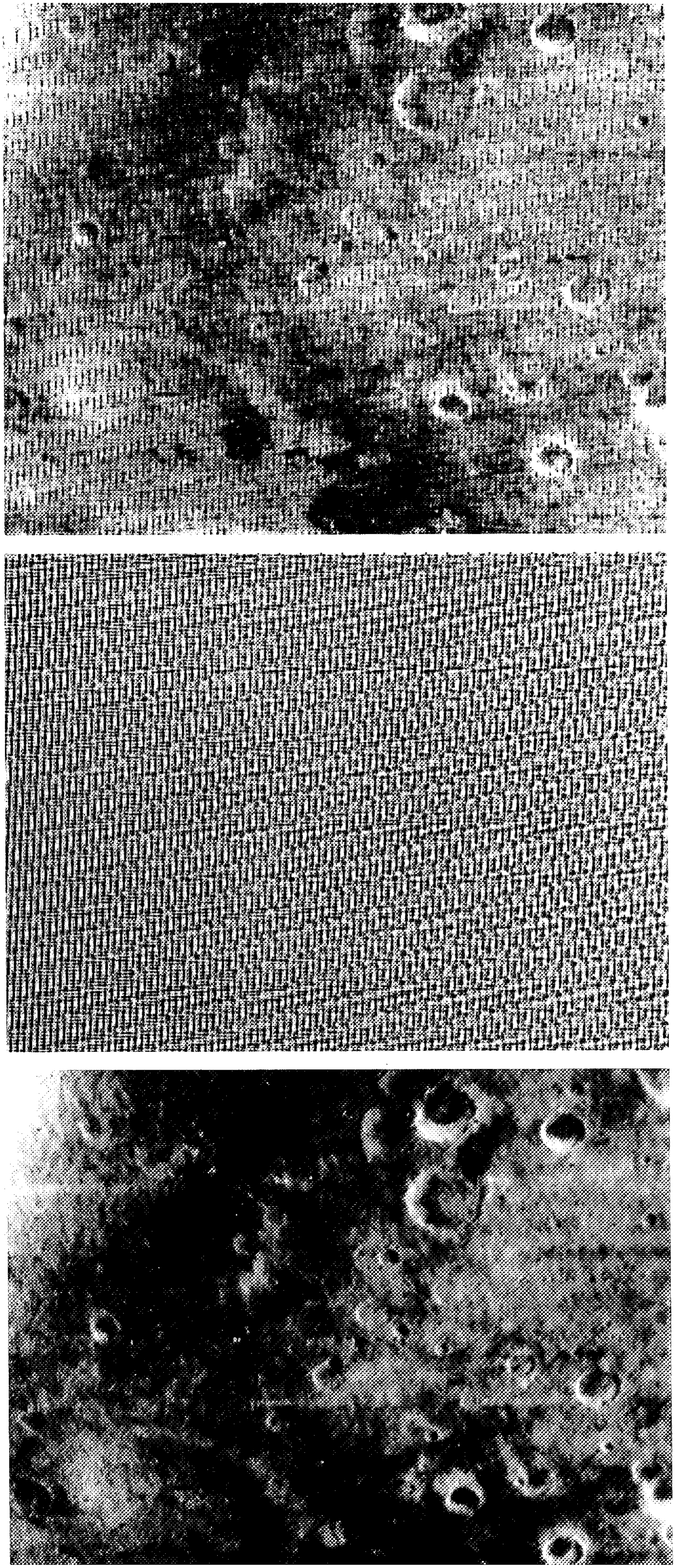


Finally, several effects had been introduced into the pictures by the television system and had to be removed by the Jet Propulsion Laboratory's Image Processing Laboratory, the computer facility designed for and devoted to processing television data. The primary unwanted feature of the pictures was the coherent, or periodic, noise, which appears as a basket weave pattern overlying the picture. Through the use of computers it was possible to extract this and other patterns.

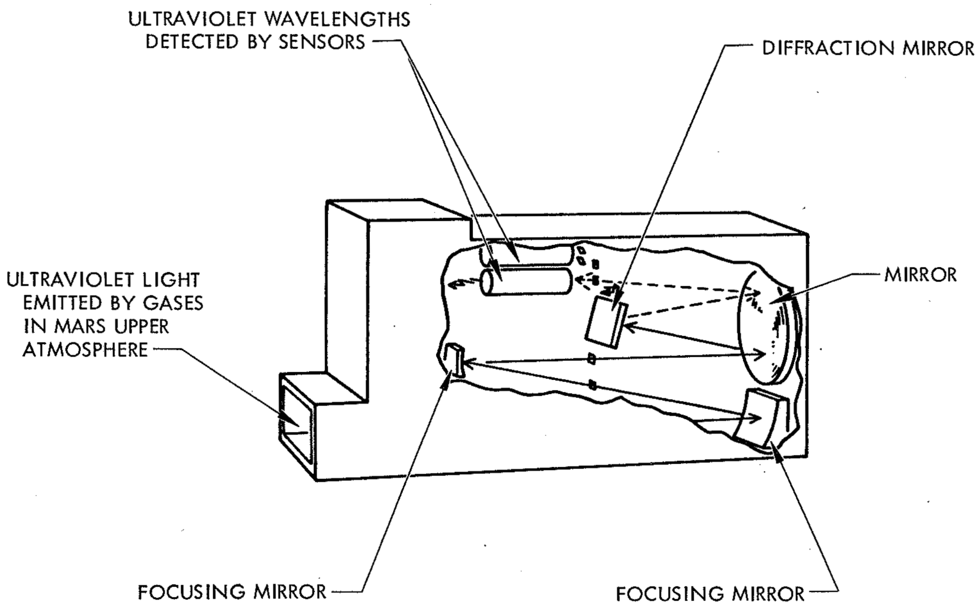
A second uninvited feature in the pictures was the residual image of previous pictures. Because vidicon television tubes do not entirely erase the previous picture before they record the next scene, a faint image of the previous picture can be seen in most pictures. This effect was especially pronounced in limb pictures. Using computers, the image processor removed this residual in the photometric pictures. Because of the effects of the enhancement technique used, such removal was impossible in the maximum-definition pictures in this volume. Finally, the slightly nonrectangular shape of the pictures is due to a geometric correction applied to them to compensate for optical and electronic distortions.

Thus the pictures shown here are the final output from a long and complex sequence of operations both on the spacecraft and on Earth.

Opposite: A comparison between the maximum-definition and photometric versions of 6N13 is presented here. The top figure is a maximum-definition version, and the bottom shows the photometric version of the same picture, after the analog and digital data have been recombined. In the bottom figure, the dark eastern point of Meridiani Sinus appears prominently as the dark area in the center of the picture, contrasting with the lighter desert to the right. In the maximum-definition version, this light–dark contrast, which actually appears on Mars, has been removed, and both areas are about the same shade of gray. However, in the maximum-definition version, craters are much more clearly visible in both the light and dark regions.



This sequence illustrates the way in which computer processing was able to remove coherent noise from the pictures. Notice the "basket weave" pattern overlying the picture information (top). The computer analyzed such a picture and separated the repeating pattern (center) from the random scene. This pattern was then subtracted from the original picture, leaving only the noise-free picture (bottom).



The Mariner 1969 ultraviolet spectrometer was designed to study the upper atmosphere of Mars.

Other Scientific Experiments

In addition to the television investigations, Mariners 6 and 7 performed several other experiments designed to improve our understanding of Mars and the solar system.

Ultraviolet Spectrometer

Atoms, ions, and simple molecules of hydrogen, oxygen, nitrogen, and such compounds as carbon monoxide and cyanogen were sought in the upper atmospheres of Mars by the dual-channel ultraviolet spectrometer. Prototype Mariner instruments were flown aboard sounding rockets before the Mars launch, providing comparison spectral surveys of Earth's atmosphere. One channel covered the range of 1050–1900 Å and the other covered the 1900–4350 Å spectrum.

The ultraviolet spectrometer experiment found no ozone in the atmosphere of Mars and indicated that solar ultraviolet light was reaching the highly reflective South Polar Cap virtually unimpeded by the atmosphere. Nitrogen, the major constituent of Earth's atmosphere, was conspicuously absent. Hydrogen and oxygen, both ionized and neutral, were detected in small quantities, possibly the result of the breakup of water vapor and carbon dioxide by solar energy.

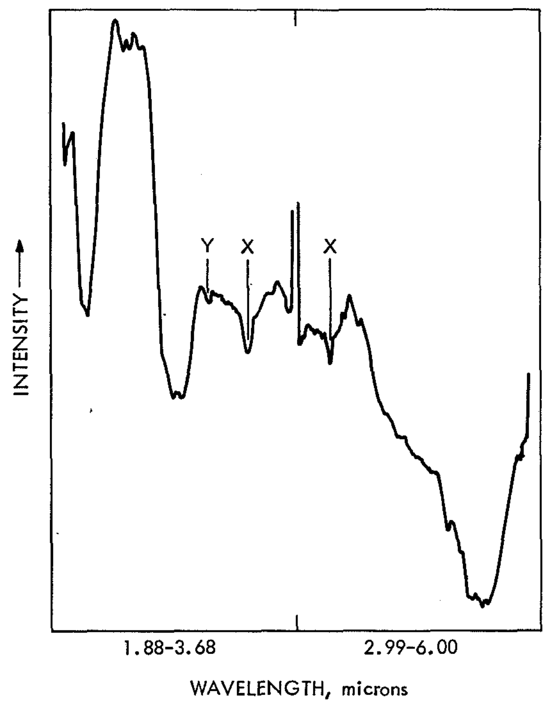
Infrared Spectrometer

The infrared spectrometer was designed to detect a wide variety of possible atmospheric species, including oxides and other compounds of hydrogen, carbon, nitrogen, and sulfur. In addition the instrument provided a measure of surface temperature and offered the possibility of obtaining reflection spectra identifying surface constituents.

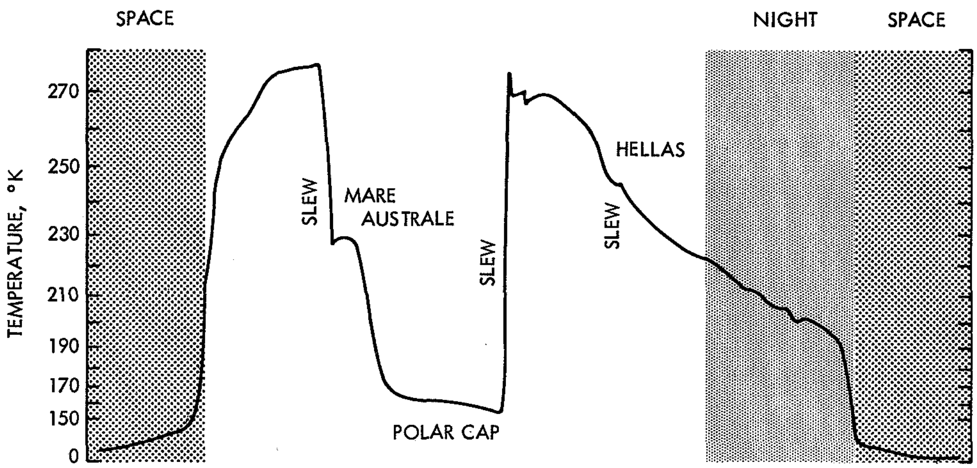
The instrument used two semiconductor detectors, one cooled to 165°K by radiation, the other to 22°K by a two-stage Joule–Thompson cryostat using N_2 and H_2. Rotating filters provided a spectral scan from 1.9 to 6.0 microns on the first channel and from 4.0 to 14.3 microns on the cryogenic channel. Most of the chemical species sought were not present at the detection limit; however, clouds of solid carbon dioxide and of water ice were observed, and solid carbon dioxide was detected in the vicinity of the South Polar Cap. In addition, reflection spectra indicative of silica or silicates were detected above the limb, suggesting either dust clouds or finely divided surface material. Surface topography could be inferred from varying carbon dioxide abundance (corresponding to the height of the atmosphere).

Infrared Radiometer

The infrared radiometer measured the surface temperature along the path viewed by the television cameras. It consisted of an optical



This spectrum of the South Polar Cap, obtained by the infrared spectrometer, contains features (labeled X and Y) indicating solid carbon dioxide is present either on the cap or in the atmosphere above the cap.



Since the infrared radiometer was aligned parallel to the television cameras, this infrared temperature data acquired by Mariner 7 shows the temperature at the centers of television pictures and along lines connecting these centers. Notice the temperature of the Polar Cap, approximately as cold as frozen carbon dioxide would be at the prevailing Martian conditions.

system with dual thermopile detectors which sensed the thermal radiation in the 8- to 12-micron and 18- to 25-micron bands from a tiny region along the track of the centers of the television pictures.

Temperatures as warm as the 280–290°K range were observed in the equatorial latitudes, and a value approximating the frost point of carbon dioxide at prevailing conditions was reached near the South Pole. Few thermal anomalies were observed; generally the sunlit dark regions were warmer than corresponding bright deserts, and the temperature declined as expected as the field of view approached and crossed the evening terminator. The darkest classical feature on Mars, Syrtis Major, was observed beyond the terminator and appeared still to be warmer than the surrounding terrain.

S-Band Occultation

Four times during the Mariner Mars 1969 encounters, the radio signal between the spacecraft and Earth passed through the atmosphere of Mars. Each spacecraft trajectory was designed so that the Mariner passed behind Mars as seen from Earth, permitting the occultation analysis at four widely separated points above Mars. The coherent radio signal was bent and retarded by the intervening atmosphere, and the physical properties of the air were investigated. The four locations and the planetary radius and atmospheric pressure and temperature at the surface are given below:

Location	Radius, kilometers	Pressure, millibars	Temperature, °F
Meridiani Sinus, 4°N, 4°W	3393	6.6	37
North Polar, 79°N, 276°W	3373	6.4	−172
Hellespontus, 58°S, 330°W	3383	3.8	− 79
Amazonis, 38°N, 148°W	3378	7.0	− 99

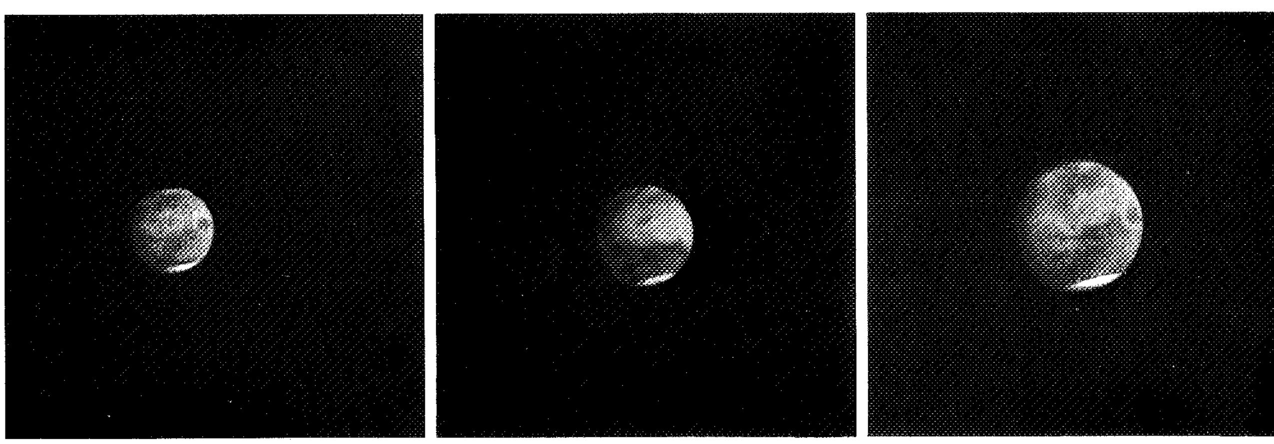
Celestial Mechanics

The accuracy with which the Mariner spacecraft were tracked permitted investigators to infer the masses, positions, and motions of those celestial bodies whose gravitational fields influence the spacecraft. These include the Sun, the Earth and Moon, Mars, and to a lesser extent, Jupiter and other planets. Data obtained from Mariner 6 and 7 confirmed calculations based on previous flights.

FAR ENCOUNTER PICTURES

CHAPTER 3
The Far Encounter Pictures

Earth-based investigators were unable to photograph details smaller than about 100 kilometers (62 miles) on Mars. The Mariner 4 television experiment, therefore, was a significant advance, for it showed detail as small as about 3 kilometers. However, the area covered by an entire Mariner 4 picture was comparable to the smallest "point" seen from Earth, and thus it was not possible to confidently relate the "microscopic" Mariner 4 views to the telescopic Earth-based views. To compensate for this resolution disparity, Mariners 6 and 7 took a far encounter sequence of pictures showing the entire Martian disk at much higher resolution than was possible from Earth. These far encounter pictures permitted more reliable interpretation of the later near encounter pictures. Moreover, since the near encounter pictures show only about 20% of the Martian surface, the far encounter pictures, providing coverage of almost the entire planet, contain much data that is independently interesting.

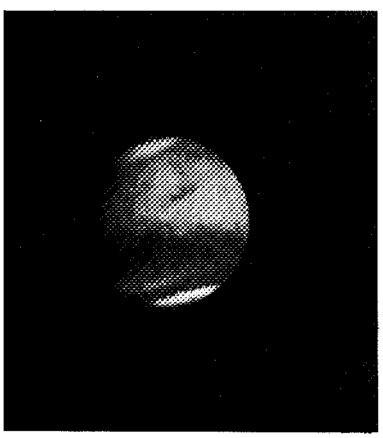


7F0 7F15 7F35

Two days before its closest encounter with Mars, Mariner 6 began taking telephoto pictures of the approaching planet. Mariner 7, starting 4 days later, took such pictures during 3 days prior to encounter. Both spacecraft approached Mars from slightly south of the equator, so that the South Pole was always tilted about 5 deg toward the camera and the North Pole was out of view just over the northern horizon.

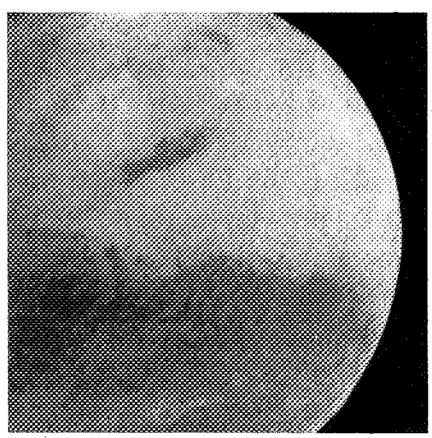
As Mars rotated, features emerged from the western morning terminator, moved to the right (north is at the top) across the planet's disk, and disappeared behind the eastern late afternoon limb. Because the sun was not directly behind the spacecraft, a portion of the disk was not illuminated. It should be remembered, also, that the automatic gain control, described in Chapter 2, was not used during far encounter, and thus the pictures closely represent the actual appearance of Mars.

During the 3 days of Mariner 7's far encounter, the spacecraft's distance from Mars changed from approximately 1,840,000 to 130,000 kilometers, causing a corresponding increase in the apparent size of Mars.



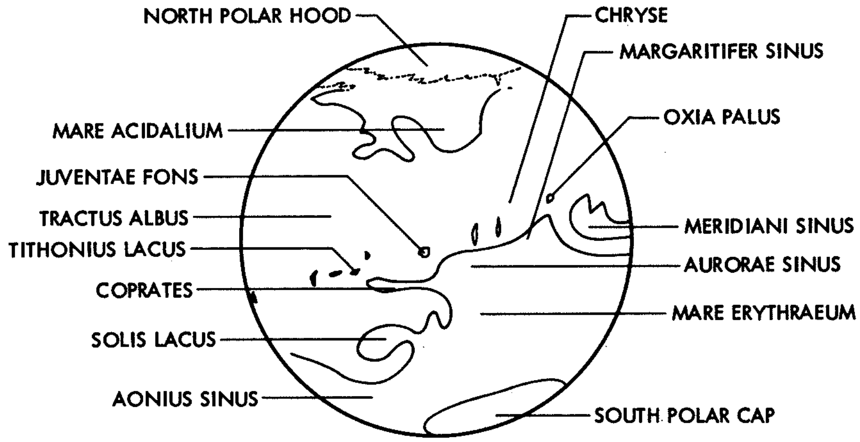
7F54

7F69

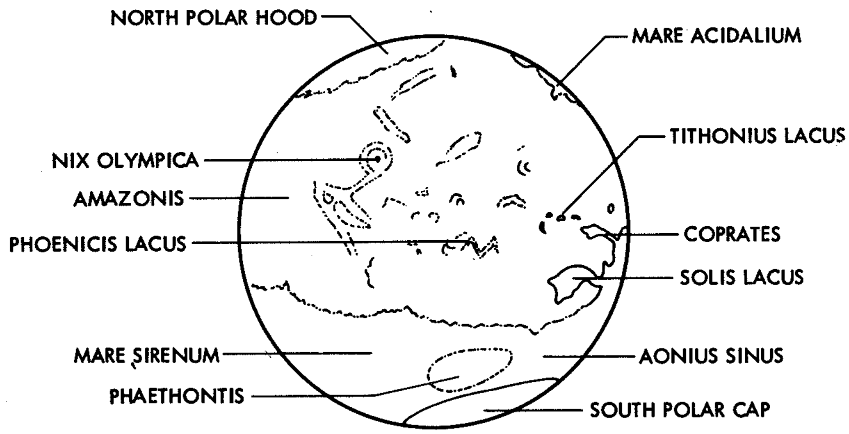


7F81

7F92



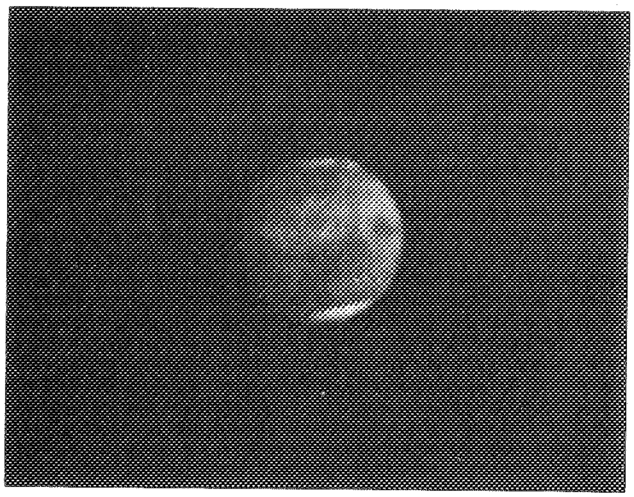
7F0



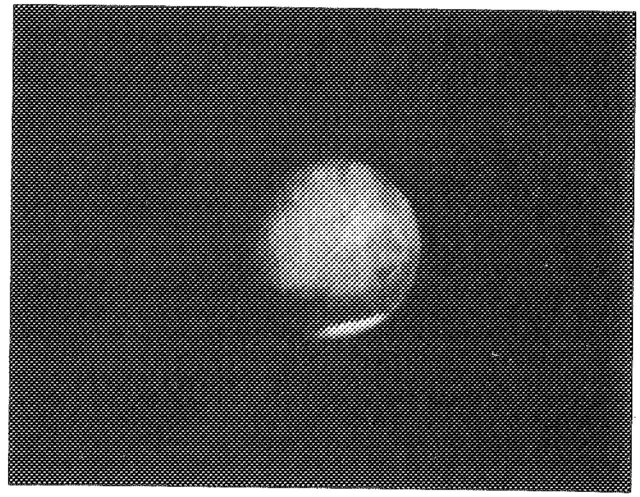
7F1

7F0, the last picture taken to calibrate the camera pointing direction, is interesting because it was one of the few taken of this area of Mars. Normally during this segment of Mars' rotation, the tape recorders were being played back to Earth and thus no pictures were acquired.

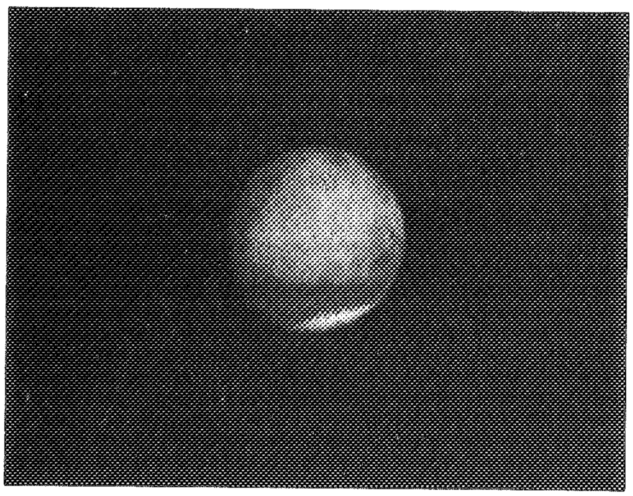
In 7F0, the dark features in the center are Aurorae Sinus and Margaritifer Sinus (see sketch simulating 7F0). Protruding from the eastern limb is Meridiani Sinus, and just emerging from the western terminator is the Earth-observed "canal," Coprates. Frame 7F1, taken almost 5 hours later, shows that Coprates has rotated to the extreme eastern side of the disk (see sketch simulating 7F1). Also visible, just southwest of Coprates, is the prominent dark feature Solis Lacus. Across the center of the disk stretches the desert Amazonis, whose mottled and streaked appearance suggests that greater detail is present than can be seen in this very early view. The dark area between Amazonis and the South Polar Cap is Mare Sirenum and Aonius Sinus.



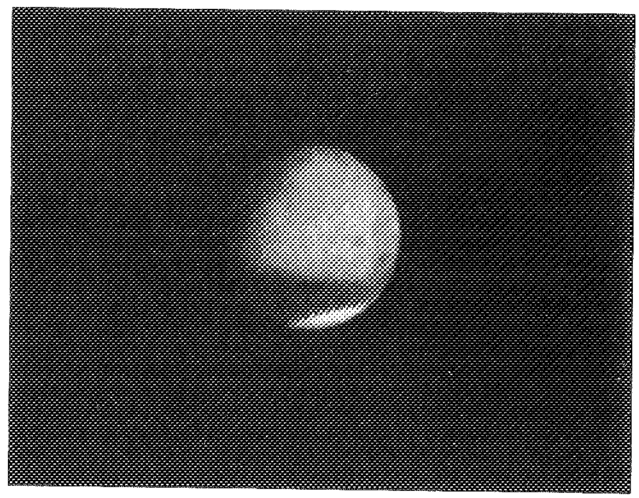
7F0



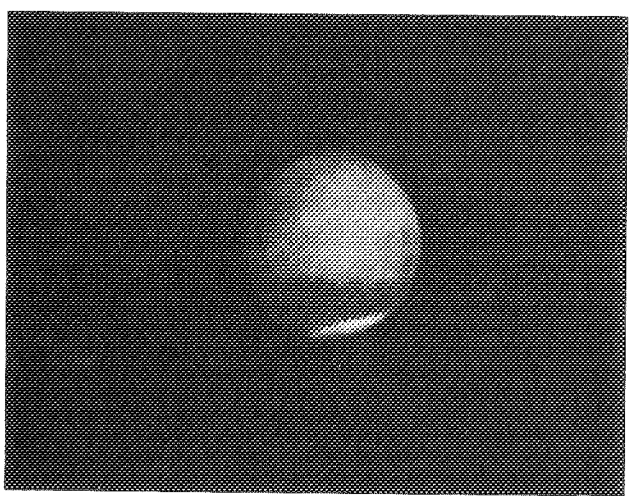
7F1



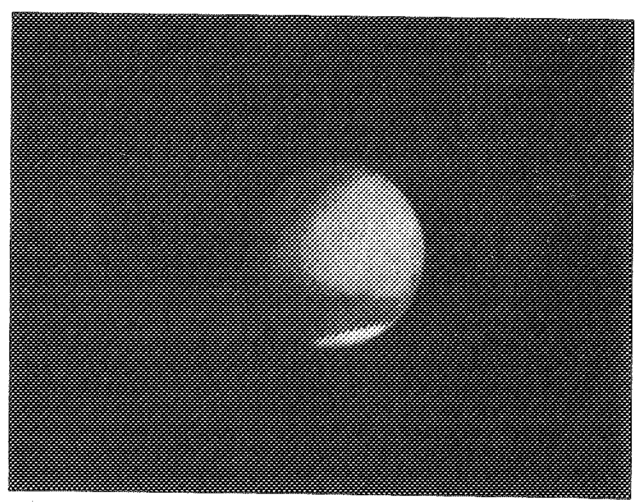
7F3



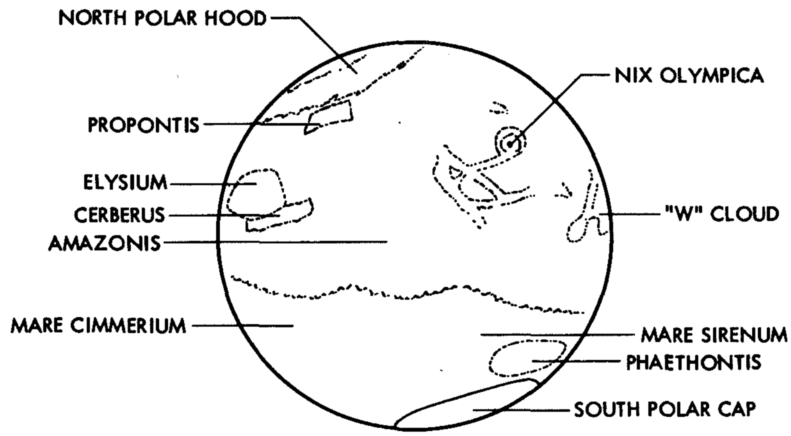
7F4



7F5

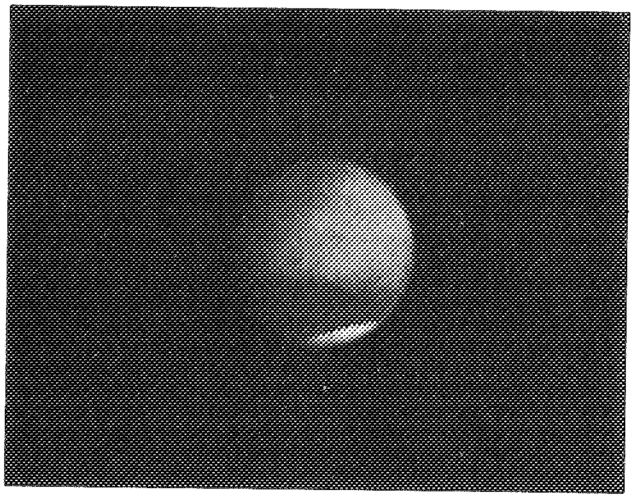


7F6

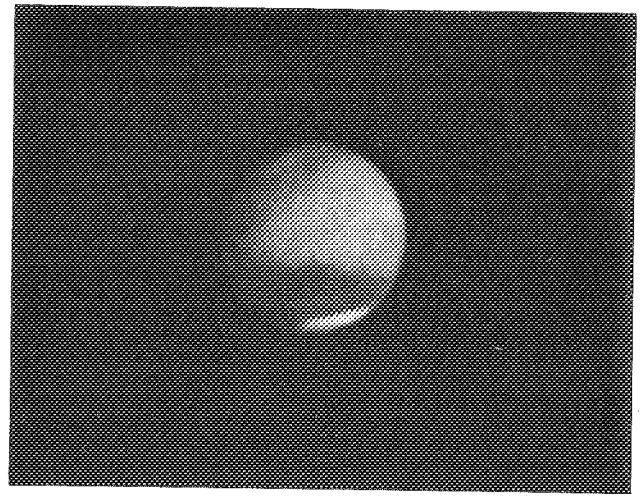


7F9

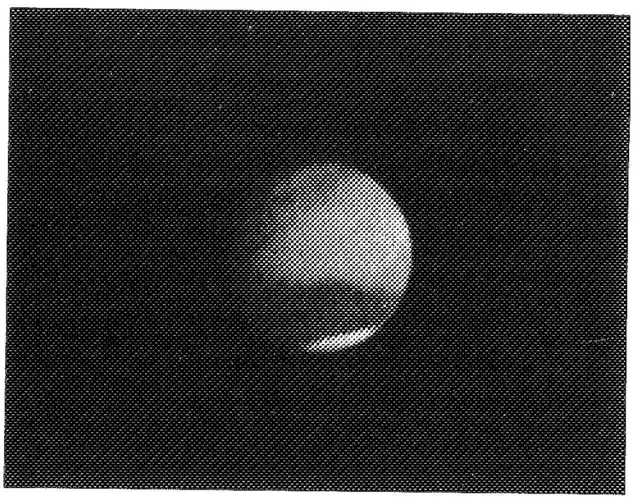
From these far encounter pictures, it has been determined that the South Polar Cap extended northward to about 60 degrees south latitude. This is within a degree of the seasonal location predicted by astronomers and illustrates the regularity with which the cap advances and recedes. Just visible near the terminator in 7F9 are two small dark spots: Cerberus and Propontis (see sketch simulating 7F9). These features border the eastern part of the desert Elysium. Also, near the limb of 7F9, there is a bright area which becomes brighter in the later afternoon pictures, 7F10–11, climaxing as a very bright spot right at the limb in 7F12 and 7F13. This afternoon brightening correlates with Earth observations of this region but remains unexplained. Release of water vapor from the soil is an interesting possibility.



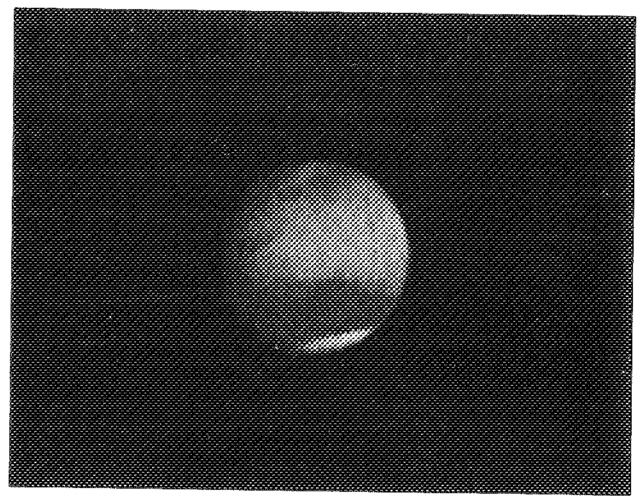
7F7



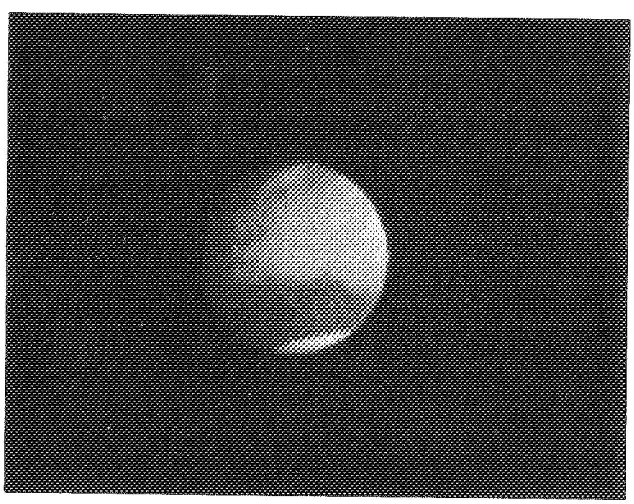
7F8



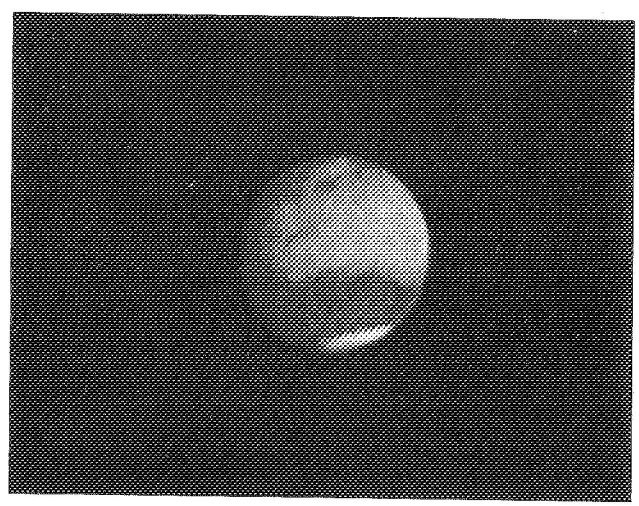
7F9



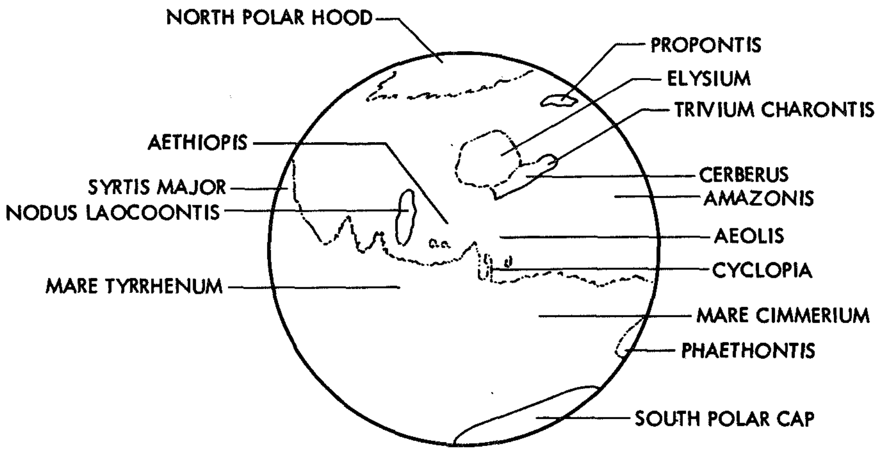
7F10



7F11

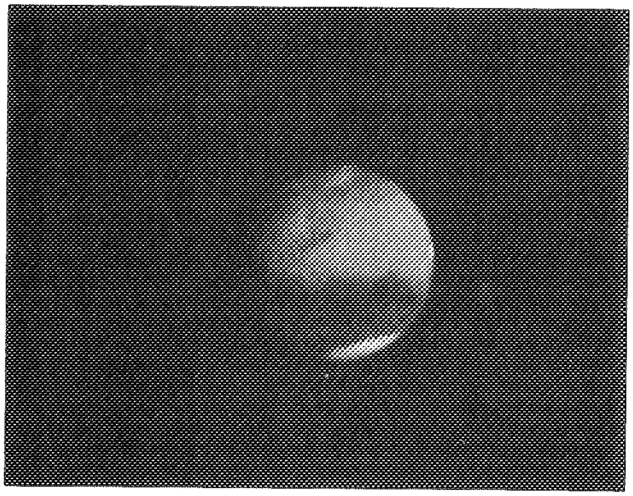


7F12

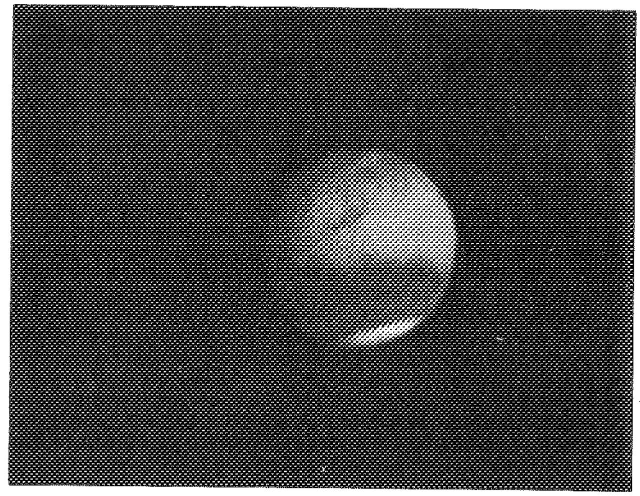


7F17

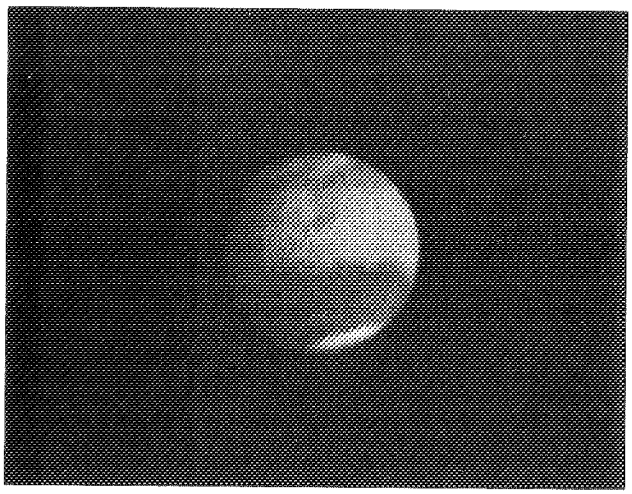
As Cerberus and Propontis continue across the disk, the Polar Cap begins to show ragged detail along its northern edge, as in 7F15. Similarly, in 7F16, it becomes evident that the boundary between the dark Mare Cimmerium and the light Aeolis is ragged and broken, not smooth and regular. Also, light and dark variations become prominent near the North Pole (see sketch simulating 7F17).



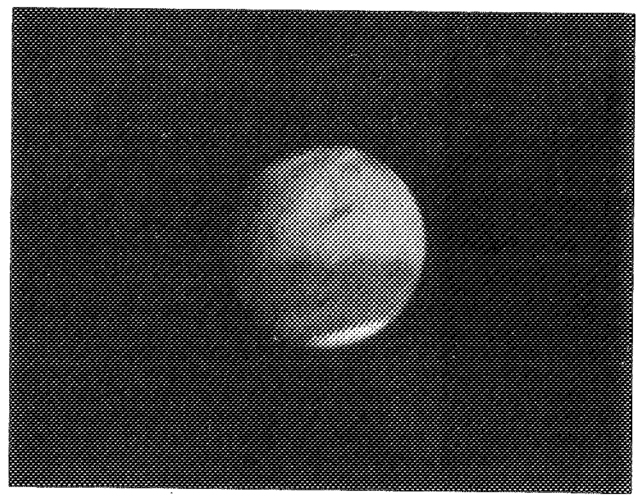
7F13



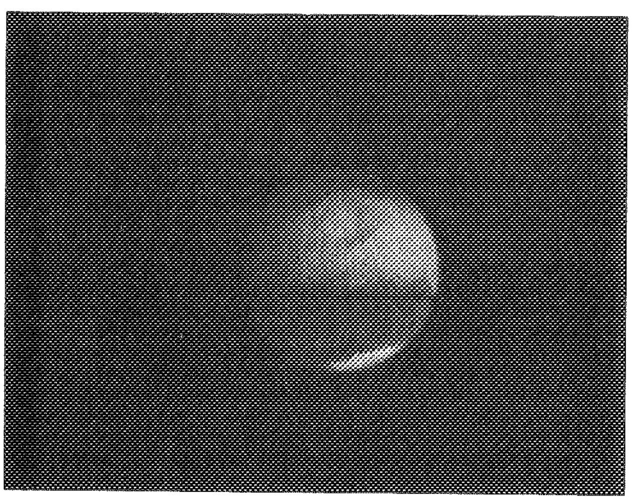
7F14



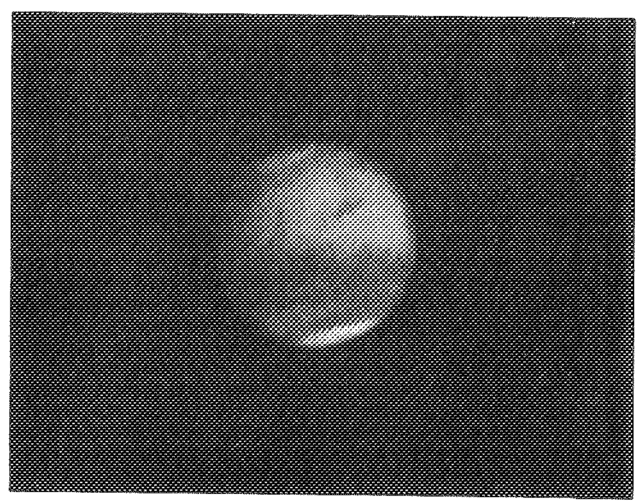
7F15



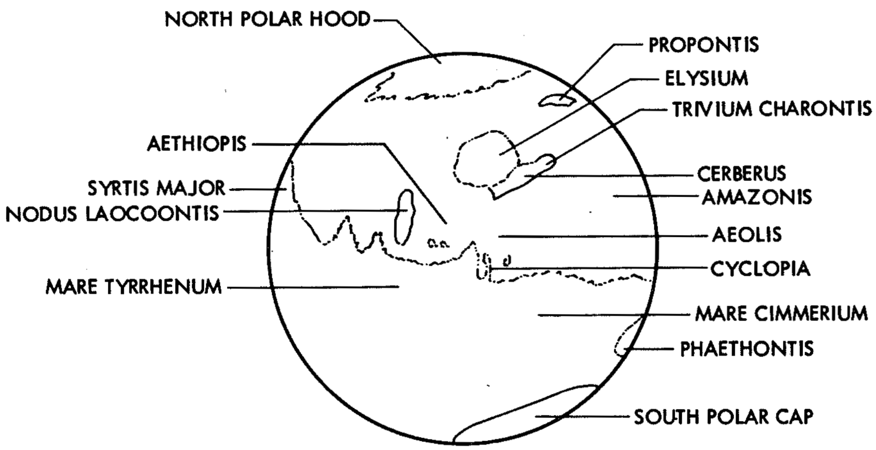
7F16



7F17

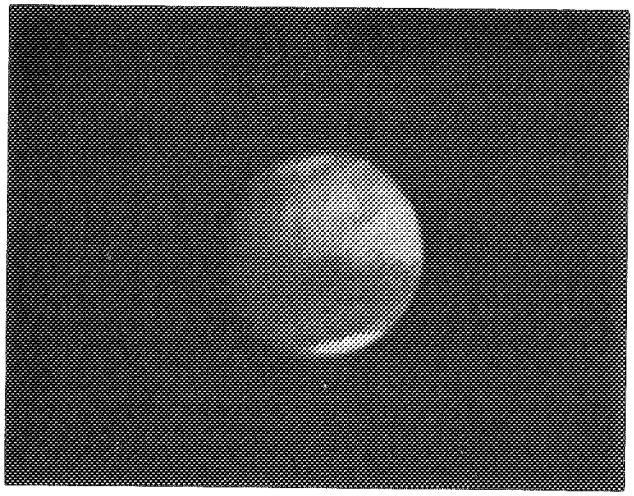


7F18

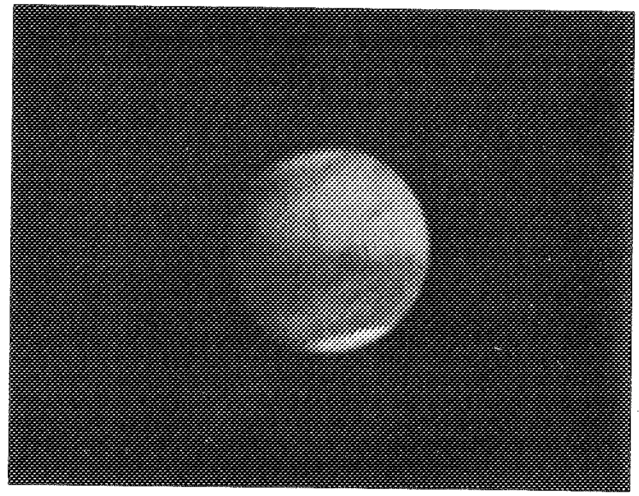


7F17

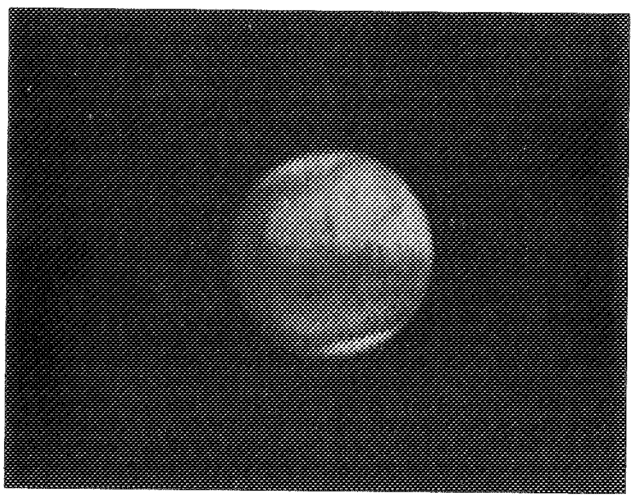
Syrtis Major, a large, dark, triangular-shaped feature, appears in the morning sunlight in 7F23. Midway between Syrtis Major and Cerberus is the dark spot Nodus Laocoontis. Also more apparent in these pictures is the bright "hood" around the North Pole. This hood appears to consist of a haze which had formed over the north polar region at the time of encounter.



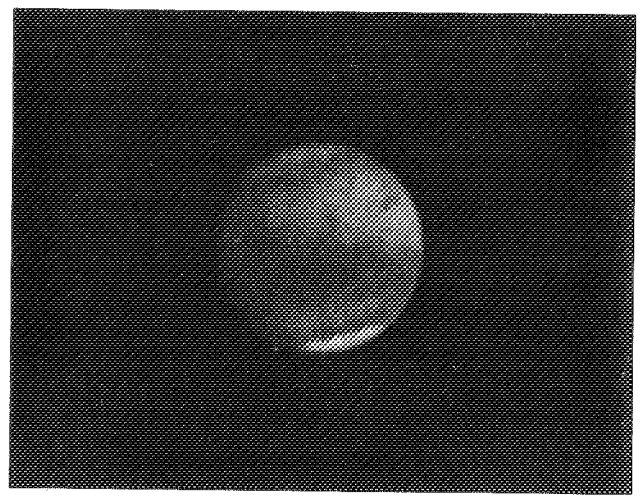
7F19



7F20



7F21



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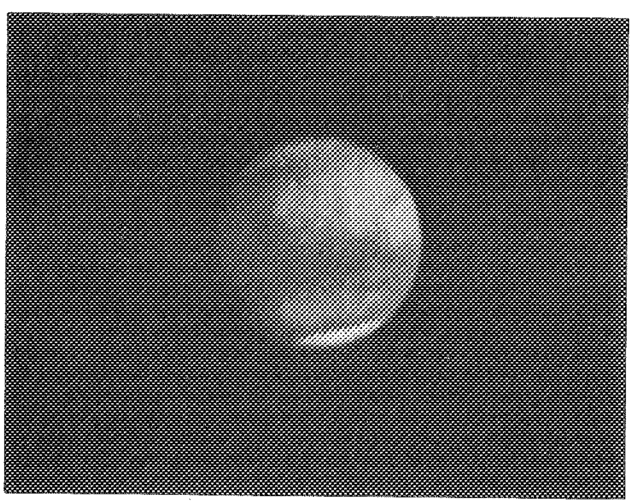
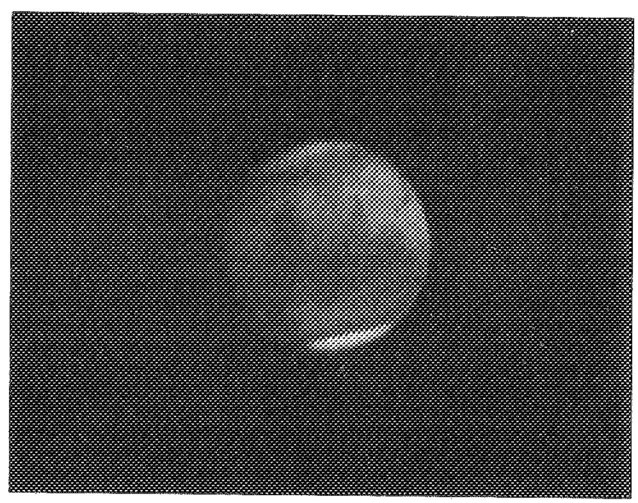
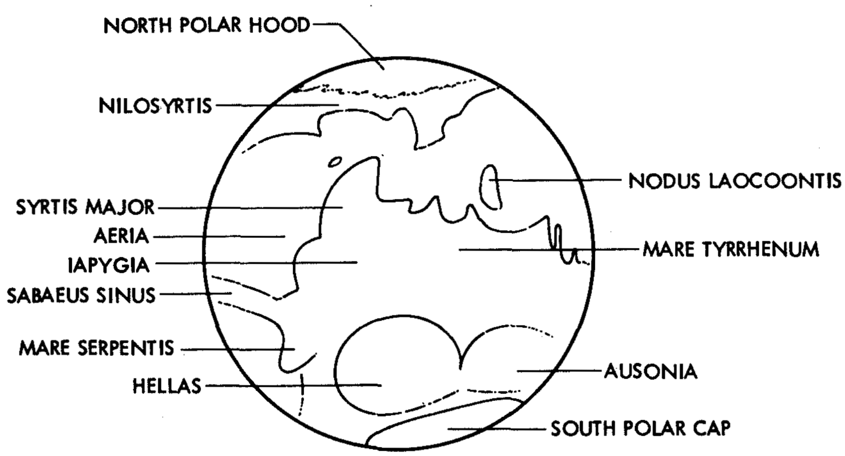


7F23

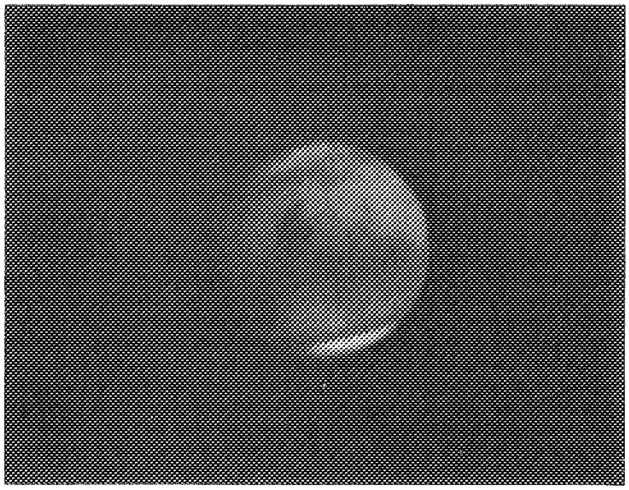


7F24

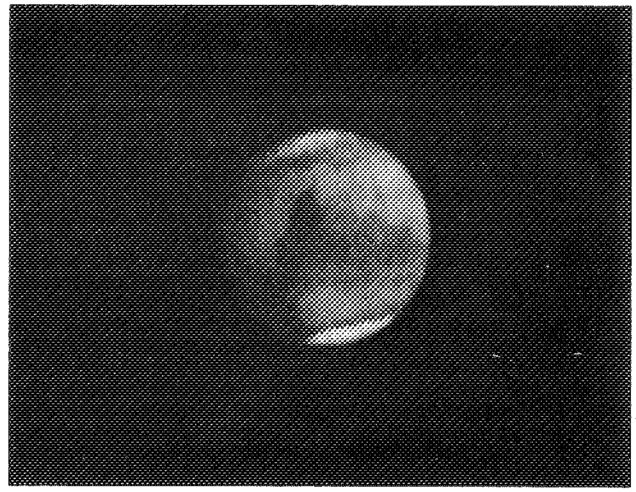


7F25

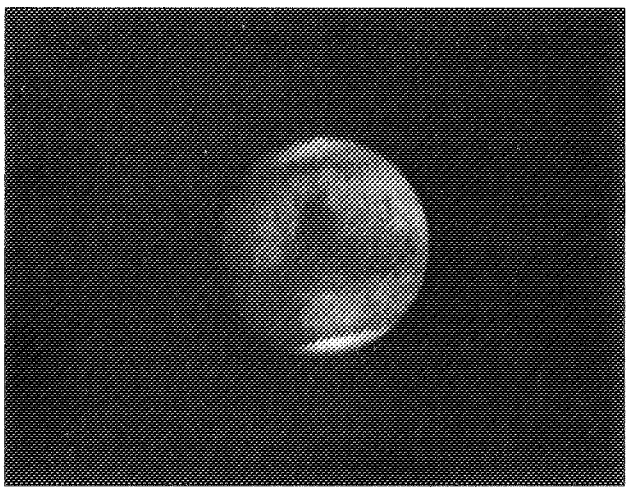
The circular desert Hellas is very apparent south of Syrtis Major and just north of the South Polar Cap (see sketch simulating 7F25). Hellas, like the regions in Amazonis, brightens as it approaches the limb. However, unlike the Amazonis features, Hellas is plainly visible from the early morning terminator throughout the day.



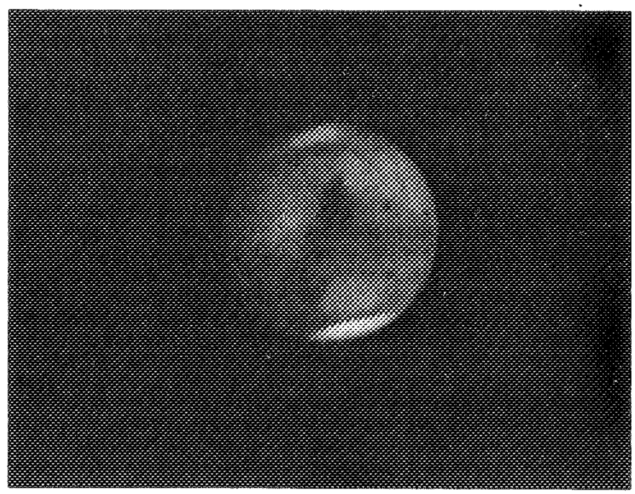
7F25



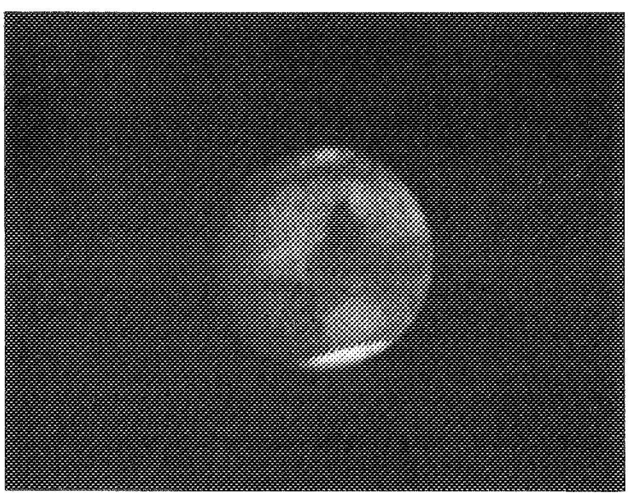
7F26



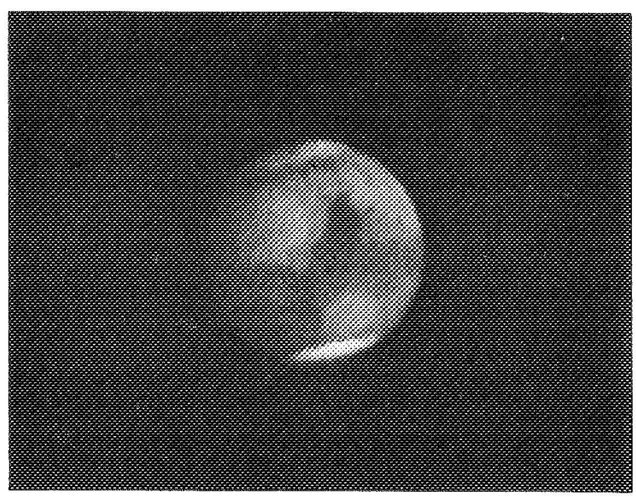
7F27



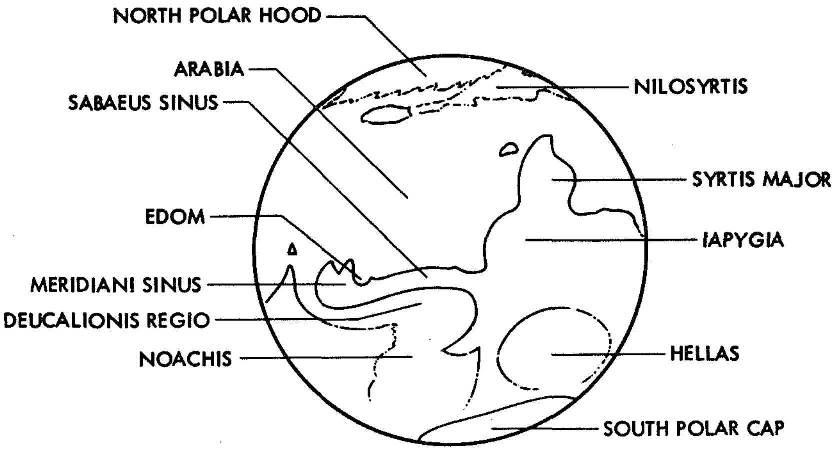
7F28



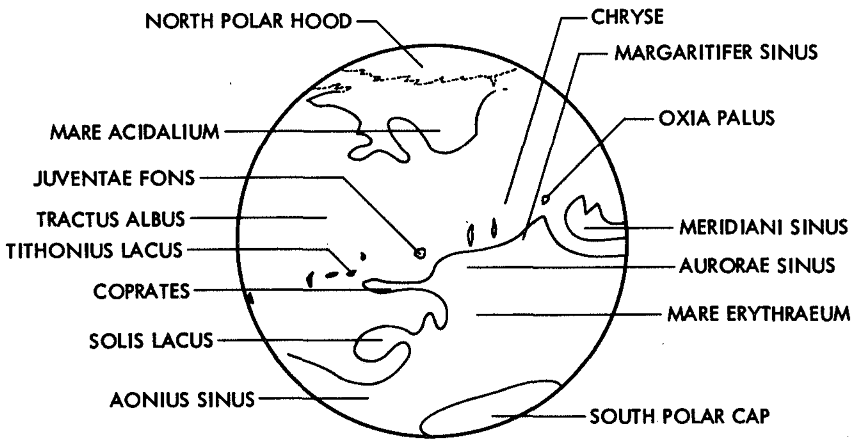
7F29



7F30



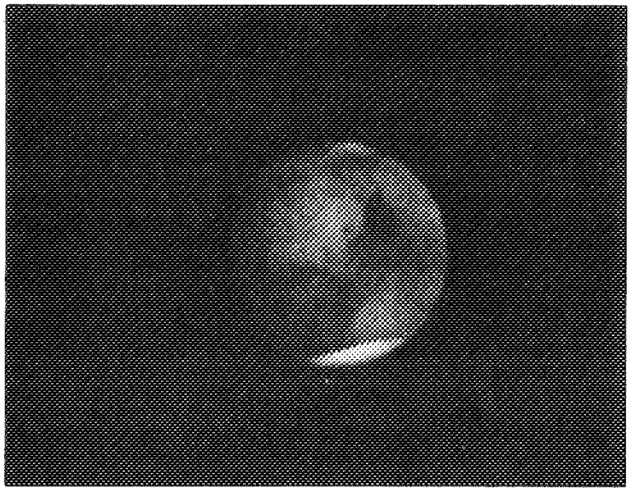
7F33



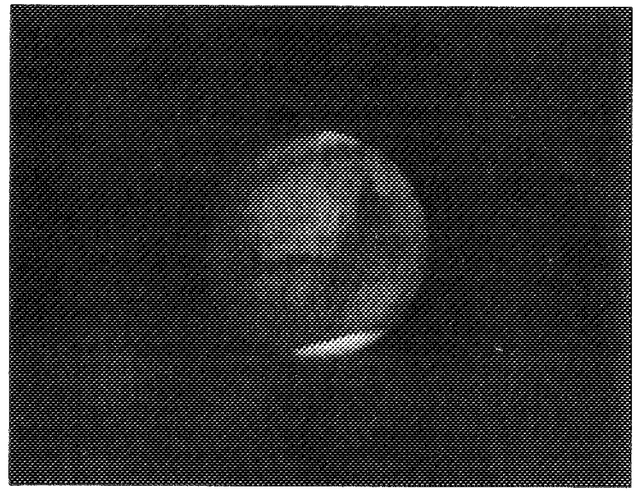
7F0

Extending to the west of Syrtis Major is the long dark Sabaeus Sinus, culminating in the two-pronged Meridiani Sinus (see sketch simulating 7F33). Meridiani Sinus marks the zero point of the Martian longitude system.

7F33 was the last picture to be recorded on the first Mariner 7 tape load. During the next 6 hours, these 33 pictures were read from the recorder and transmitted to earth. Also, during this time Mars rotated so that Meridiani Sinus was on the eastern limb when the next picture, 7F35, was taken. Frame 7F35, showing much the same view of Mars as 7F0, now reveals greater detail. The northern boundary of Aurorae Sinus is seen to be ragged with several disconnected small markings in the lighter area. Another dark spot, Oxia Palus, is now visible just north of the tip of Margaritifer Sinus. North of Coprates is an additional marking, Juventae Fons.

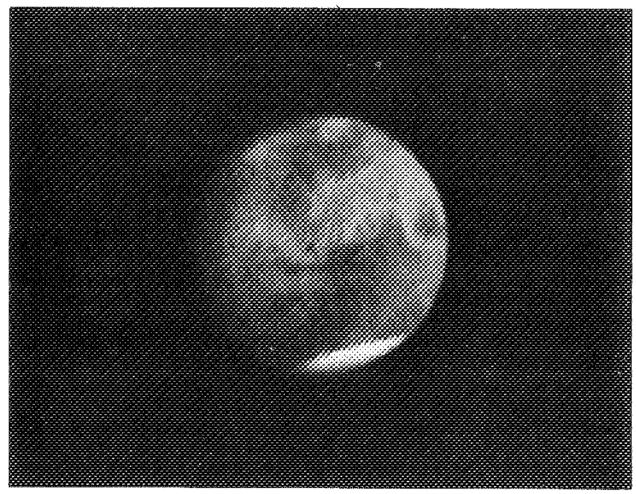


7F31



7F32

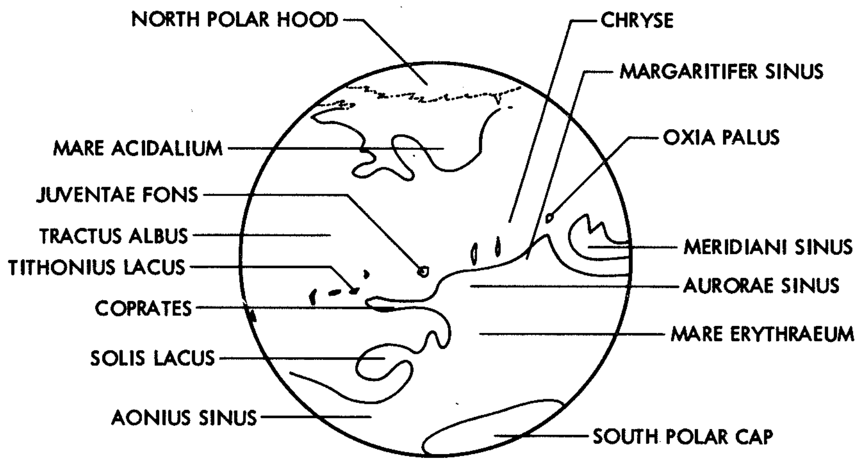
7F33



7F35

7F36

7F37

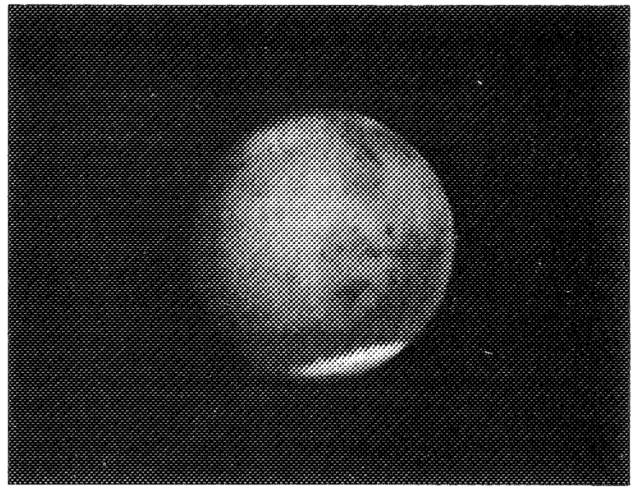


7F0

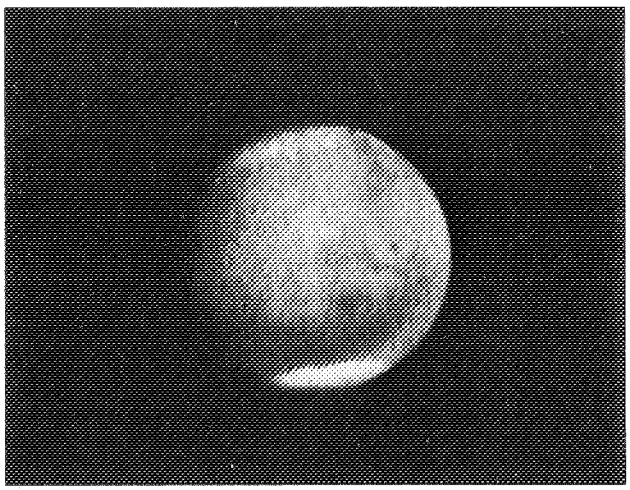
This page begins the side-by-side comparison of similar Mariner 6 and 7 far encounter pictures. For both spacecraft, these pictures were taken between 48 and 24 hours prior to flyby. Each Mariner 6 picture was taken 5 days before the corresponding Mariner 7 picture. After extensive analysis and computer correction, there remains a significant difference between the appearance of pictures from the two spacecraft, a difference that is still unexplained, but is probably due to the television system, not to Mars.

These pictures show more clearly the irregularity of the South Polar Cap edge and the dark Mare Acidalium, in the northern latitudes.

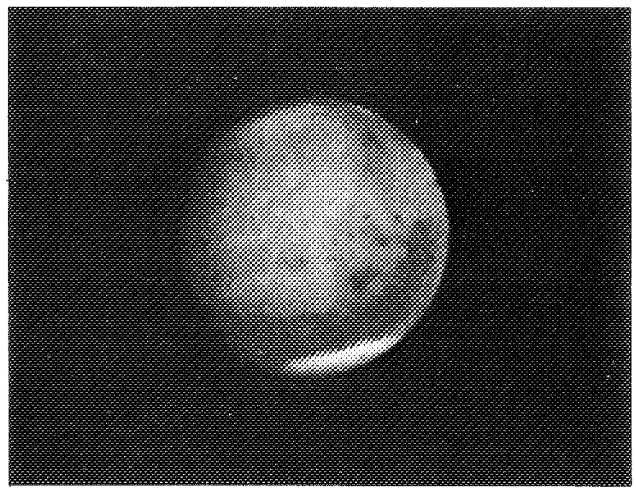
7F38



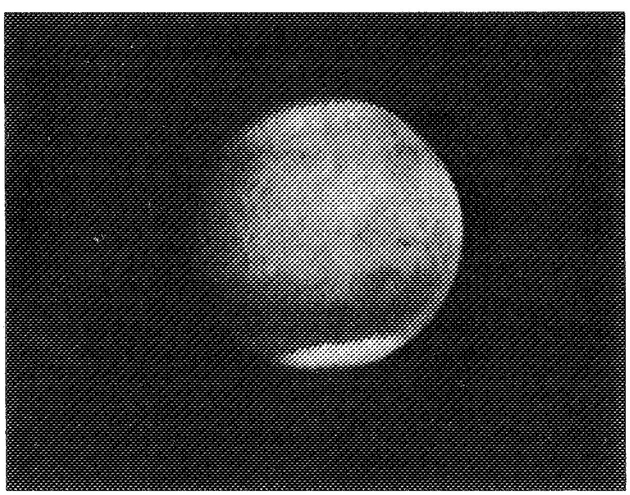
7F39



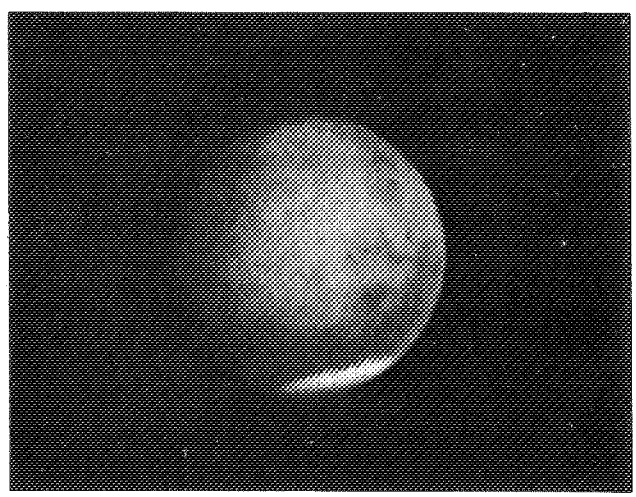
6F1



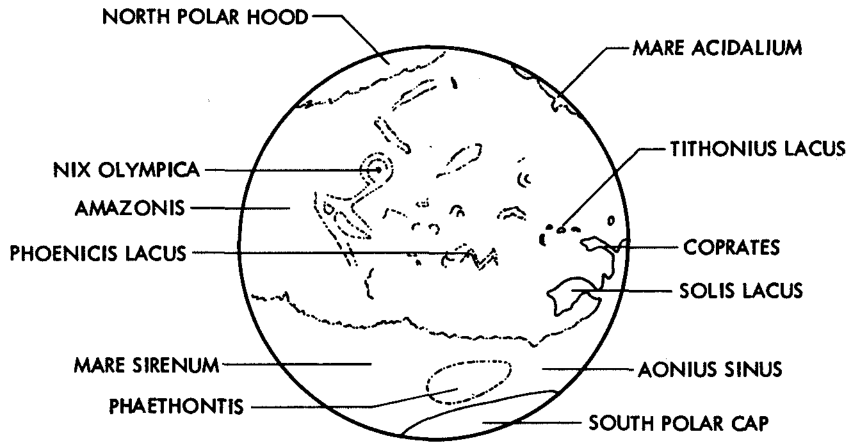
7F40



6F2

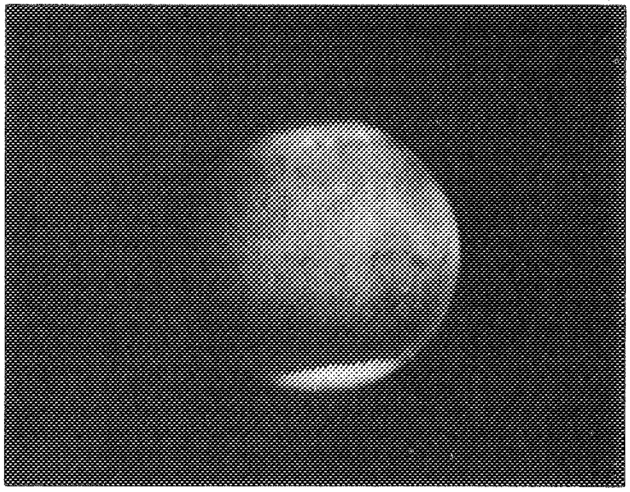


7F41

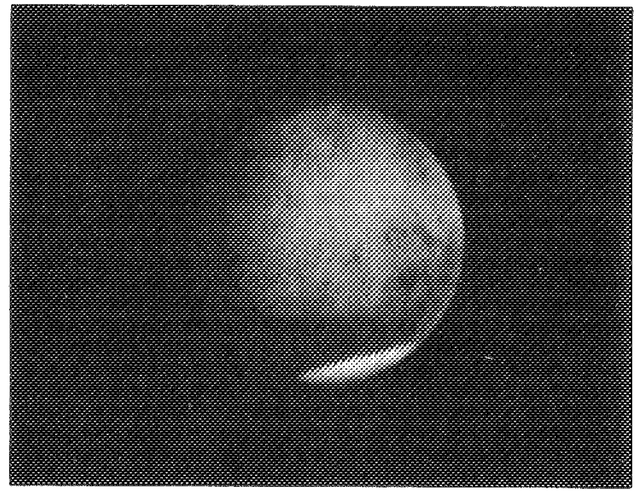


7F1

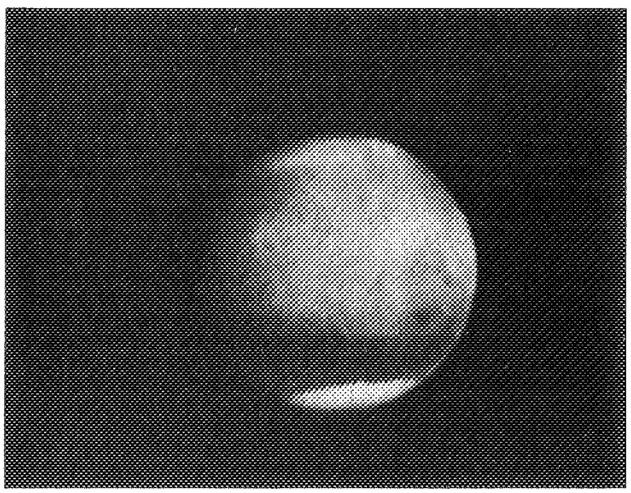
As Solis Lacus and Coprates move towards the limb, it becomes evident that Amazonis, long thought to be an uninteresting area of Mars, exhibits a great deal of fine detail. Apparent in 7F44 is the circular feature Nix Olympica, which had been known from Earth as an area that often showed seasonal variations in brightness. There appears to be a very complex and interesting arrangement of light features on this face of Mars.



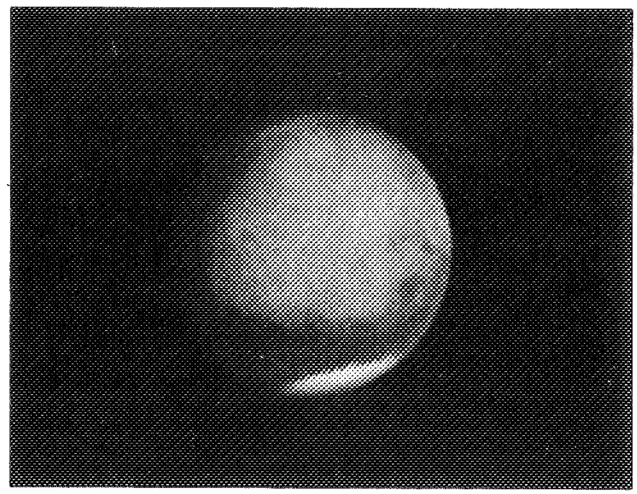
6F3



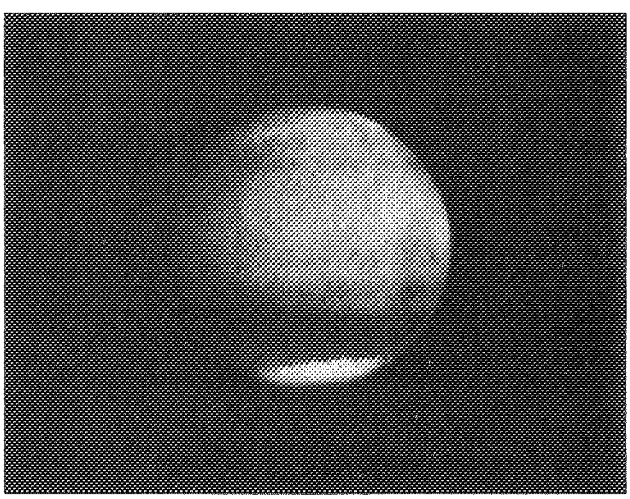
7F42



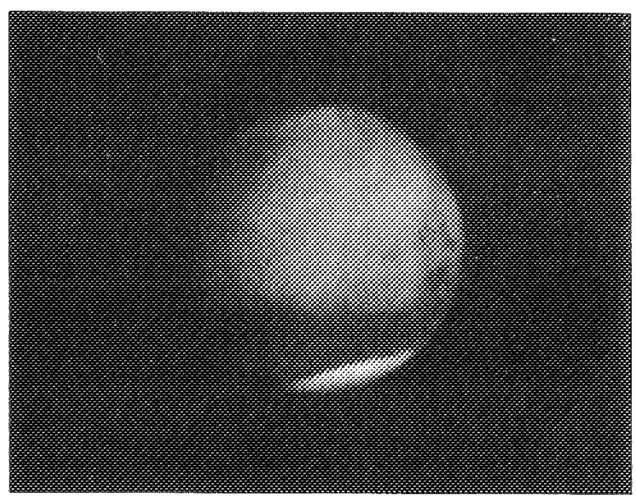
6F4



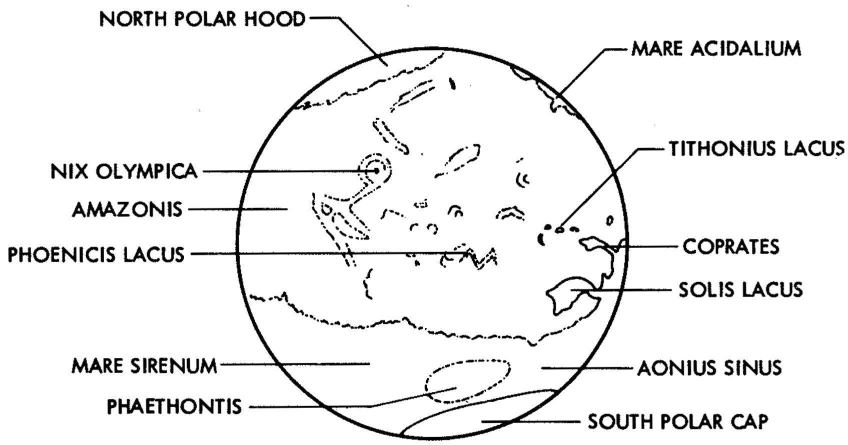
7F43



6F5

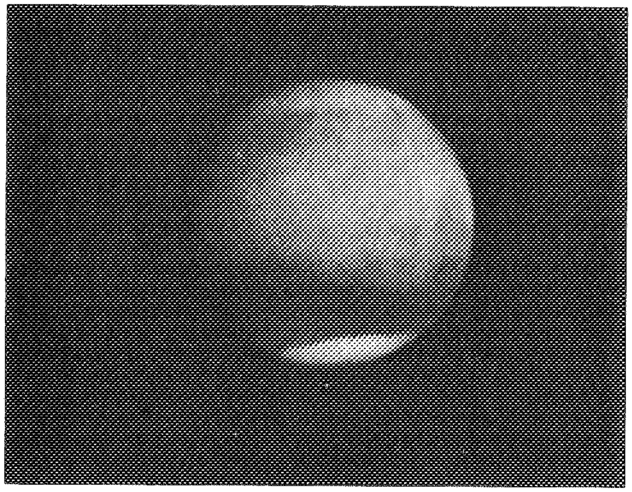


7F44

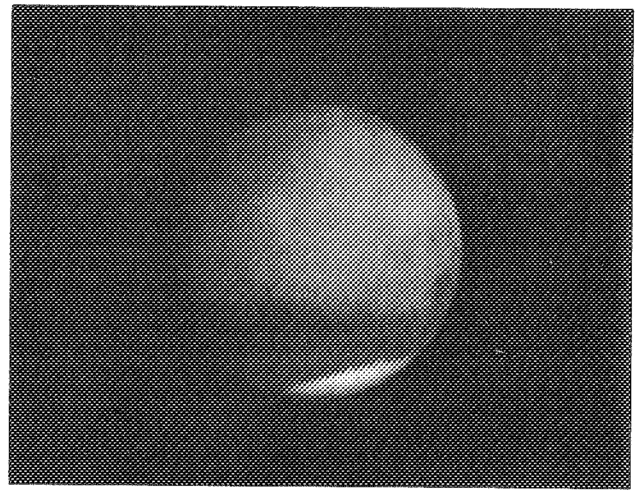


7F1

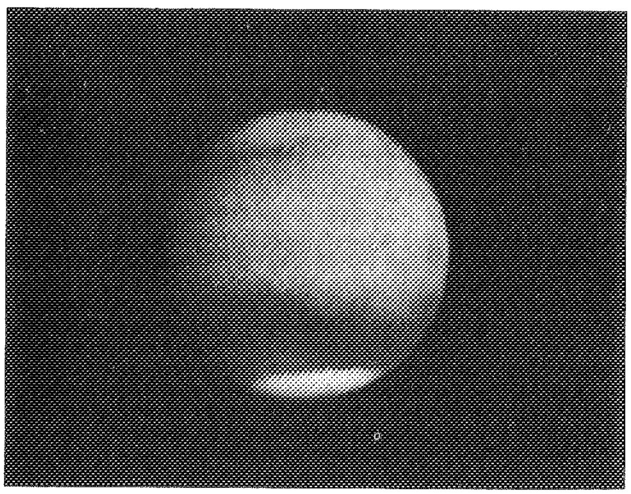
Both 6F8 and 7F47 show Cerberus and Propontis once again emerging from nighttime. They also reveal the gradual brightening of the features in Amazonis as these features moved toward afternoon.



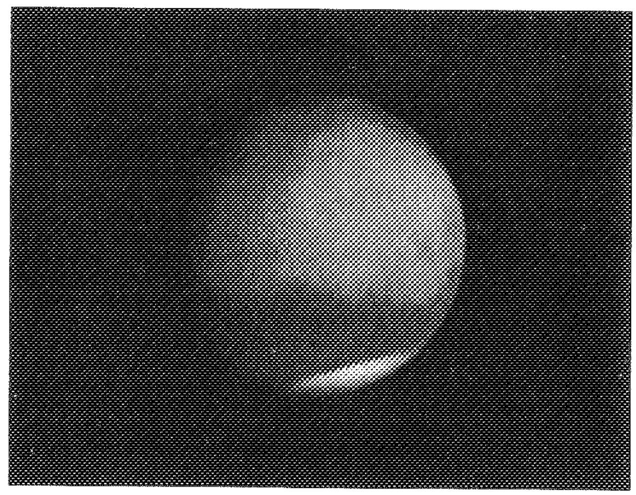
6F6



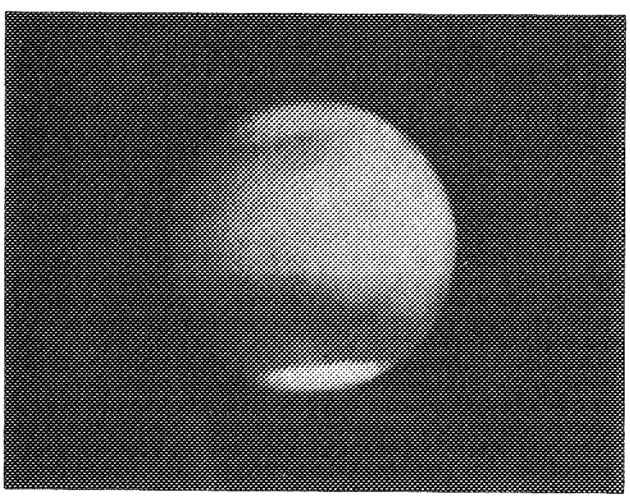
7F45



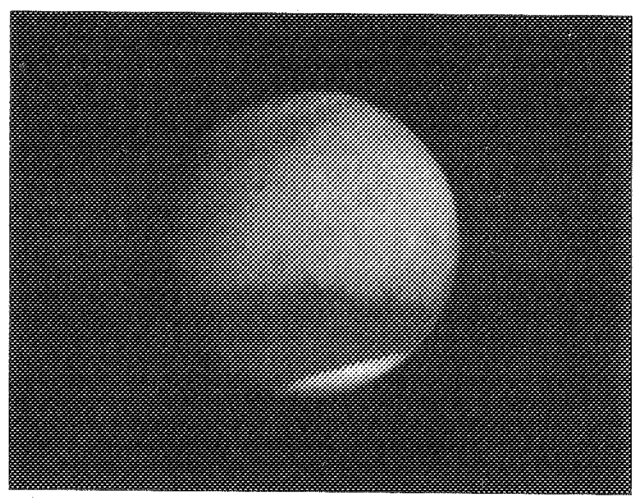
6F7



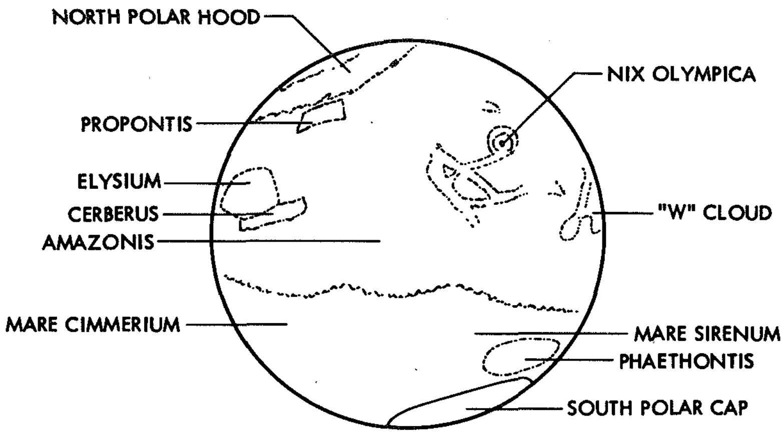
7F46



6F8

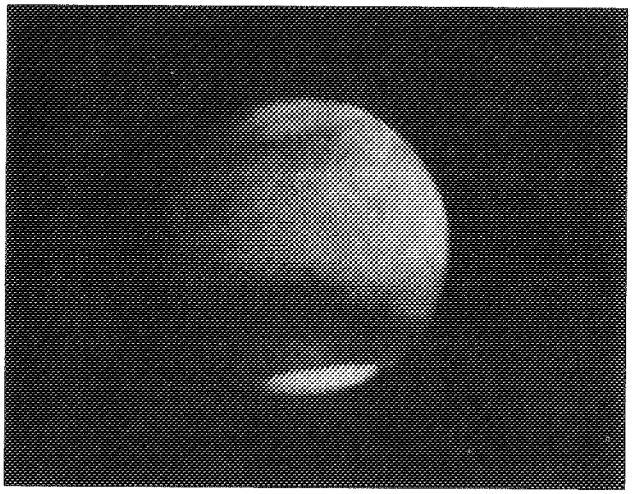


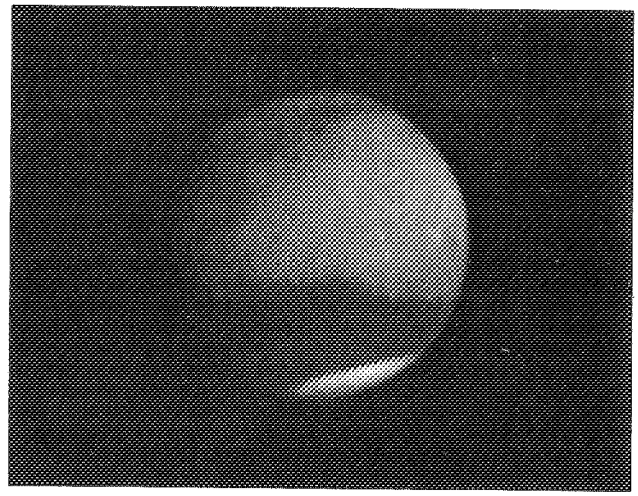
7F47

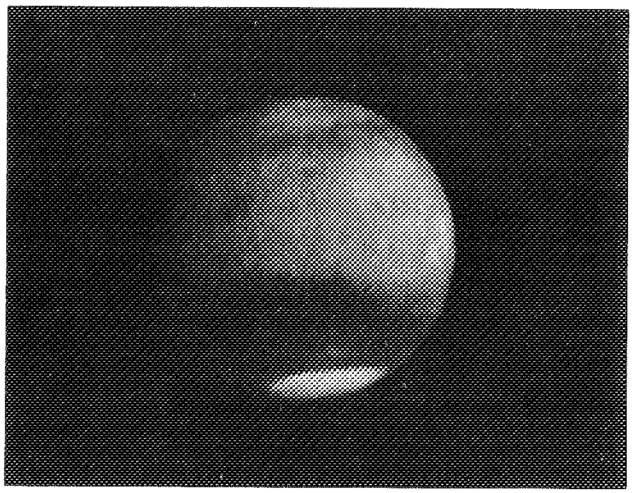


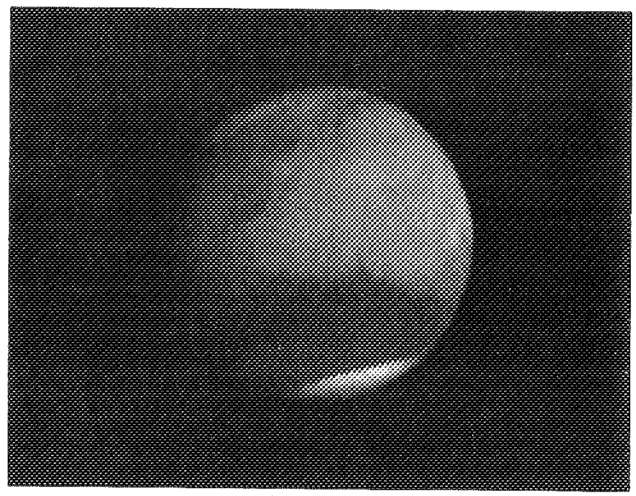
7F9

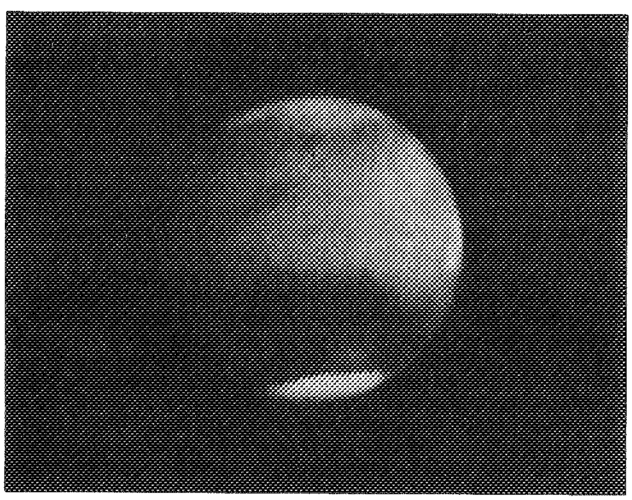
The brightening of the Amazonis features climaxes in 6F11 and 7F50, where several of the spots are seen right at the limb. The bright region seen in 7F9 can now be identified as several smaller spots. Another bright region, Phaethontis, does not brighten appreciably as it moves toward the afternoon limb. Rather, like Hellas, it appears to remain fairly constant in brightness.

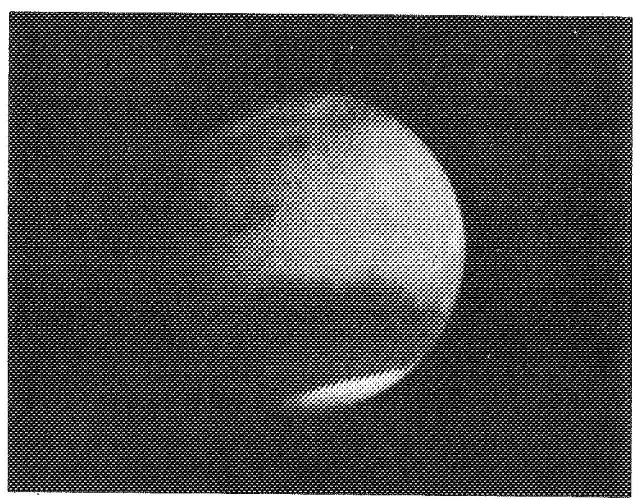

6F9

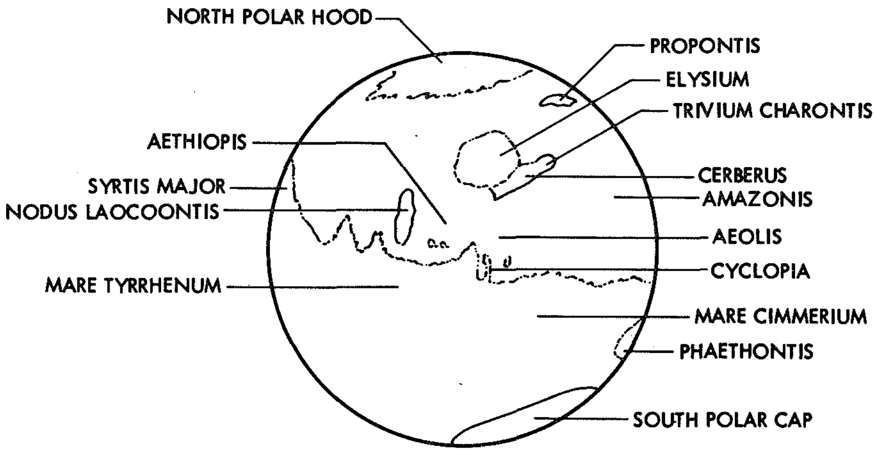

7F48


6F10


7F49

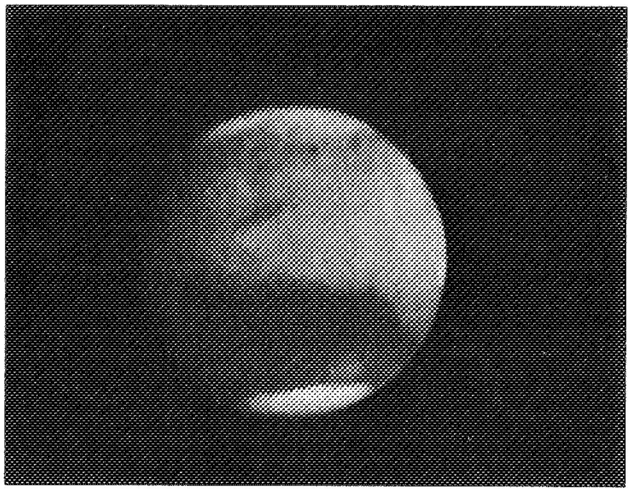

6F11


7F50



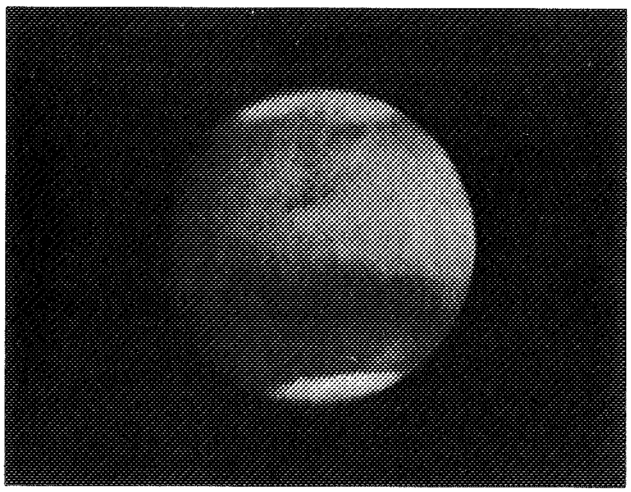
7F17

Careful comparison of the Mariner 6 pictures with those from Mariner 7 suggests that the Polar Cap edge had changed very little if at all during the 5 days between observations. Comparing these pictures with those taken farther from the planet, e.g., 7F15, one notices that these pictures show much greater detail in the northern boundary of Mare Cimmerium. Particularly prominent is the linear projection Cyclopia, pointing toward the circular Elysium. Also, the northern polar "hood" is more clearly defined than in the earlier pictures.

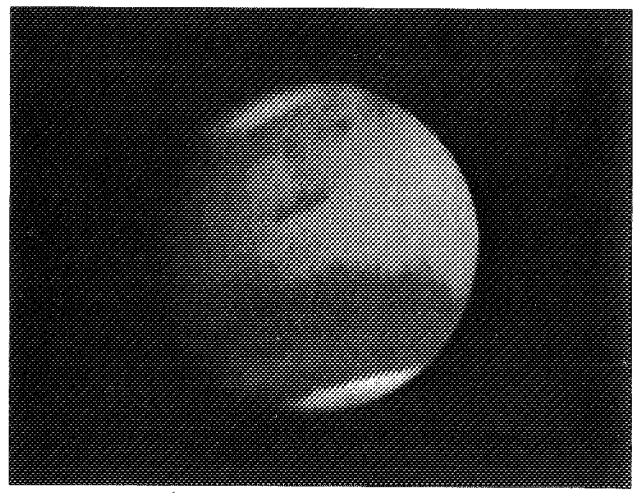


6F12

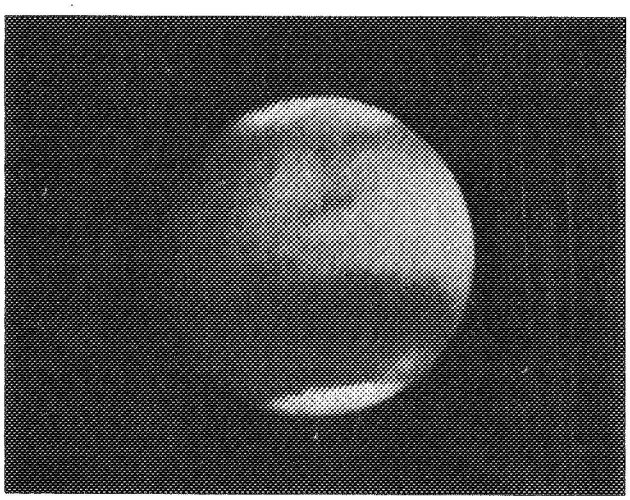
7F51



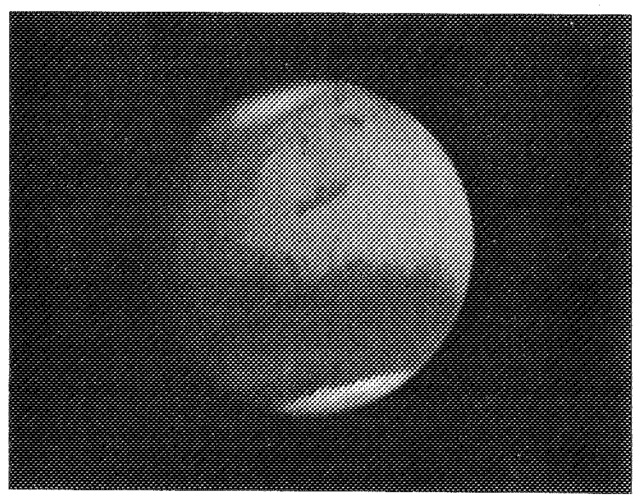
6F13



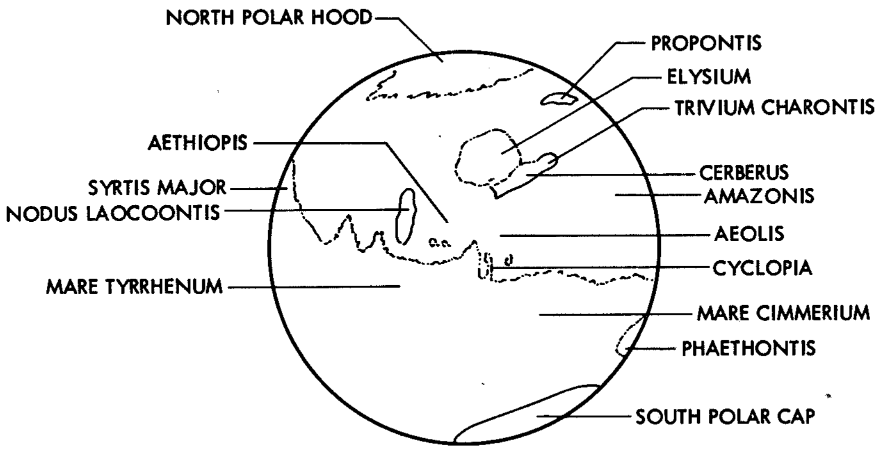
7F52



6F14

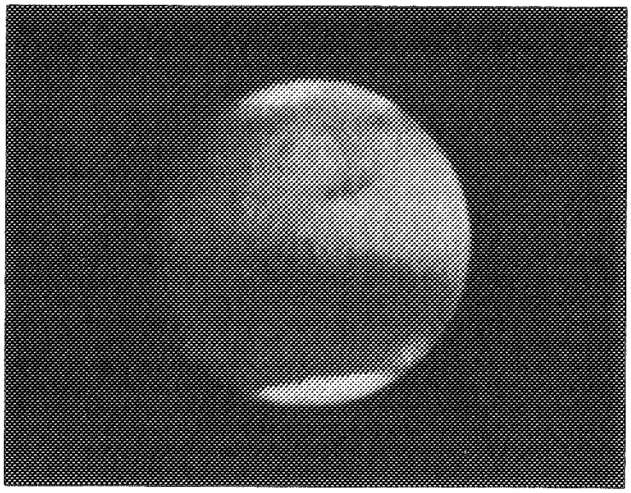


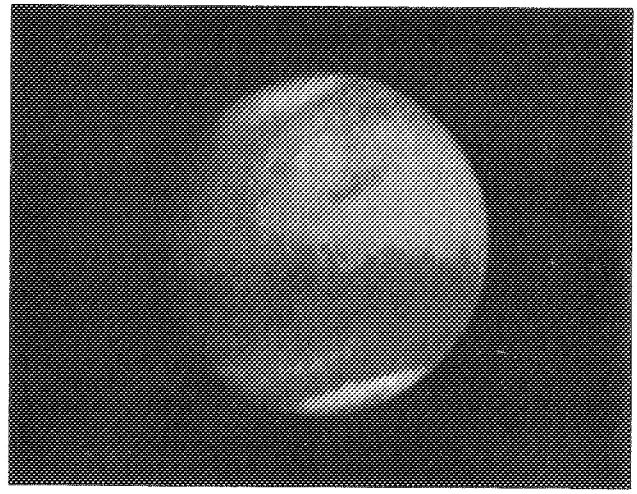
7F53

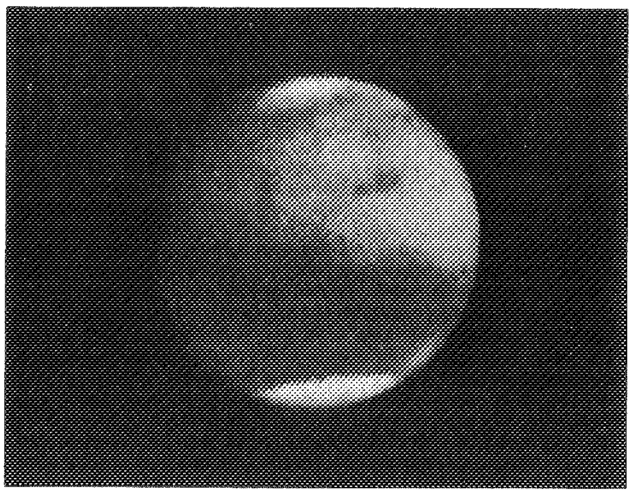


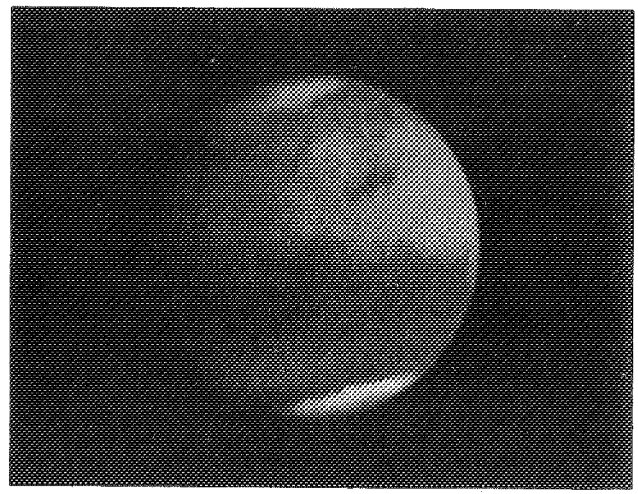
7F17

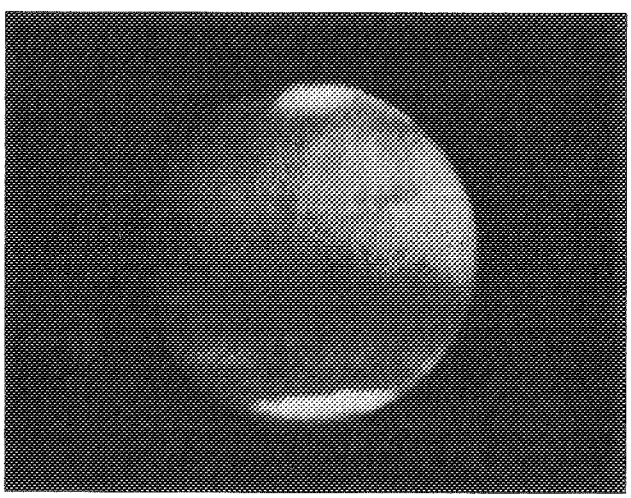
In these pictures, Nodus Laocoontis is seen more clearly to be a diffuse dark region in Aethiopis. Also, there now appears to be a fairly definite western boundary or gap in the north polar "hood."

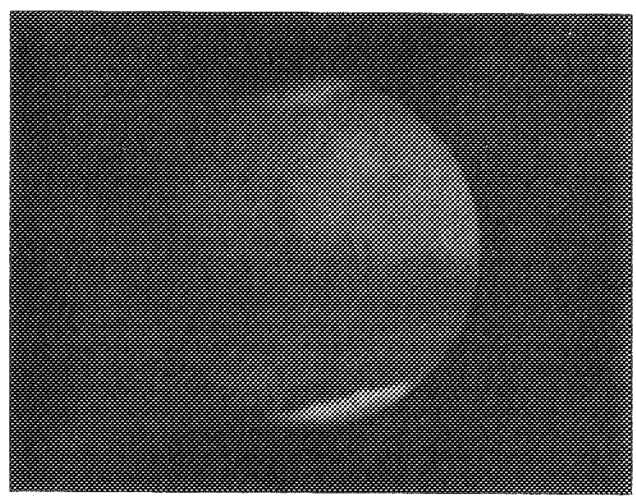

6F15

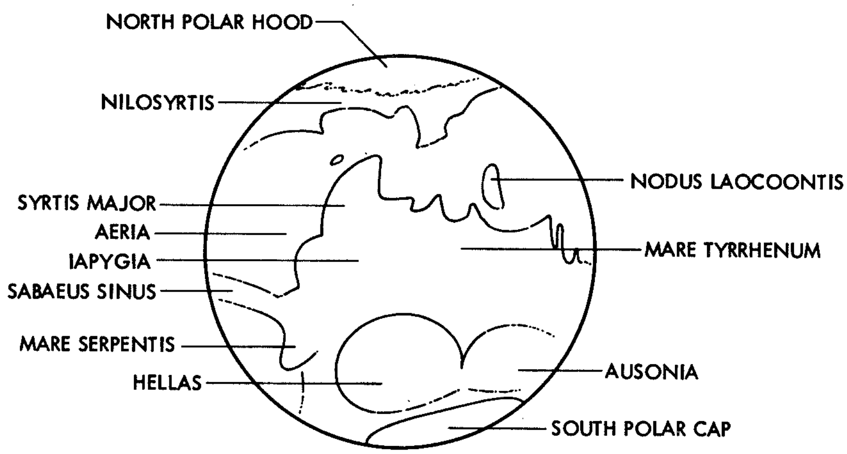

7F54


6F16


7F55

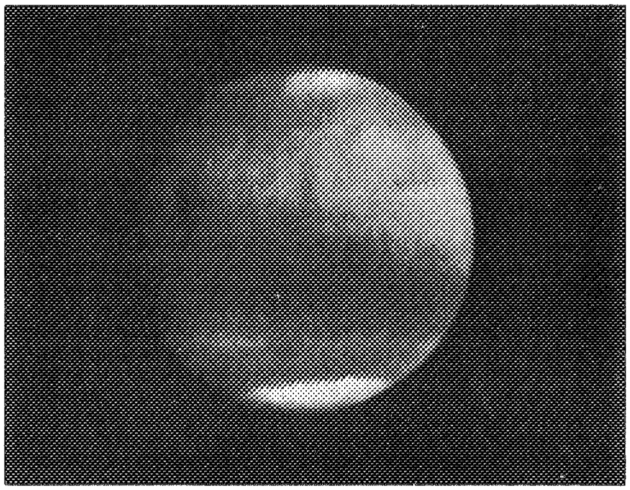

6F17


7F56

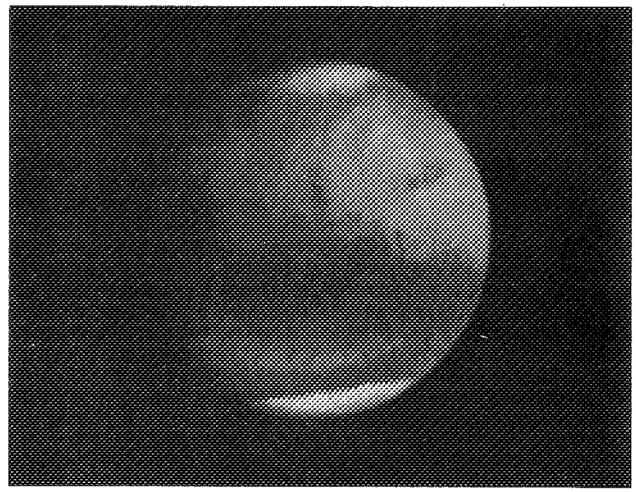


7F25

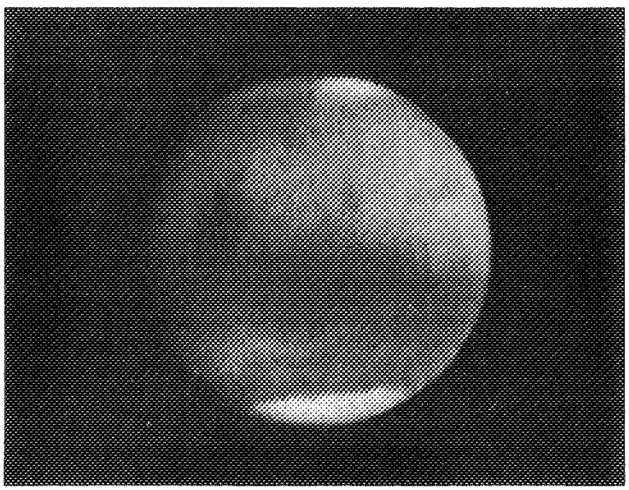
The region between Syrtis Major and Nodus Laocoontis is now seen in greater detail and reveals a mottled appearance. Compare these pictures with the Earth-based photograph in Chapter 1.



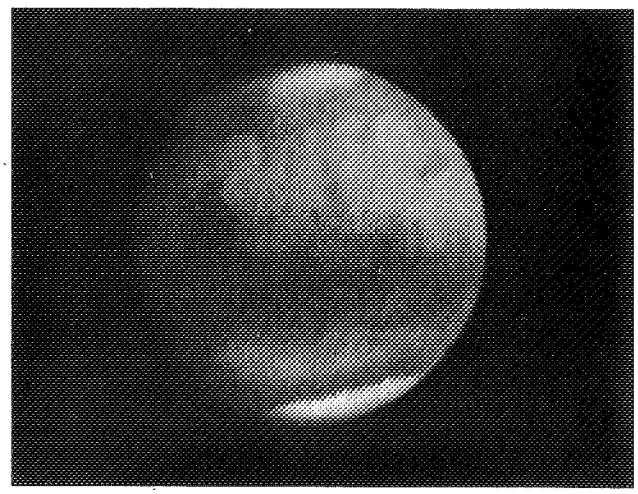
6F18



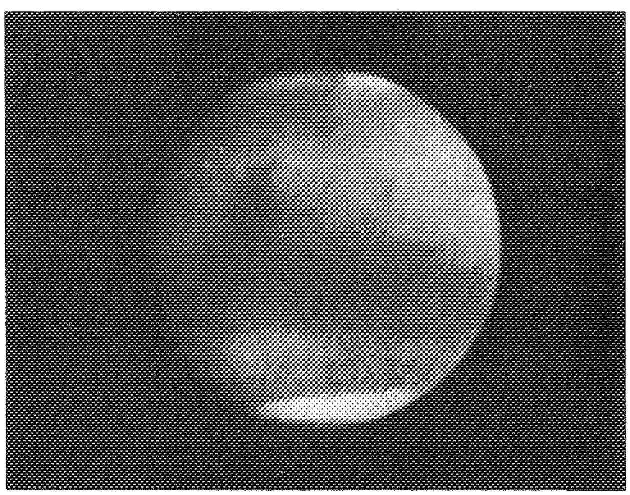
7F57



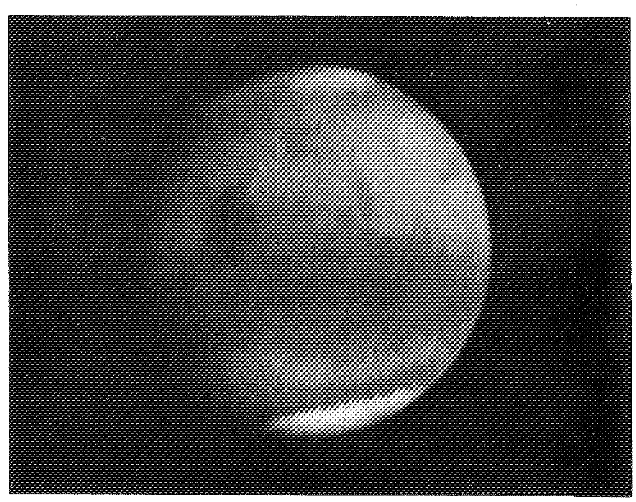
6F19



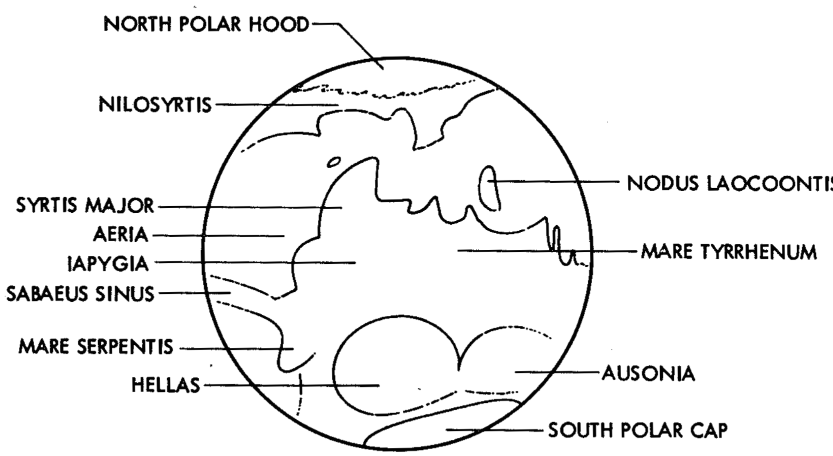
7F58



6F20

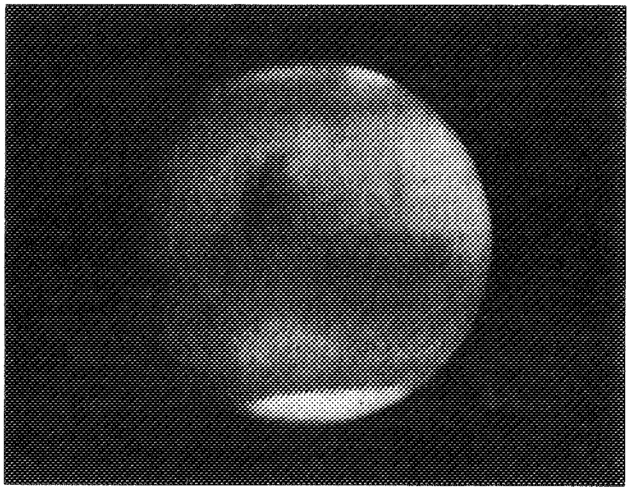


7F59

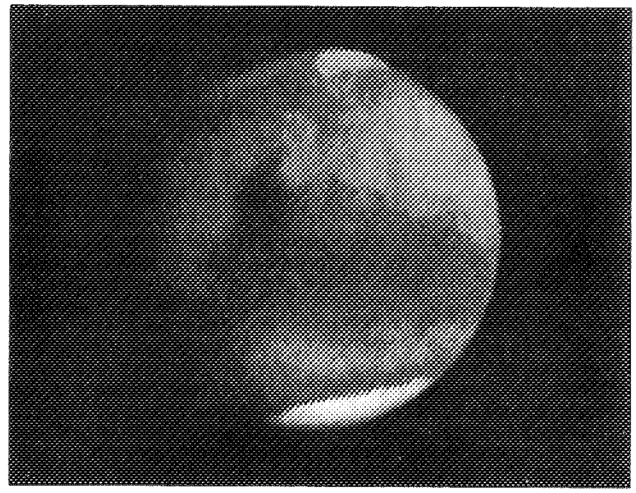


7F25

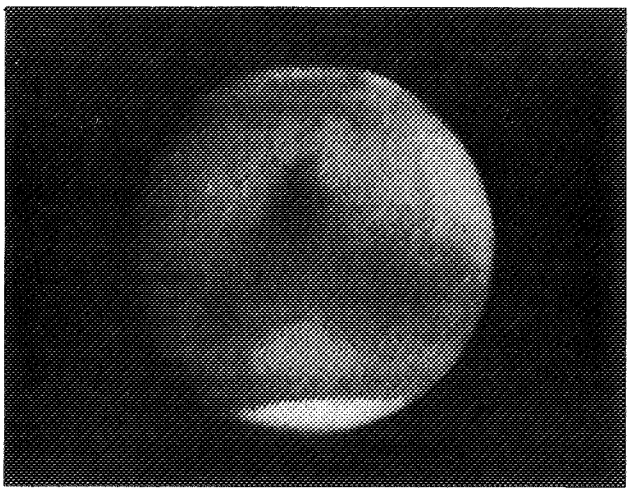
At this distance, a small dark feature may be identified just west of the tip of Syrtis Major. The resolution of these pictures is substantially better than that attainable from the best Earth-based observations.



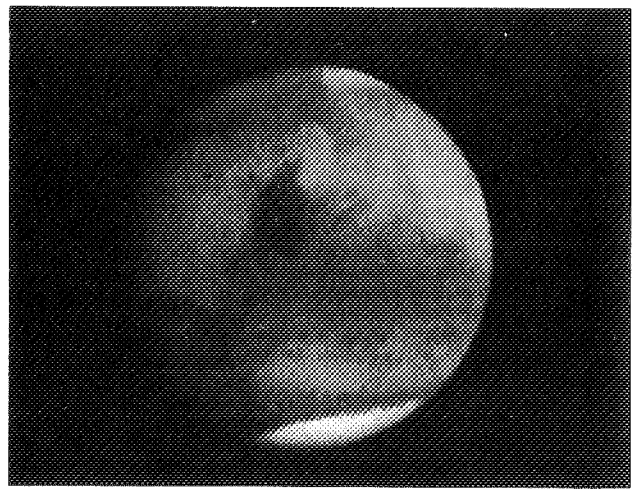
6F21



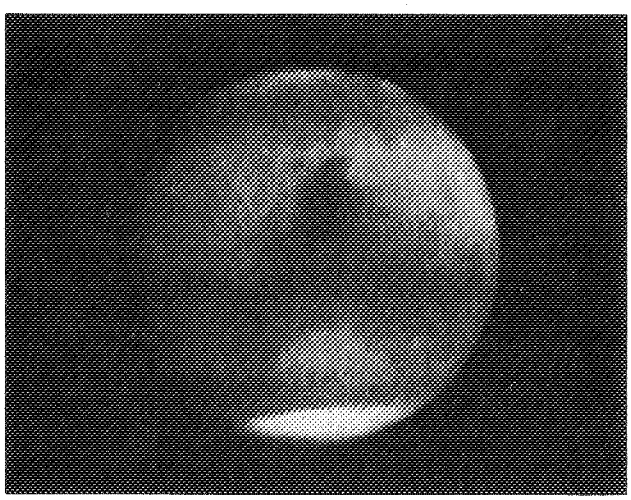
7F60



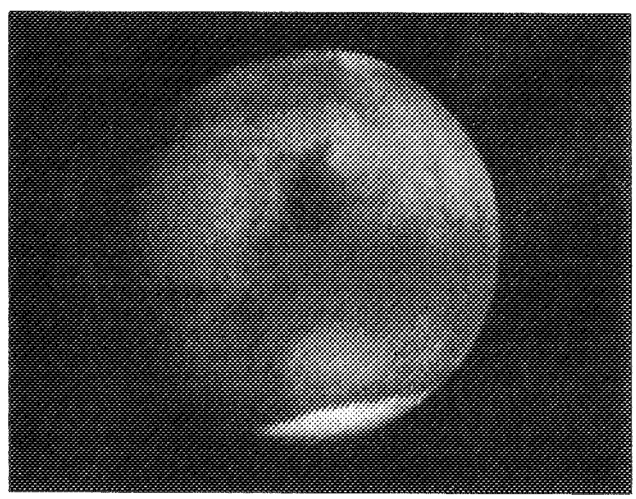
6F22



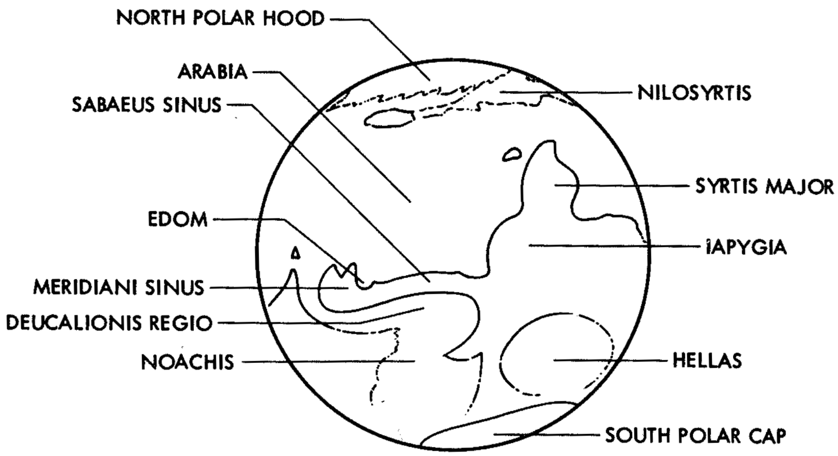
7F61



6F23

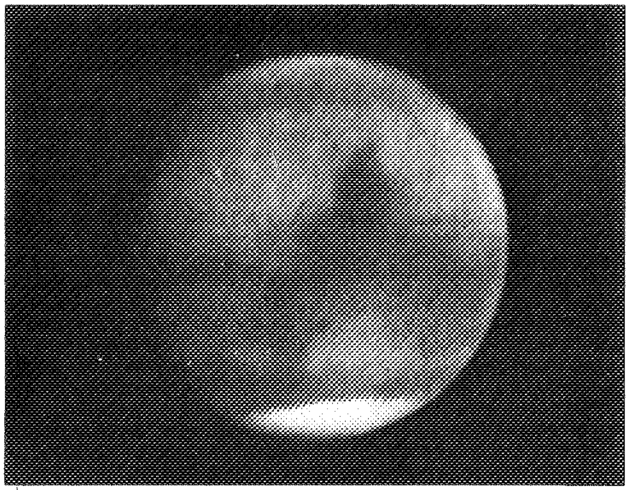


7F62

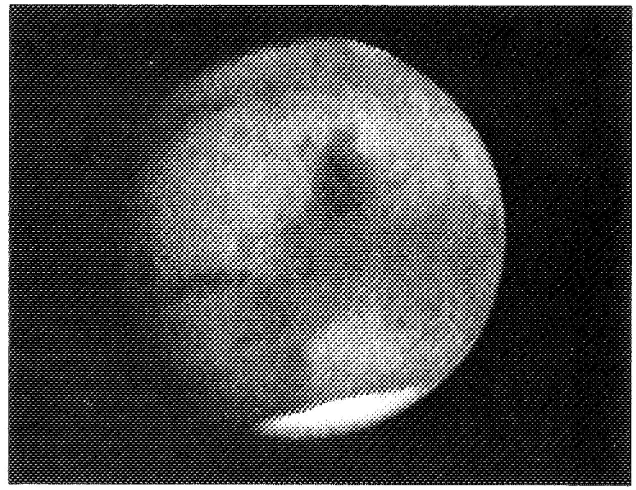


7F33

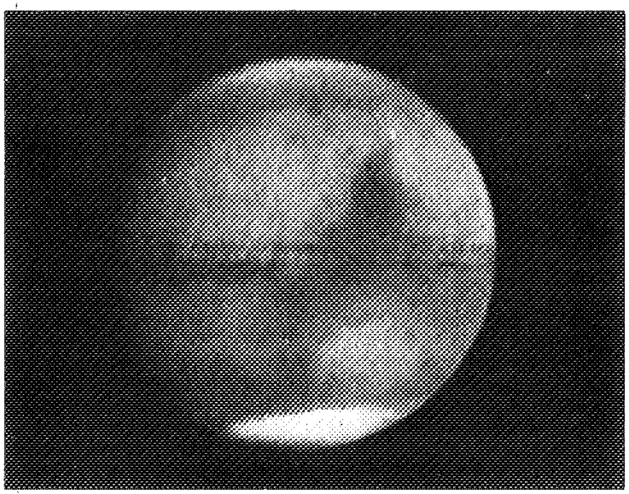
The pictures from both spacecraft show a definite darkening over the southern limb. This could be either a surface property or a haze that had accumulated over the Polar Cap.



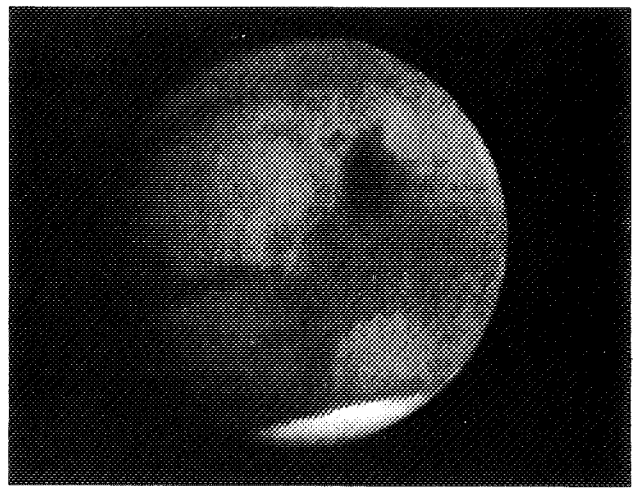
6F24



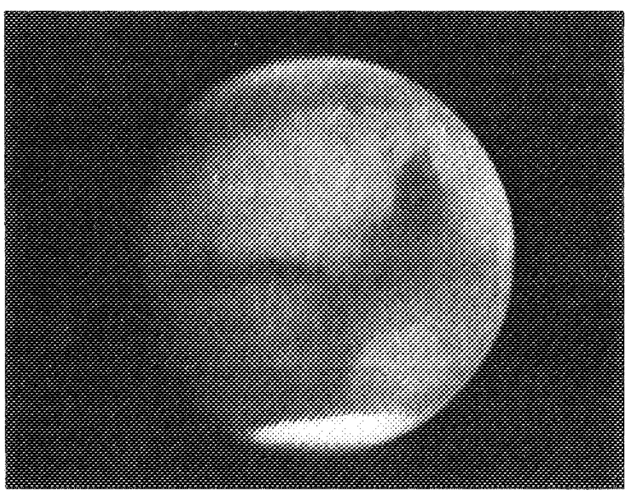
7F63



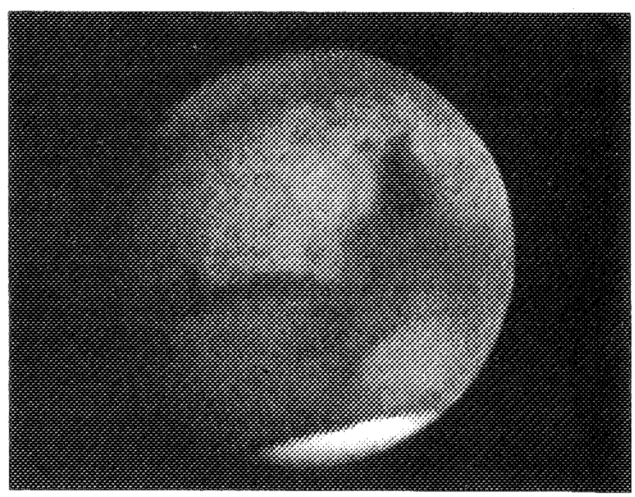
6F25



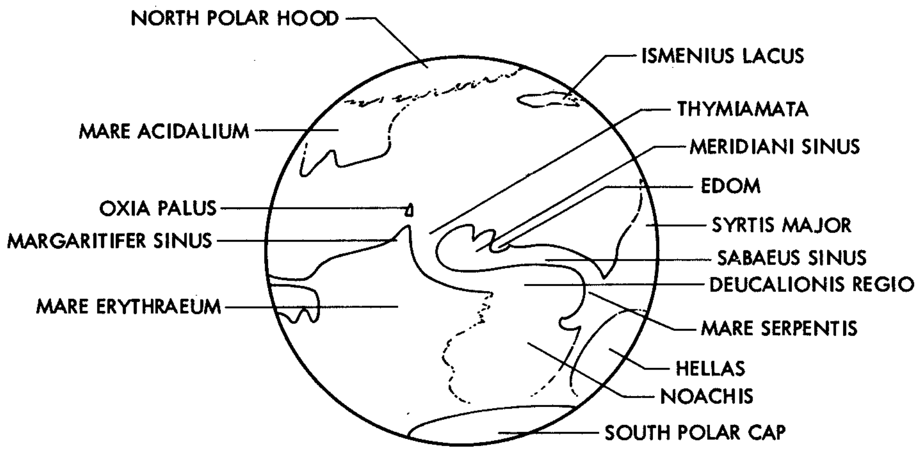
7F64



6F26

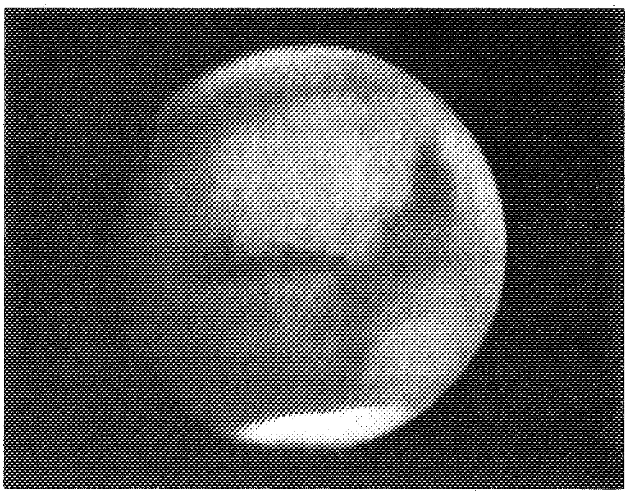


7F65



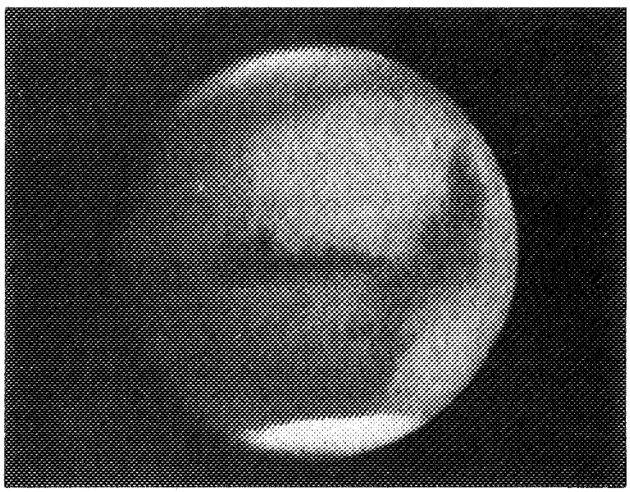
6F30

7F66 and 7F67 reveal clearly that the feature Edom, in the notch at the junction of Meridiani Sinus and Sabaeus Sinus, is actually an oval crater approximately 600 kilometers in diameter. Notice also the definite brightening of Syrtis Major as it approaches the limb. This effect contrasts with the relatively constant brightness of another dark feature, Solis Lacus, as can be seen in 7F43–45.

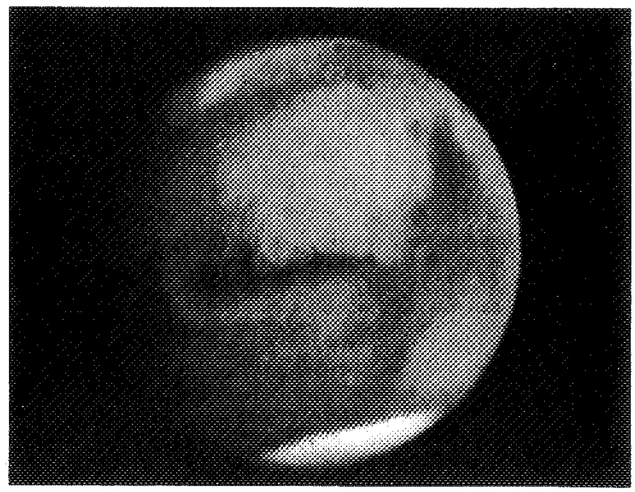


6F27

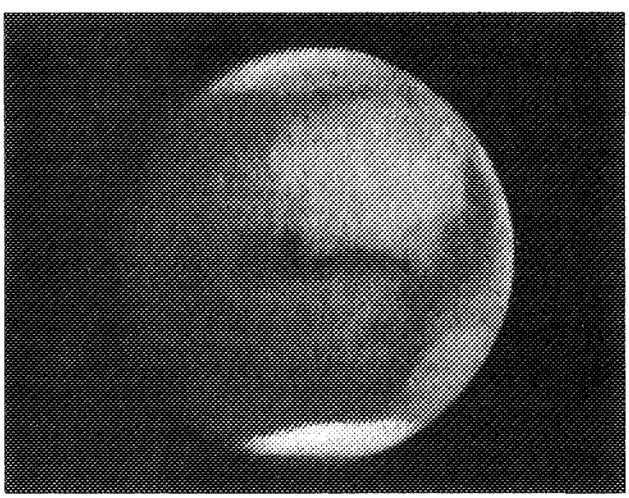
7F66



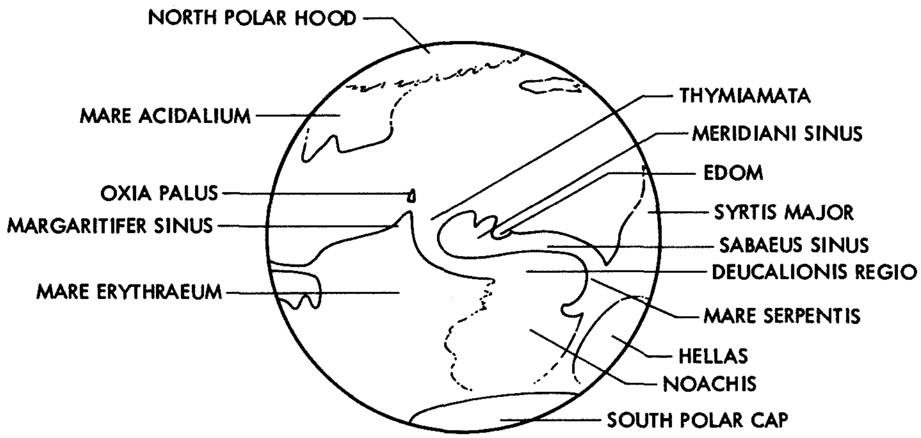
6F28



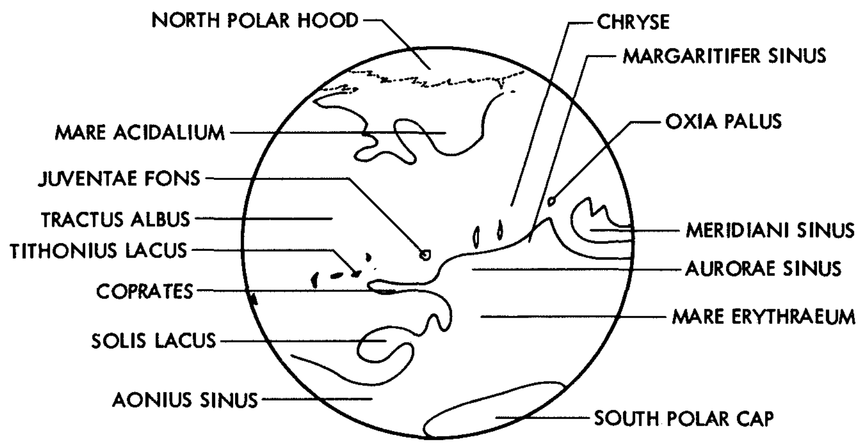
7F67



6F29



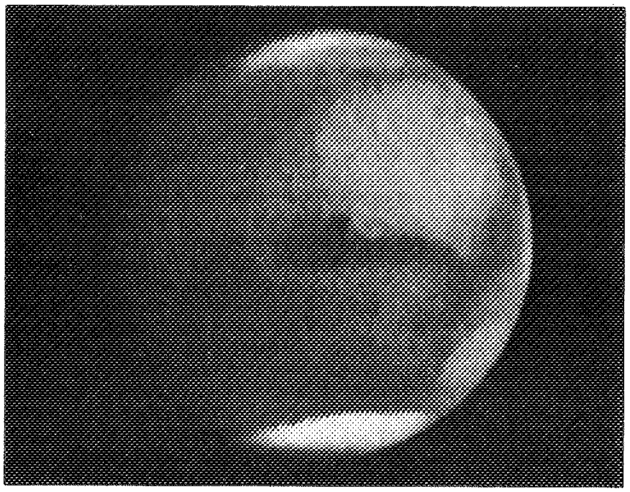
6F30

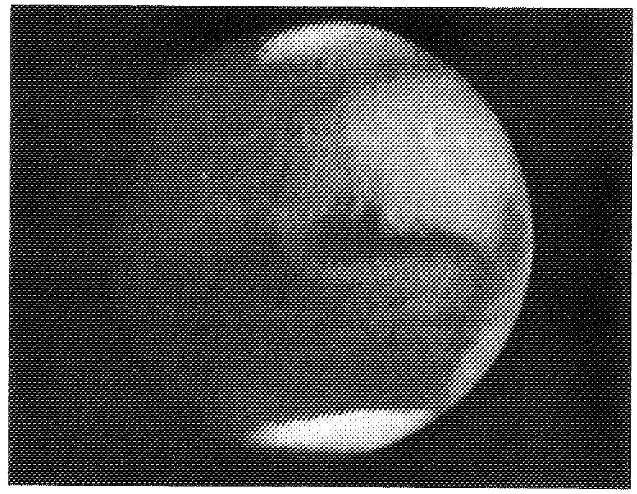


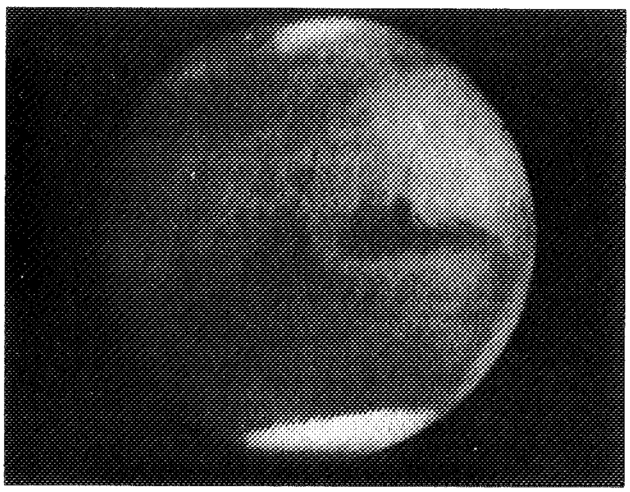
7F0

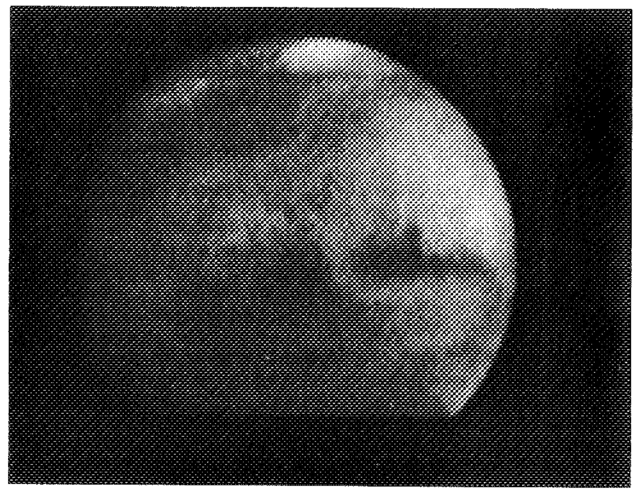
The pictures on this page are arranged sequentially because the Mariner 6 and 7 pictures of this region do not correspond. Frame 6F33 was being recorded when the Mariner 6 tape recorder reached the end of its tape after the first day of far encounter, and 7F69 was the first picture to be taken by Mariner 7 during its third day of far encounter. The remaining far encounter pictures, starting with 7F69, are printed at half the scale of the previous pictures.

These Mariner 6 pictures provide the best far encounter coverage obtained of the Margaritifer Sinus region and show very clearly Oxia Palus and the definite mottling north of Aurorae Sinus (see sketch simulating 6F30). Frames 7F69 and 70 show this same Aurorae Sinus region farther along toward the limb. Notice in these two pictures the three dark north–south streaks in this mottled area. Notice also that the "canal" Coprates can now be identified as a sequence of separate dark features aligned roughly east–west.

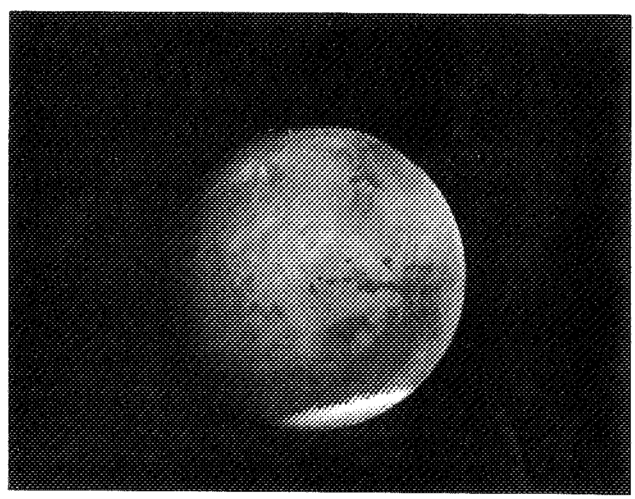

6F30

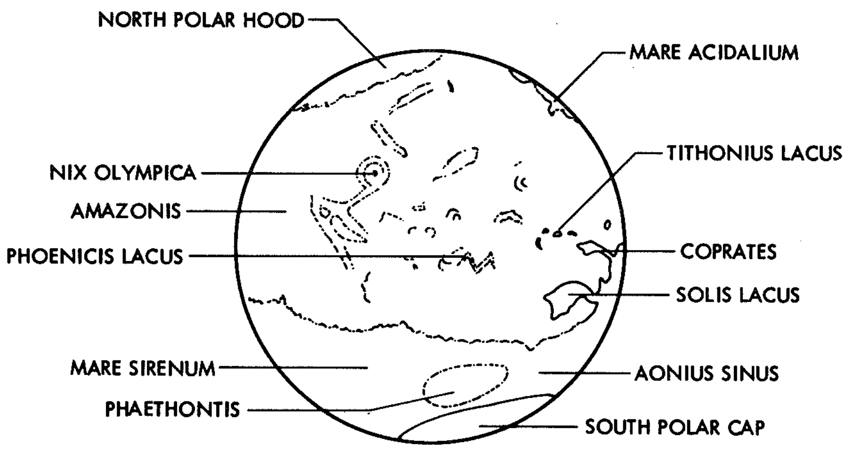

6F31


6F32


6F33

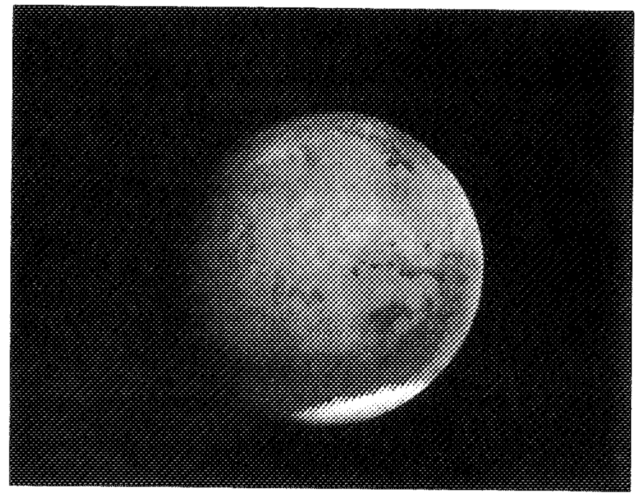

7F69


7F70

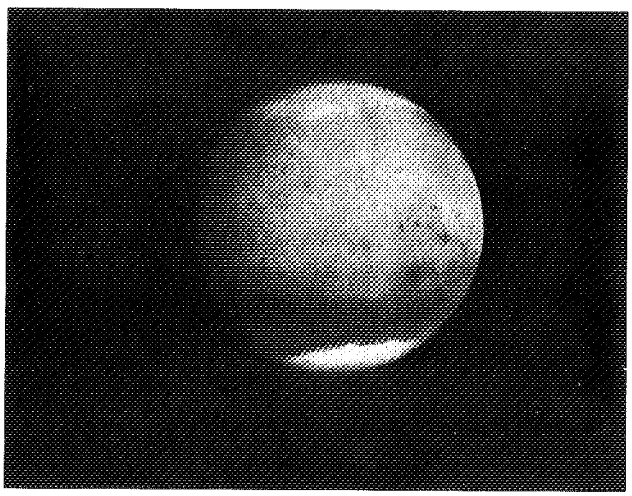


7F1

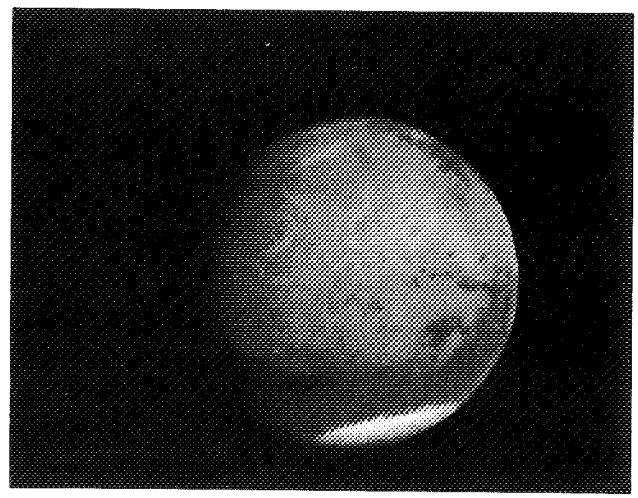
6F34 is the first picture taken during the final day of the Mariner 6 far encounter. These views clearly show the abundant Amazonis detail promised by the previous day's pictures (e.g., 7F42). Nix Olympica is seen as two bright concentric rings, possibly a very large crater; and other similar, circular features appear throughout the "scrambled" area northwest of Coprates. In addition, several bright linear "wisps" appear in these pictures near the North Pole. They too brighten noticeably as they move toward afternoon. It has been suggested that they are clouds, but their identical position after 5 days tends to refute this possibility. Another interesting feature now visible is the dark area with an "M" shape, Phoenicis Lacus.



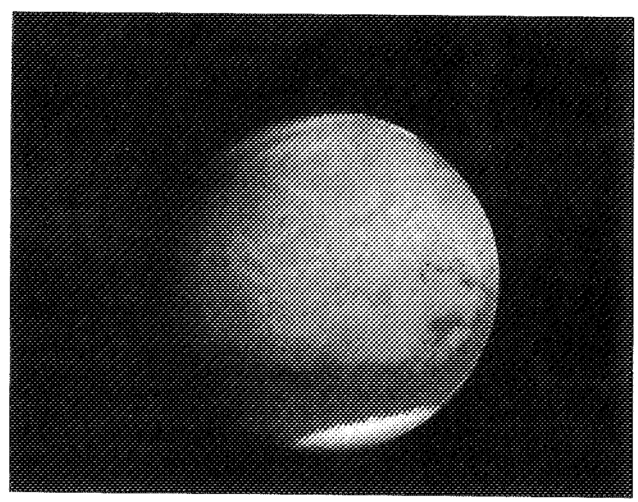
7F71



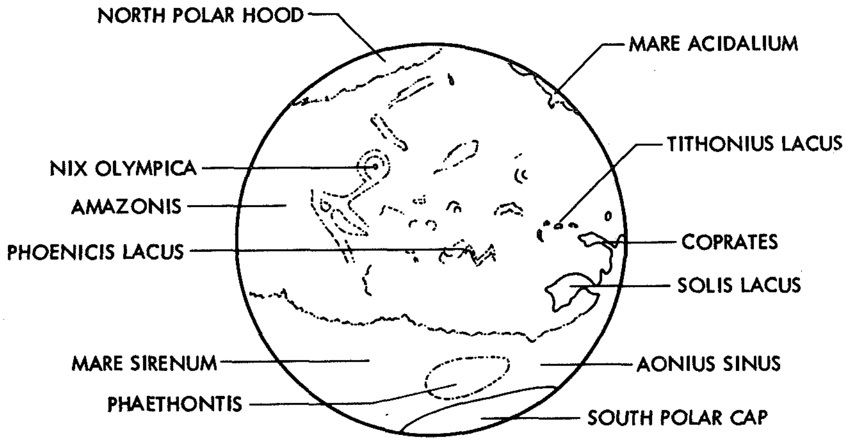
6F34



7F72

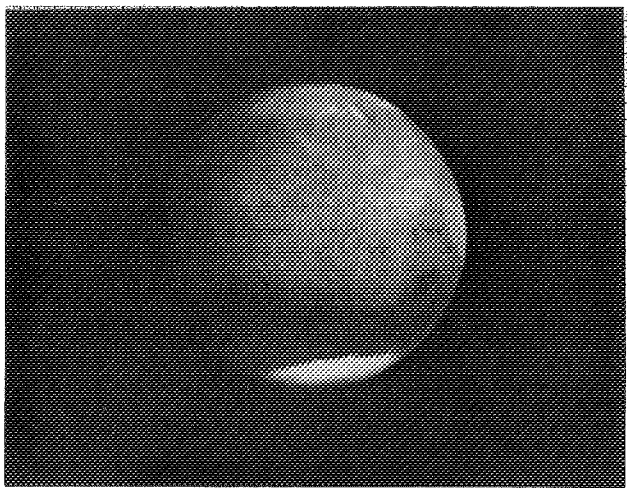


7F73

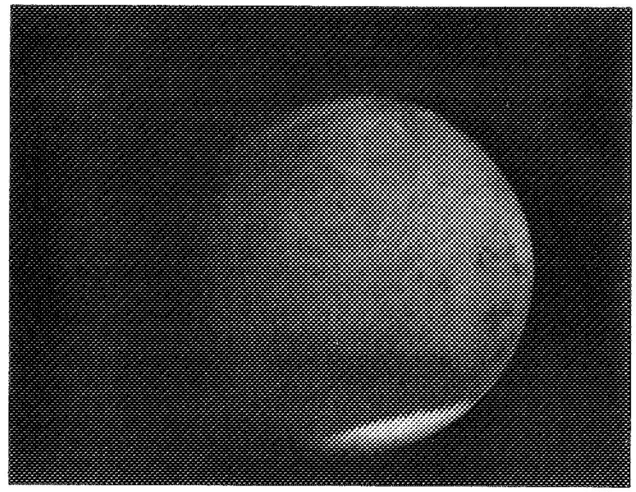


7F1

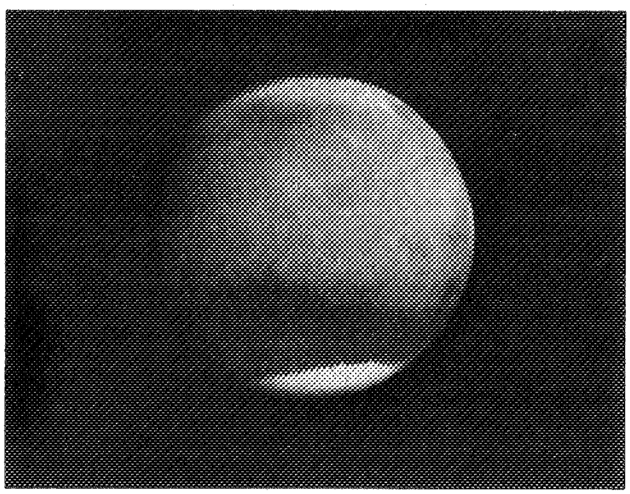
As the Amazonis region moves toward the limb, many of the bright markings become less distinct while the northern "wisps" continue to brighten. The South Polar Cap edge now reveals a crater due south of Nix Olympica in 6F36 and 7F75. Such apparent topographic detail suggests that some of the ground underlying the snow is cratered, similar to other Martian areas.



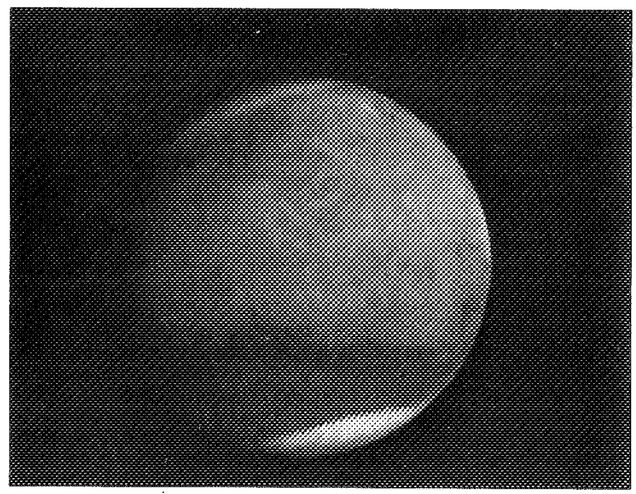
6F35



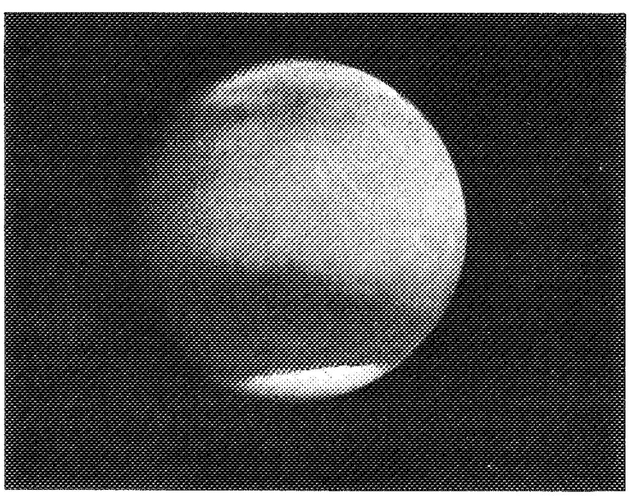
7F74



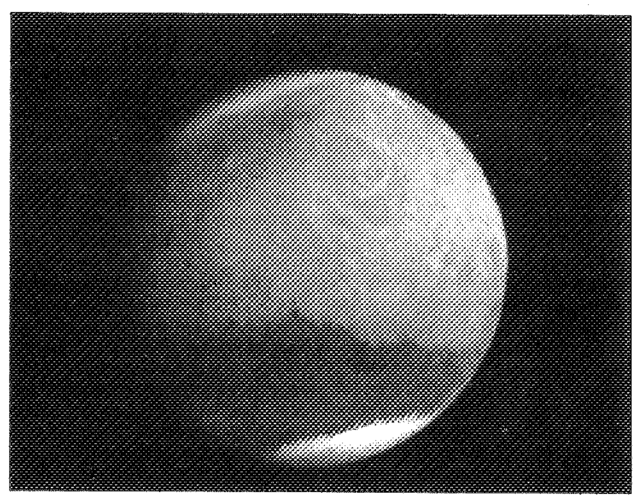
6F36



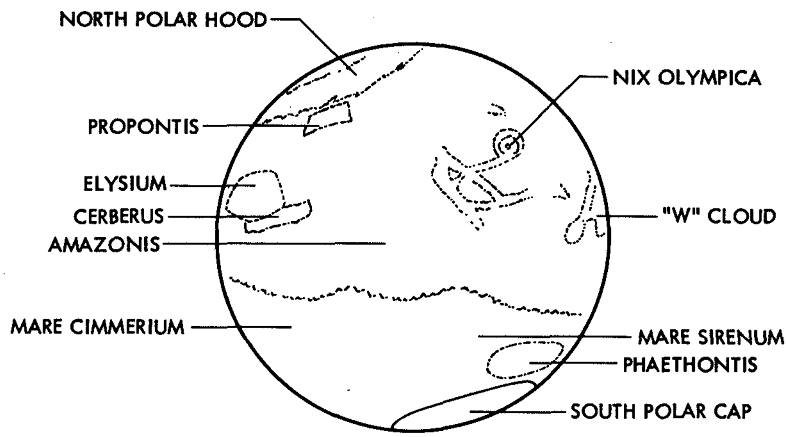
7F75



6F37

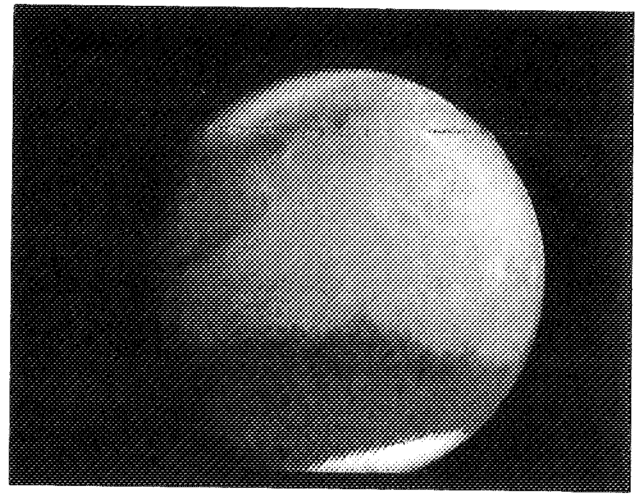


7F76

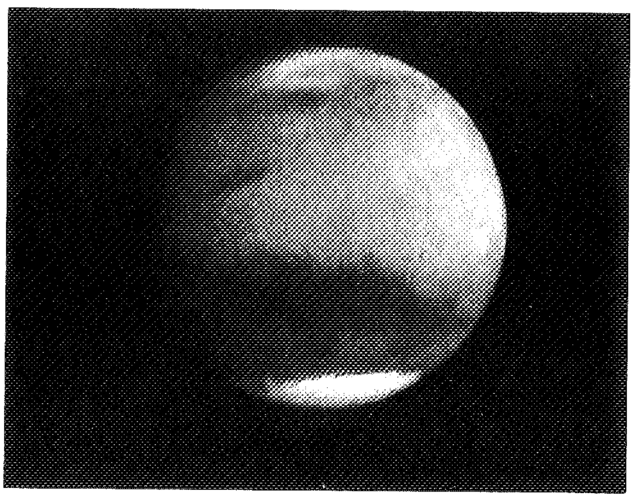


7F9

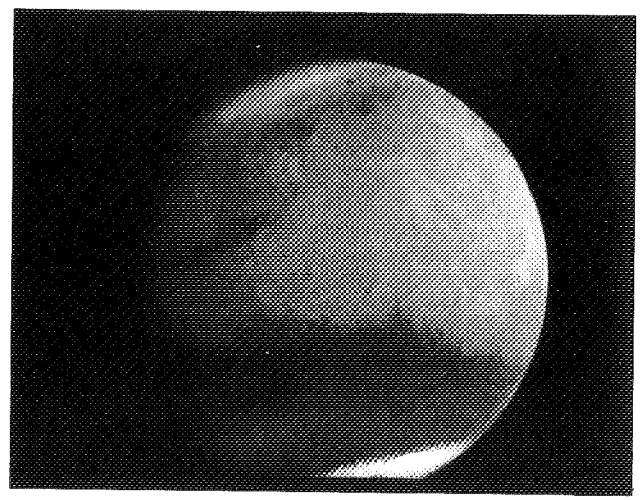
As Cerberus emerges from night and assumes a distinctive "fish" shape, parts of Amazonis, which were not identifiable at the center of the disk, become brilliant spots near the limb. Frame 7F79 is interesting, for it shows the larger of the two Martian moons, Phobos, as a small dot just east of Cerberus. From this and other pictures showing Phobos, its location has been defined more accurately than Earth-based data had permitted.



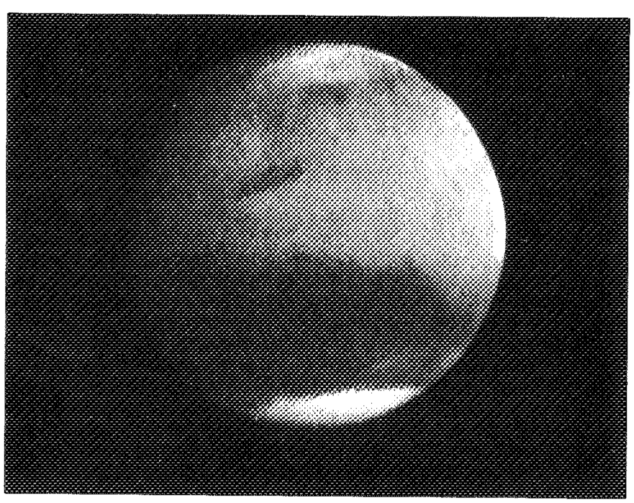
7F77



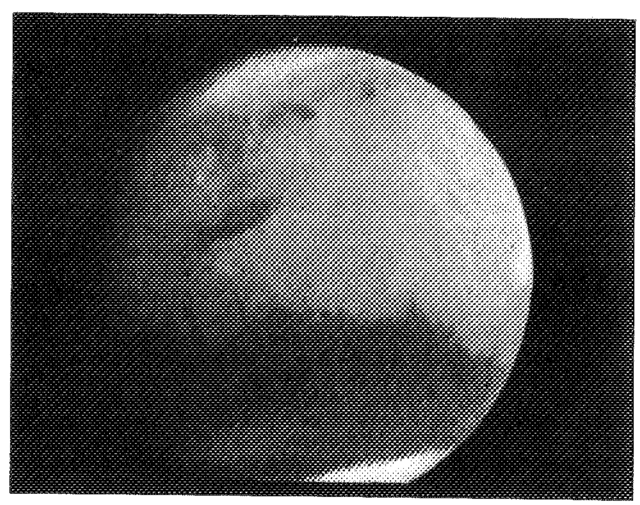
6F38



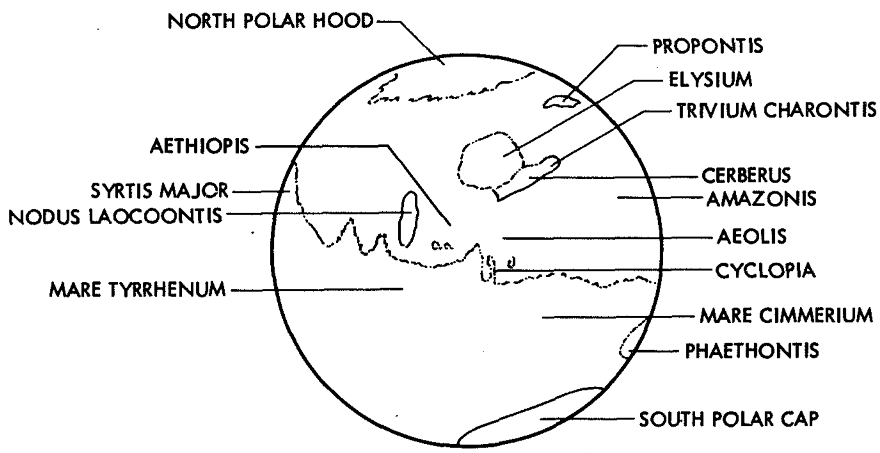
7F78



6F39

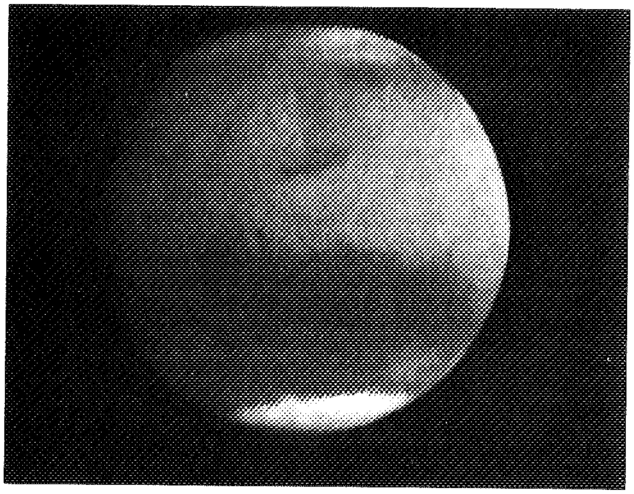


7F79

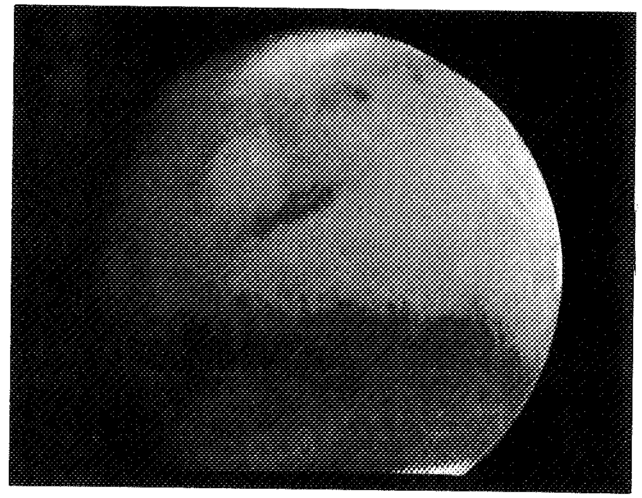


7F17

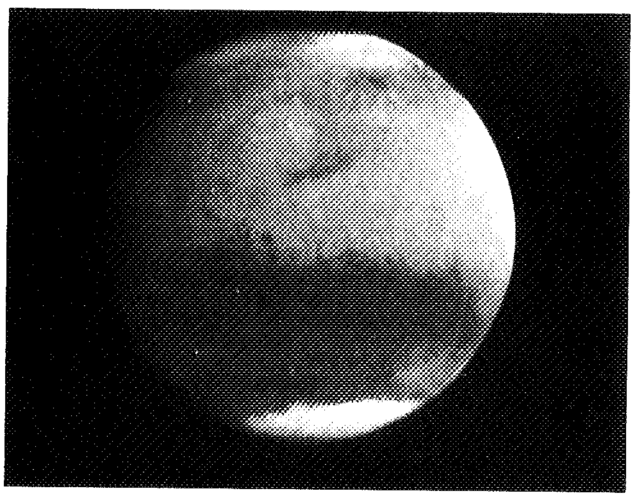
As the spacecraft continues to approach Mars, the ragged northern boundary of Mare Cimmerium becomes still more diffuse and ill-defined. In the Mariner 7 pictures, the dark mottled areas now begin to reveal numerous craters, and a distinct crater is now visible at the northern tip of Cyclopia. Frames 7F81 and 7F82 show an interesting "lump" on the southeastern limb. Subsequent analysis has shown this "lump" to be a detached haze layer in the atmosphere above the Martian surface. The Mariner 6 pictures show a bright area, Phaethontis, southeast of Mare Cimmerium.



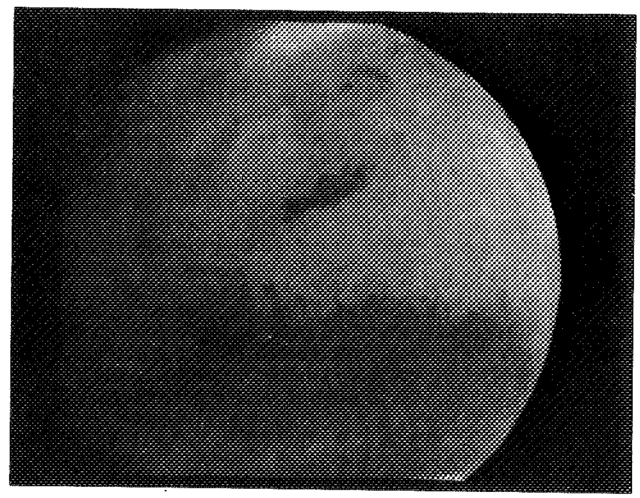
6F40



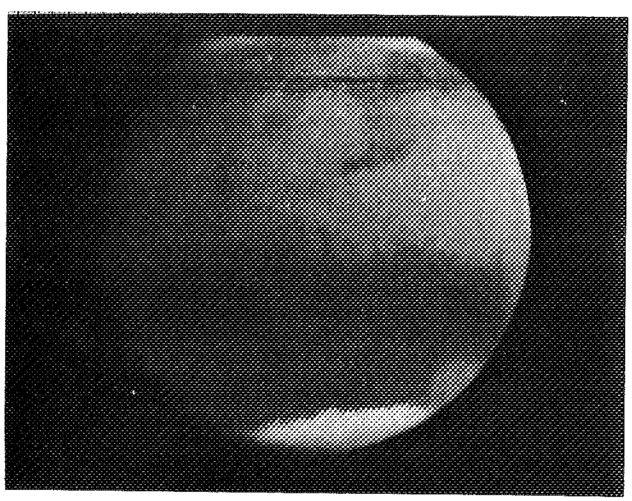
7F80



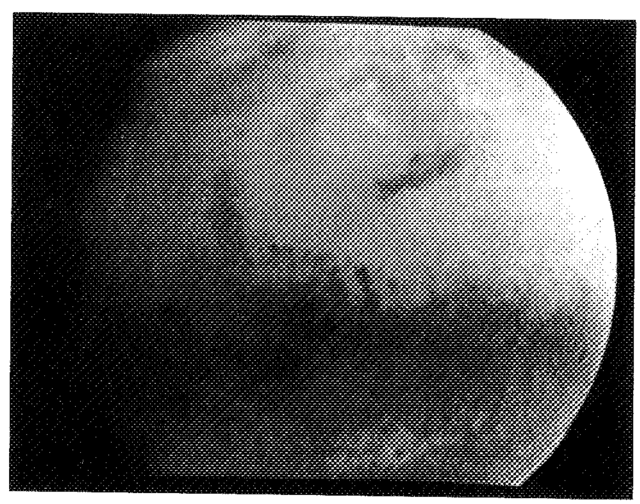
6F41



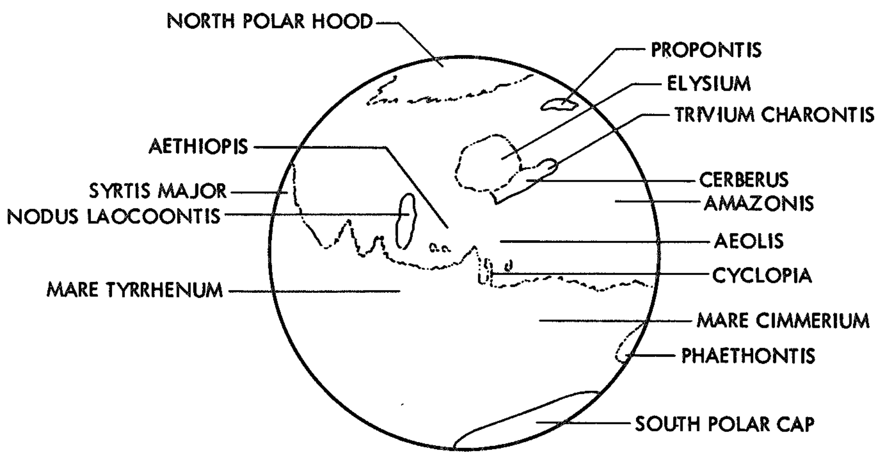
7F81



6F42

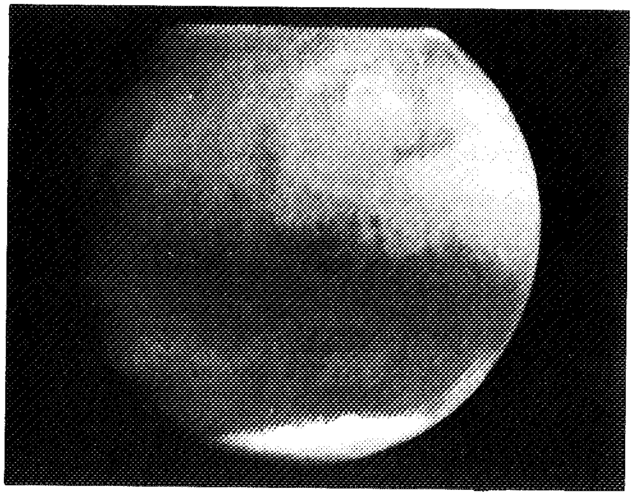


7F82



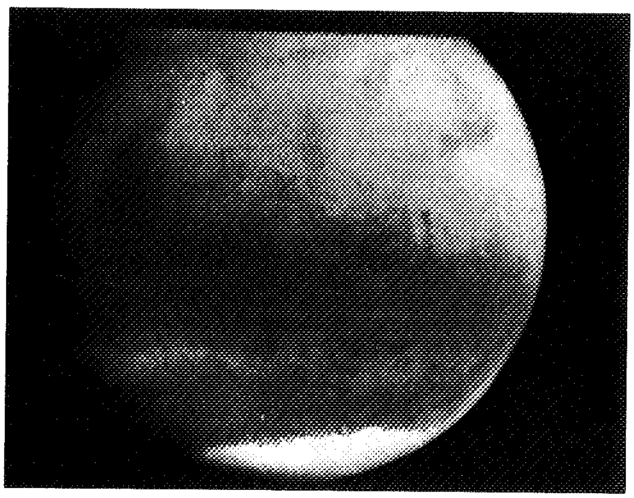
7F17

Closer views continually reveal more craters in the dark areas. Also, in 7F83 there are two very bright spots in the northern half of Elysium. These pictures correspond roughly to the Earth-based view in Chapter 1.



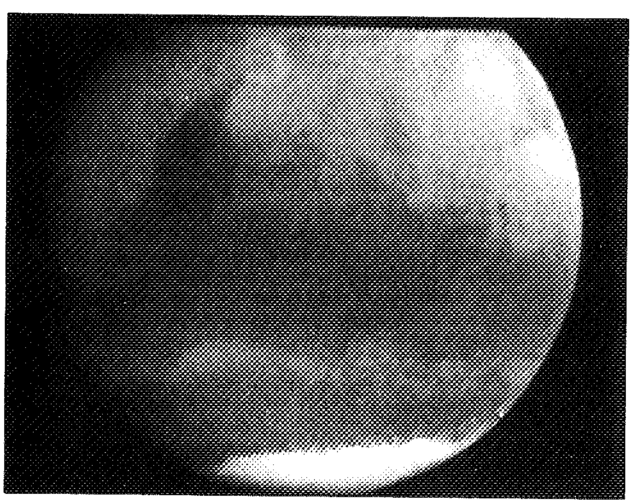
6F43

7F83

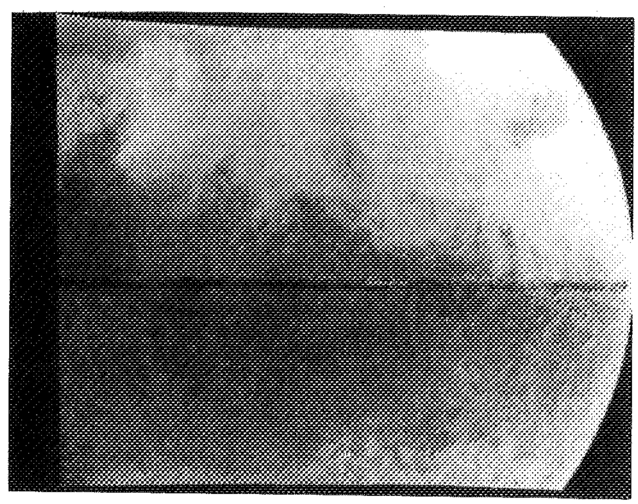


6F44

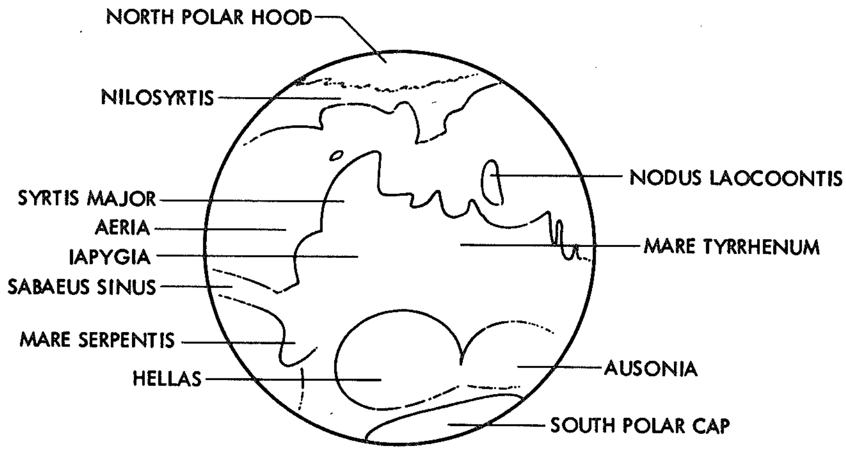
7F84



6F45



7F85



7F25

A large crater (about 500 kilometers in diameter) appears in Iapygia, near Sabaeus Sinus.

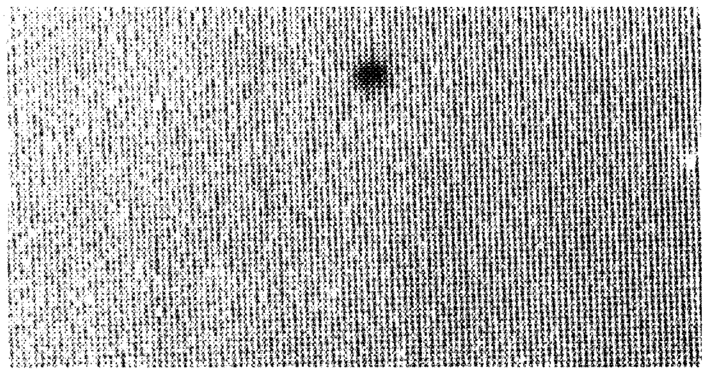
7F86

6F46

7F87

6F47

7F88



Phobos, magnified ×10 from frame 7F91.

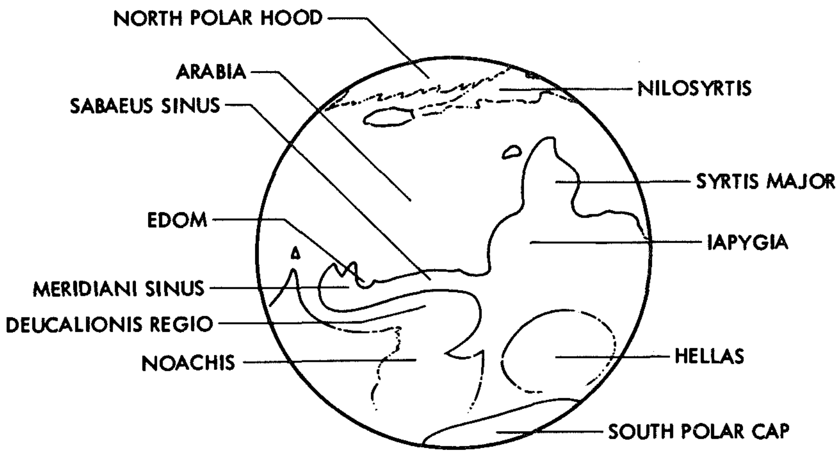
The small, dark spot near the top of 7F91 over the desert Aeria just west of Syrtis Major is Phobos, one orbit after it appeared in 7F79. This image of Phobos covers about 40 picture elements. From this data, Phobos was found to be an oval object approximately 22.5 kilometers long and 17.5 kilometers wide. Also, it was concluded that Phobos is a very dark object—the darkest object so far identified in the solar system.

7F89

7F90

6F48

7F91



7F33

These pictures show a multitude of craters in Syrtis Major. Like 7F82, Frame 6F49 shows a definite layer of haze off the eastern limb. From a study of the far encounter limb data, it has been determined that there are definite haze layers in the Martian atmosphere but that these layers are not uniformly distributed over the whole planet.

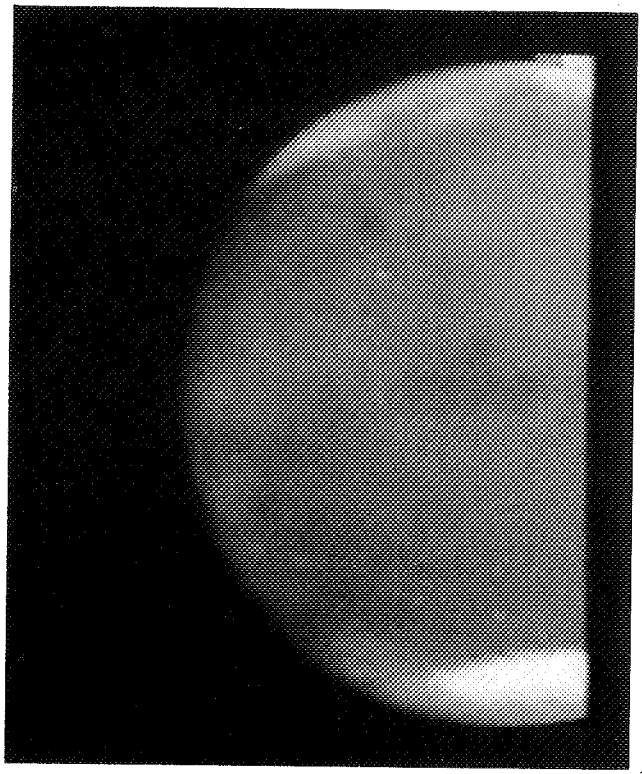
7F92

7F93

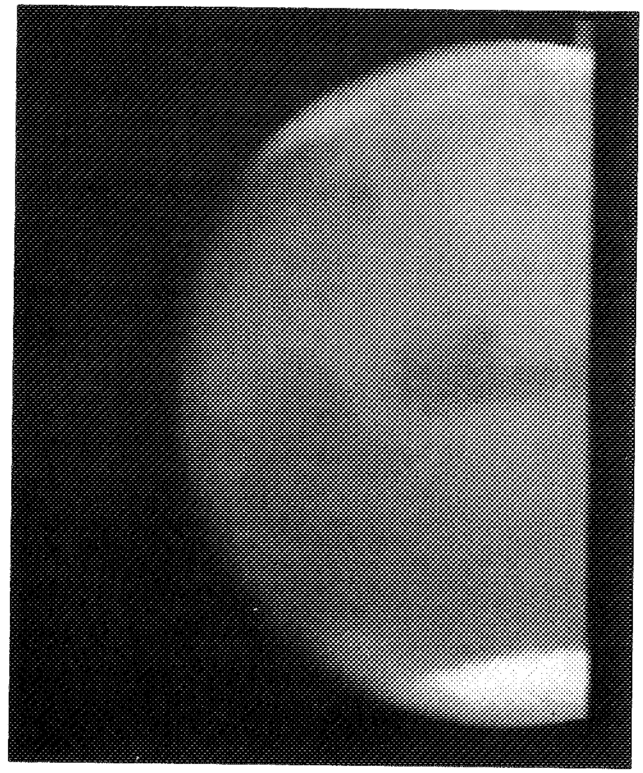
6F49

Playback of the final 25 Mariner 7 far encounter pictures was completed about 3 hours before the spacecraft was to fly by Mars. During the remaining time, the cameras were once again turned toward Mars to acquire the closest far encounter pictures of the mission (down to 42,000 kilometers from the surface). These pictures were not recorded on the tape recorder, soon to be needed during near encounter; instead, the digital video form of these pictures was transmitted directly to Earth as the pictures were taken. In the digital video format, a column, known as the "jail bar," in the central area of the picture is blocked out and only every seventh pixel is transmitted for the remaining four-fifths of the picture. (Three of these pictures were combined to make the color picture in the Frontispiece of this atlas.)

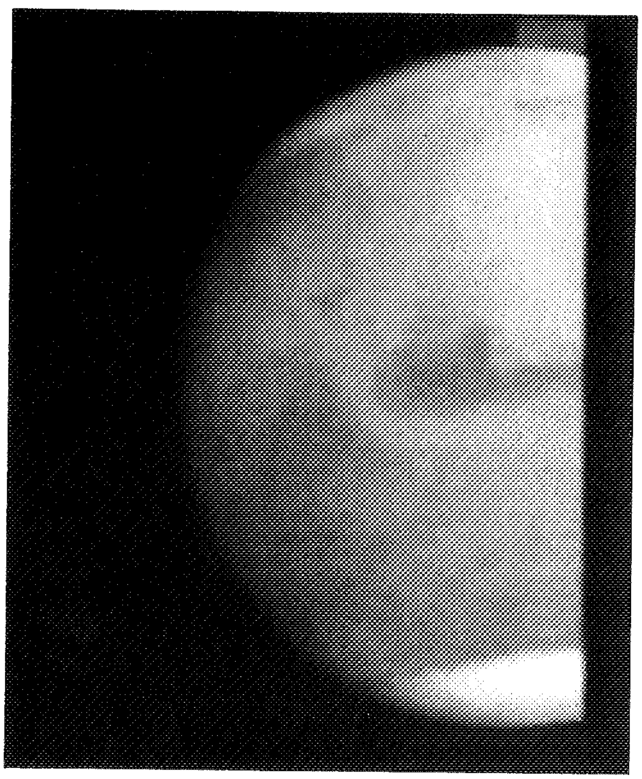
This close to the planet, it was possible to begin using the wide-angle Camera A with its four color filters: red, blue, and two greens. In these pictures, the blacked-out "jail bar" obscured the eastern portion of the planet. As observed from Earth, the Martian surface shows greatest contrast in red light and least in blue. Near the North Pole in the blue picture there is a conspicuous bright feature which does not appear so prominently in the red and green. This evidence suggests that there was a blue-colored haze in the polar region at the time of Mariner encounter.



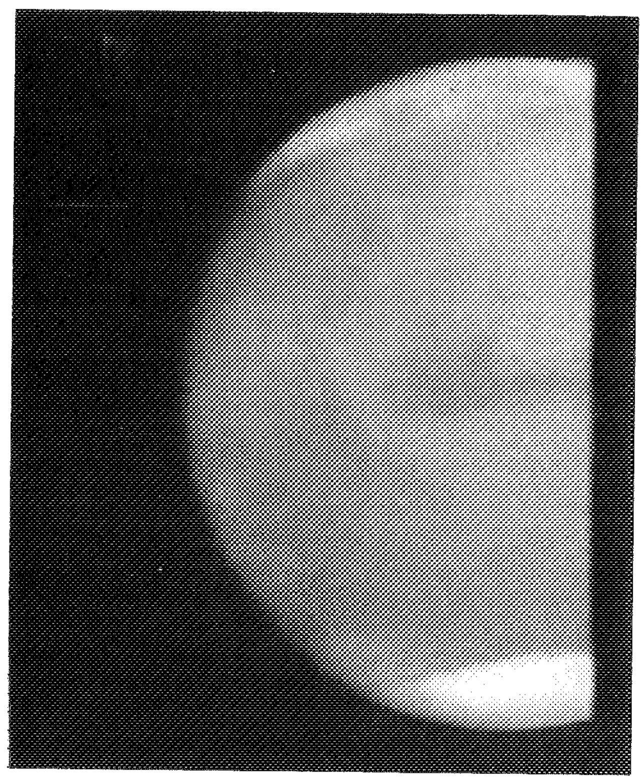
BLUE



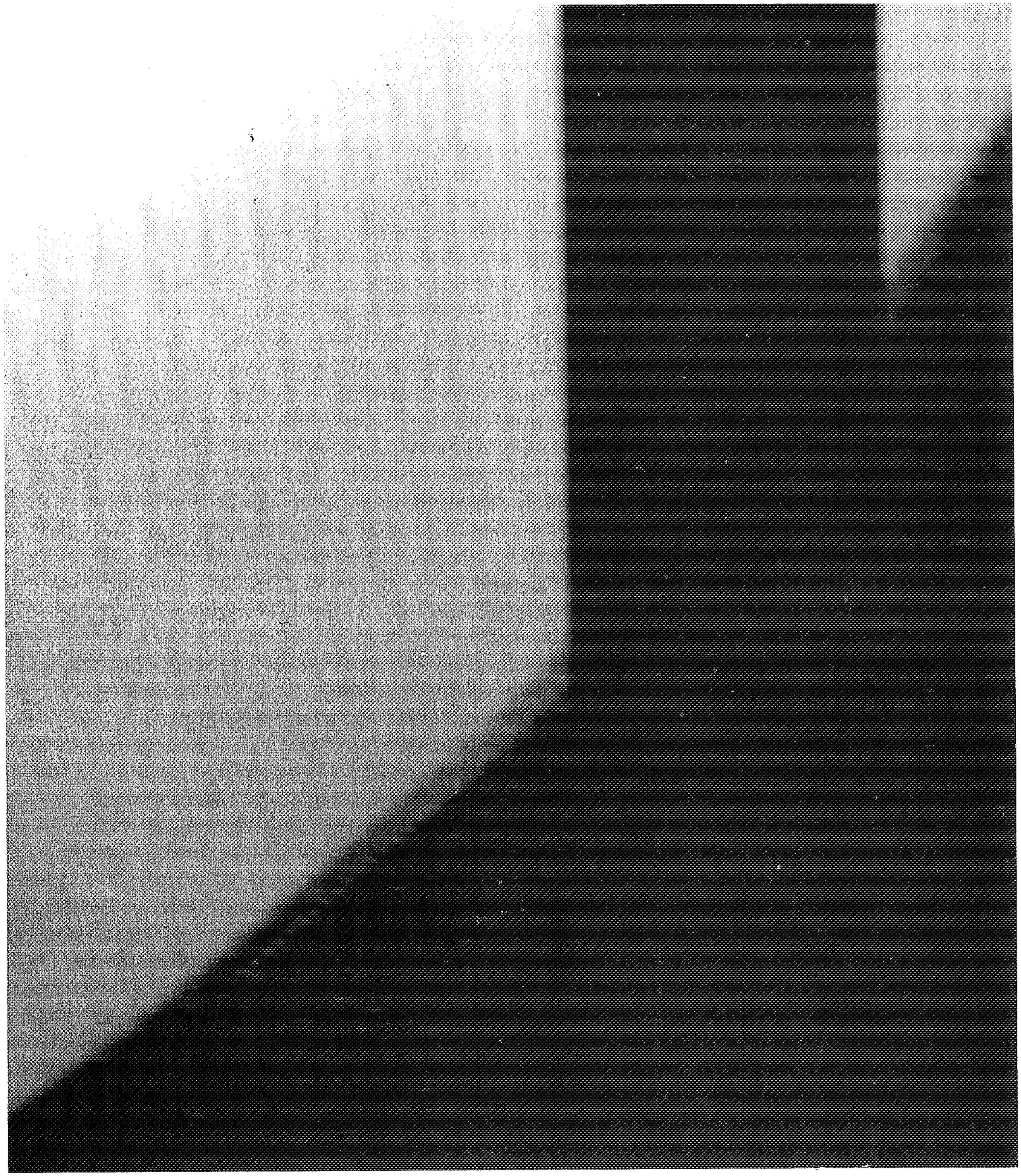
GREEN



RED



GREEN



This narrow-angle picture shows the southeast limb of the planet. Visible just beyond the limb is evidence of an atmospheric haze layer.

NEAR ENCOUNTER PICTURES

CHAPTER 4

The Near Encounter Pictures

The near encounter pictures are presented here in chronological order. The total set of 57 pictures has been divided into five groups, each corresponding to a contiguous series of pictures taken while the cameras were pointed in a specific direction. The odd-numbered frames, e.g., 6N9, were taken with the wide-angle camera and are called "A" frames; the even-numbered pictures, taken with the narrow-angle camera, are called "B" frames. The five picture groups are:

6N1–8, Aurorae Sinus

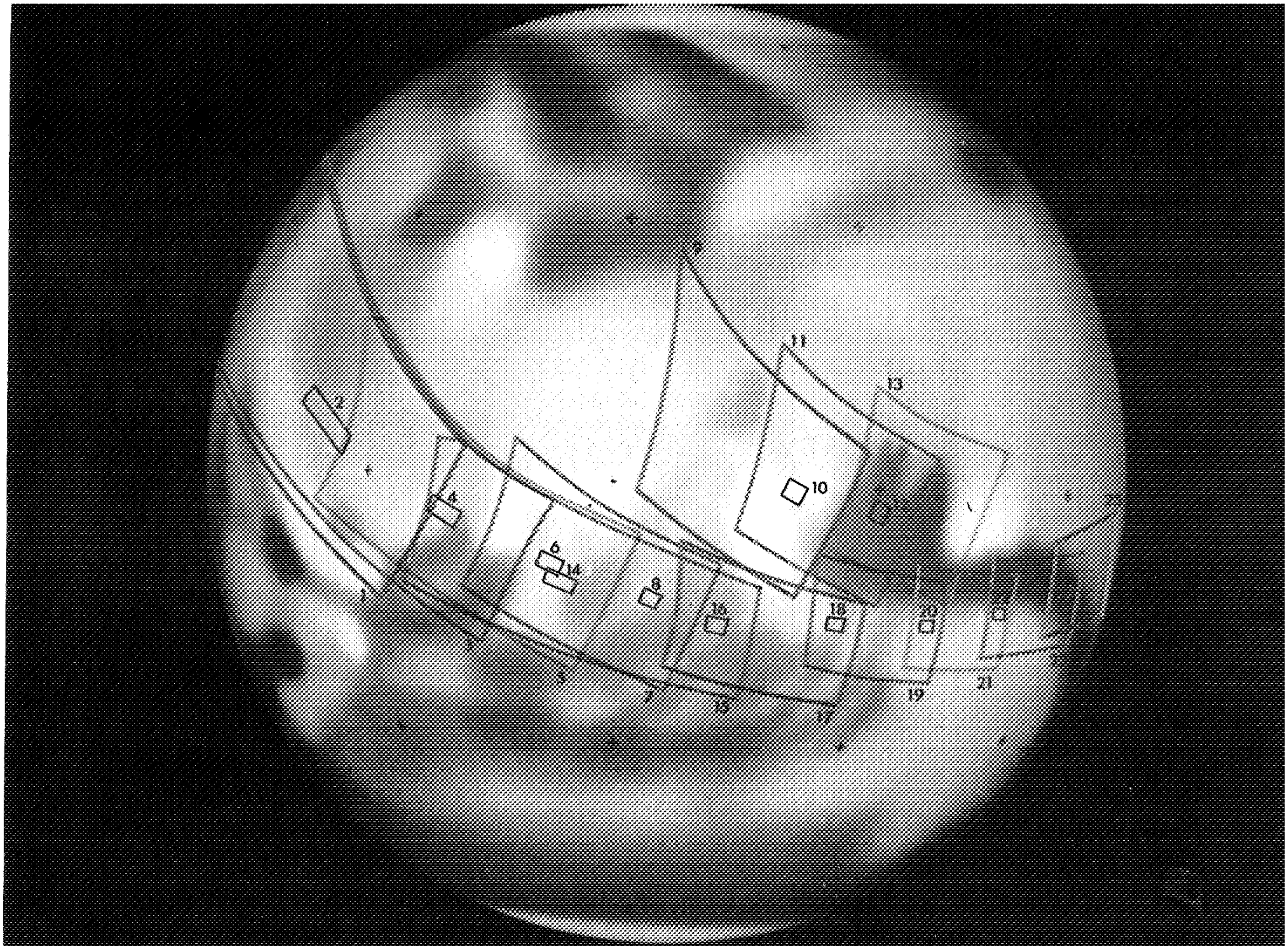
6N9–25, Meridiani Sinus

7N1–9, Meridiani Sinus

7N10–20, South Polar Cap

7N21–32, Noachis–Hellas

Opposite: Mariner 6 (top) took pictures of the equatorial region of Mars; Mariner 7 (bottom) flew by farther south, taking pictures primarily of the southerly latitudes and the South Polar Cap. The picture outlines have been superimposed upon a globe made from Earth-based observations.



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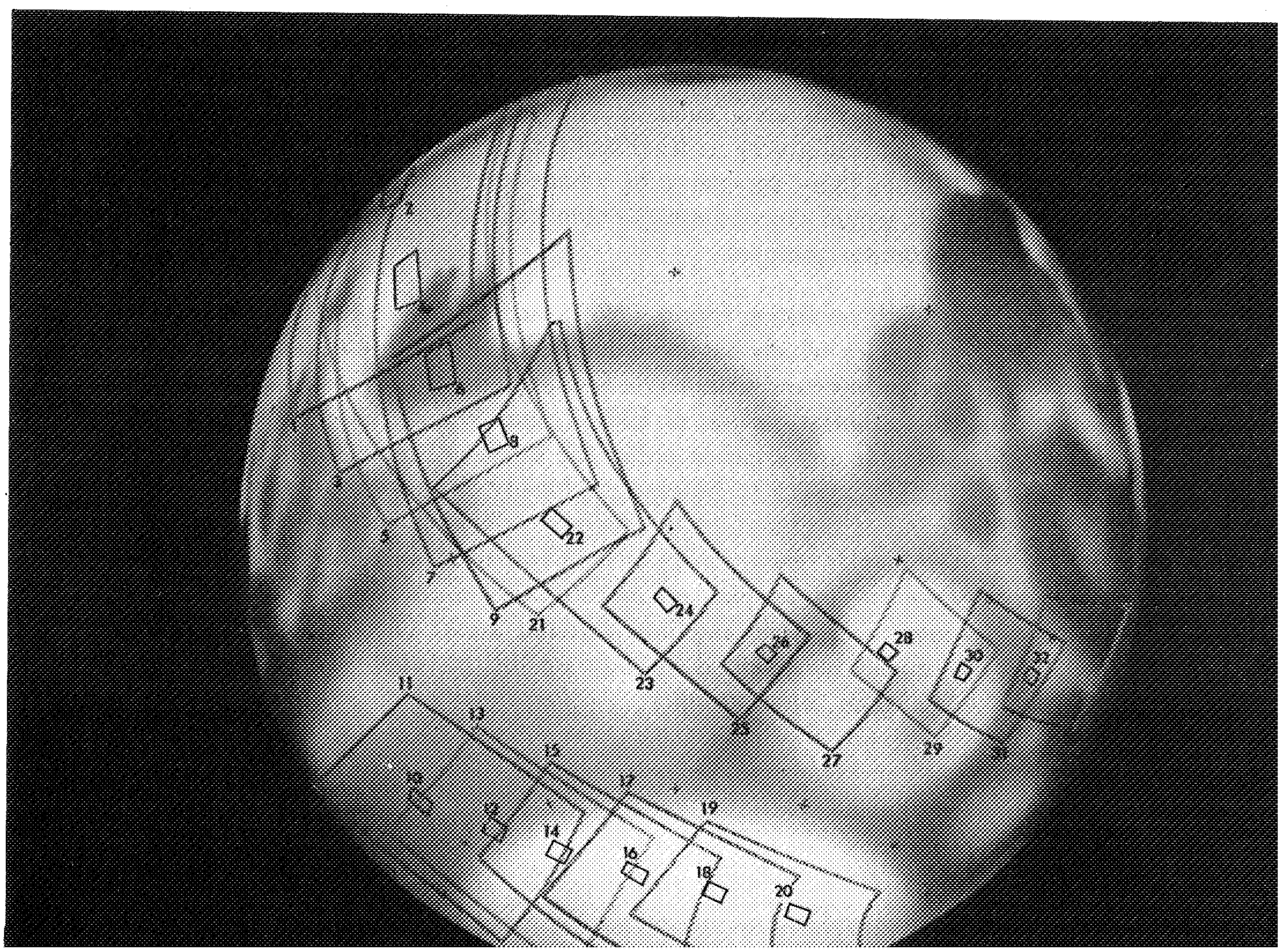

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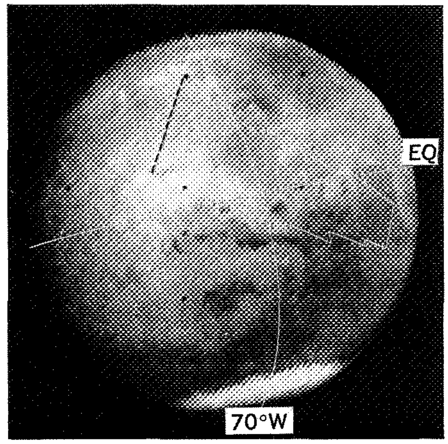
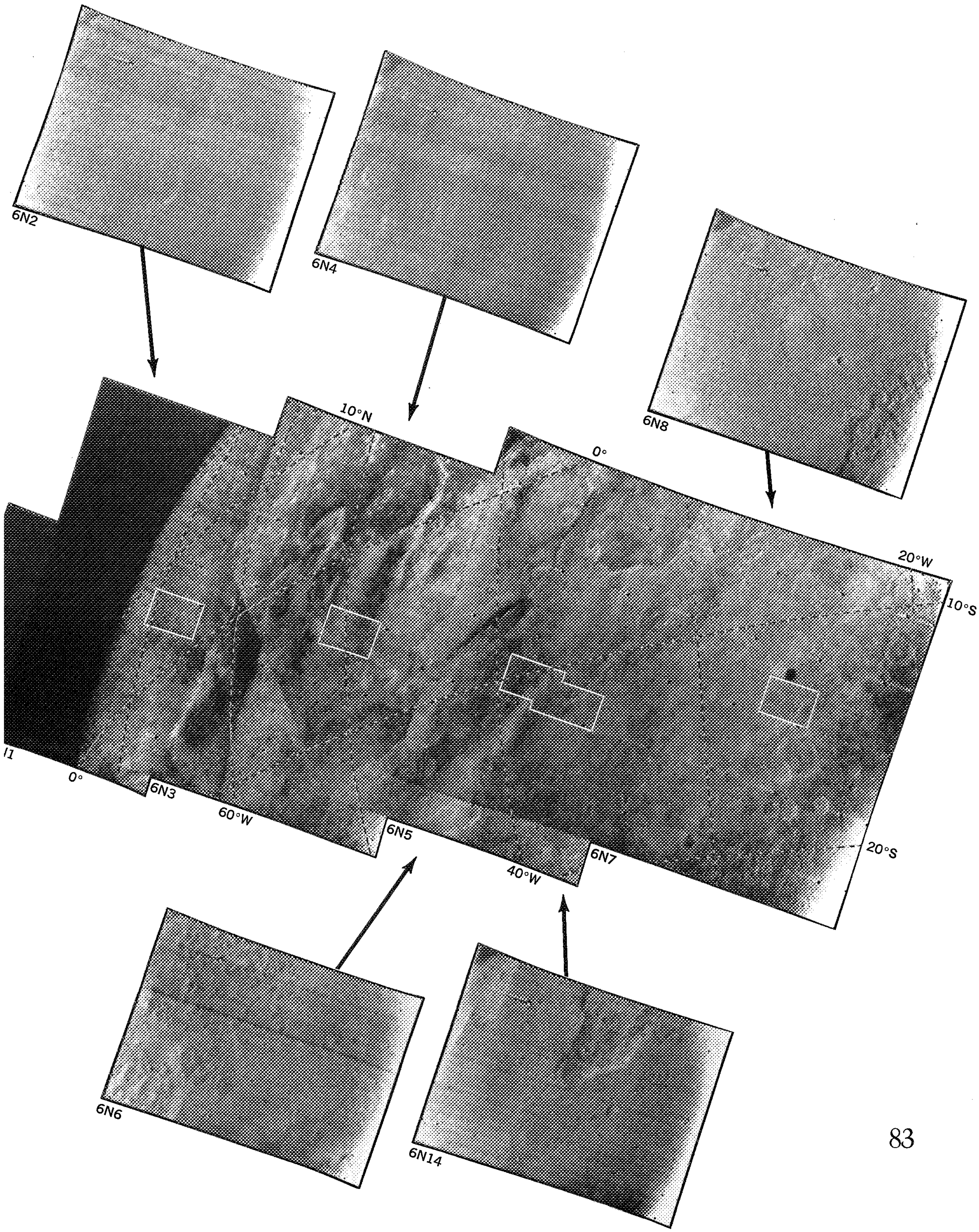


6N1-8, Aurorae Sinus

7F69

As Mars appeared in the television field-of-view, Mariner 6 began to record pictures on its tape recorders. The first eight pictures, taken of the limb, Aurorae Sinus, and Pyrrhae Regio, revealed two significant features: evidence of atmospheric haze at the limb and a previously unidentified, uncratered type of "chaotic" terrain. Far encounter pictures of this area, such as 7F69, showed several dark north–south streaks and a very mottled texture. Although it is not positively identifiable, there appears to be a haze layer just beyond the limb in 6N1. This would corroborate the thin haze layers seen in some of the far encounter pictures.

High resolution frames 6N6, 8, and 14 show a jumbled, broken type of terrain which has been labelled "chaotic." Careful study of both the narrow- and wide-angle frames suggests that chaotic terrain covers a substantial portion of 6N5, 7, and 9, and that it does not clearly resemble any areas on either the Earth or Moon. In the B frames this terrain appears to be topographically depressed, lower than the surrounding cratered areas. Since there are few if any recognizable craters in this chaotic area, it is inferred that chaotic terrain is younger than the surrounding cratered terrain and, perhaps, is presently developing and expanding into cratered areas. (Frame 6N14, which fortuitously overlapped this group of pictures, is discussed in the Meridiani Sinus group.)



6N2
6N4
6N8
10°N
0°
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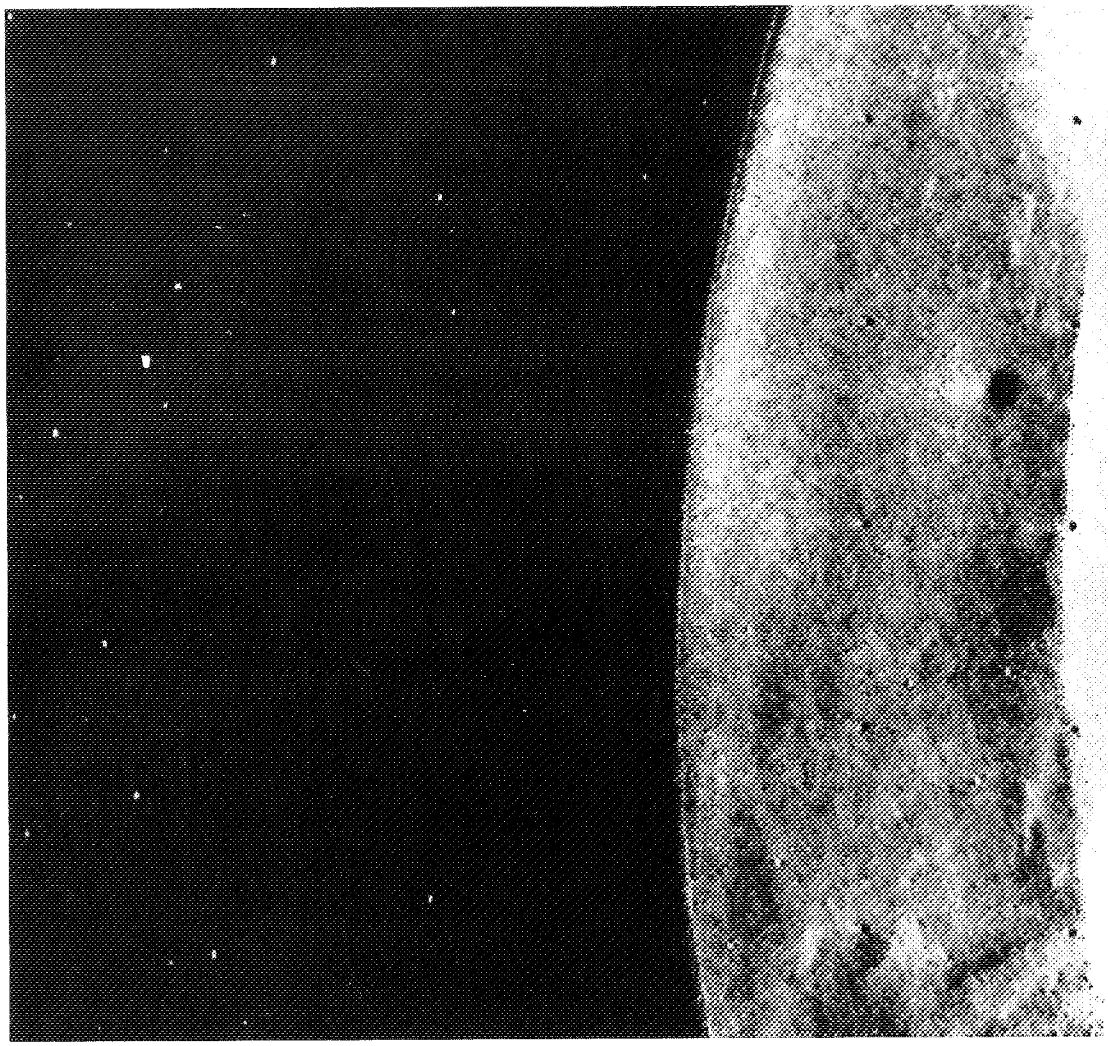
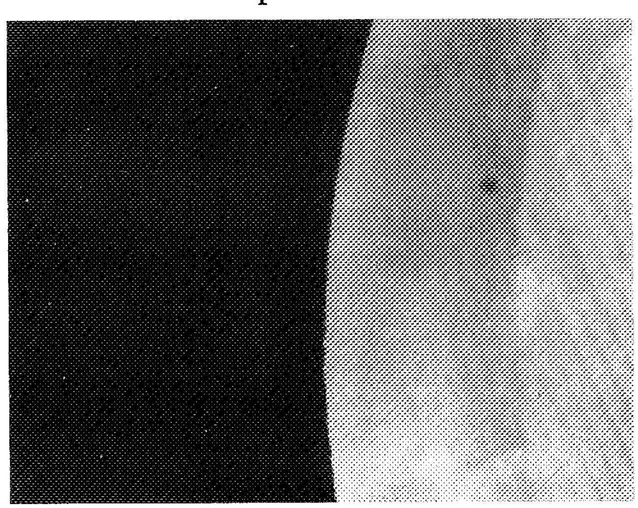
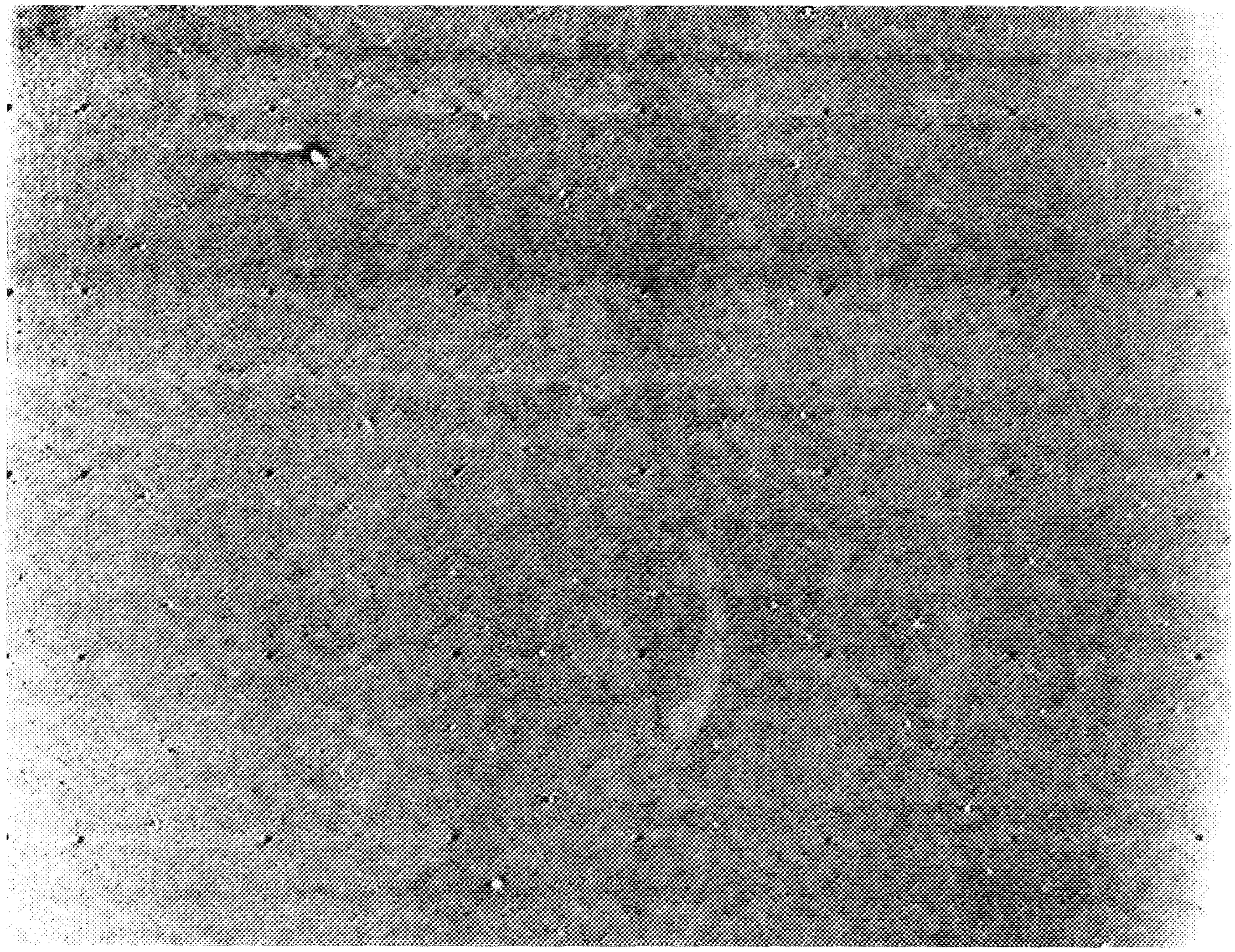
10°S
0°
6N3
60°W
6N5
40°W
6N7
20°S
6N6
6N14



Enhanced photometric version

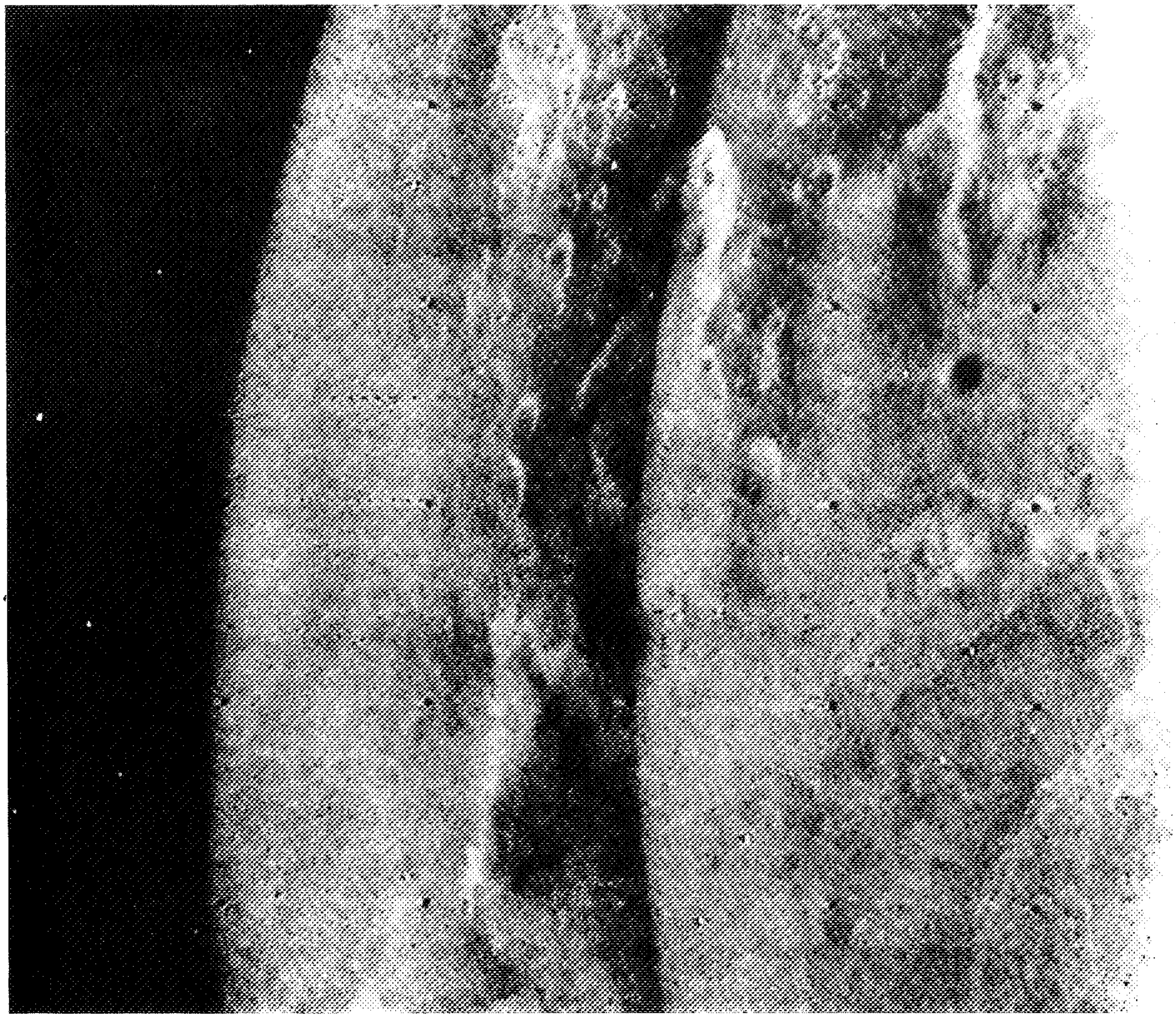




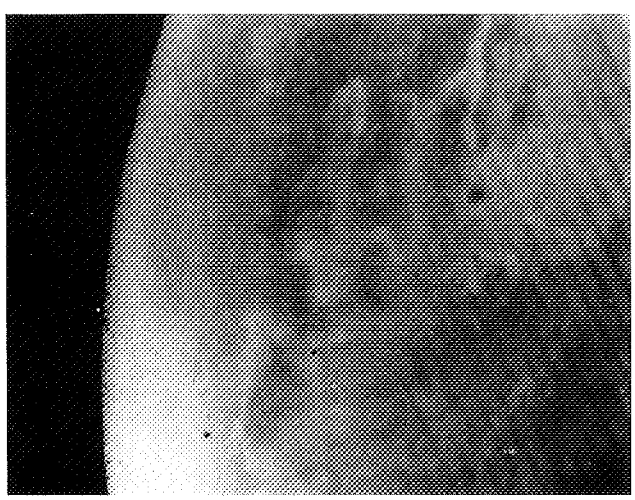
6N1 (opposite), of the Martian limb over the Candor region, shows evidence of an atmospheric haze layer just beyond the limb. At bottom is an enhanced photometric version of 6N1.

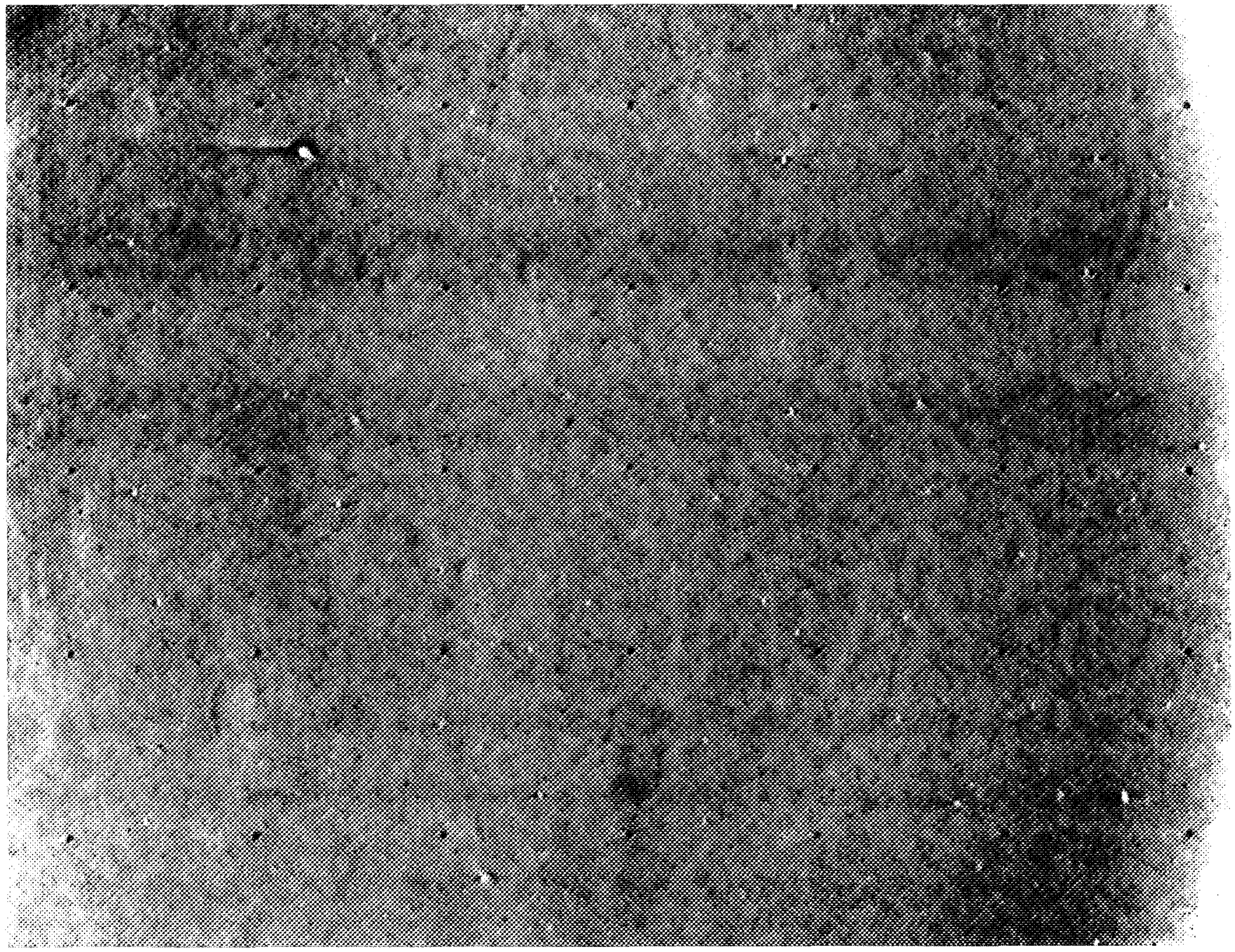
Beginning with 6N1, a photometric version of each wide-angle picture will be included (except for 6N23 and 6N25). This version, which has been contrast-enhanced, provides an indication of the actual appearance of Mars.

6N2 (above) is a highly foreshortened, high-resolution picture of the region very close to the limb.



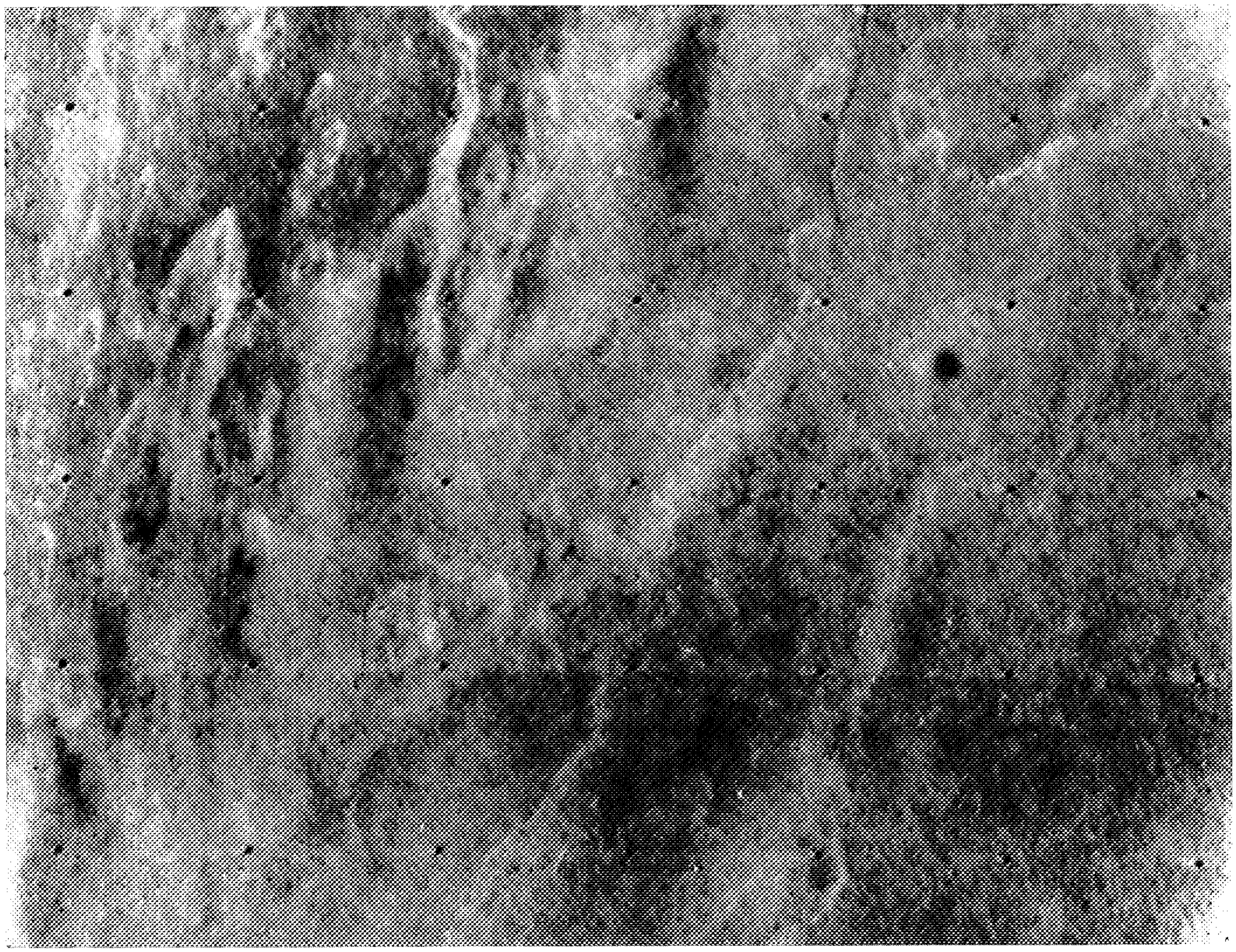
Enhanced photometric version



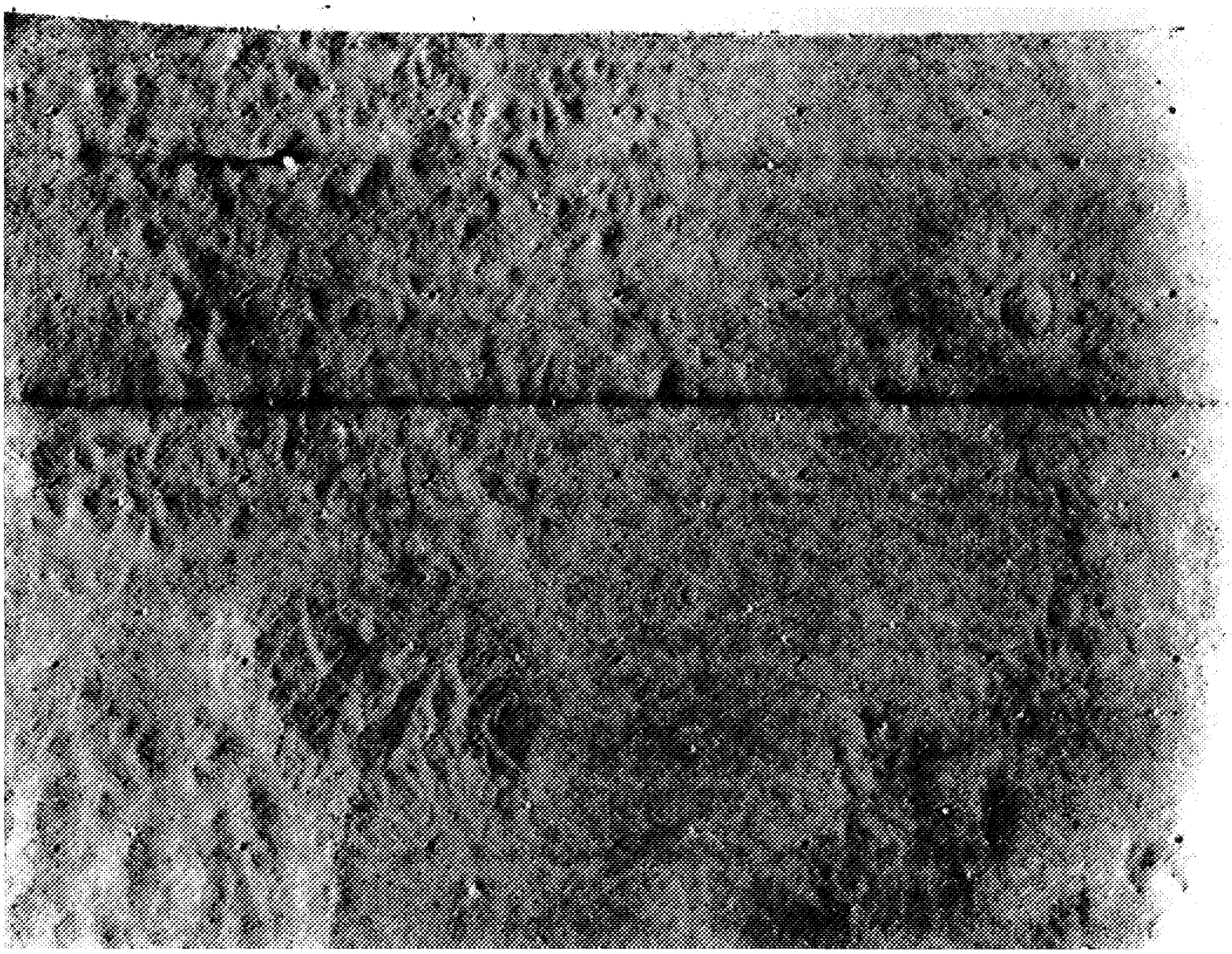


6N3 (opposite), including northern Aurorae Sinus, shows some of the dark streaks that were prominent in 7F69. The dark band down the center of the picture is due to the residual image (an instrumental defect described in Chapter 2) of 6N1 and does not actually appear on the Martian surface. At bottom is an enhanced photometric version of 6N3.

6N4 (above) hints at topographic detail, but no features have yet been positively identified.

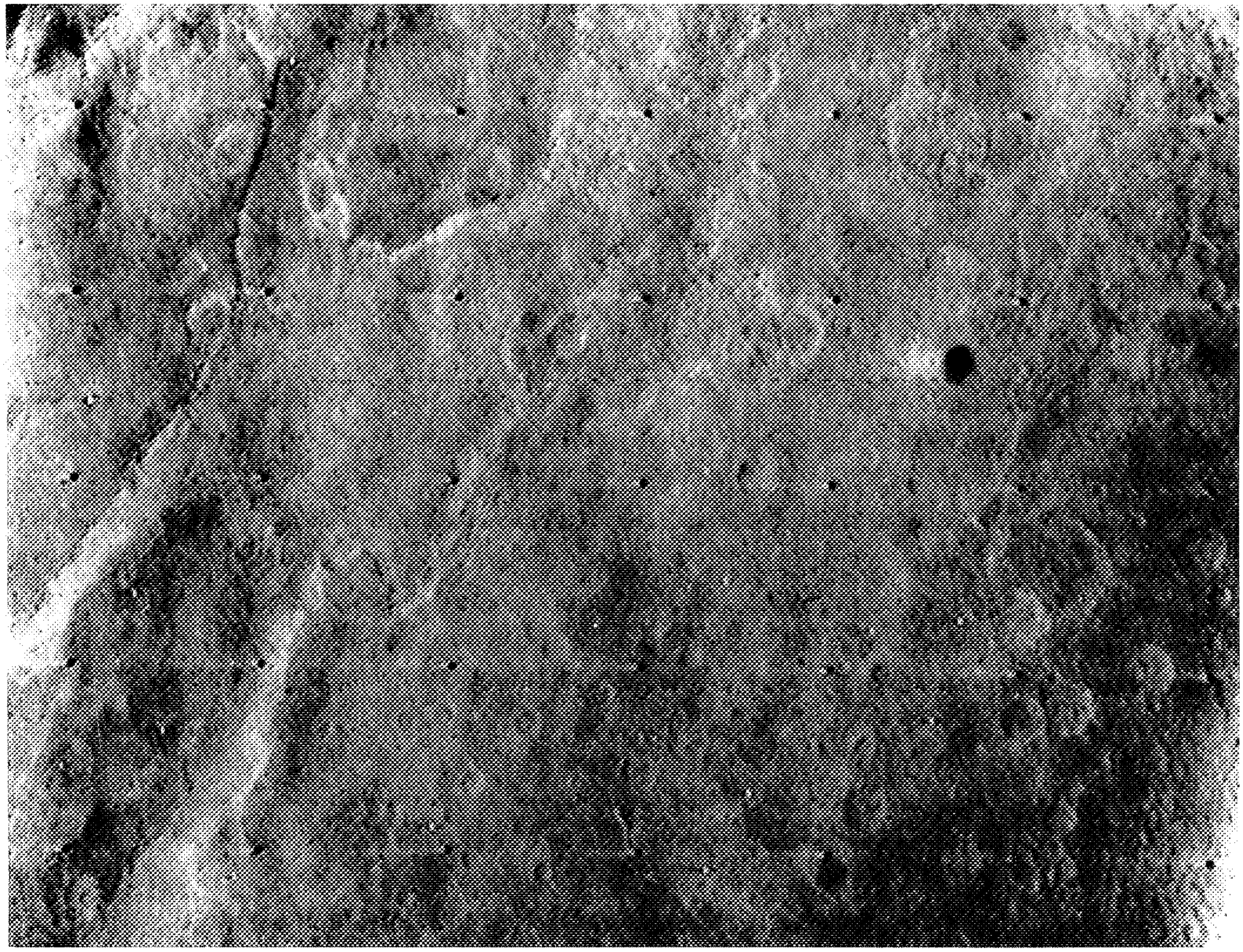


Enhanced photometric version

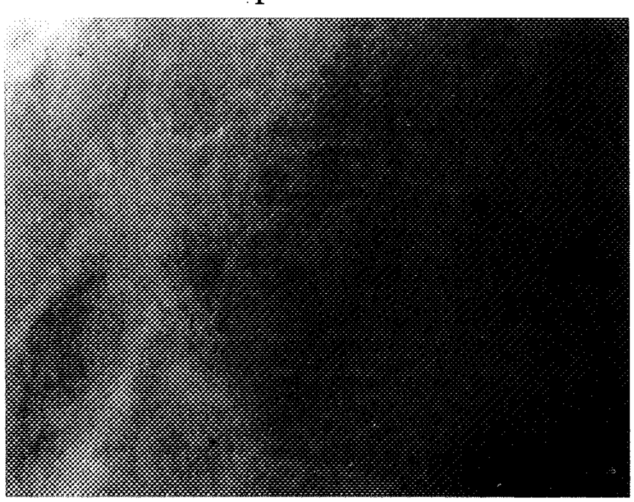


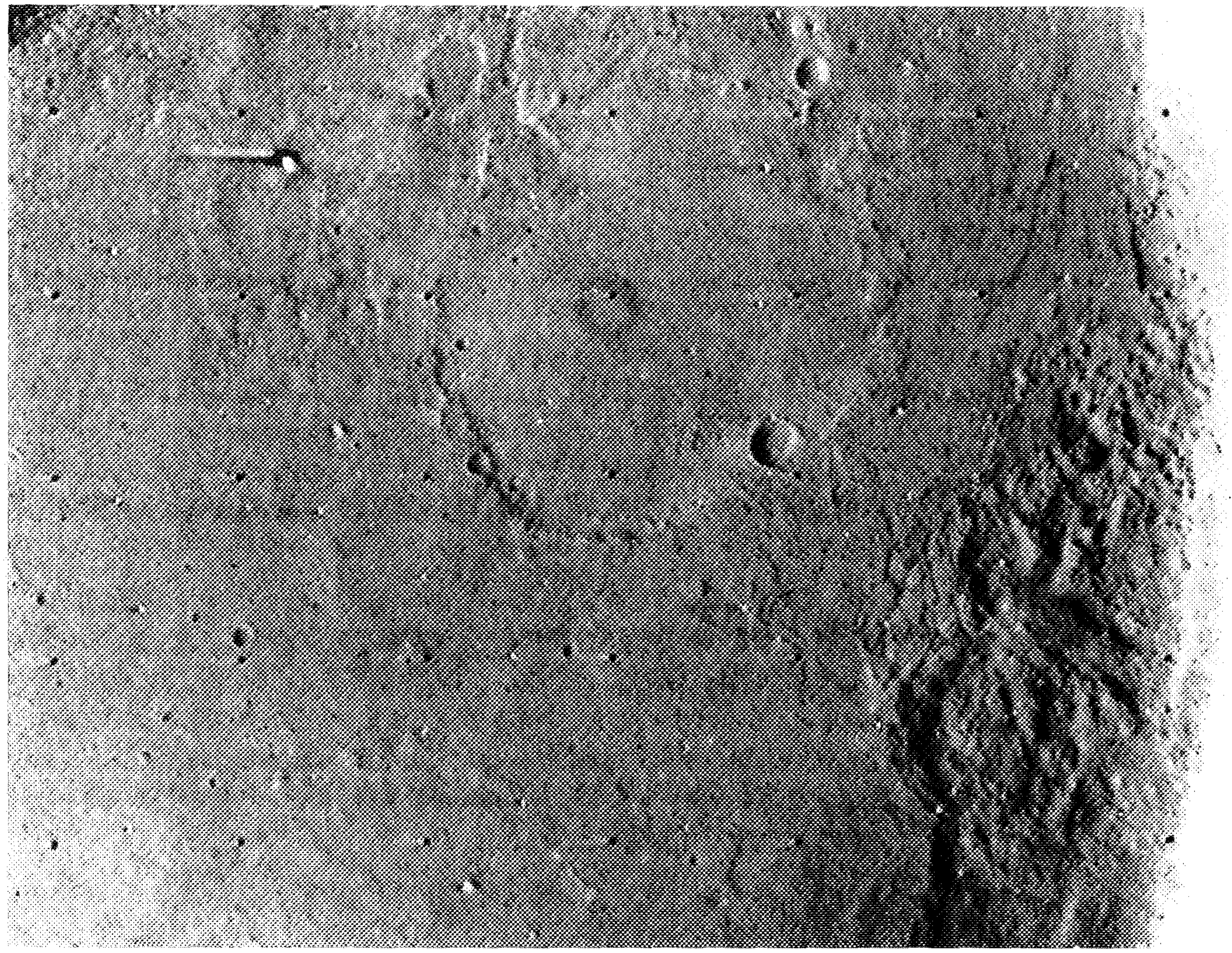
6N5 (opposite) provides a panorama of territory in which chaotic terrain has been located. At the moderate resolution of this wide-angle view, it is not possible to identify this terrain's small tell-tale detail—such identification depends on use of the narrow-angle frames located within these A frames. At bottom is an enhanced photometric version of 6N5.

6N6 (above) is a narrow-angle frame that clearly shows the jumbled, broken, and blocky terrain. There is a definite boundary, down the center of this picture, between the chaotic terrain in the western half and the smoother, cratered terrain to the east.



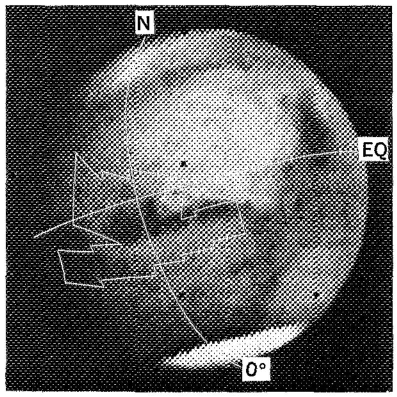
Enhanced photometric version





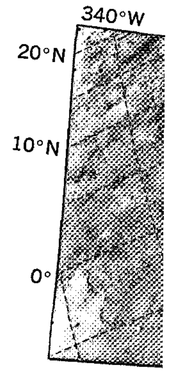
6N7 (opposite) is the only A frame sharp enough to allow direct discrimination between chaotic and cratered areas on the basis of topographic texture. It also contains all three B frames, 6N6, 8, and 14, which show these boundaries at higher resolution. At bottom is an enhanced photometric version of 6N7.

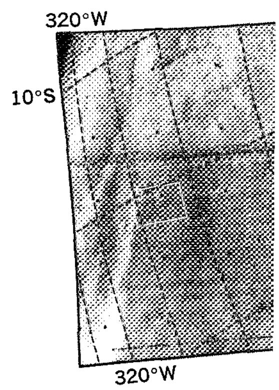
6N8 (above) shows another example, in the lower right corner, of a boundary between cratered and chaotic areas. Notice the fissures apparently extending from this boundary into the cratered terrain. Such fissures add to evidence that chaotic terrain is probably younger than and encroaching upon the cratered terrain.

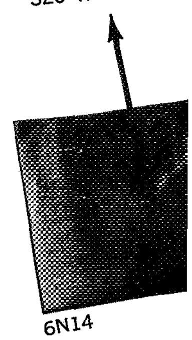


6N9-25, Meridiani Sinus

7F67

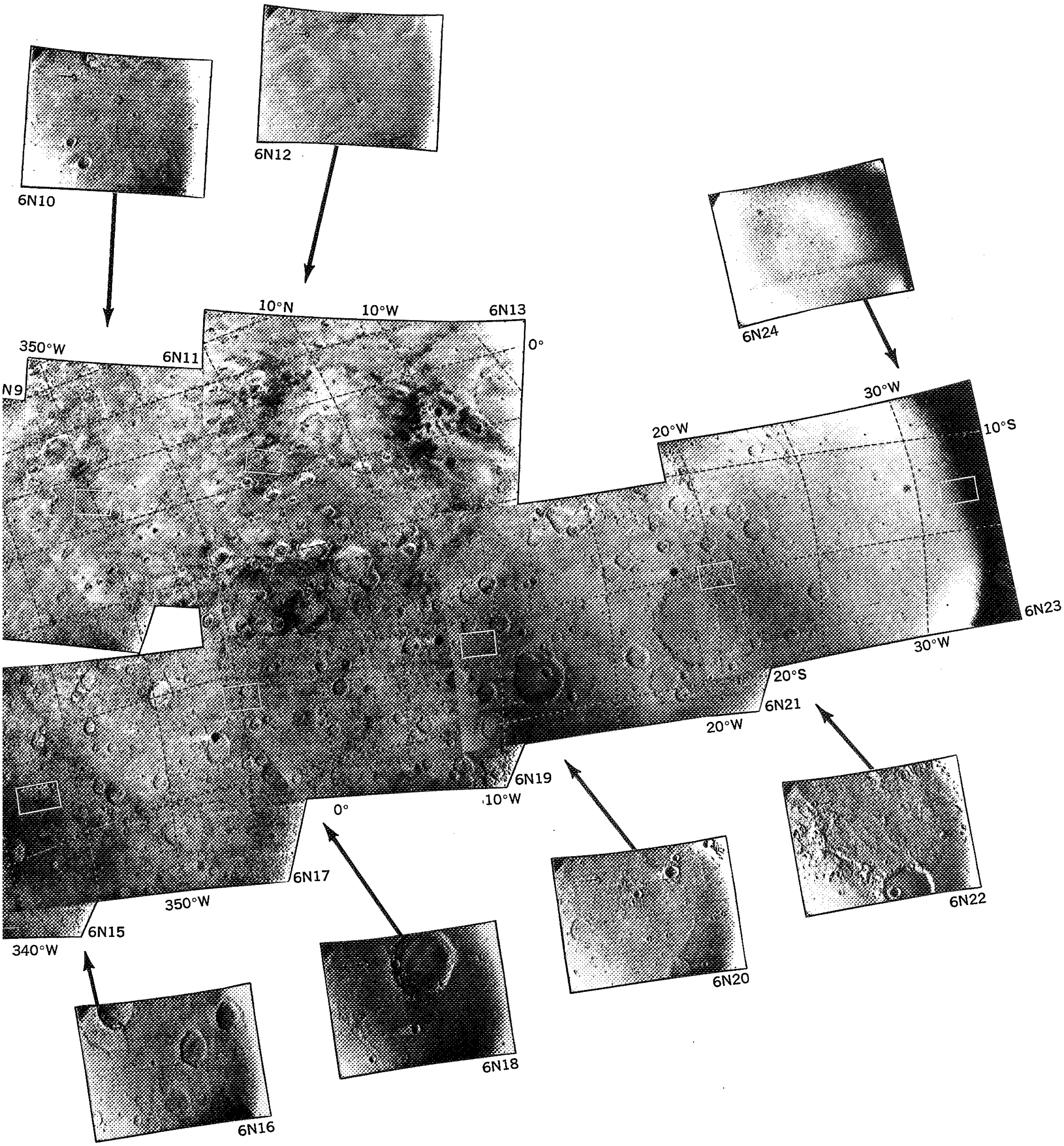






After recording 6N8, the Mariner 6 computer "slewed" the television cameras to point farther north and photograph the dark feature Meridiani Sinus. Later, after 6N13, a second slew directed the cameras southward again to study the boundary between the dark Sabaeus Sinus and lighter Deucalionis Regio. In far encounter, Meridiani Sinus and Sabaeus Sinus appeared as very well defined dark features extending to the west of Syrtis Major (7F67, 6F30). In trying to identify such albedo variations in these near encounter pictures, it is important to remember the on-board processing explained in Chapter 2, which served to minimize the visibility of such large albedo variations. Careful comparison of light and dark areas has not yielded any sure explanation of the difference between them. The tentative conclusion has been offered, however, that some light areas are areas of lower elevation onto which light dust has been transported, possibly by winds.

These 17 pictures also offer the most extensive and comprehensive coverage of Martian cratered terrain and thus lend themselves to comparison with pictures of the Earth's moon. Such analysis has revealed that, unlike the Moon, Mars has two distinct crater classes: small, young, bowl-shaped craters and larger, older, flat-bottomed craters, which have been strongly modified by unknown processes.


6N10
6N12
10°N
10°W
6N13
0°
350°W
6N11
N9
6N24
30°W
20°W
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6N23
30°W
20°S
6N21
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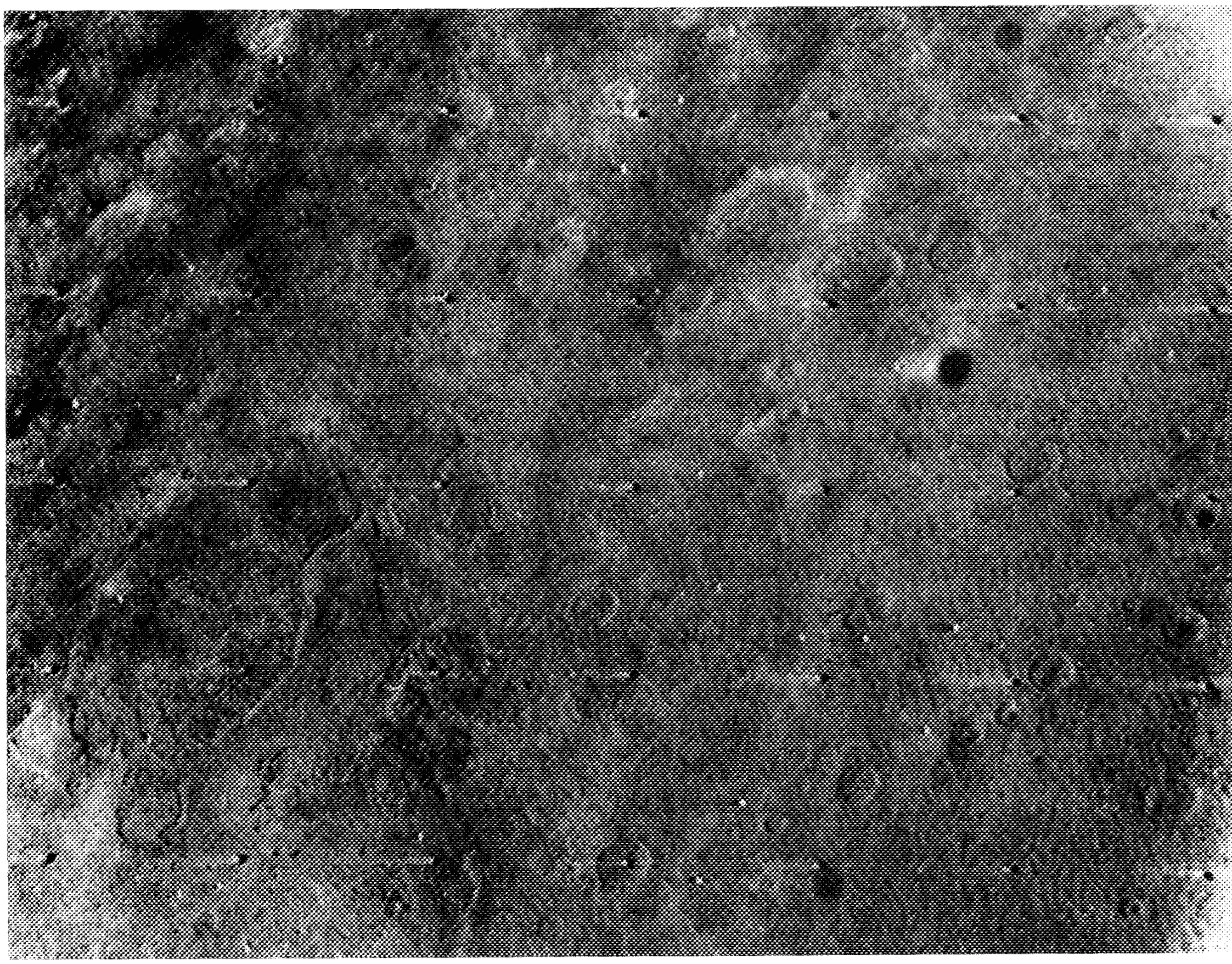
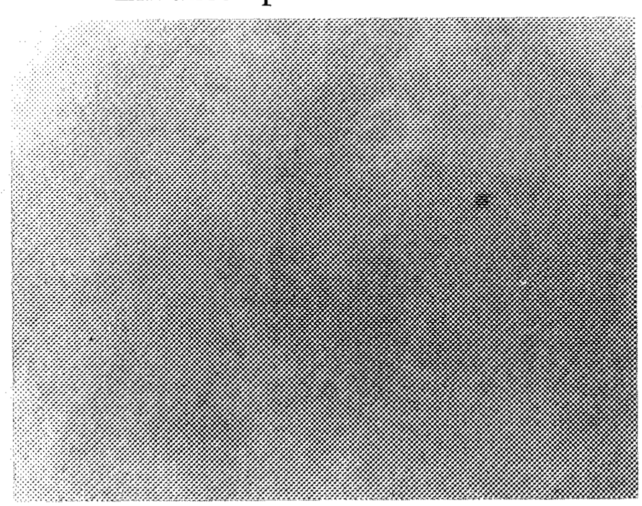
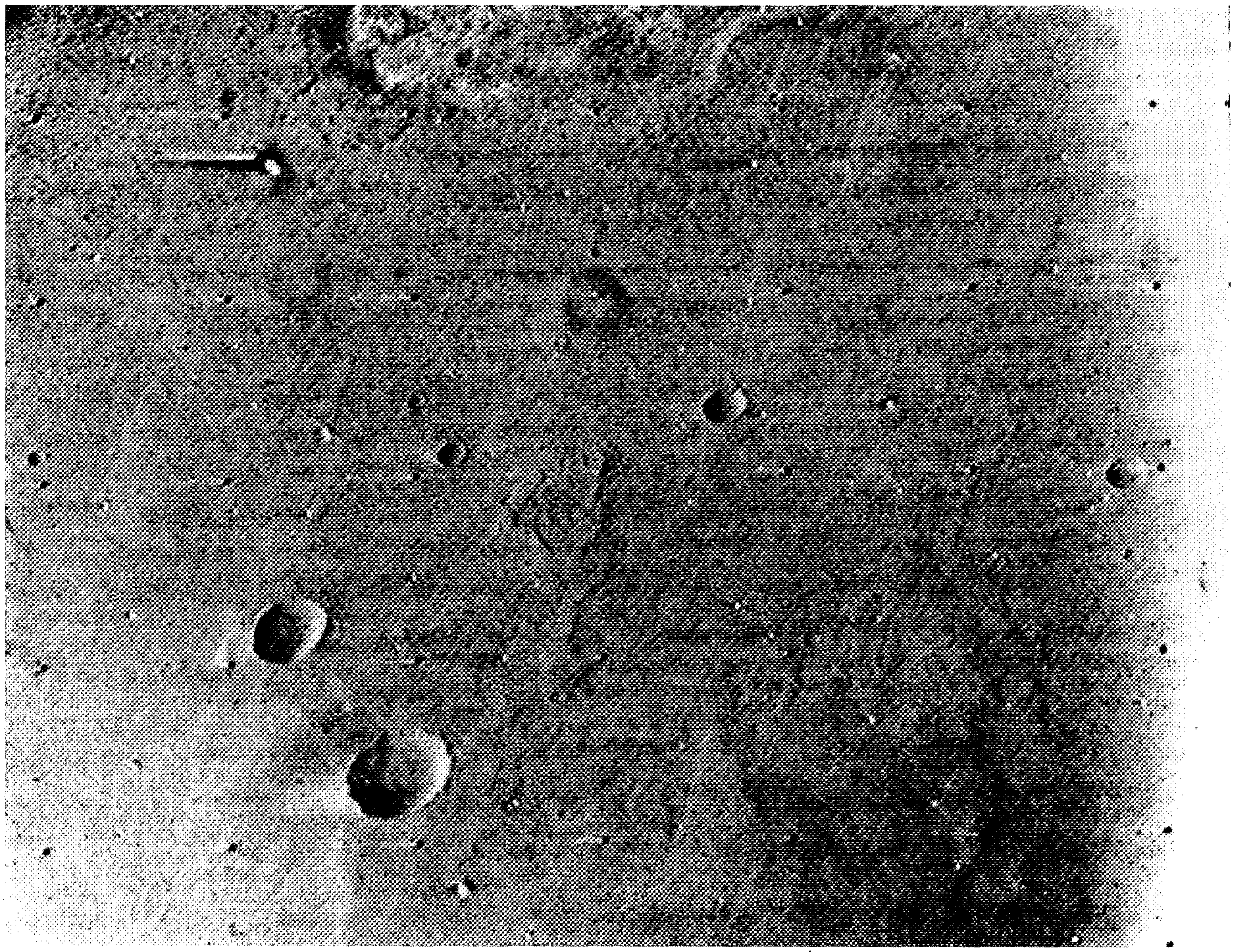
6N22
6N20
6N18
6N16



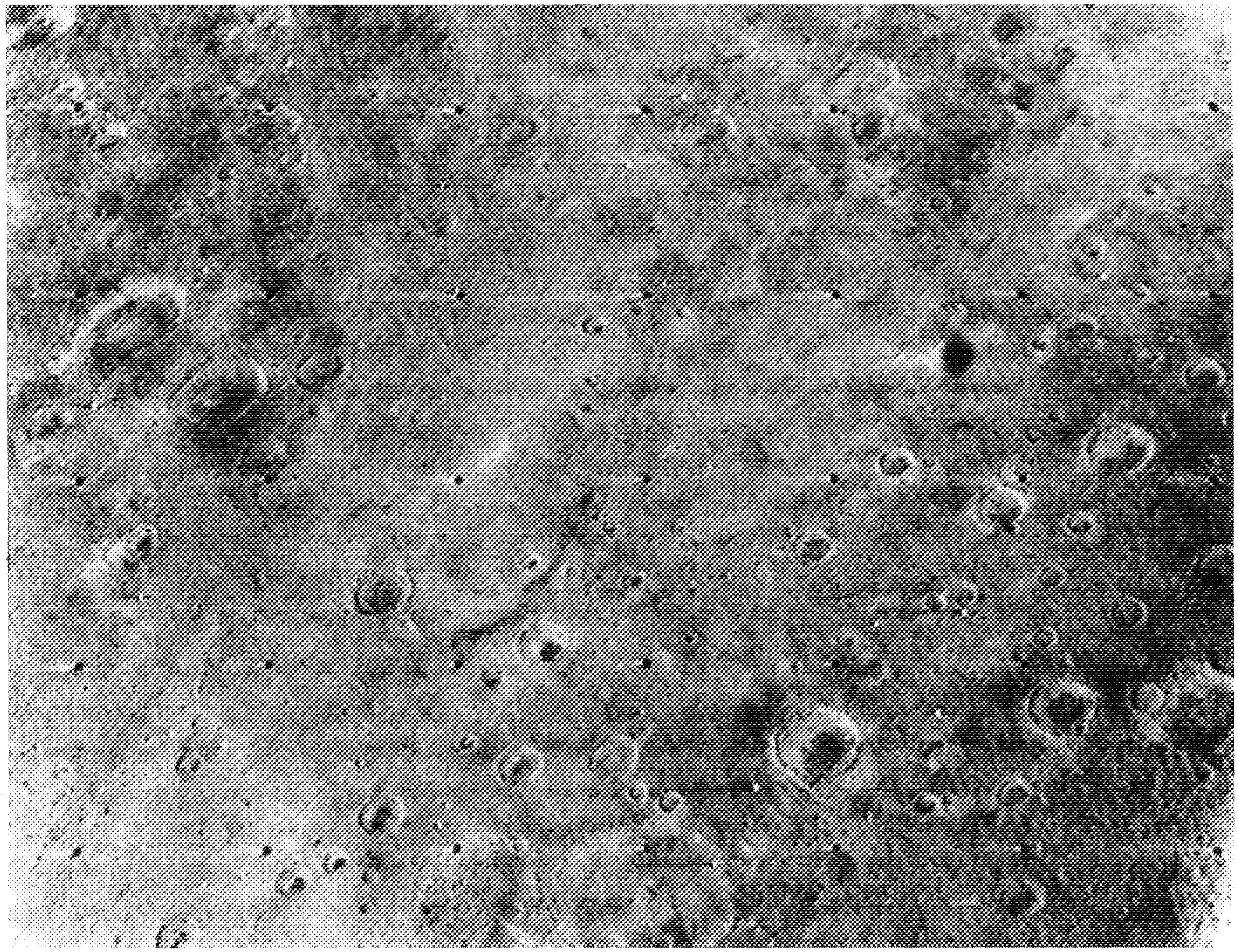
Enhanced photometric version



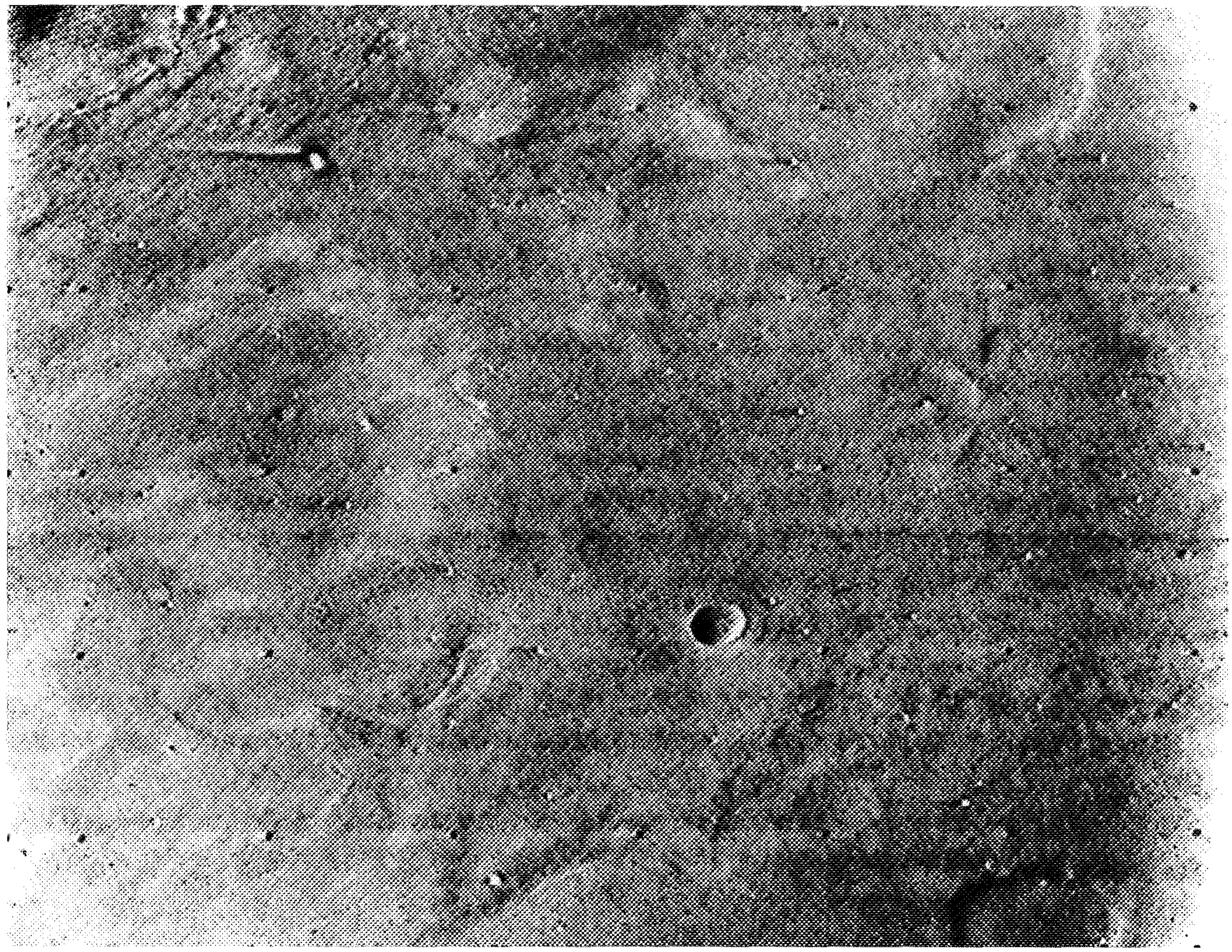


6N9 (opposite) is a somewhat oblique view of the western side of Meridiani Sinus. There are perhaps some areas of chaotic terrain in the lower left corner. At bottom is an enhanced photometric version of 6N9.

6N10 (above) shows several of the small bowl-shaped craters that are believed to be relative newcomers to the Martian landscape. Their youth is inferred from the lack of extensive erosion evident in the larger craters. The two faint, dark annular features in the upper center of 6N10 are defects of the Mariner 6 B camera, characteristic of all pictures taken with this camera; they are not markings on Mars.

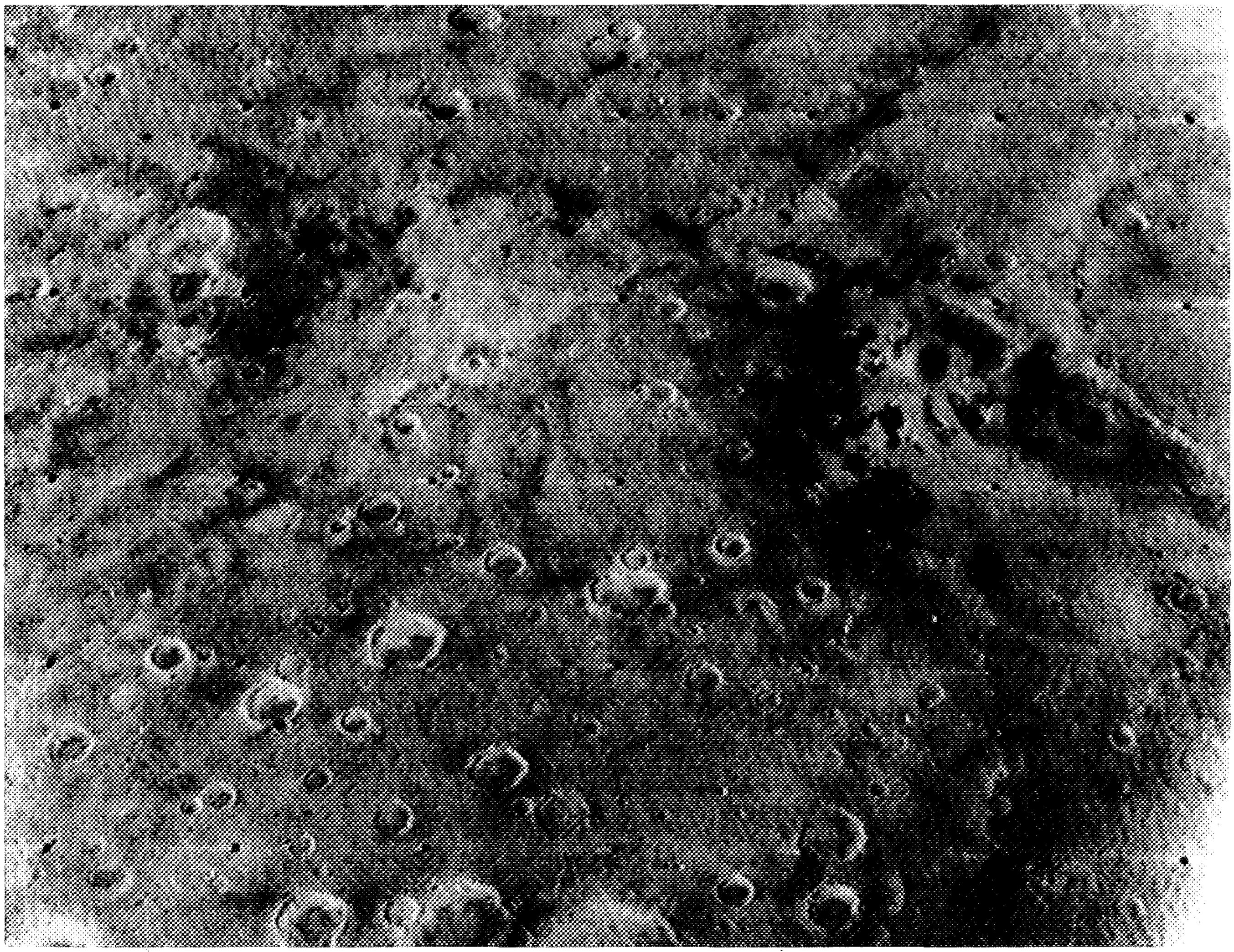


Enhanced photometric version

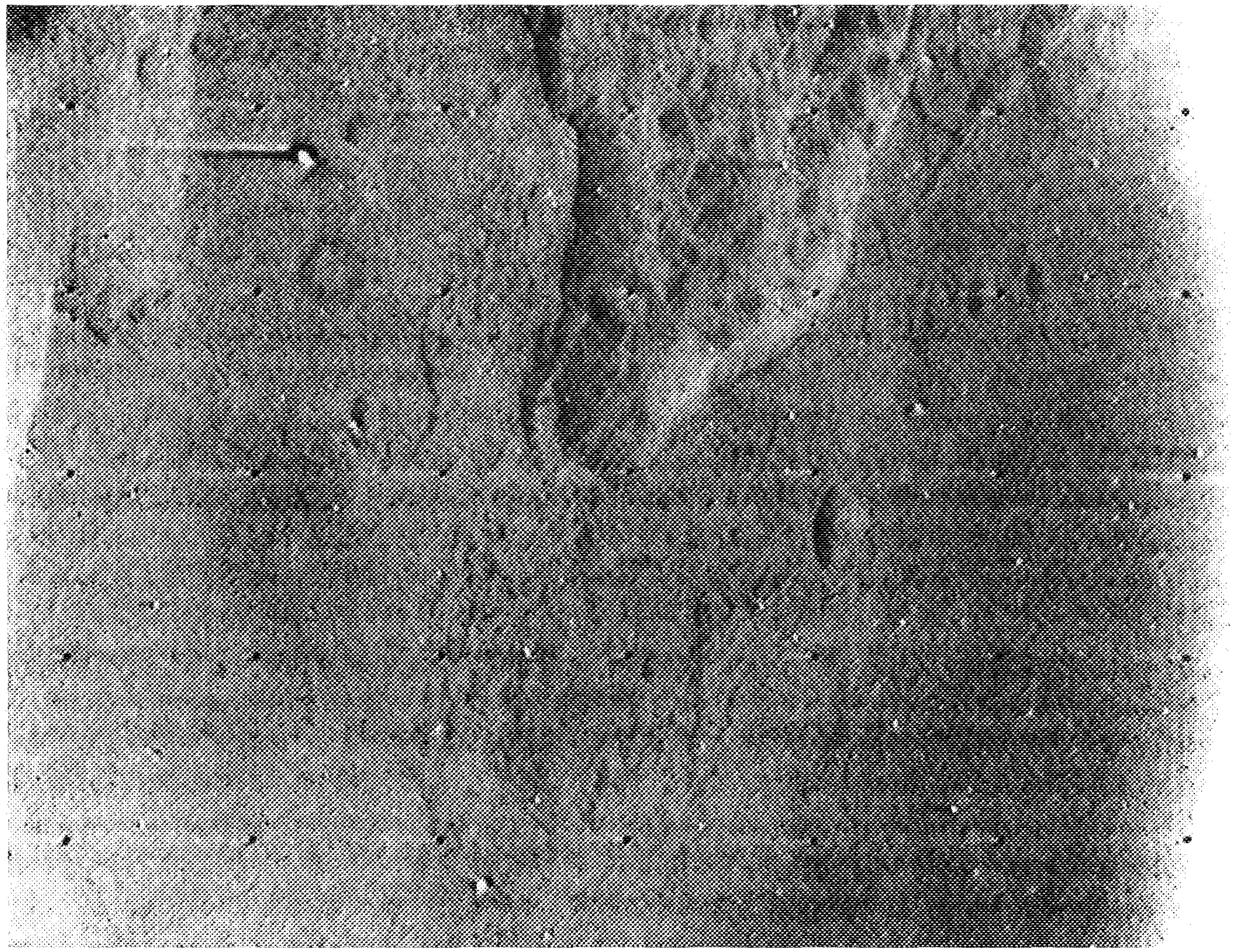


6N11 (opposite), another view of the Meridiani Sinus area, shows an abundance of the older, flat-bottomed craters. At bottom is an enhanced photometric version of 6N11.

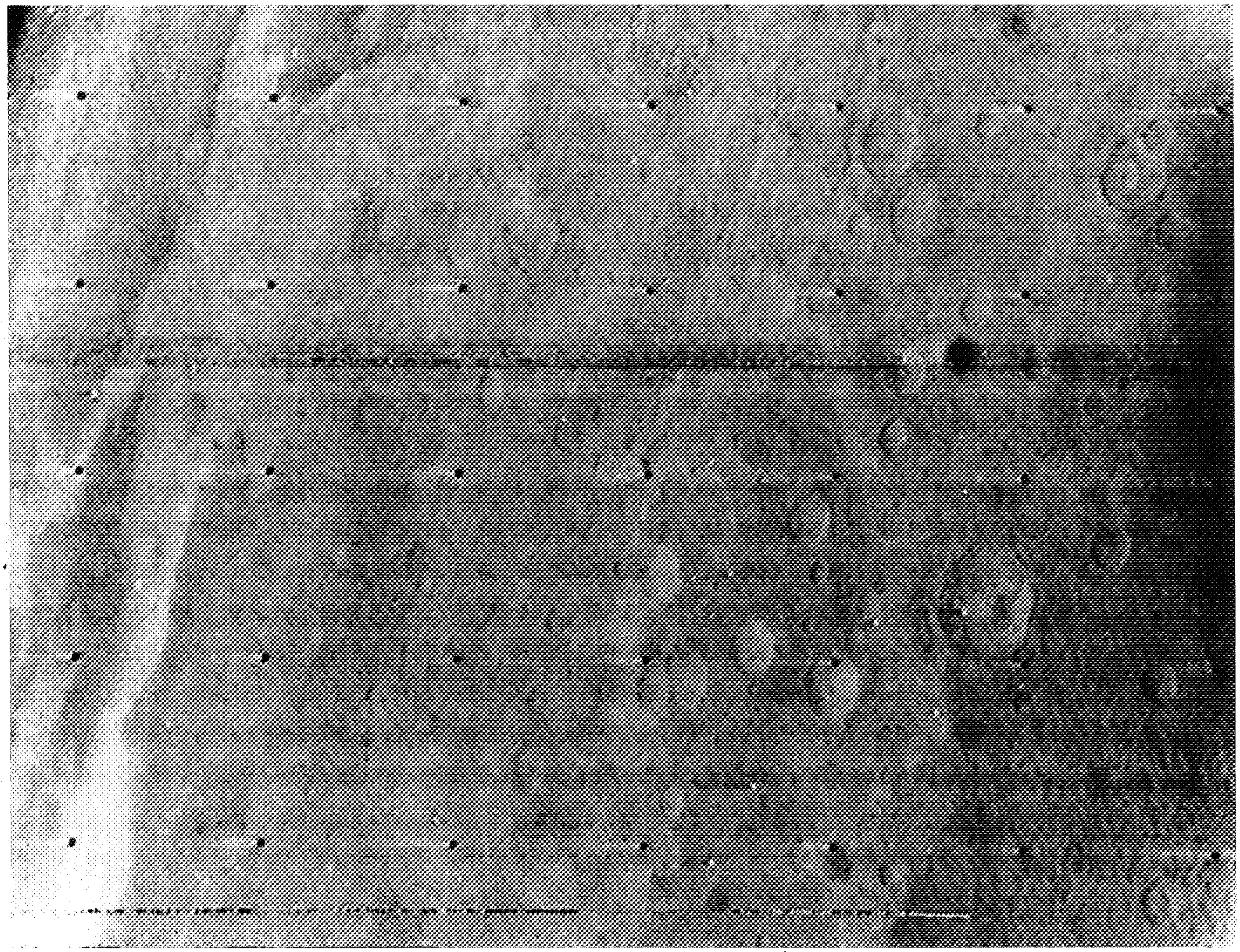
6N12 (above) provides another high-resolution view of the Meridiani Sinus area.



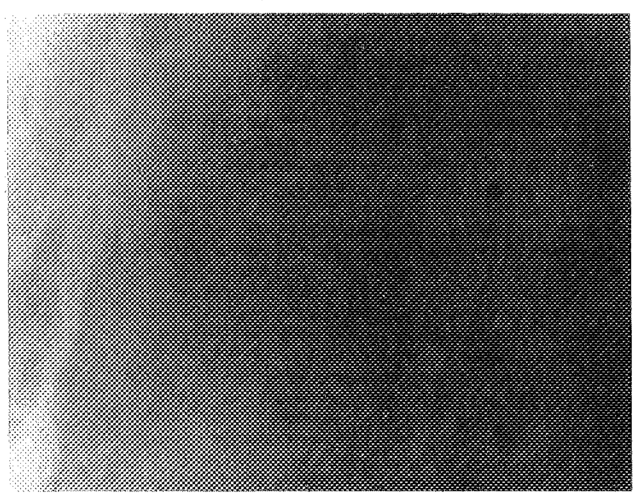
6N13 is the best Mariner 6 picture of Meridiani Sinus. An enhanced photometric version, with the albedo variations apparent, is shown in Chapter 2 and should be studied to better identify the large dark shape apparent earlier in far encounter pictures. This version, however, shows clearly the very definite and intricate eastern boundary of Meridiani Sinus. At the far right of the picture is the western portion of the large crater Edom, seen in far encounter, 7F67. Notice that the floors of many craters within Meridiani Sinus appear to be covered partially with light material and partially with dark material. This observation has led some geologists to surmise that a light-colored material, such as dust, has been transported from the light areas into the depressed crater bottoms.

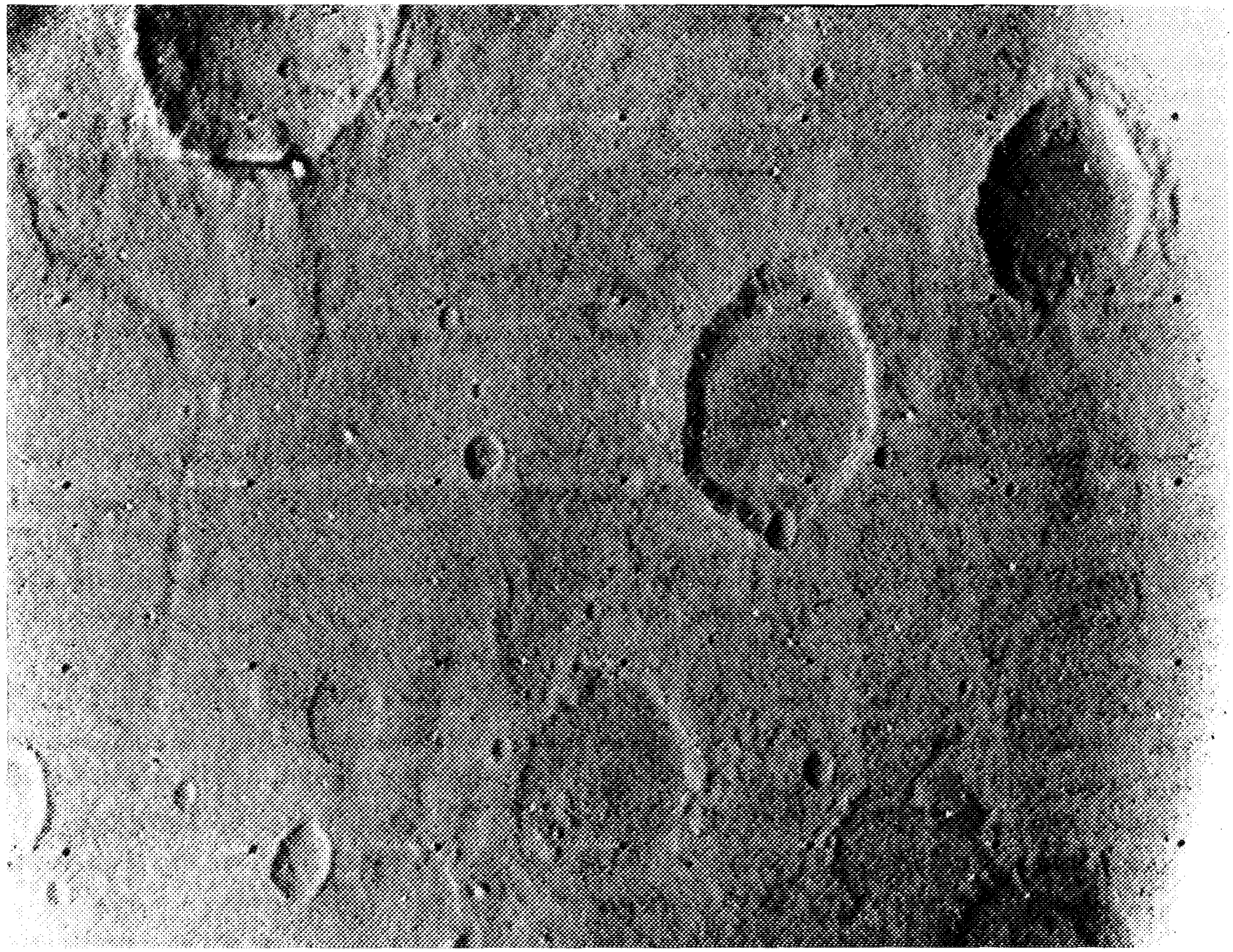


6N14 is the first picture taken after the cameras were slewed back to the original track and tilted westward. This is a highly foreshortened view of chaotic terrain; and, fortuitously, this picture overlaps 6N6, taken more than 4 minutes earlier. Notice the fissures which appear to be expanding into cratered terrain from the depressed, chaotic "valley."



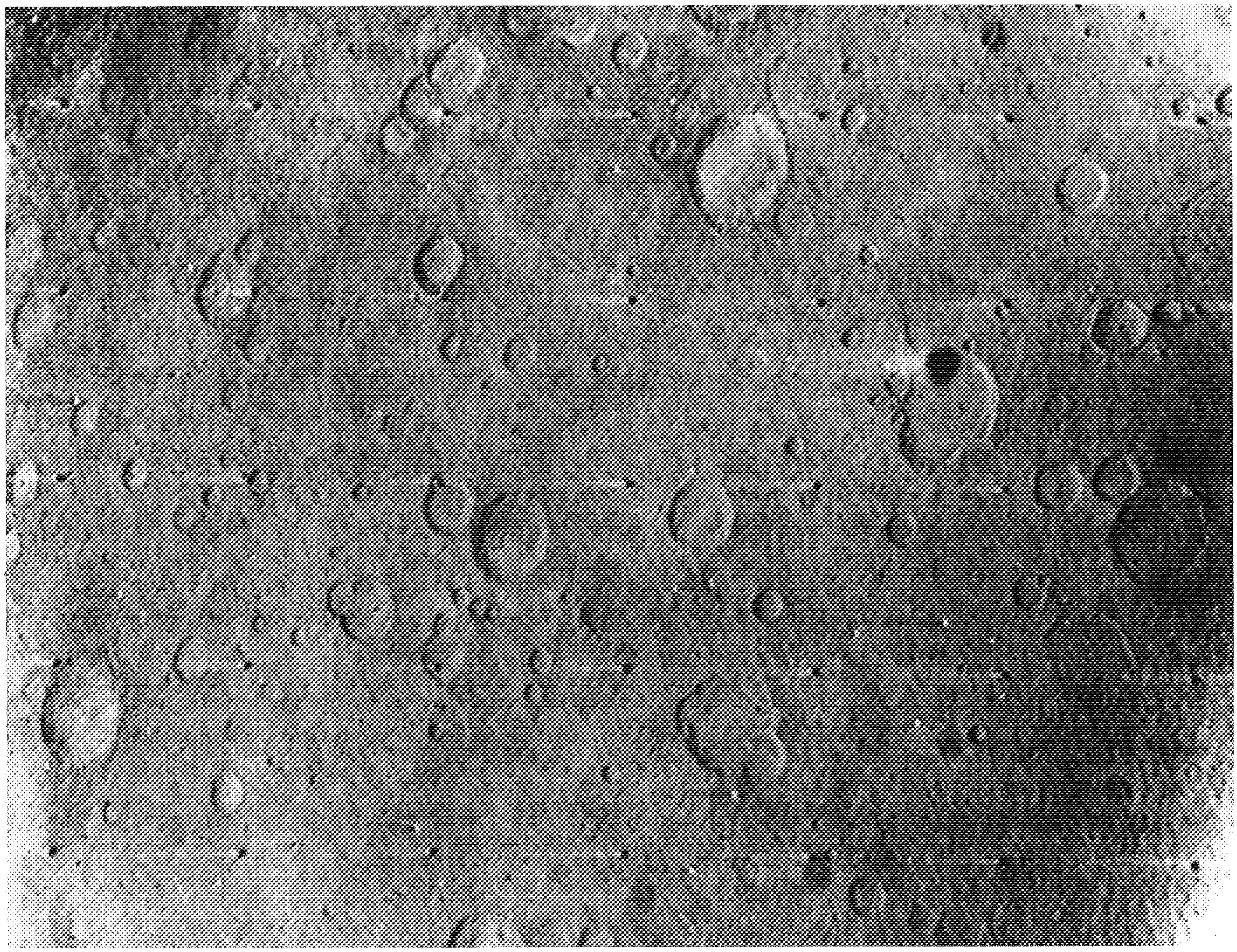
Enhanced photometric version



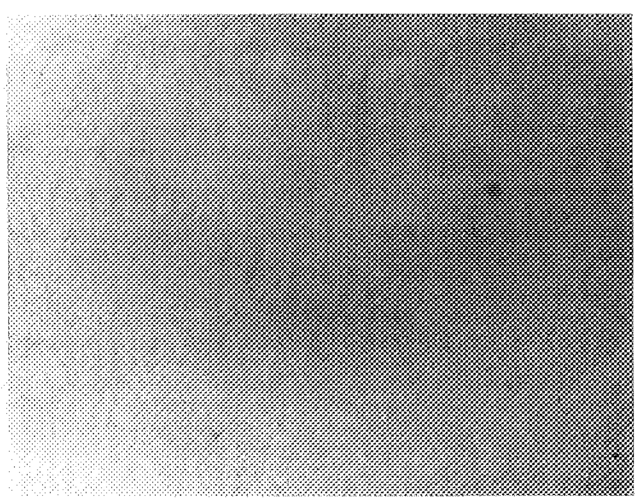


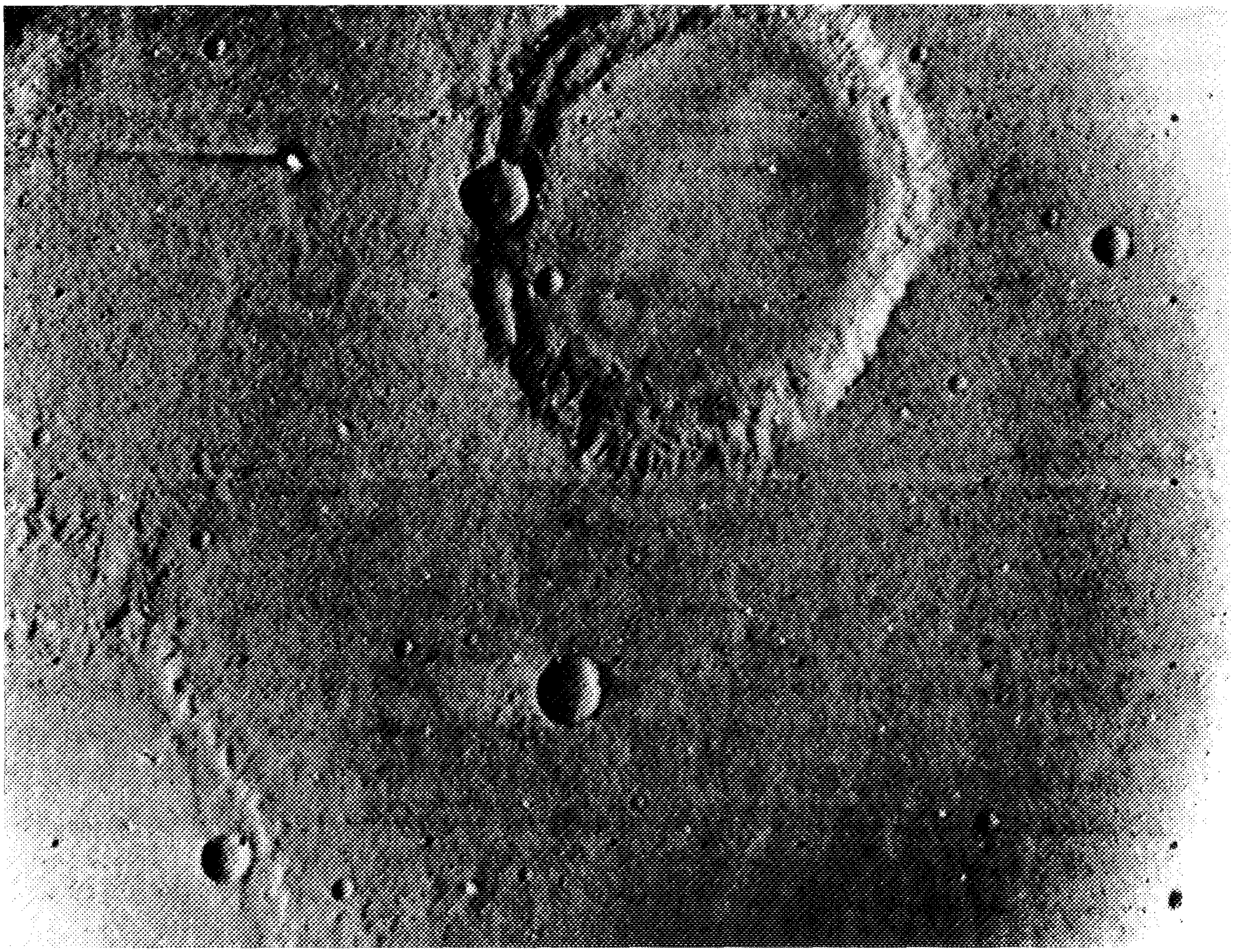
6N15 (opposite) includes a portion of the limb in the upper left corner of this view looking back at Aurorae Sinus and Pyrrhae Regio. Notice the same diagonal features as those seen in 6N7. At bottom is an enhanced photometric version of 6N15.

6N16 (above) provides a ready comparison between the two characteristic kinds of Martian craters. The large crater just right of center is an example of a large (approximately 25-kilometer diameter) flat-bottomed crater, with subdued edges and evidence of extensive modification. On its rim is a small bowl-shaped crater with very sharp edges and a lip that appears to be slightly elevated above the surrounding ground.



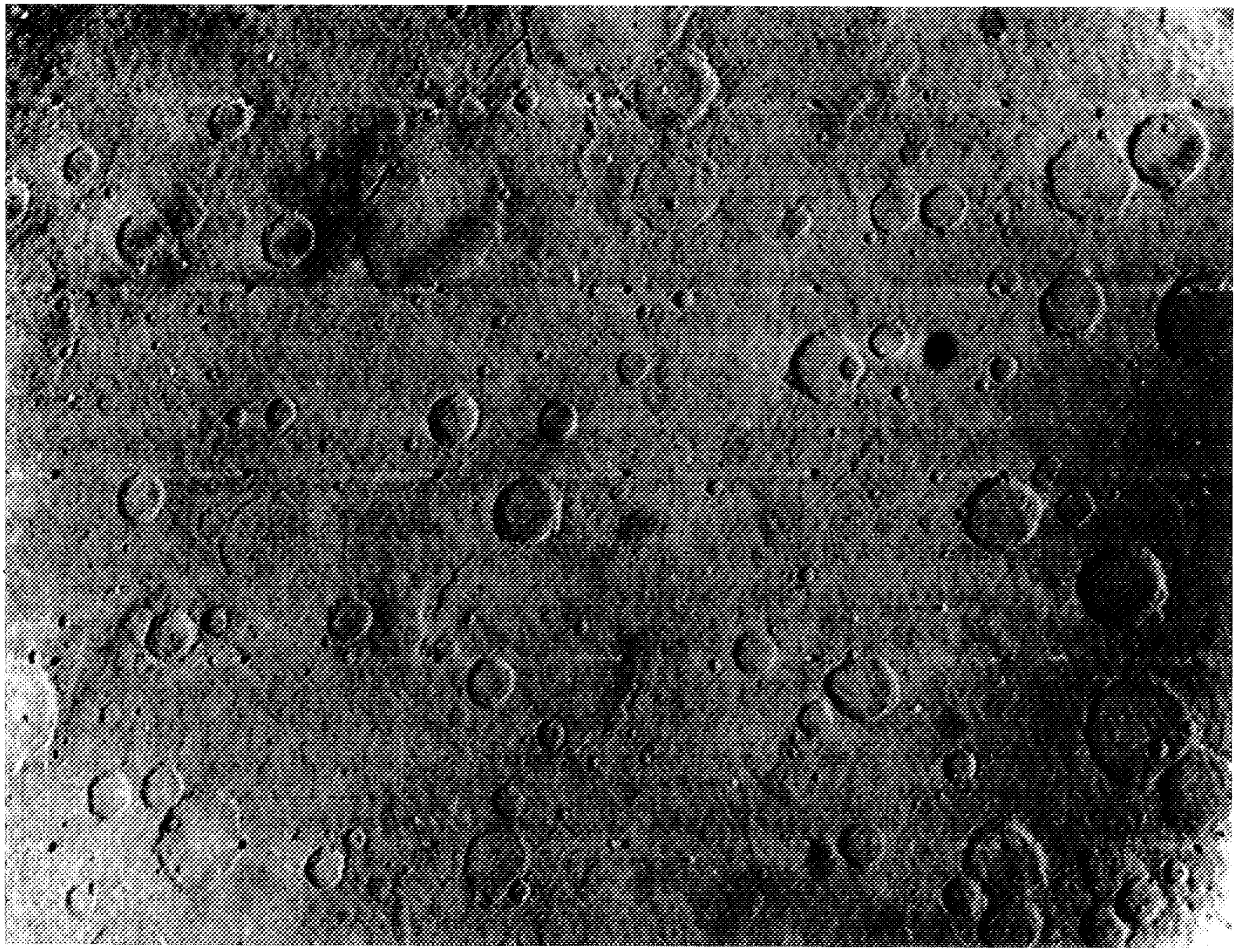
Enhanced photometric version



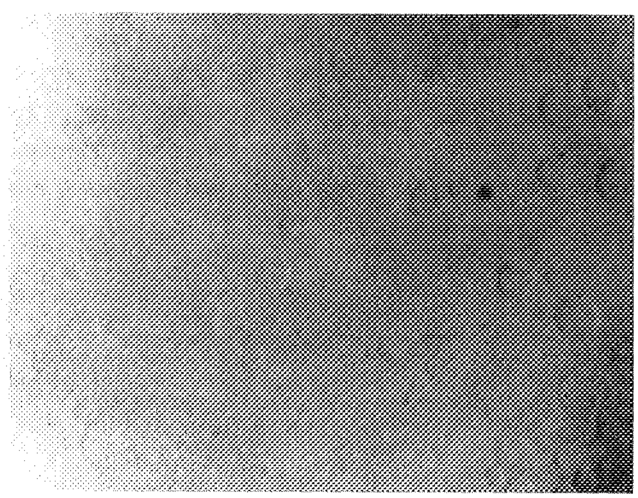


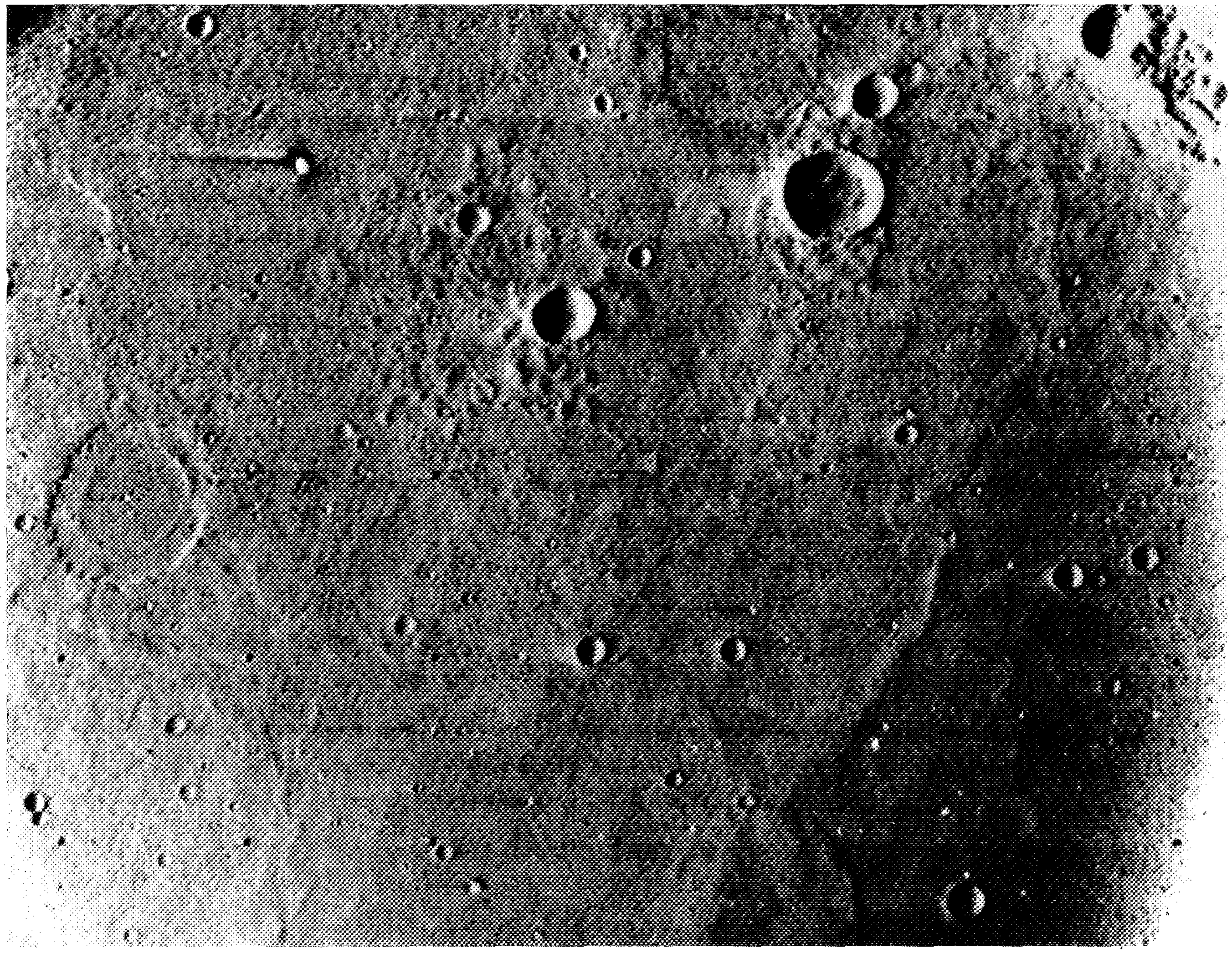
6N17 (opposite) shows another expanse of cratered terrain. At bottom is an enhanced photometric version of 6N17.

6N18 (above) contains in the lower left the edge of what is apparently a large, nearly obliterated "ghost" crater. While the prominent crater in the upper middle of 6N18 may be easily identified in 6N17, this larger "ghost" crater edge is not apparent in the A frame.



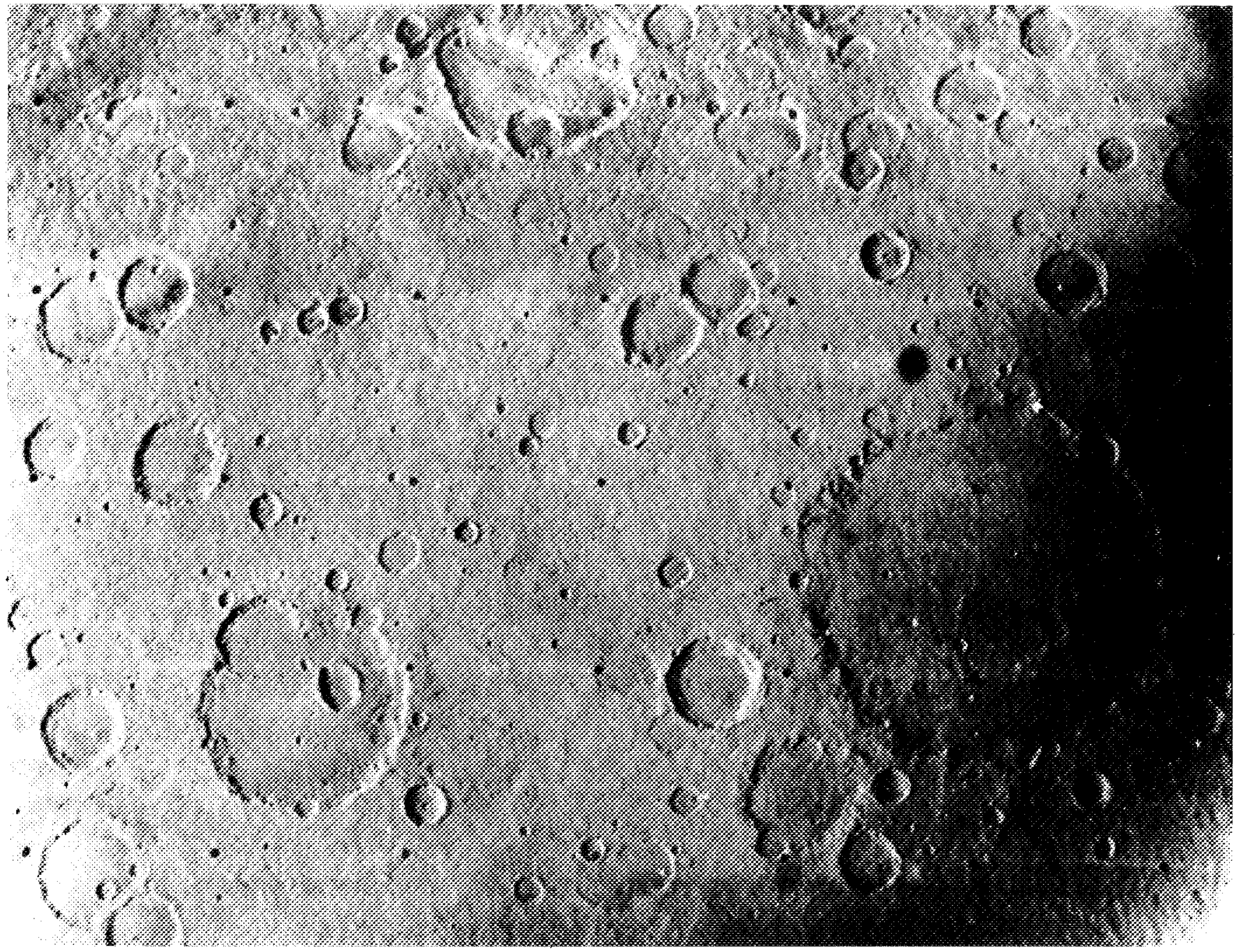
Enhanced photometric version



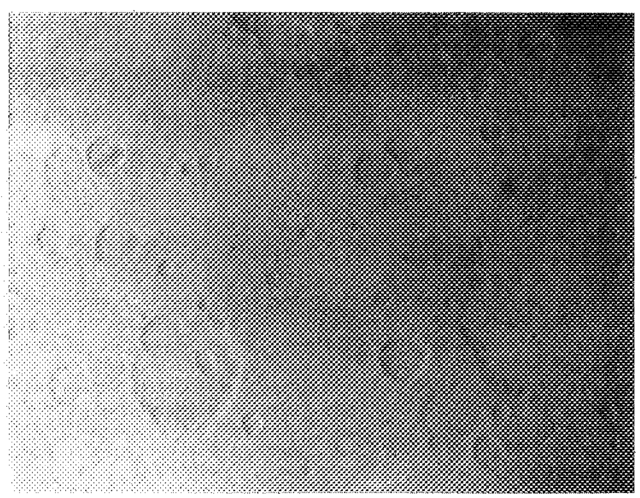


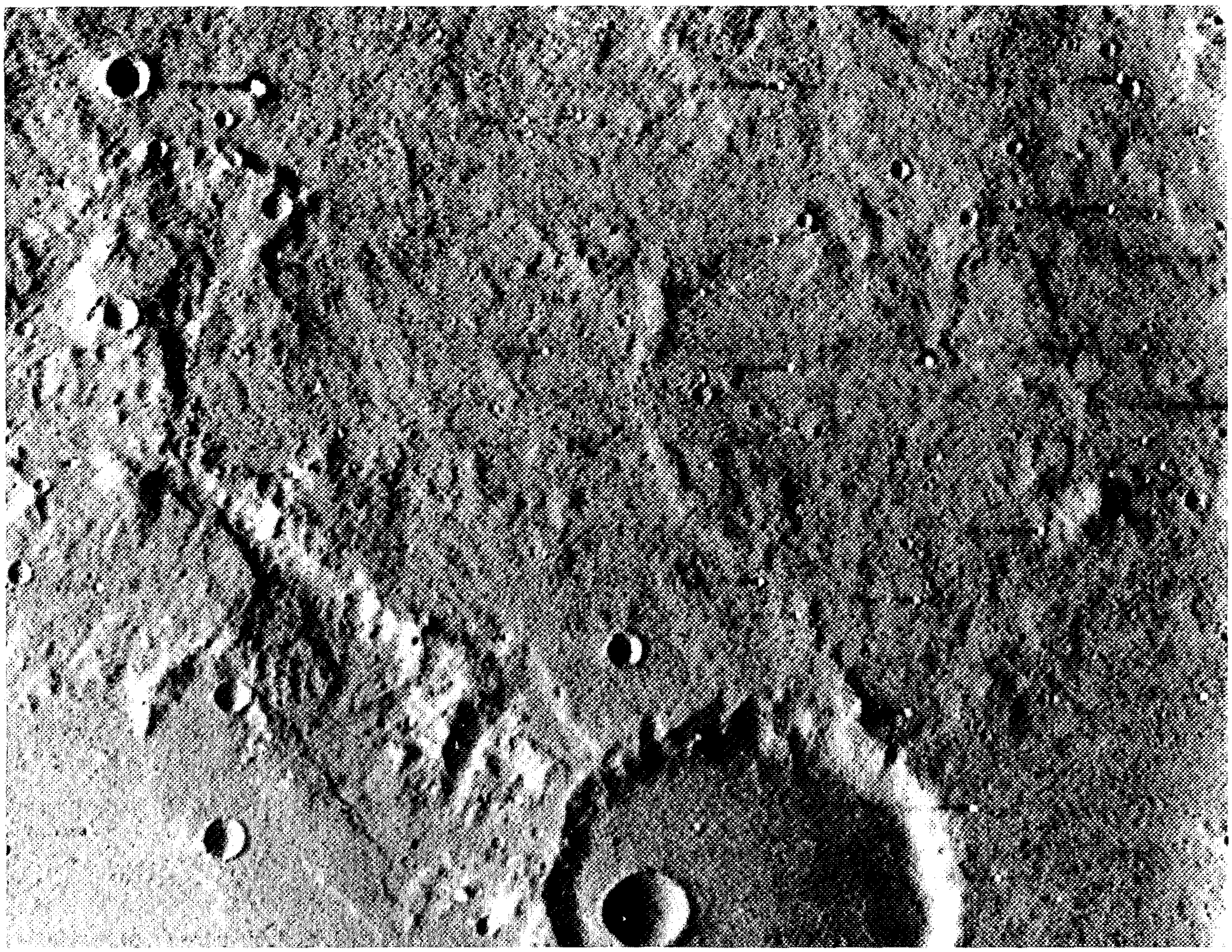
6N19 (opposite) continues the panorama of Martian craters. At bottom is an enhanced photometric version of 6N19.

6N20 (above) shows at the left a crater with a concentric double-ring appearance and, at the right, a ridge-like feature more than 50 kilometers long.



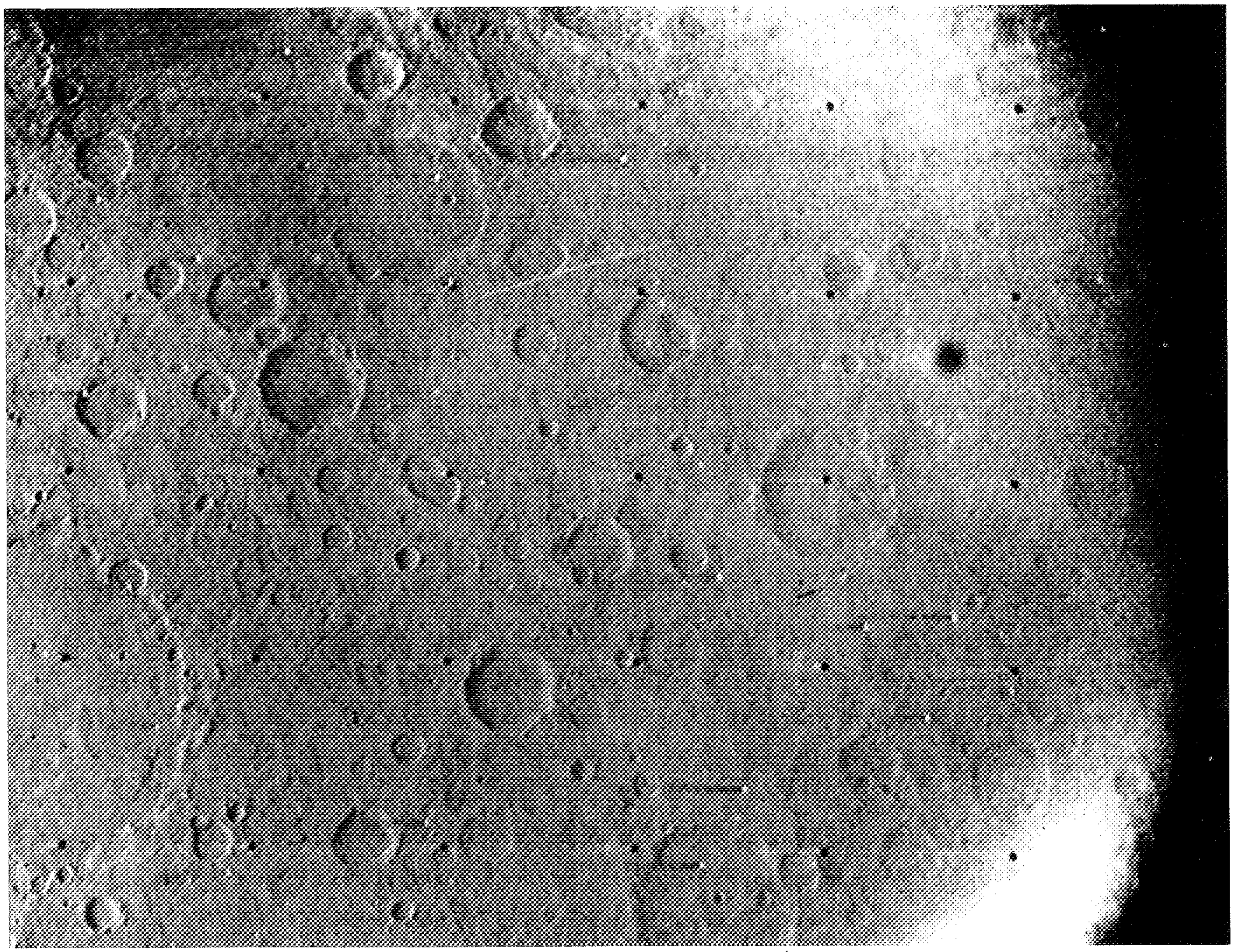
Enhanced photometric version





6N21 (opposite) includes the boundary between dark Sabaeus Sinus and light Deucalionis Regio. Careful crater counts in both regions indicate there is no significant difference between crater distributions in light and dark areas. At bottom is an enhanced photometric version of 6N21.

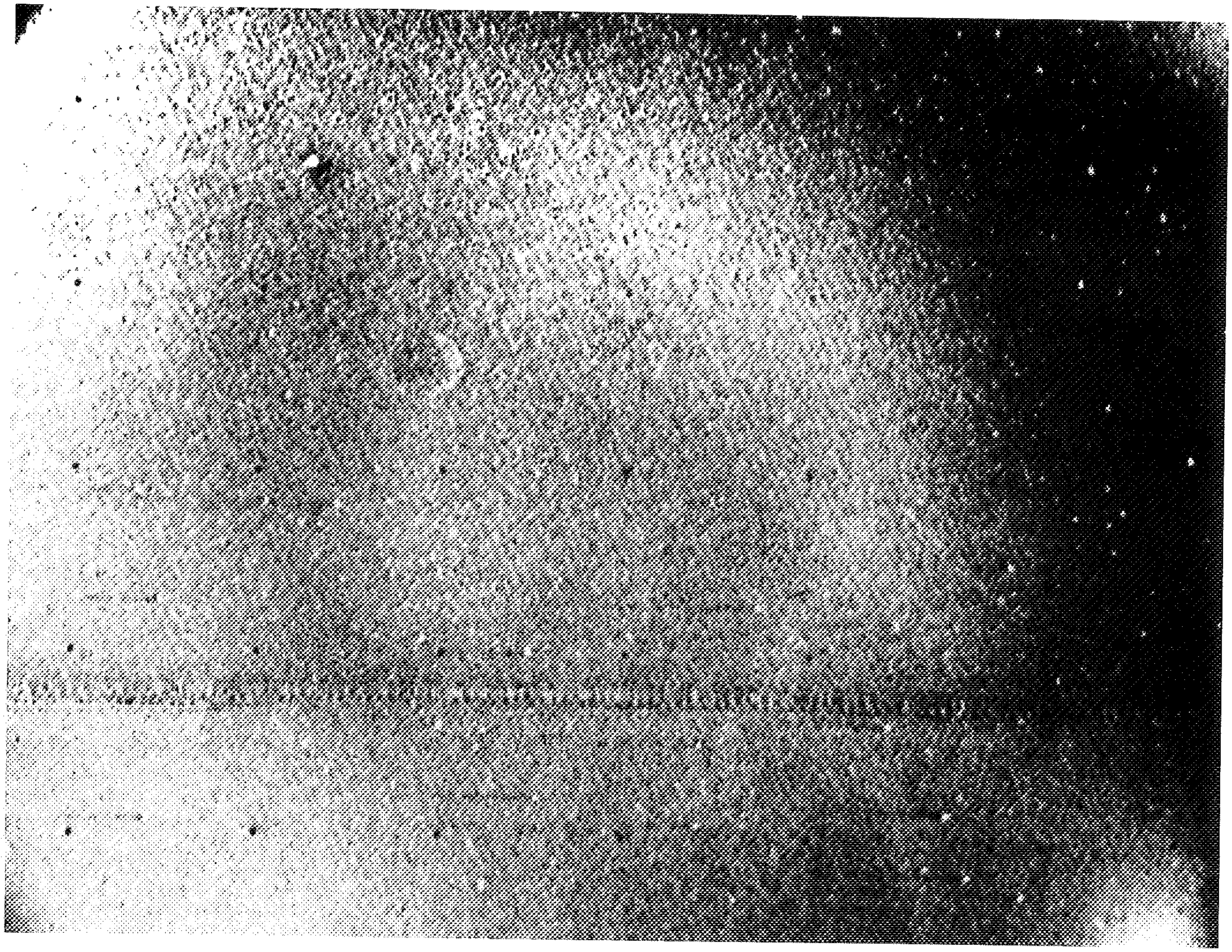
6N22 (above), illuminated by a low Sun (14 degrees above the horizon), reveals a surface with a great deal of subtle topography.

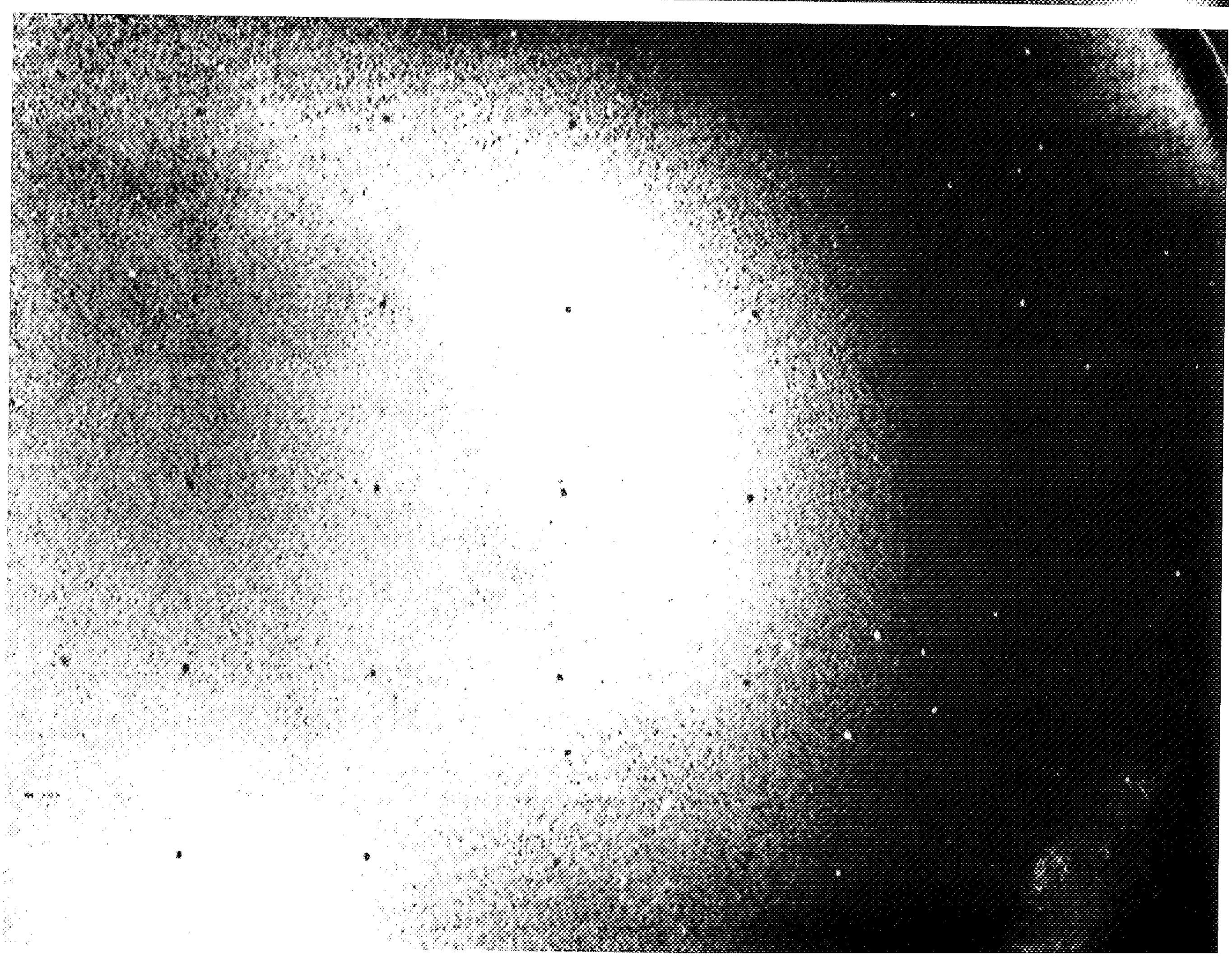


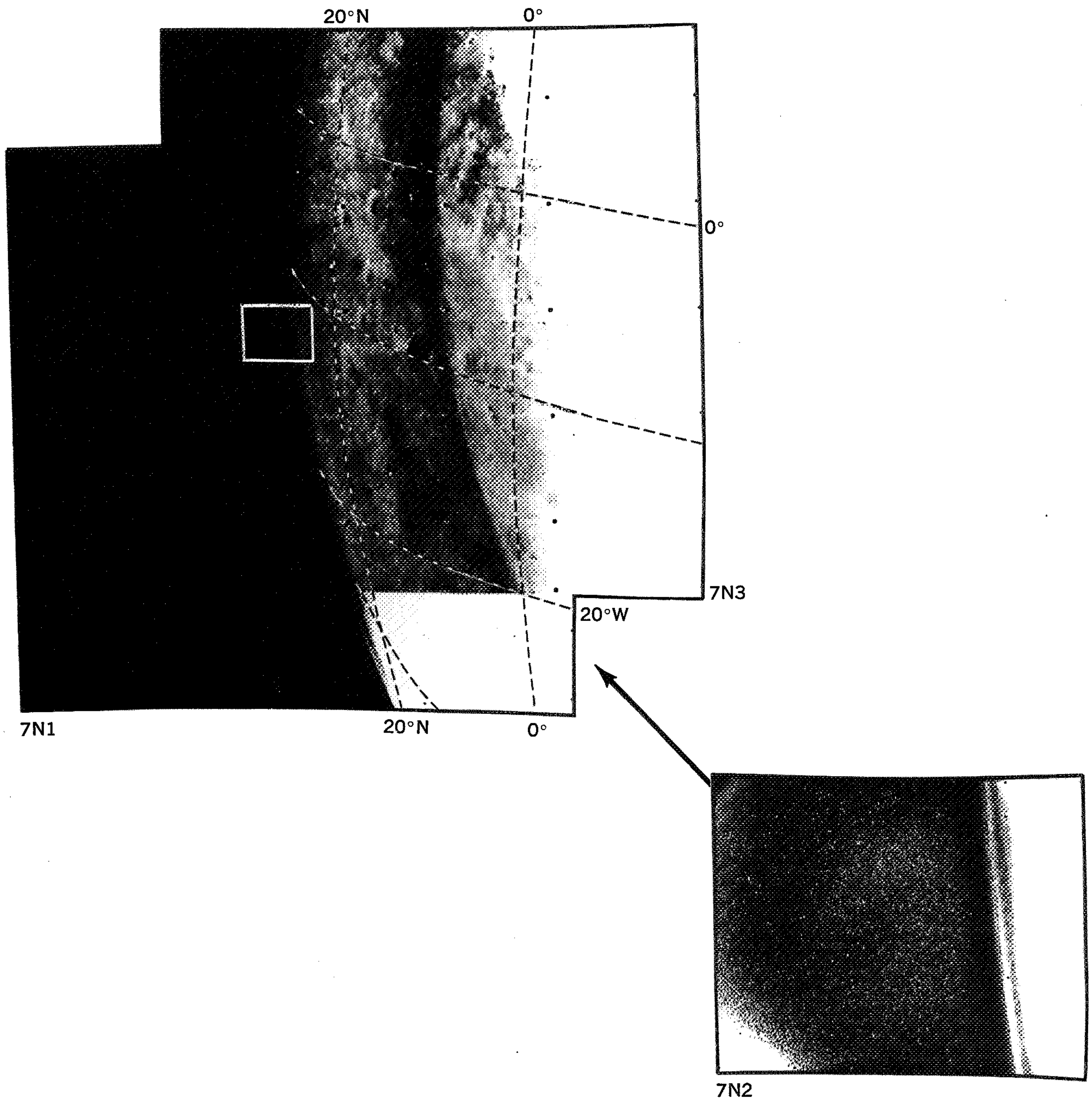
6N23 (above) was taken at the afternoon terminator. Detail is less apparent than in 6N21, an effect due perhaps to greater surface obscuration by an atmospheric haze or to the difference in filters through which the pictures were taken.

6N24 (opposite, top), taken in very dim light, shows several possible craters.

6N25 (opposite, bottom) was taken beyond the terminator.

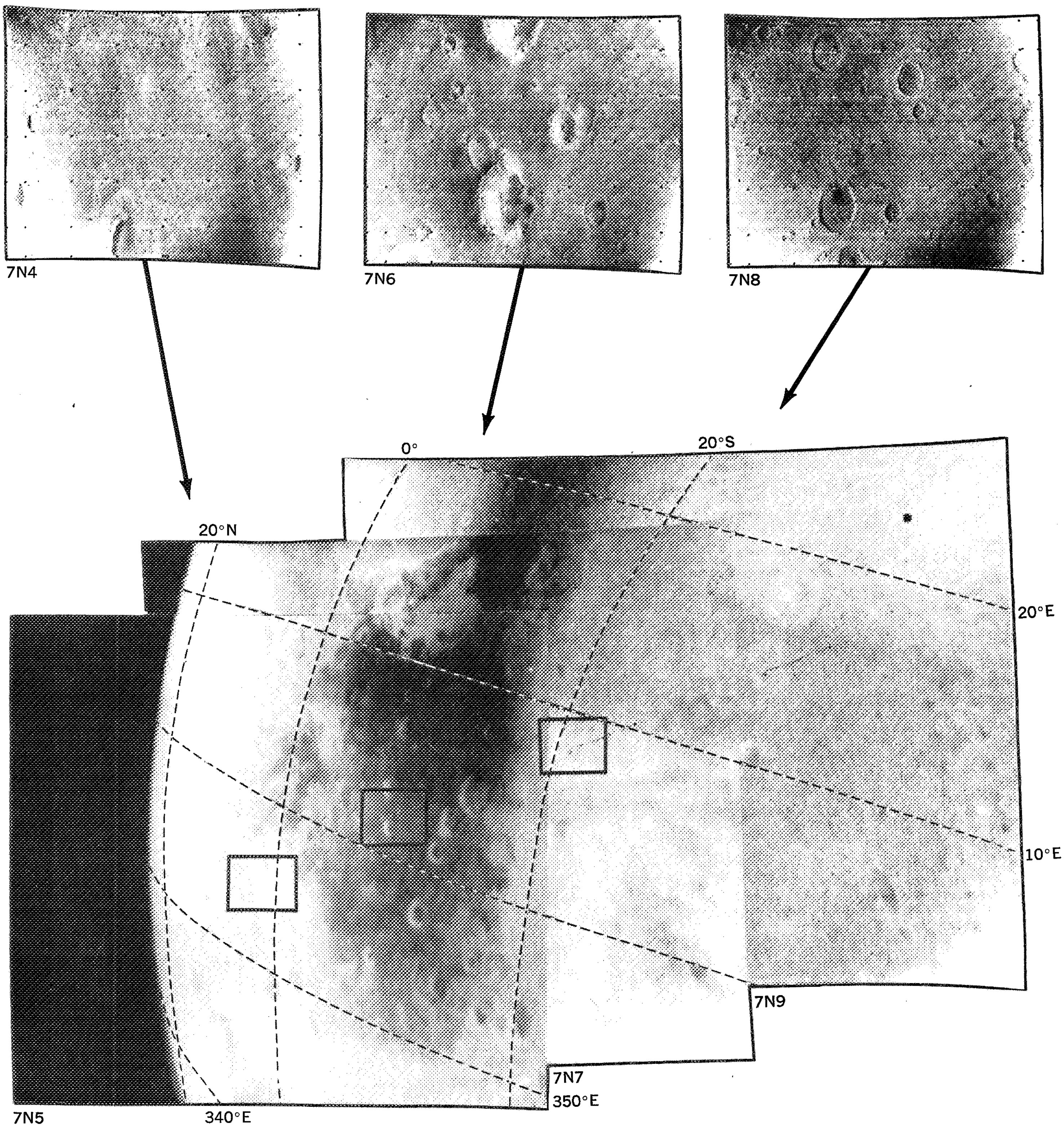


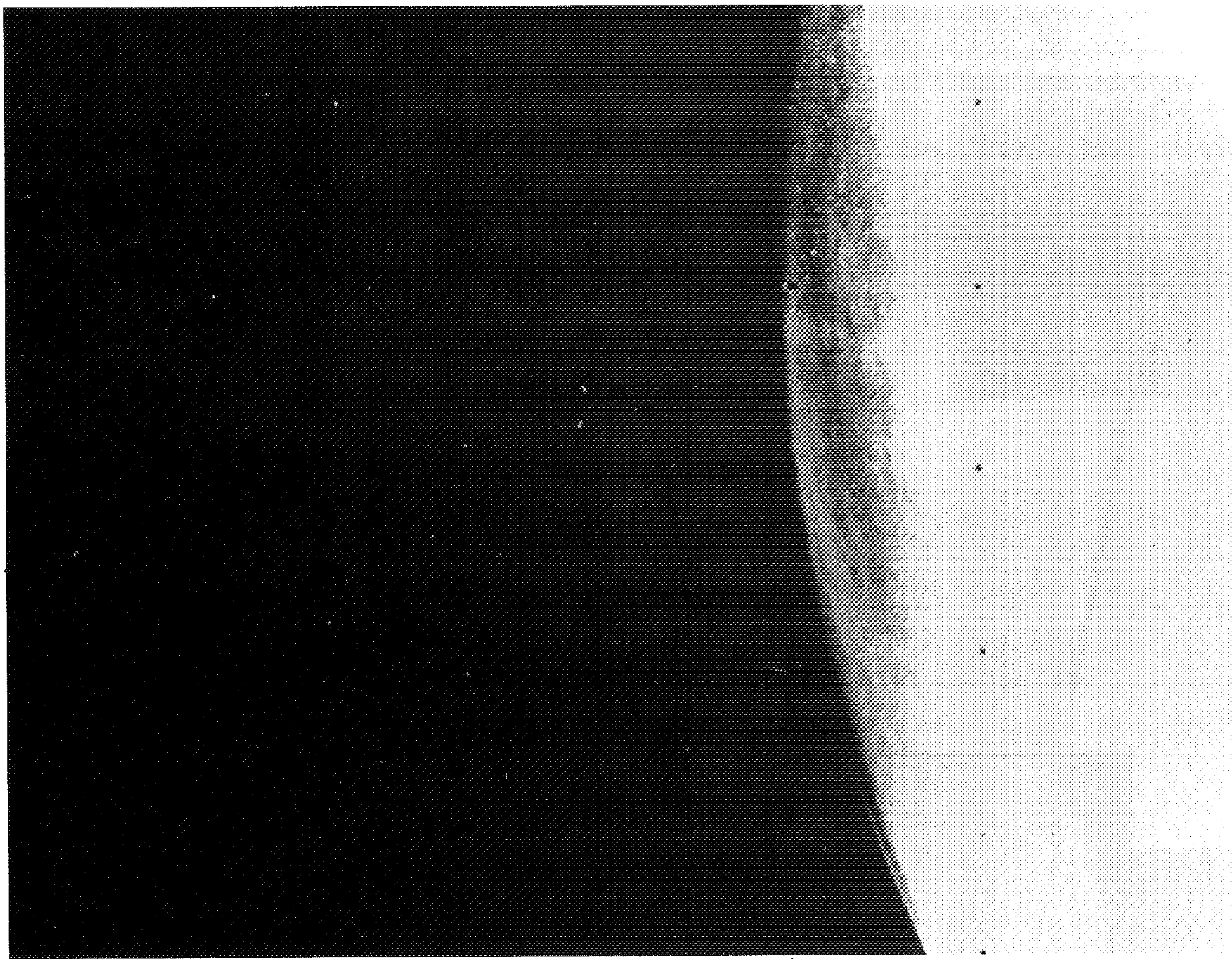




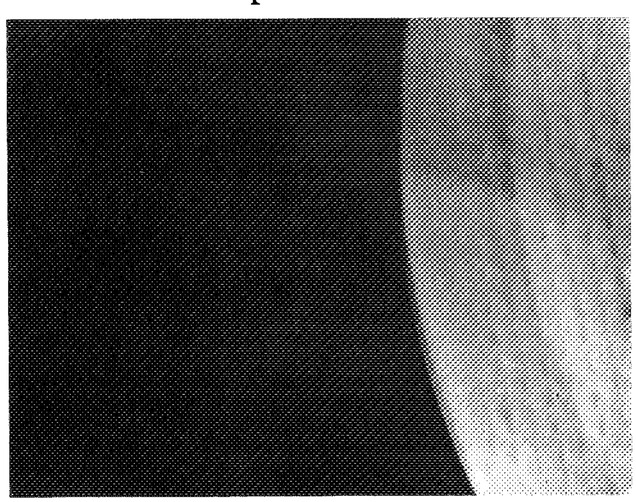
7N1-9, Meridiani Sinus

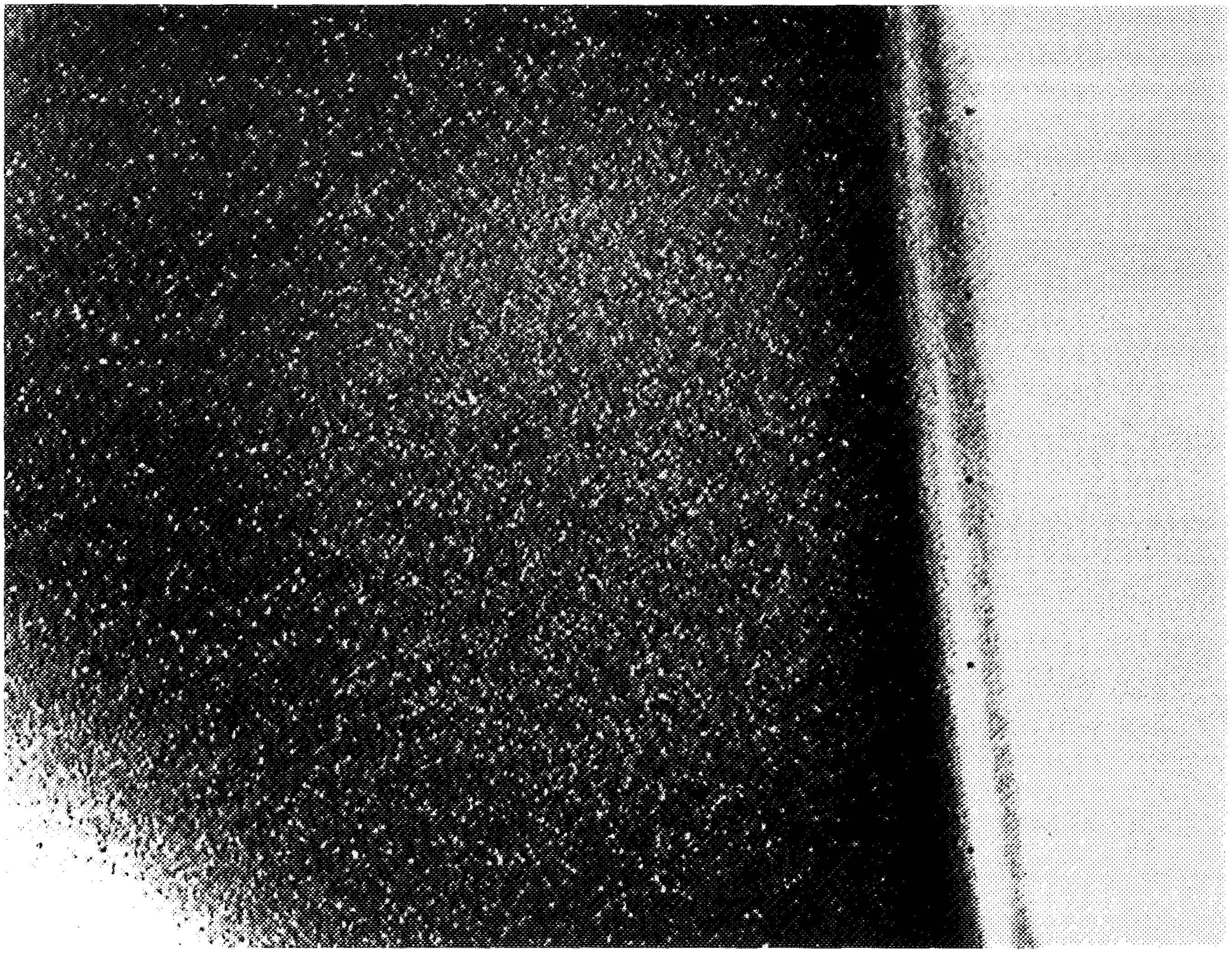
Mariner 7 also obtained pictures of Meridiani Sinus during its near encounter sequence. One of the most interesting aspects of these pictures, however, is the information they have provided about possible haze layers in the Martian atmosphere. Meteorologic analysis of this information has led to the following conclusion: Above this portion of the Martian surface there were probably three distinct, colorless haze layers located between 5 and 45 kilometers above the surface.


7N4
7N6
7N8
0°
20°S
20°N
20°E
10°E
7N9
7N7
350°E
7N5
340°E



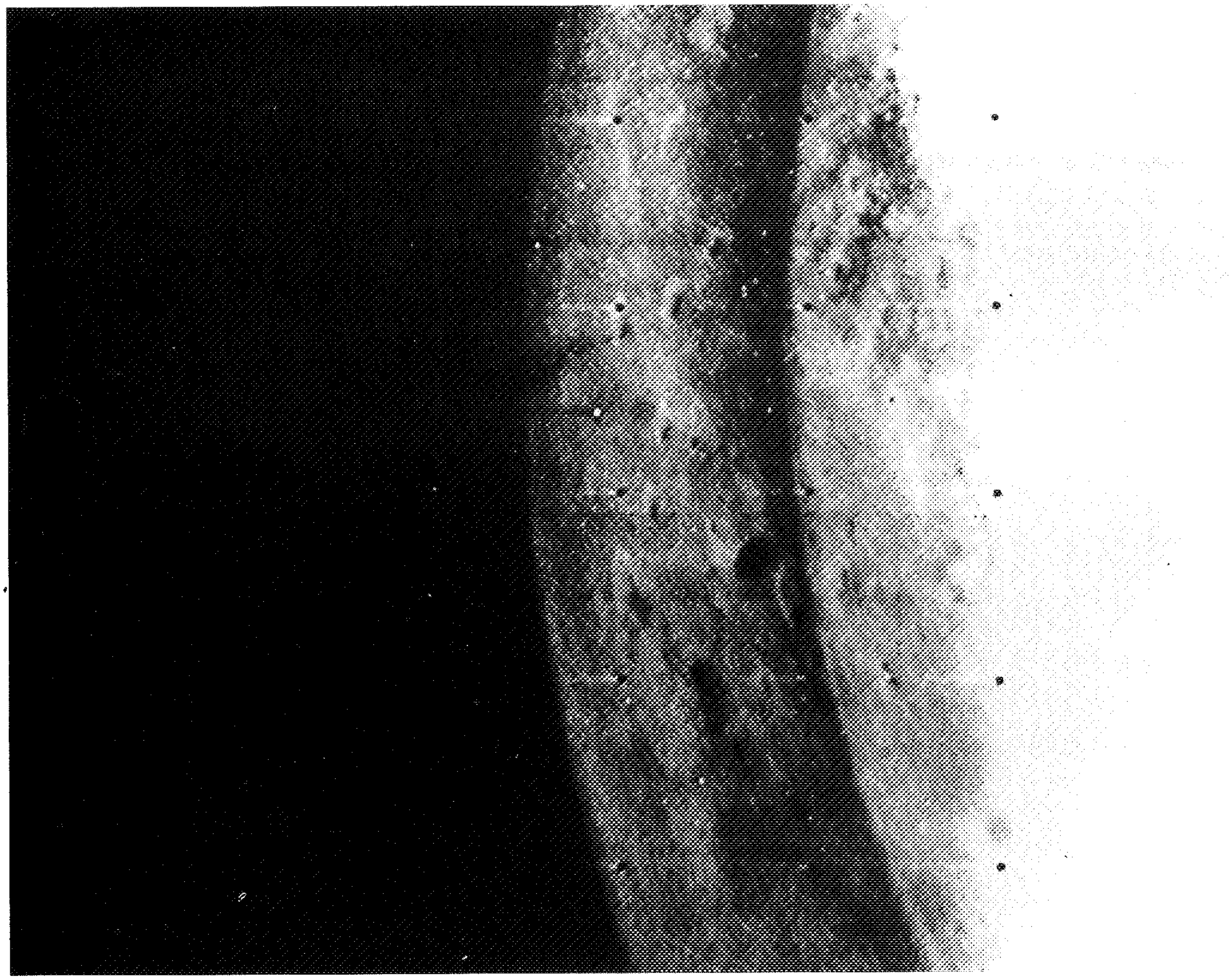
Enhanced photometric version



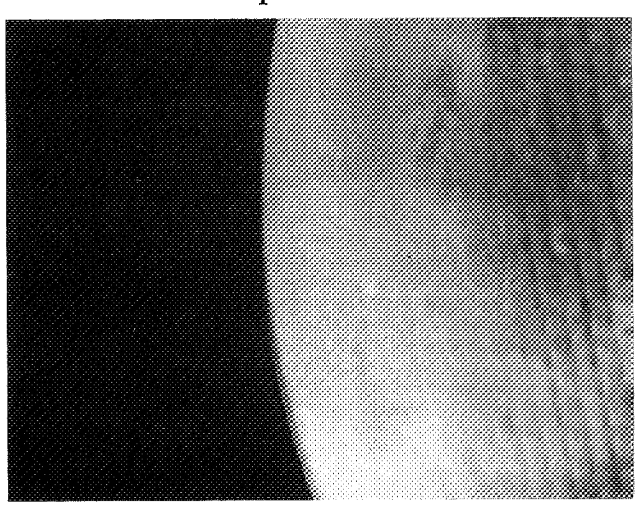


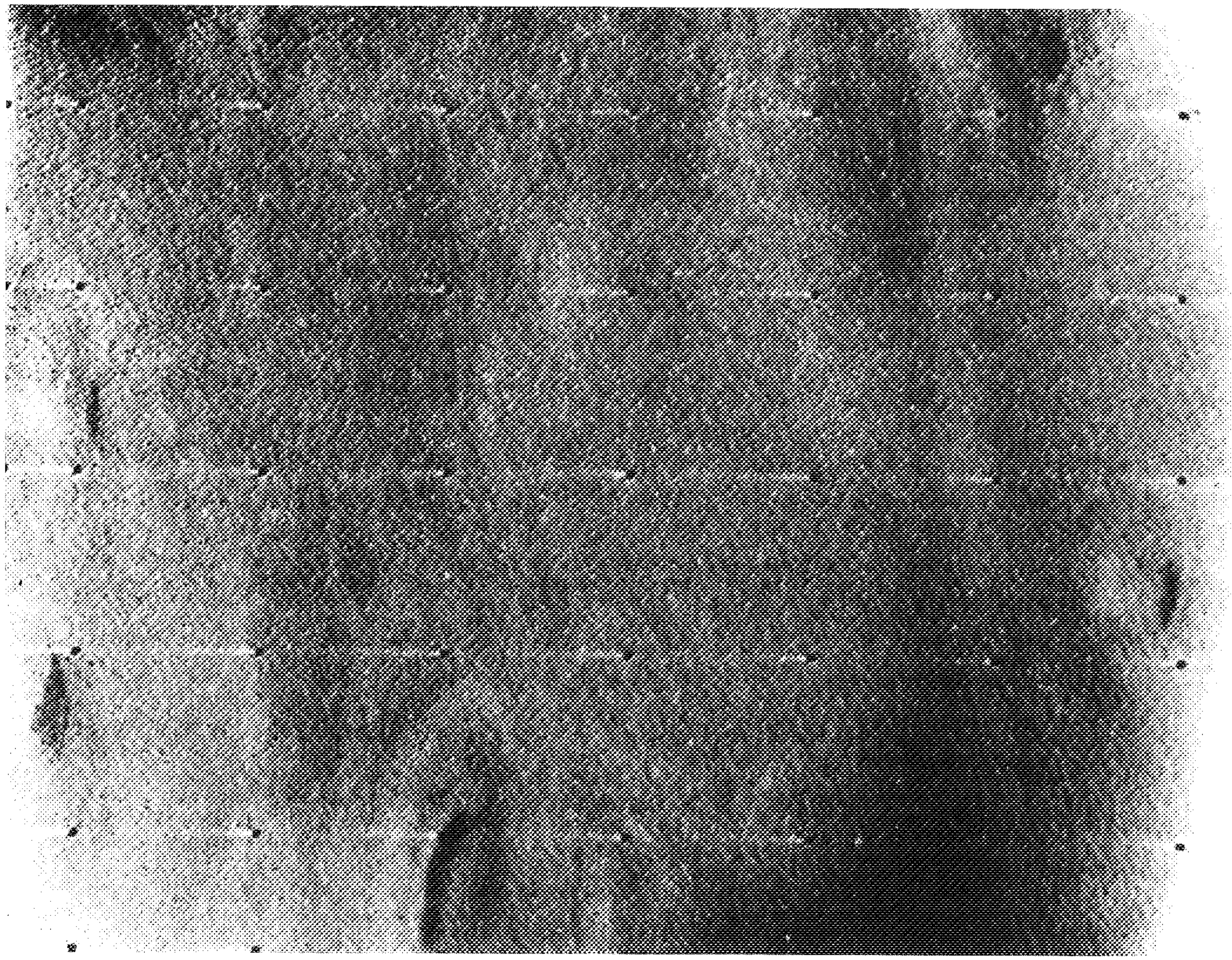
7N1 (opposite) clearly presents the limb haze at the bottom of the picture. At bottom is an enhanced photometric version of 7N1.

7N2 (above) was fortuitously taken of the limb. This high-resolution view clearly shows the detachment of the haze layer from the surface.



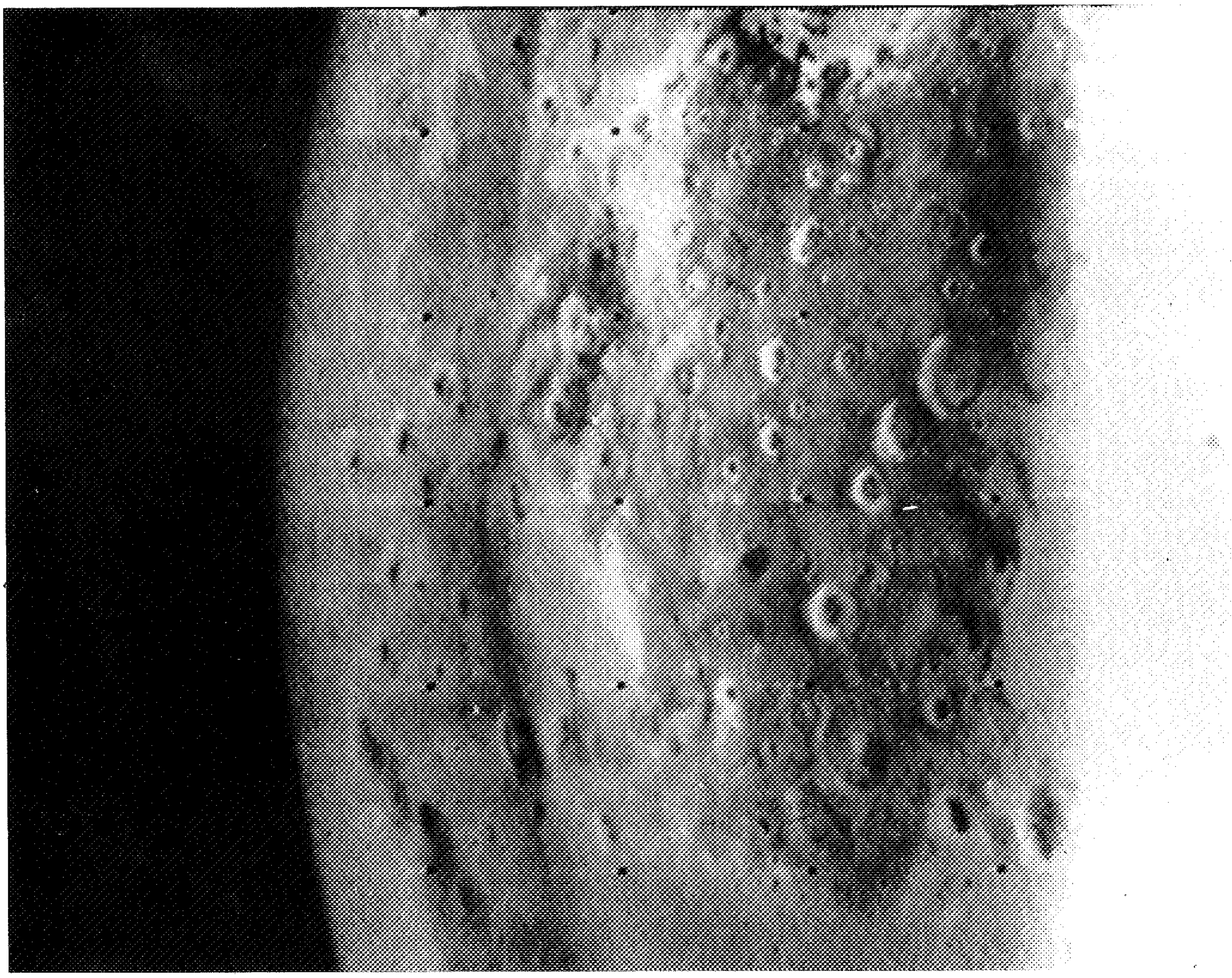
Enhanced photometric version



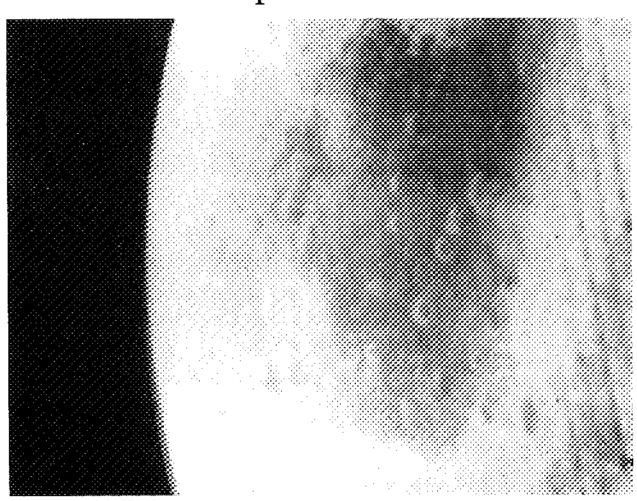


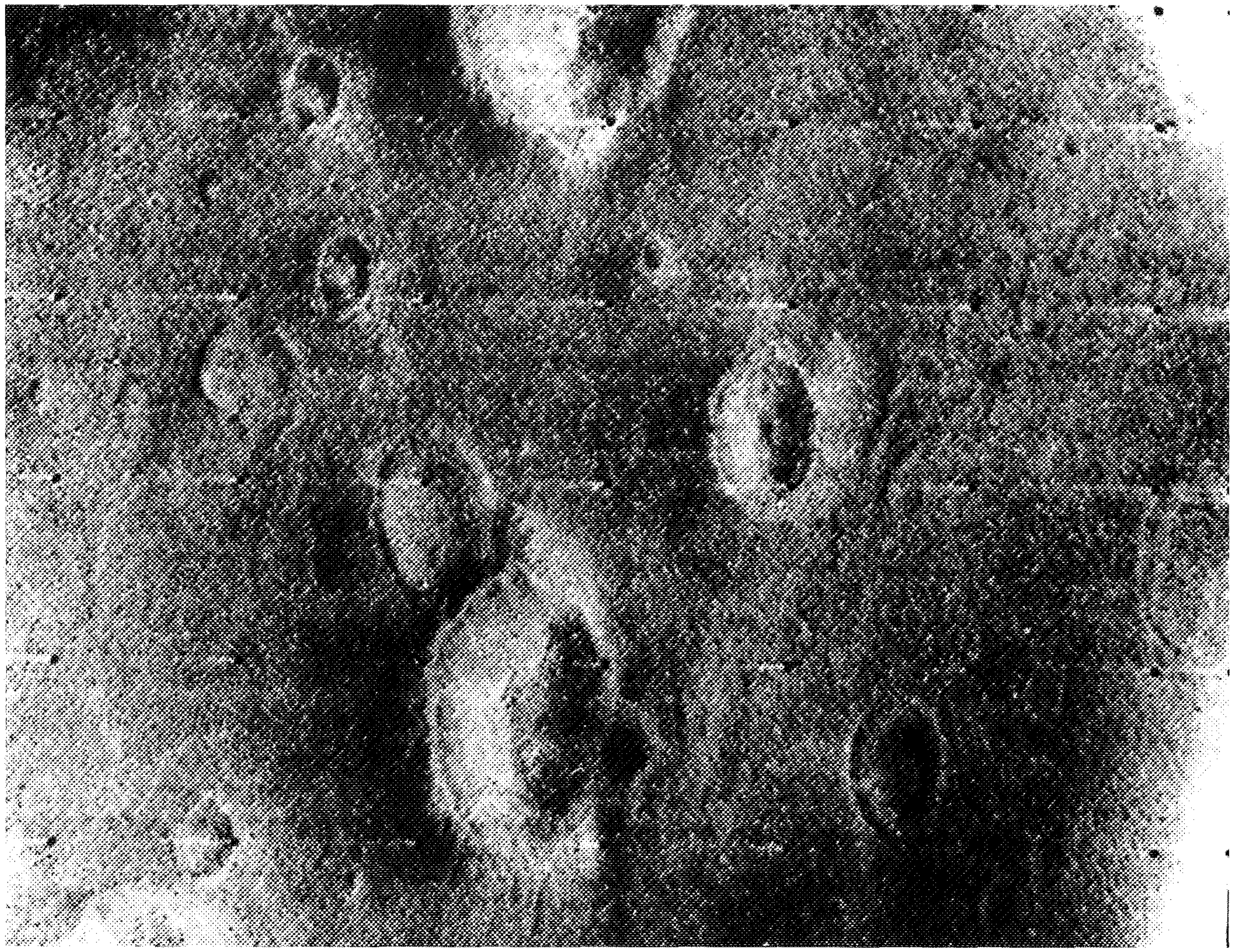
7N3 (opposite) shows the cratered terrain north of Meridiani Sinus. At bottom is an enhanced photometric version of 7N3.

7N4 (above) shows the fairly indistinct outline of several highly foreshortened craters.



Enhanced photometric version





7N5 (opposite) presents the dark mass of Meridiani Sinus. Again, reference to the photometric version is useful. Many of the craters seen here are readily identified in the Mariner 6 near encounter pictures. Also, near the limb at the bottom of the picture is the eastern portion of dark Oxia Palus (compare 7F35 and 6F33). At bottom is an enhanced photometric version of 7N5.

7N6 (above) probably overlaps a small portion of the Mariner 6 B frame, 6N12. Again notice the light appearance of part of many of the crater bottoms.

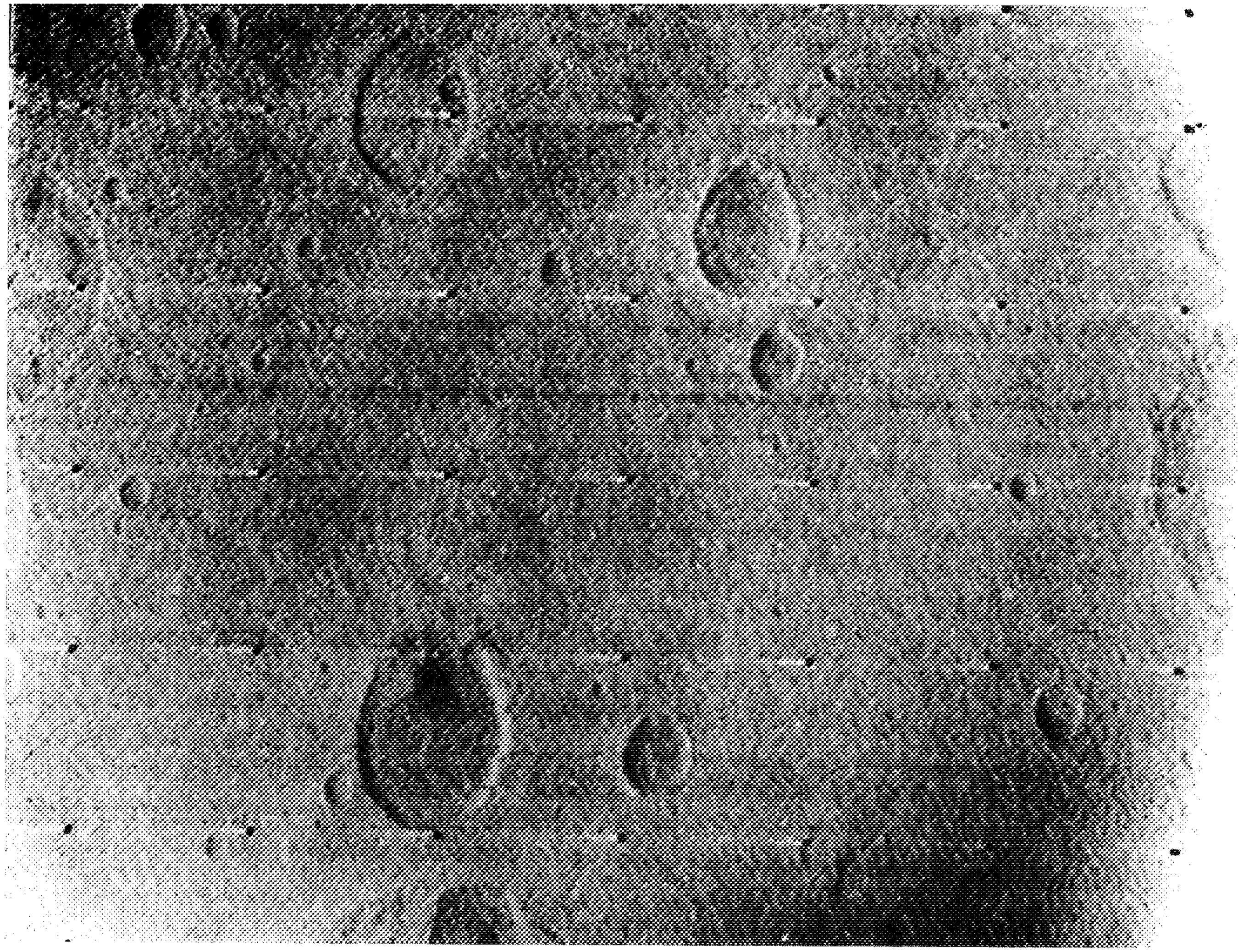
7N7 (above) shows again the intricate detail of the eastern edge of Meridiani Sinus.

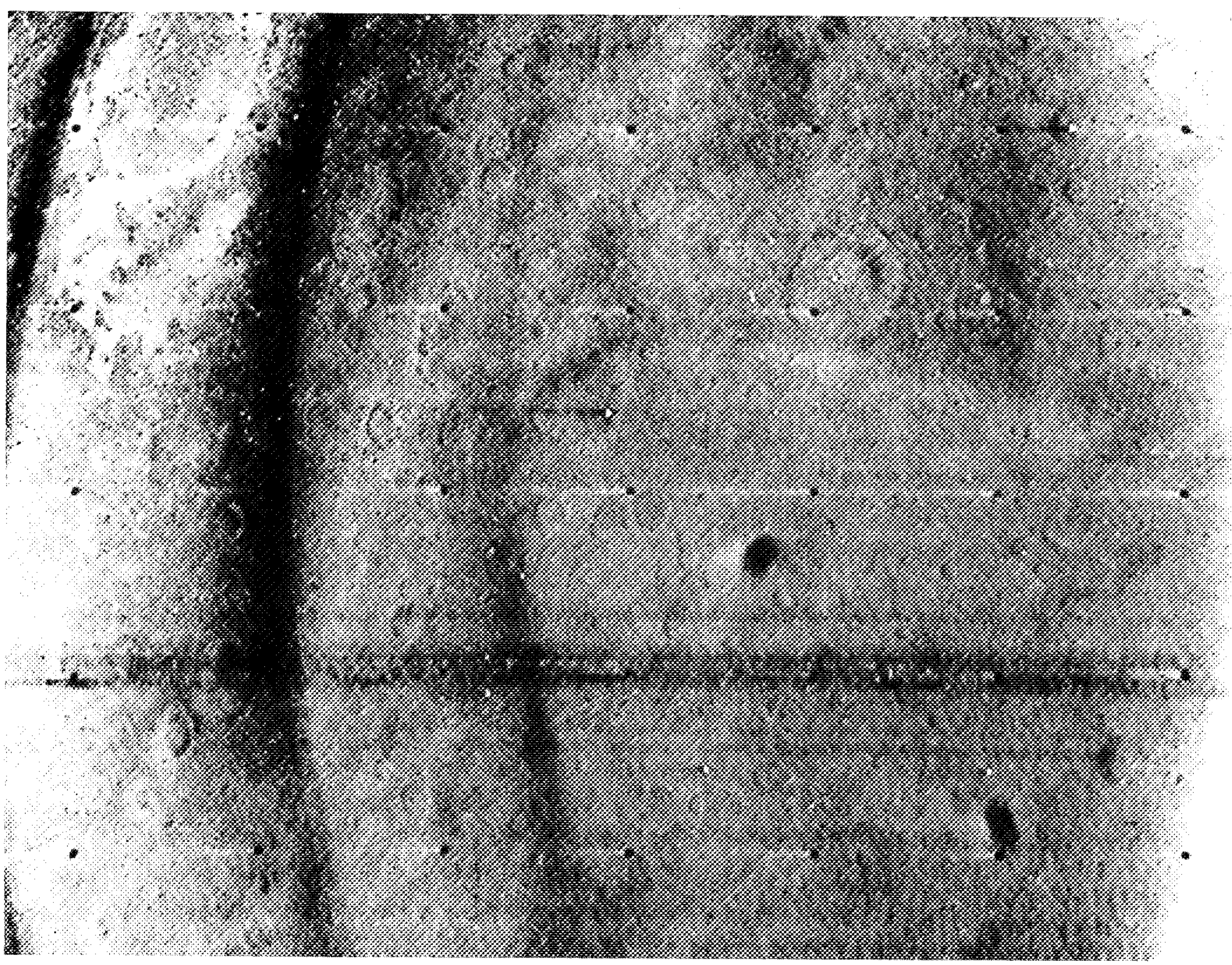
7N8 (opposite, top) provides a more detailed view of the craters south of Meridiani Sinus. The Sun is almost directly above this region, a possible explanation of the subdued appearance of this topography.

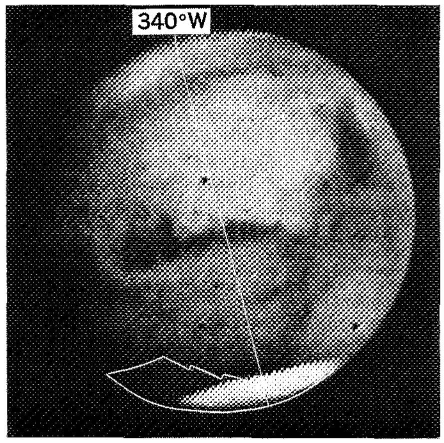
7N9 (opposite, bottom) reveals more of the crater Edom than was visible in 6N13. This picture, taken through a blue filter, shows lower contrast than 7N5 or 7, supporting Earth-based observations that the Martian surface exhibits reduced contrast in blue light.

7N7

7N9





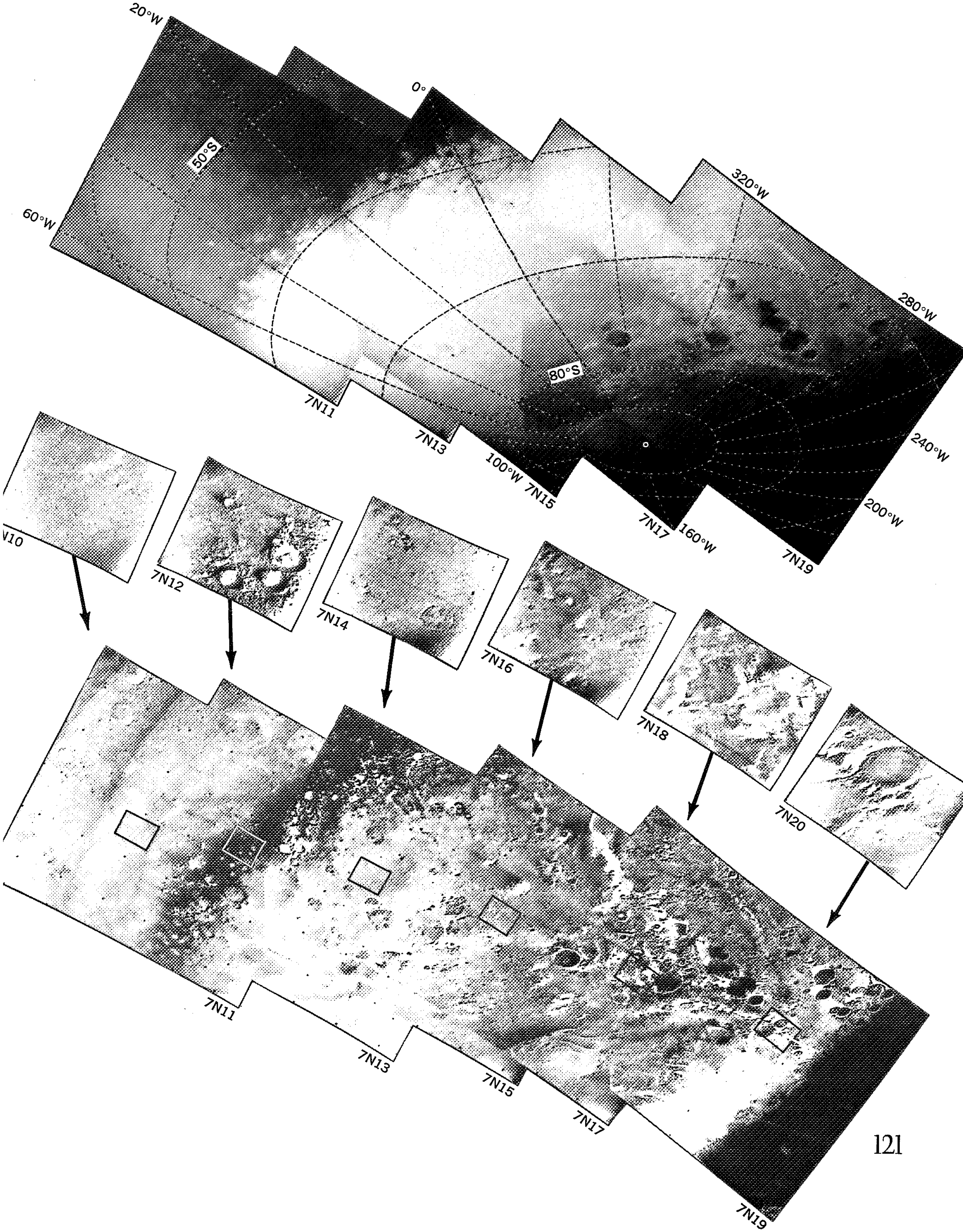


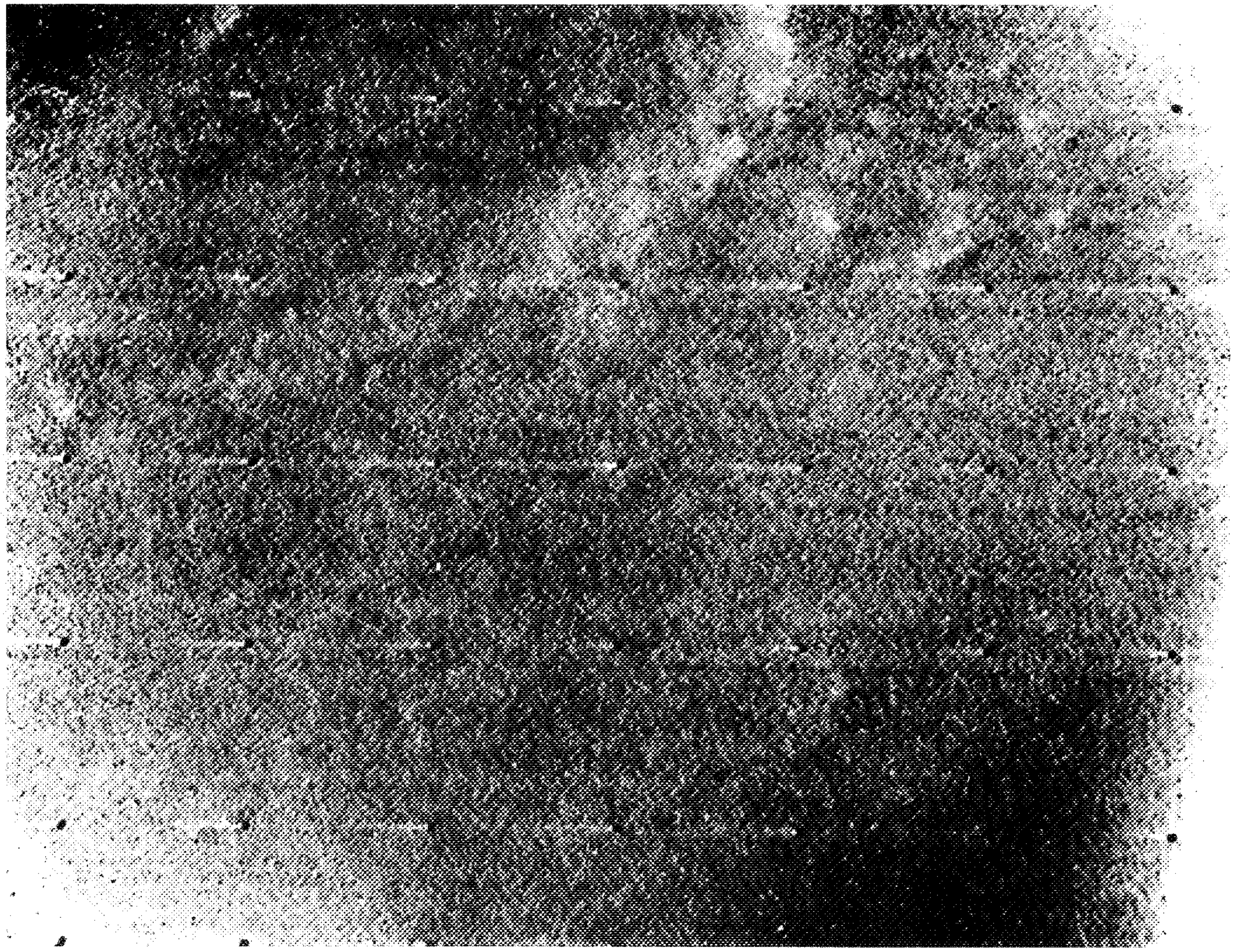
7N10-20, South Polar Cap

7F67

Mariner 6 far encounter pictures had shown there was tantalizing detail prominent both in the interior and along the edge of the South Polar Cap. This observation motivated the mission scientists and engineers to increase the Mariner 7 near encounter Polar Cap coverage from six pictures to ten pictures. After finishing their trace across Meridiani Sinus, the television cameras were slewed far south to the Polar Cap edge. These two mosaics provide the most graphic illustration of the operation of the automatic gain control, described in Chapter 2. The top mosaic shows the Polar Cap as it would have actually appeared to an observer aboard the spacecraft. The second mosaic shows the maximum definition versions of these pictures. In this lower version, notice that the Polar Cap is about the same shade of grey as the bare ground to the left and that a very dark band has been artificially introduced along the cap edge. The attributes of this second version, however, are obvious when one compares the fine detail apparent both on and off the cap to the much less detailed rendition of these same areas in the upper mosaic.

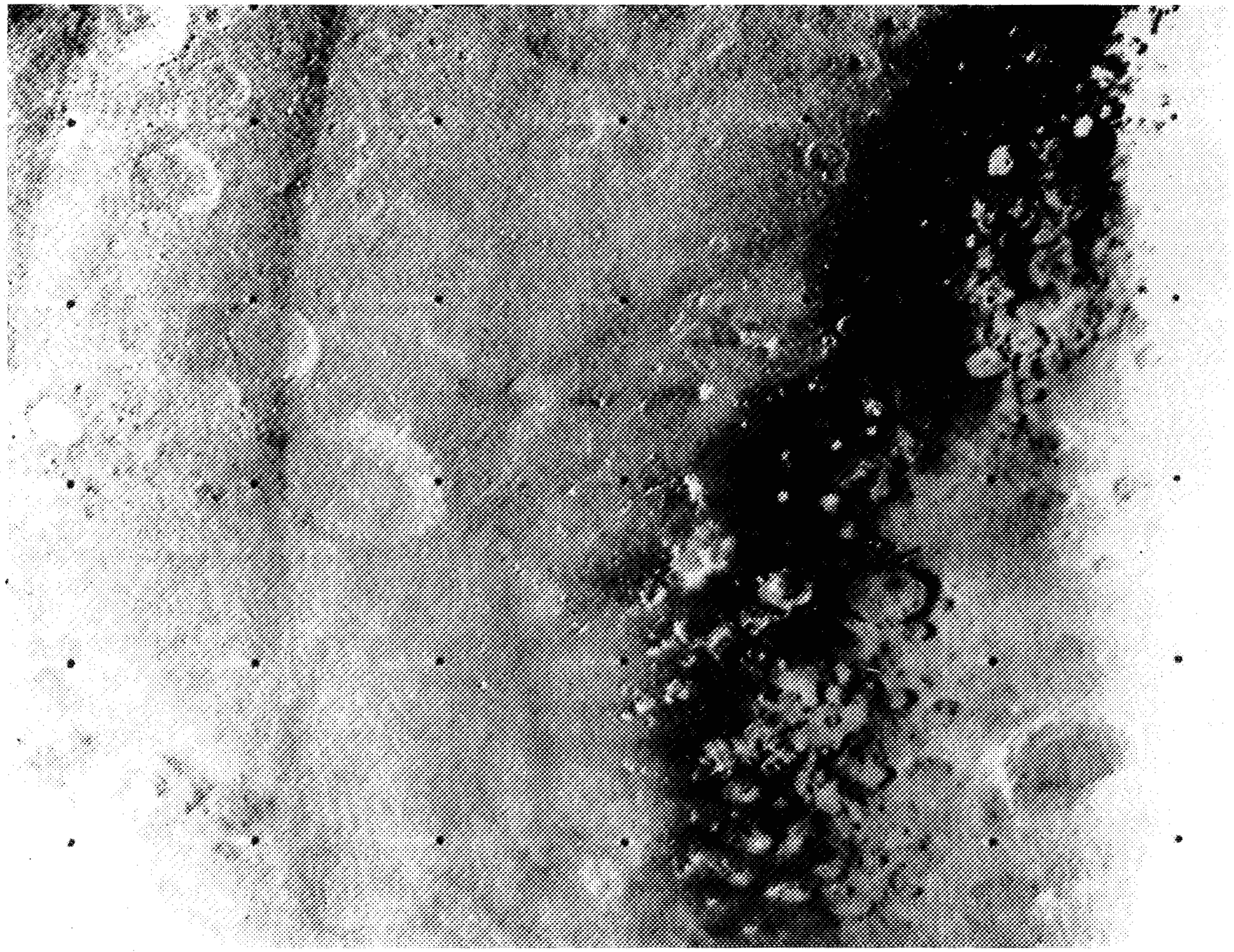
The depth of snow inferred from these pictures and the low temperatures measured on the cap by the infrared radiometer have led most investigators to conclude that the snow is frozen carbon dioxide, "dry ice," not frozen water like the Earth's polar caps.


20°W
0°
50°S
60°W
320°W
280°W
80°S
7N11
7N13
100°W
7N15
7N17
160°W
240°W
200°W
7N19
N10
7N12
7N14
7N16
7N18
7N20
7N11
7N13
7N15
7N17
7N19

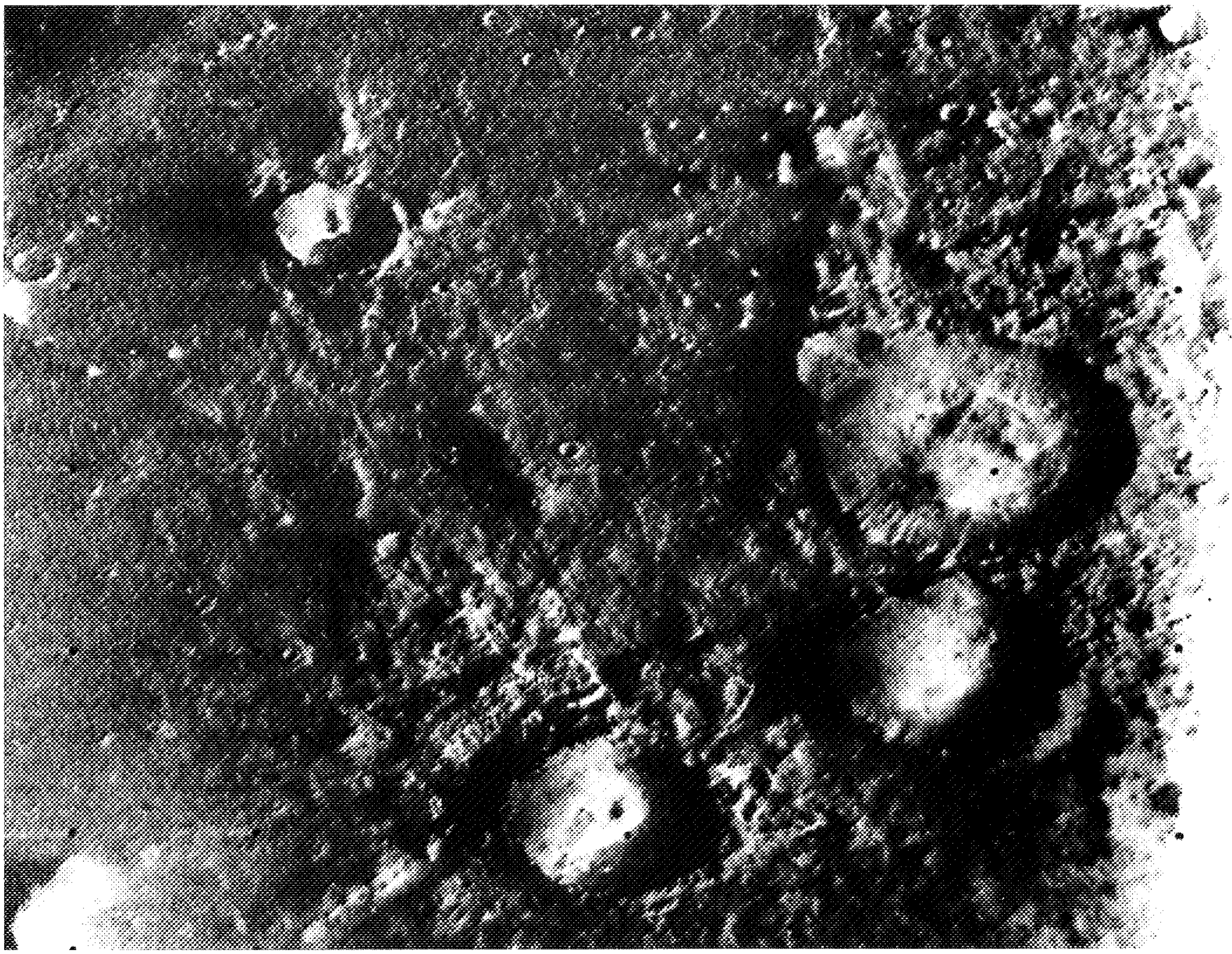


7N10 (above) shows the area just north of the cap, and, because of its bland appearance, is an enigmatic picture. Far encounter pictures, e.g., 6F40, suggested there was a haze over the morning portion of the Polar Cap; and such a haze, if present, could account for the lack of detail in 7N10.

7N11 (opposite) provides a view of the Polar Cap edge. Topographic detail is clearly seen through the snow layer. At bottom is an enhanced photometric version of 7N11.

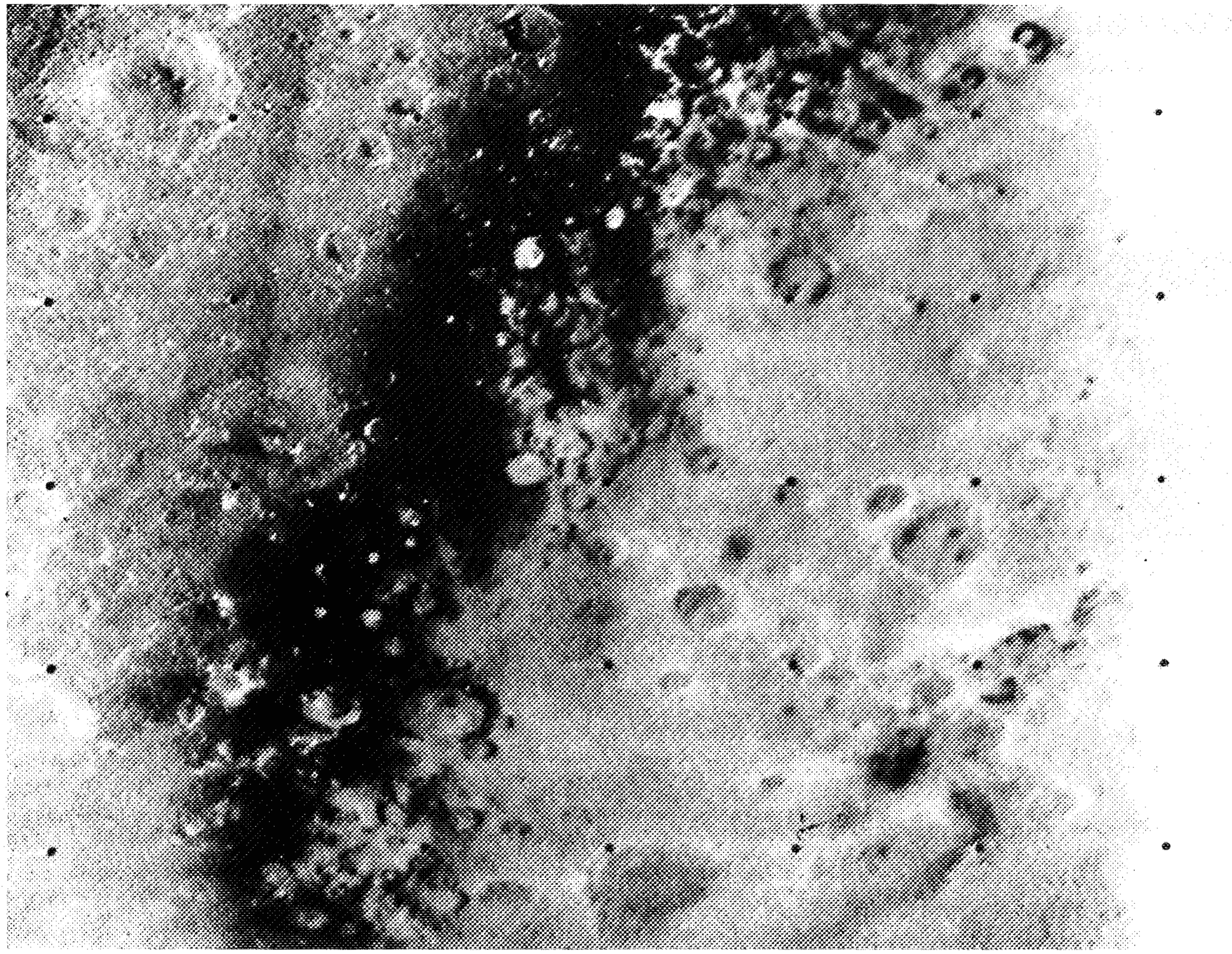


Enhanced photometric version

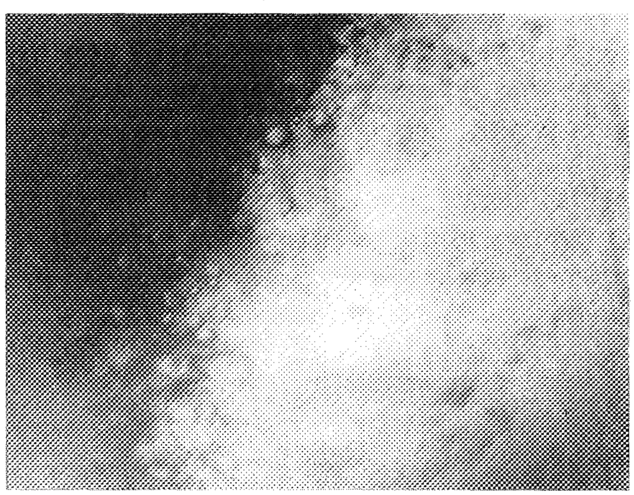


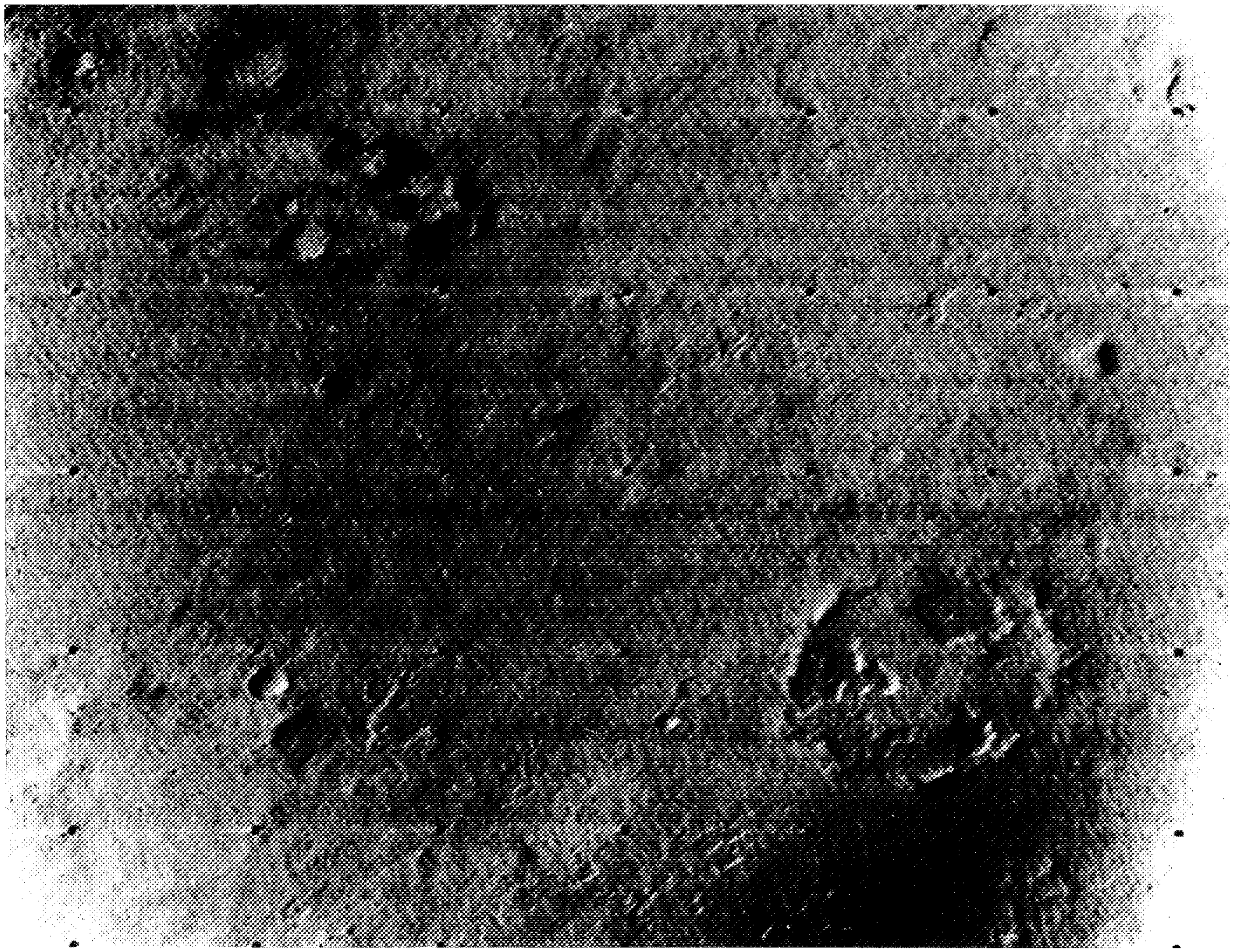
7N12 (above) is a deceptive telephoto view of the cap edge. Since the sunlight is coming from the left side of the frame, what appear to be shadowed crater walls are, in fact, the sunlit slopes from which the snow has been melted or sublimated by the direct sunlight. The bright slopes of the craters are the areas inclined away from the Sun where snow still remains.

7N13 (opposite) continues the picture track across the polar cap. For many craters, the rims appear brighter and the floors darker than the surrounding surface. In this area, crater shapes and distributions are similar to those of nonpolar regions on Mars. At bottom is an enhanced photometric version of 7N13.



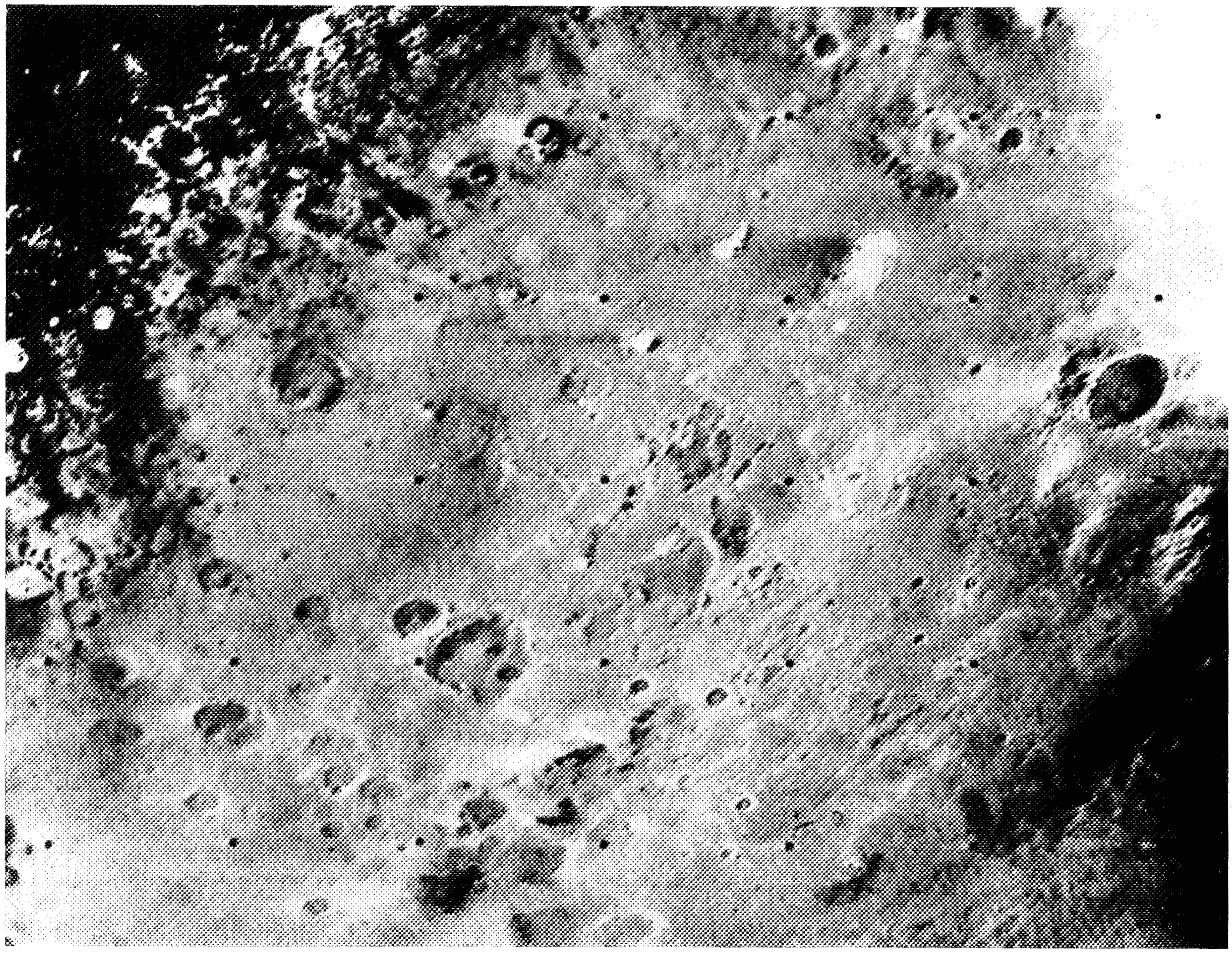
Enhanced photometric version



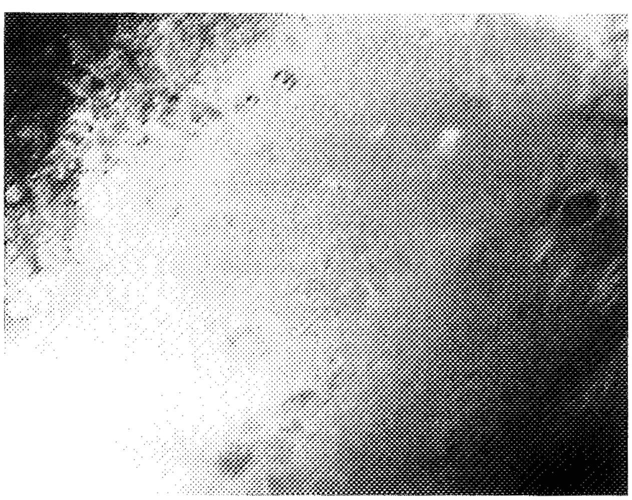


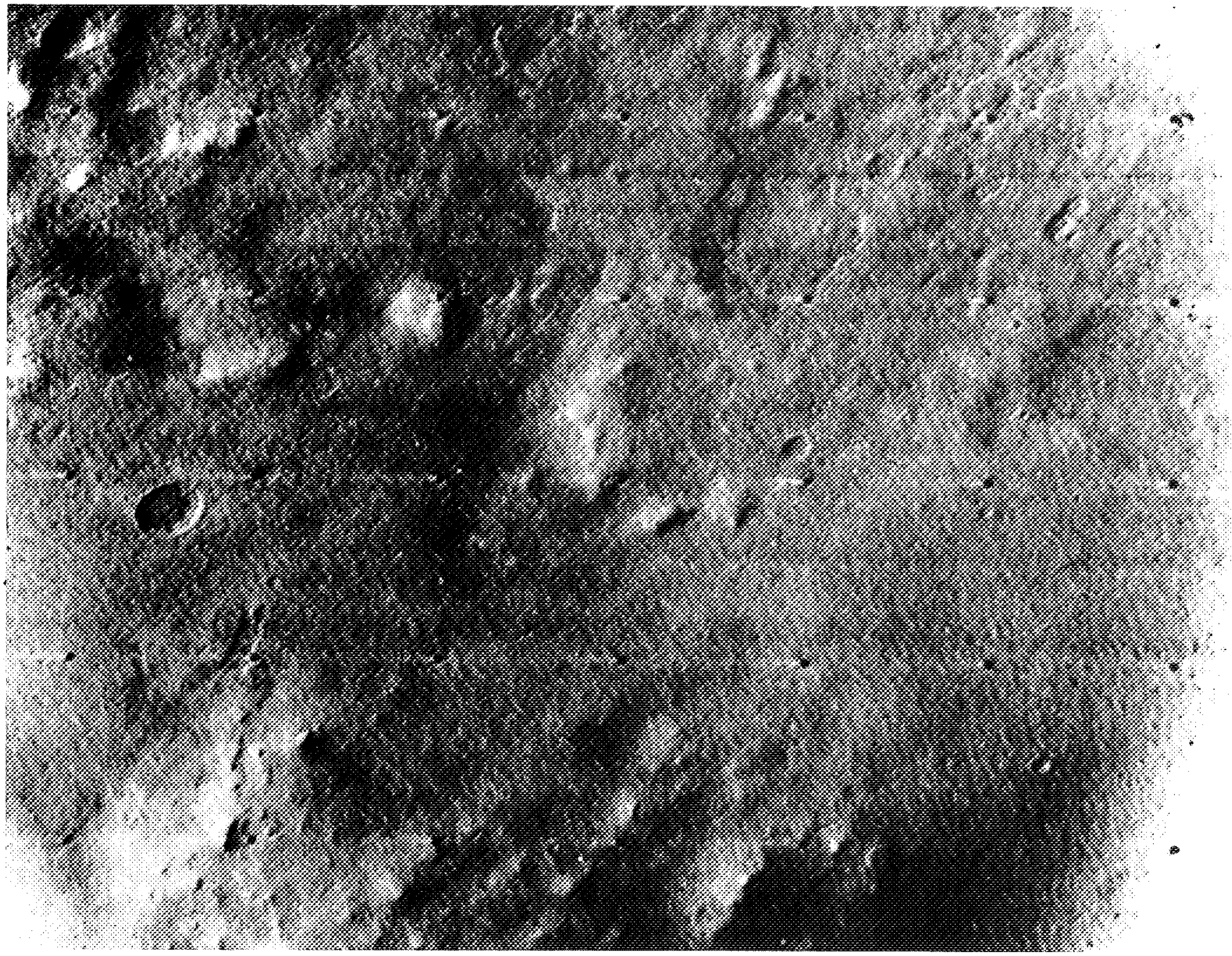
7N14 (above) presents some features apparently unlike any seen elsewhere on Mars. The large circular feature at the lower right, nicknamed the "elephant's footprint," contains several very irregularly outlined depressions that do not resemble craters. Here these features, referred to as "etch pits," appear to be quite shallow.

7N15 (opposite) shows more etch pits. In addition, there is a very unusual, lumpy texture to the surface just below and to the left of the large, flat-bottomed crater near the right margin of the picture. At bottom is an enhanced photometric version of 7N15.



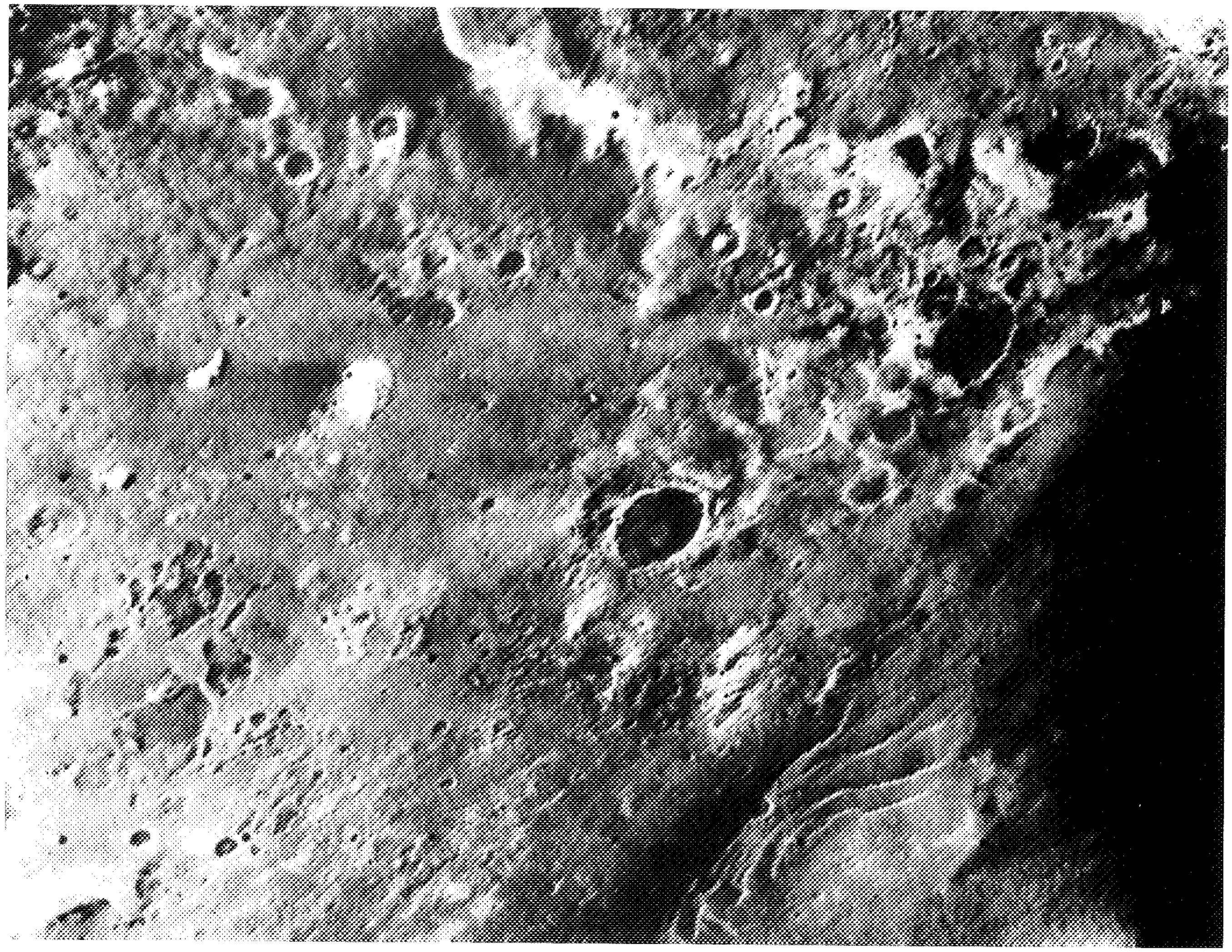
Enhanced photometric version



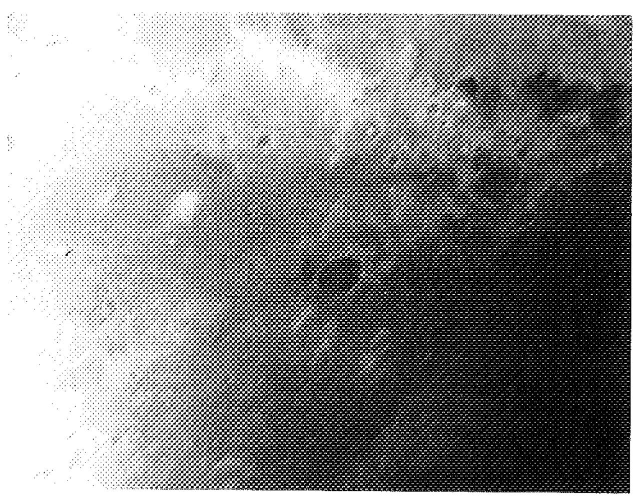


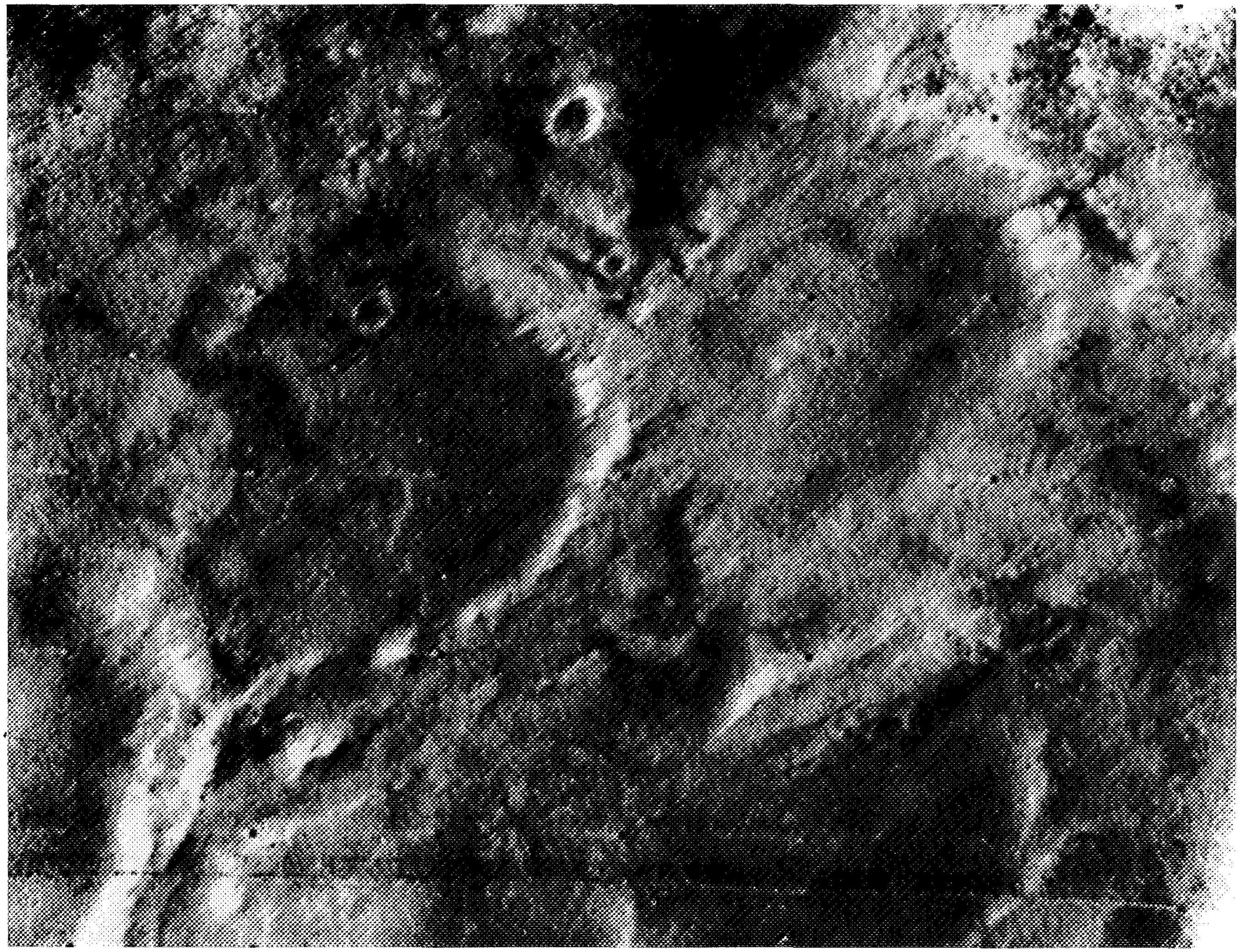
7N16 (above) introduces unusual features of seemingly positive relief such as the bright, raised area near the picture center. Isolated knobs and hills of this sort have not been identified elsewhere on Mars.

7N17 (opposite) includes the actual South Pole near the lower right corner of the picture. In the vicinity of the Pole there is a noticeable lack of craters and other features common elsewhere on the Polar Cap. Notice, also, the alignment of curved streaks around the Pole. At bottom is an enhanced photometric version of 7N17.



Enhanced photometric version



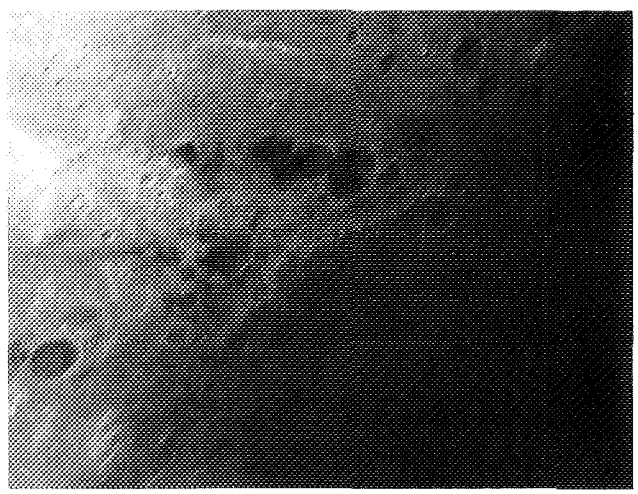


7N18 (above) reveals the small-scale surface texture and features present deep within the Polar Cap.

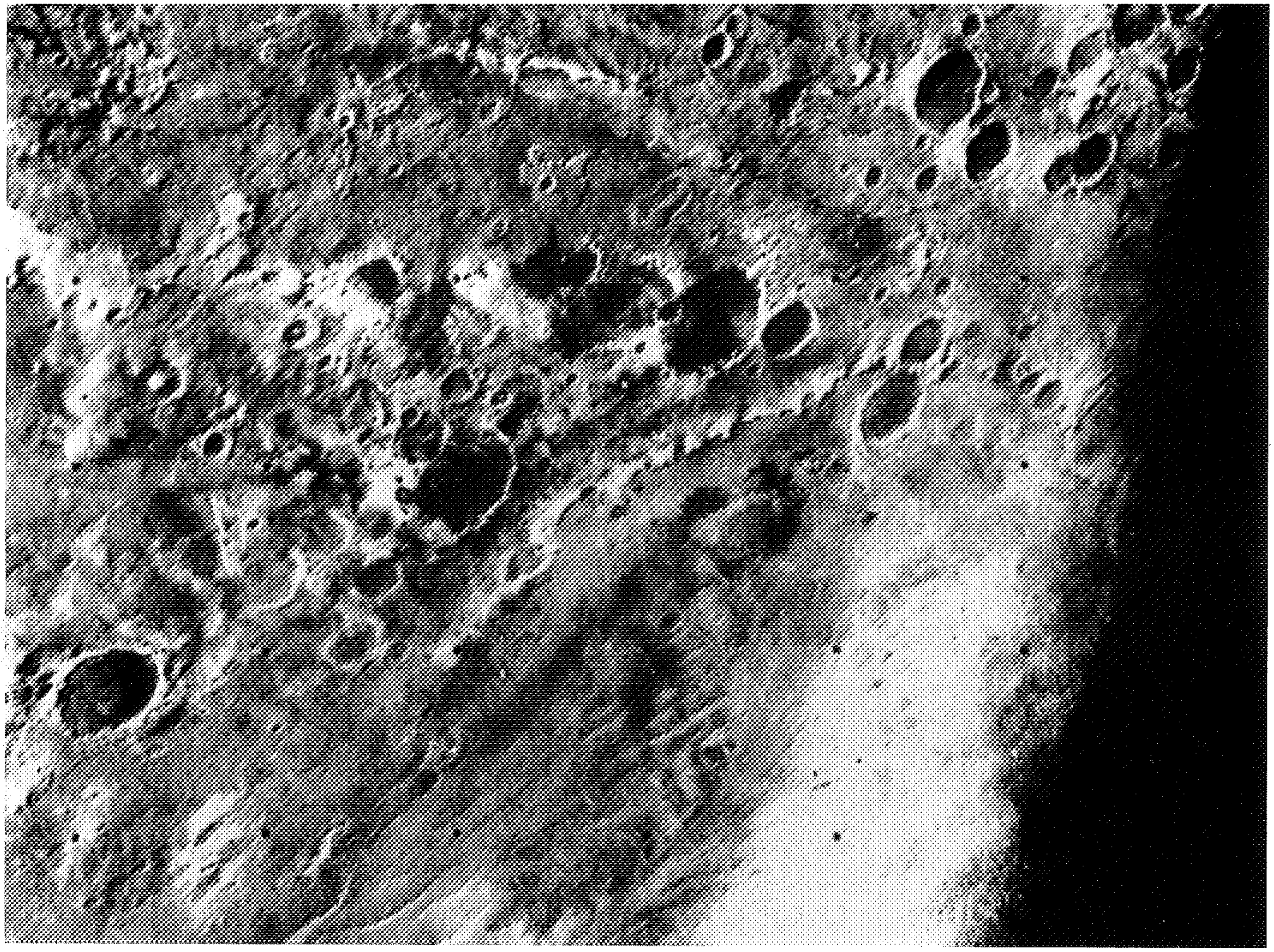
7N19 (opposite, top) displays a long, scalloped arc which stretches about 900 kilometers across the center of the picture and appears to separate the heavily cratered Cap areas from the sparsely cratered central ones. The nighttime terminator passes through the right side of this picture.

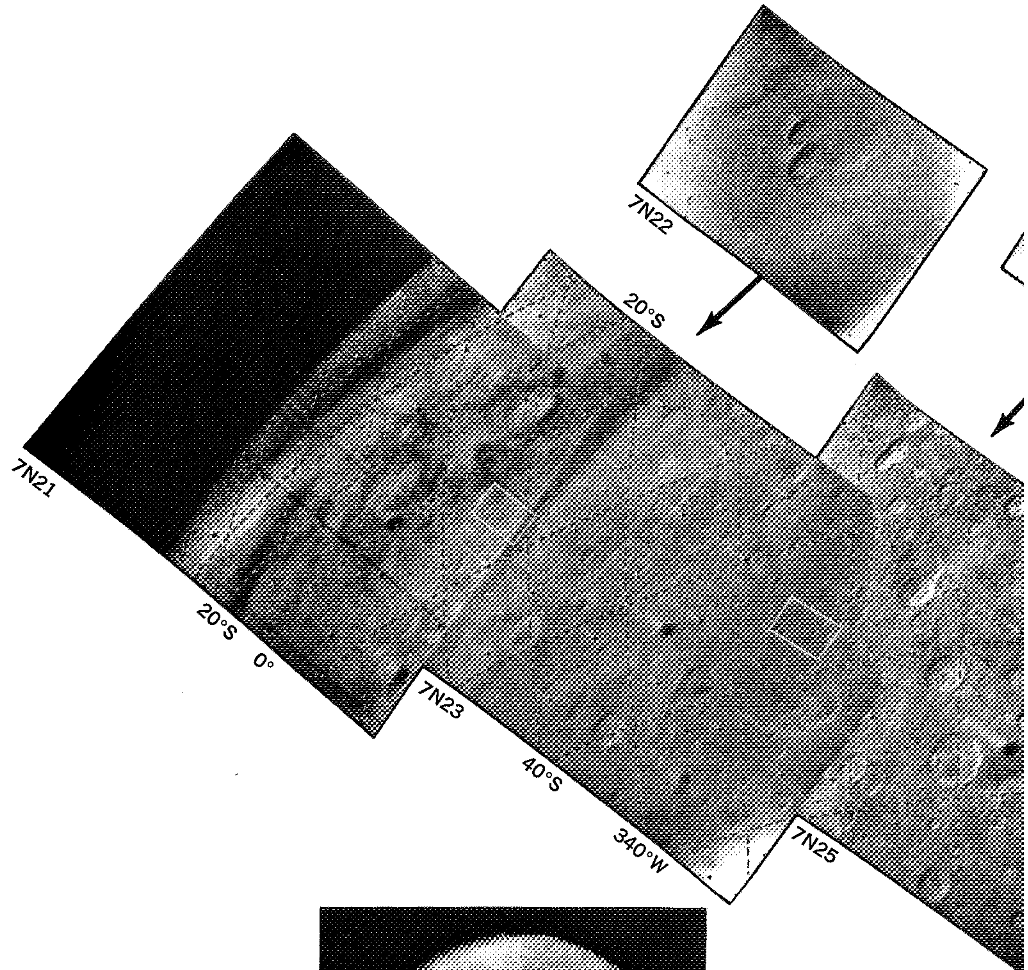
7N20 (opposite, bottom), the "giant's footprint," is a feature straddling the scalloped arc seen in 7N19.

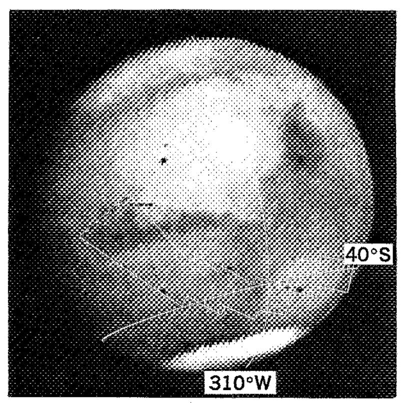
Enhanced photometric version



7N19



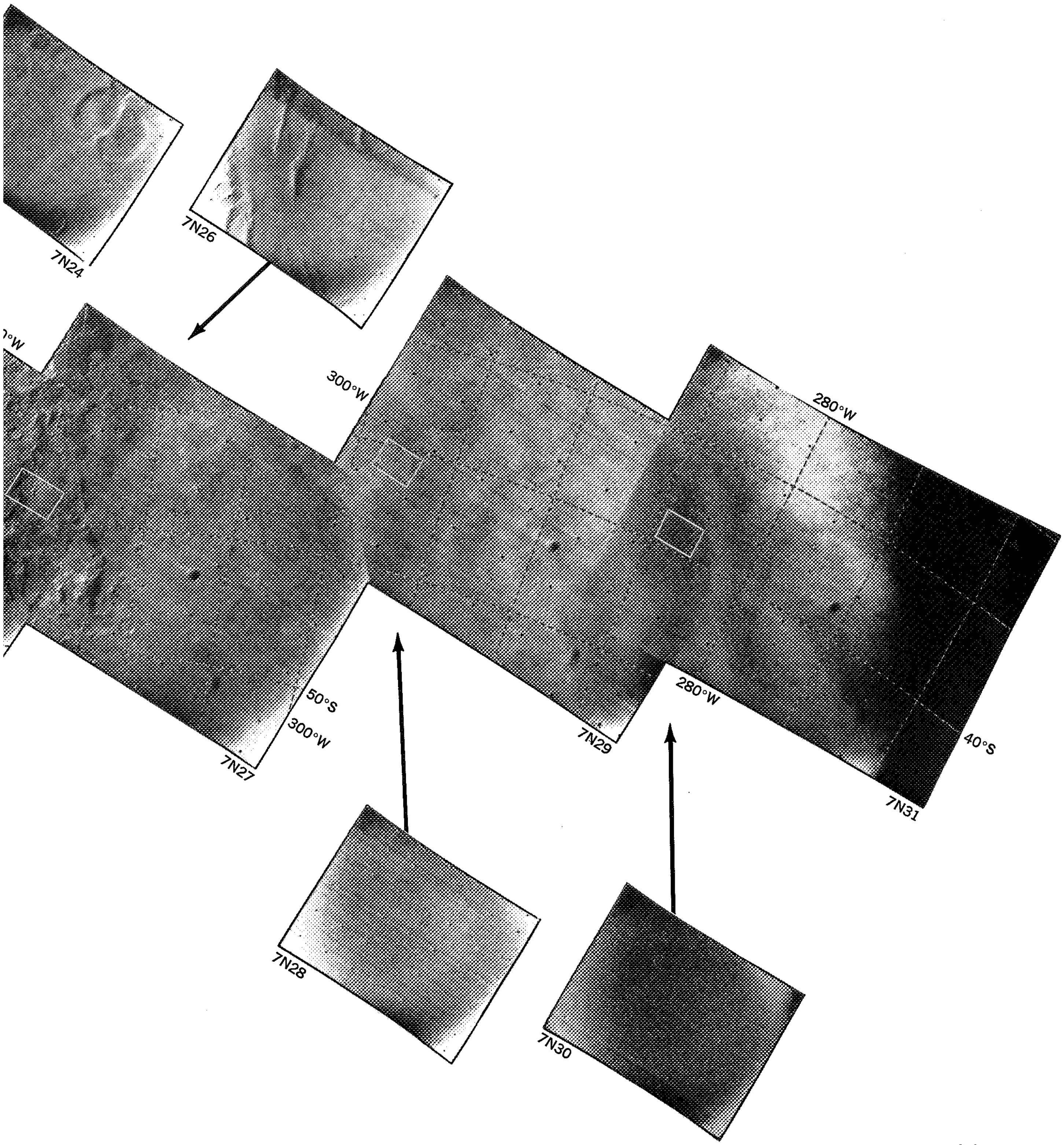


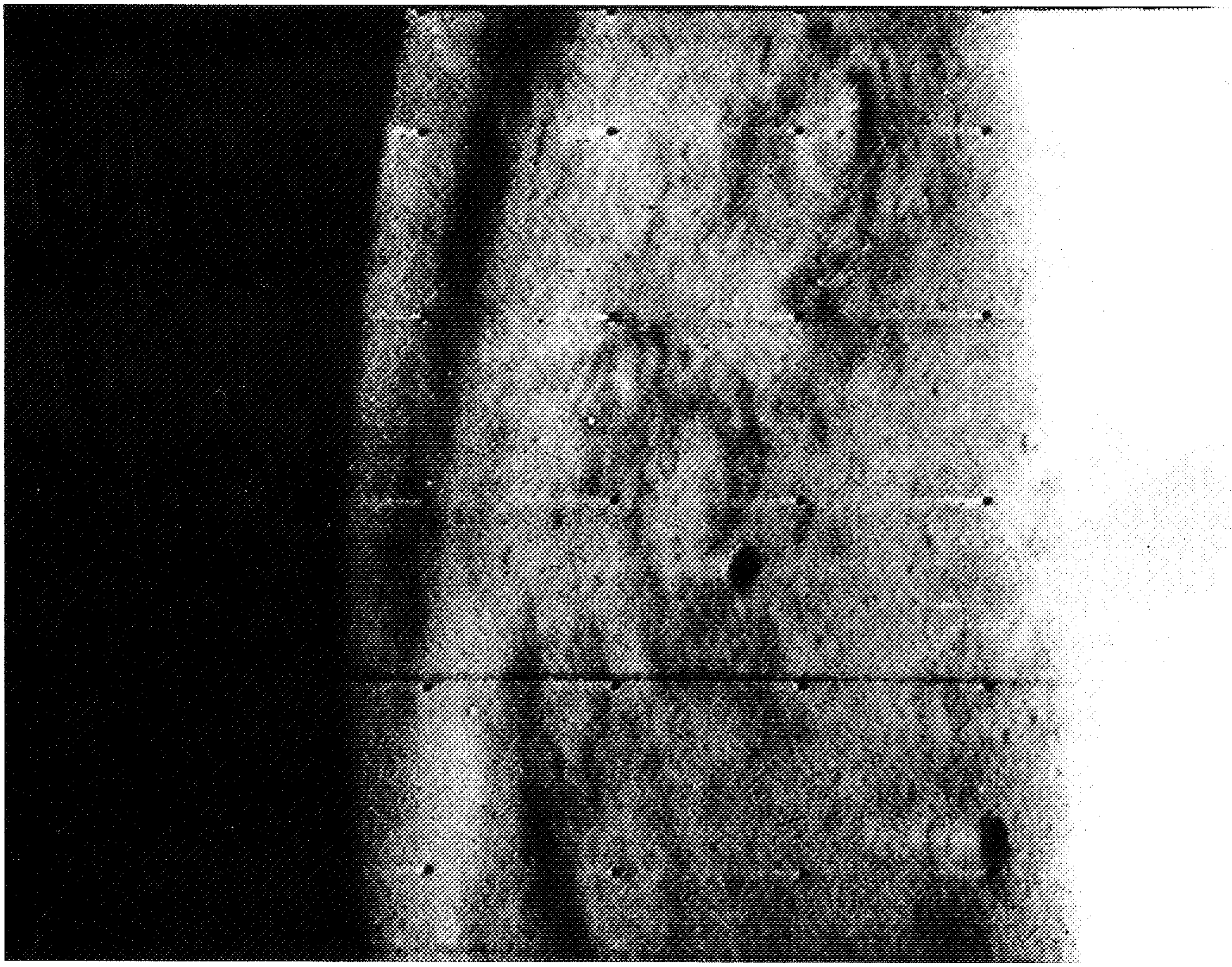


7N66

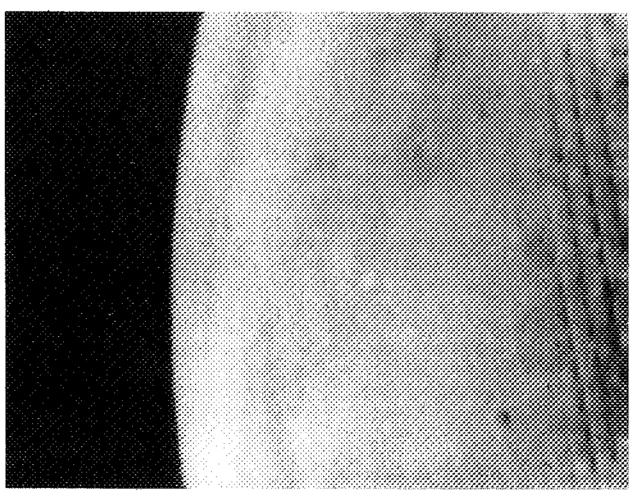
7N21-32, Noachis-Hellas

After passing beyond the Polar Cap terminator, the cameras were pointed northward and back toward the limb again. The next eleven pictures showed additional cratered areas plus a new type of terrain, which has been described as featureless, in the floor of Hellas. As seen in far encounter (e.g., 6F46), Hellas is a large circular area that appears bright throughout its crossing from terminator to limb.


7N24
7N26
300°W
280°W
50°S
300°W
7N27
280°W
7N29
40°S
7N31
7N28
7N30

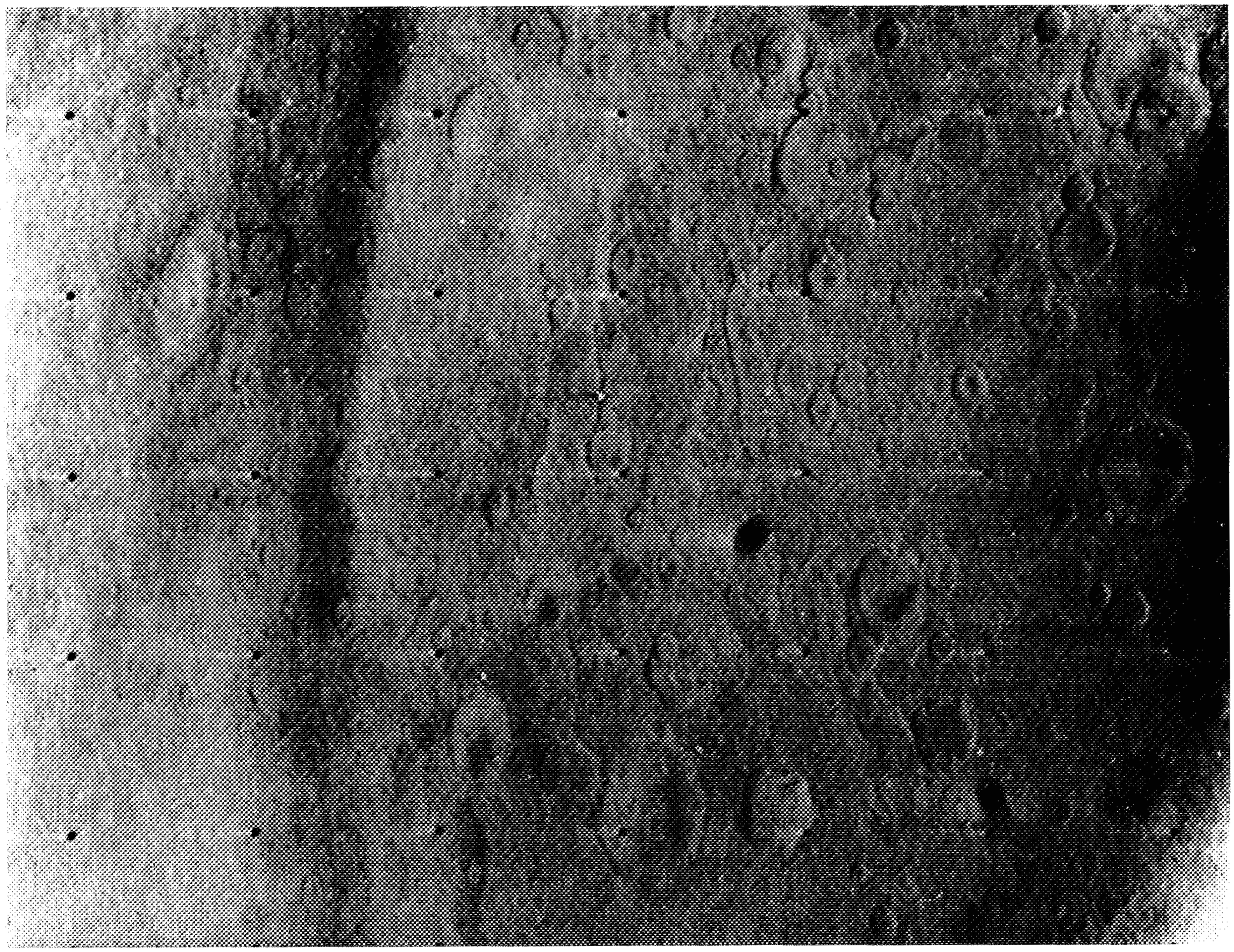


Enhanced photometric version

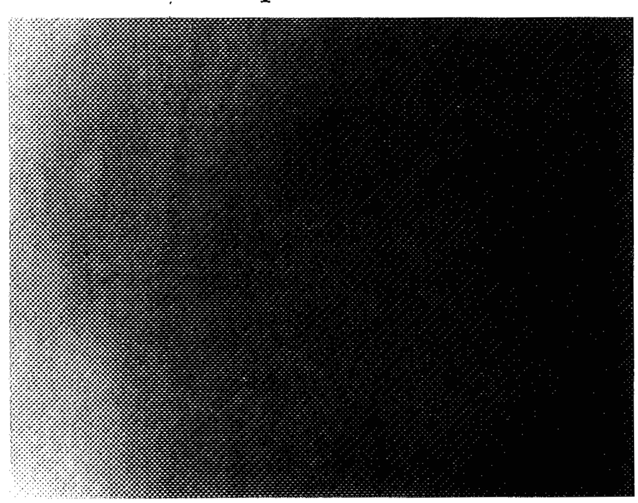


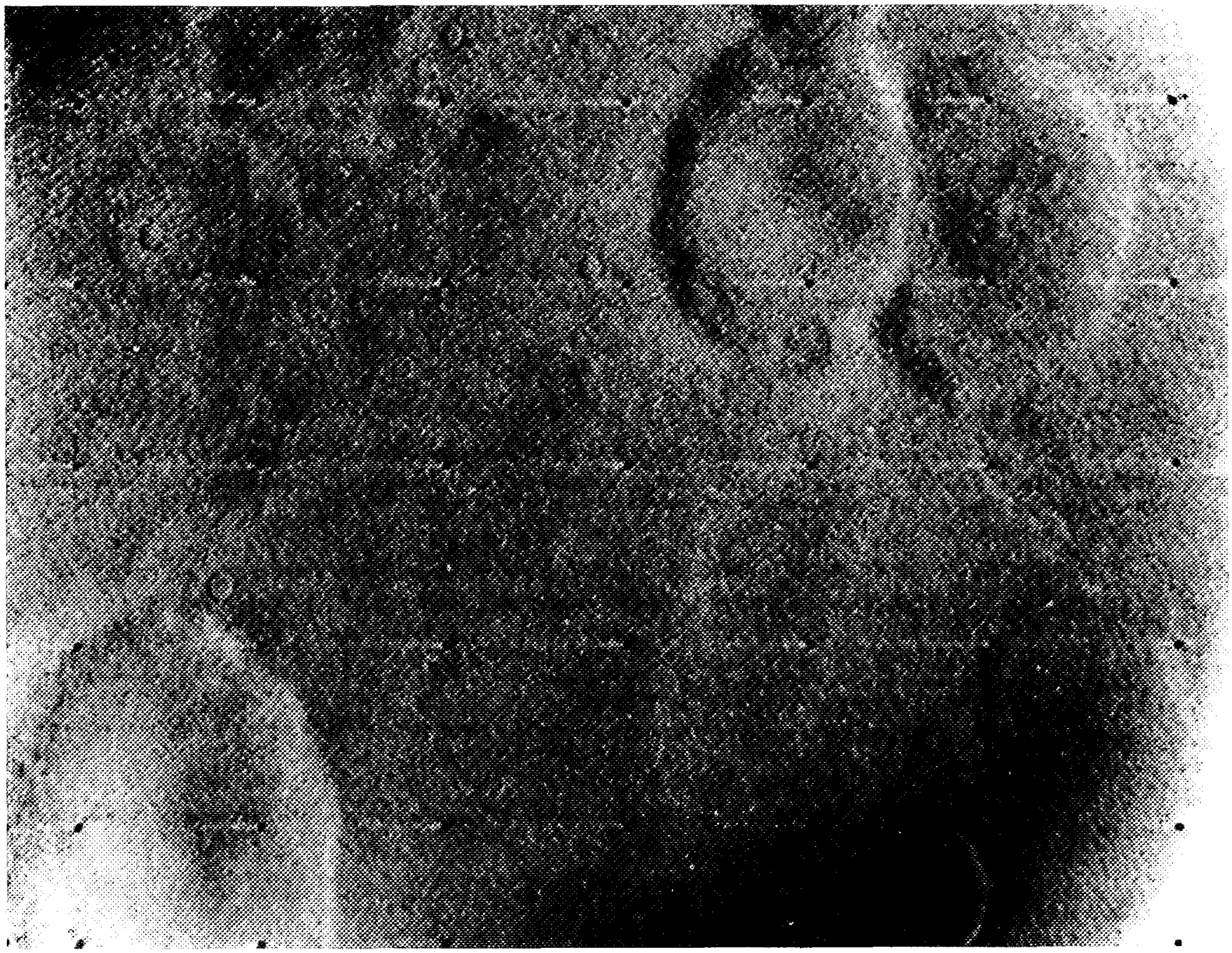
7N21 (opposite), our final view of the limb, looks north toward Meridiani Sinus, the dark area near the horizon. At bottom is an enhanced photometric version of 7N21.

7N22 (above), highly foreshortened, shows some indistinct craters and subtle linear markings.



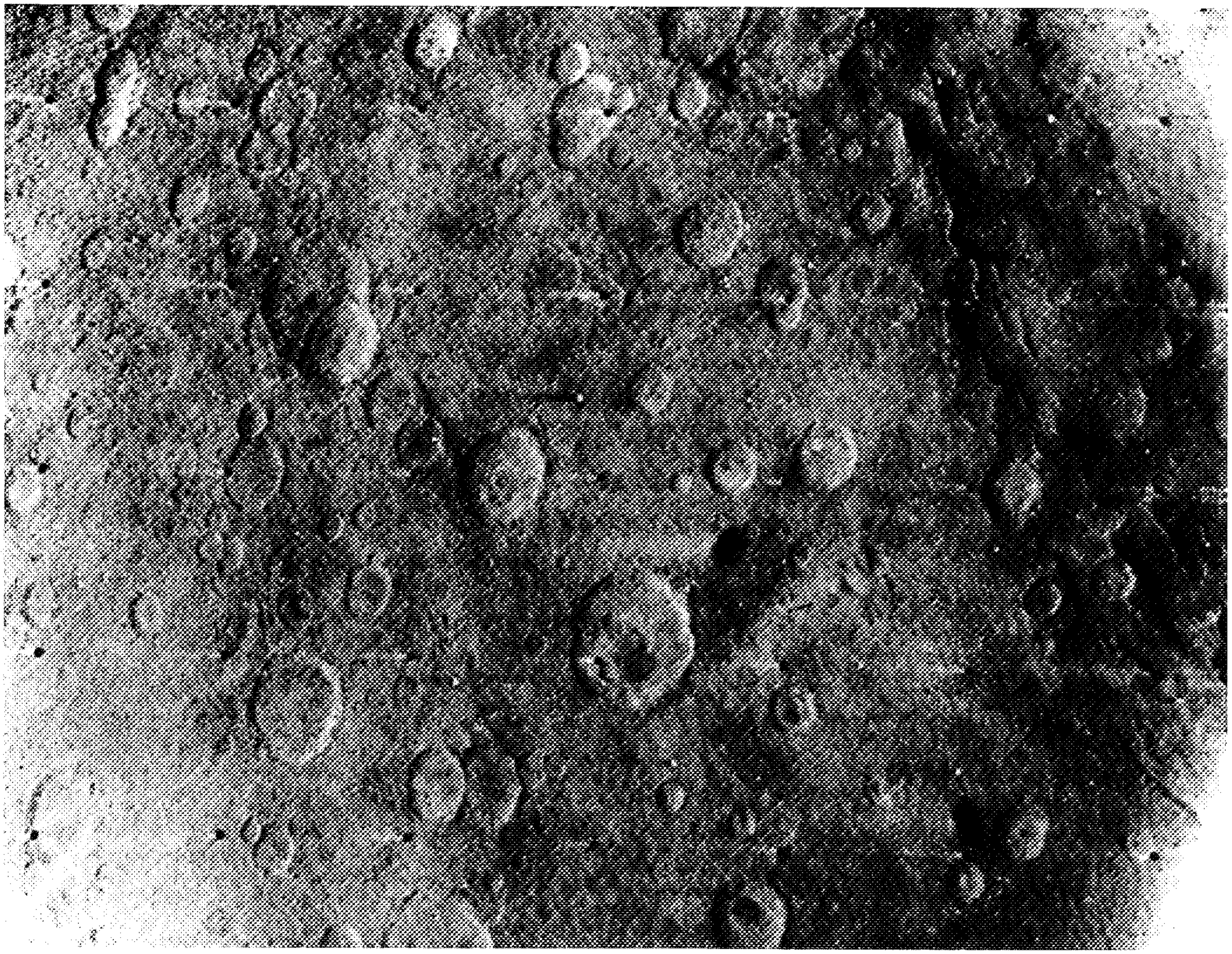
Enhanced photometric version



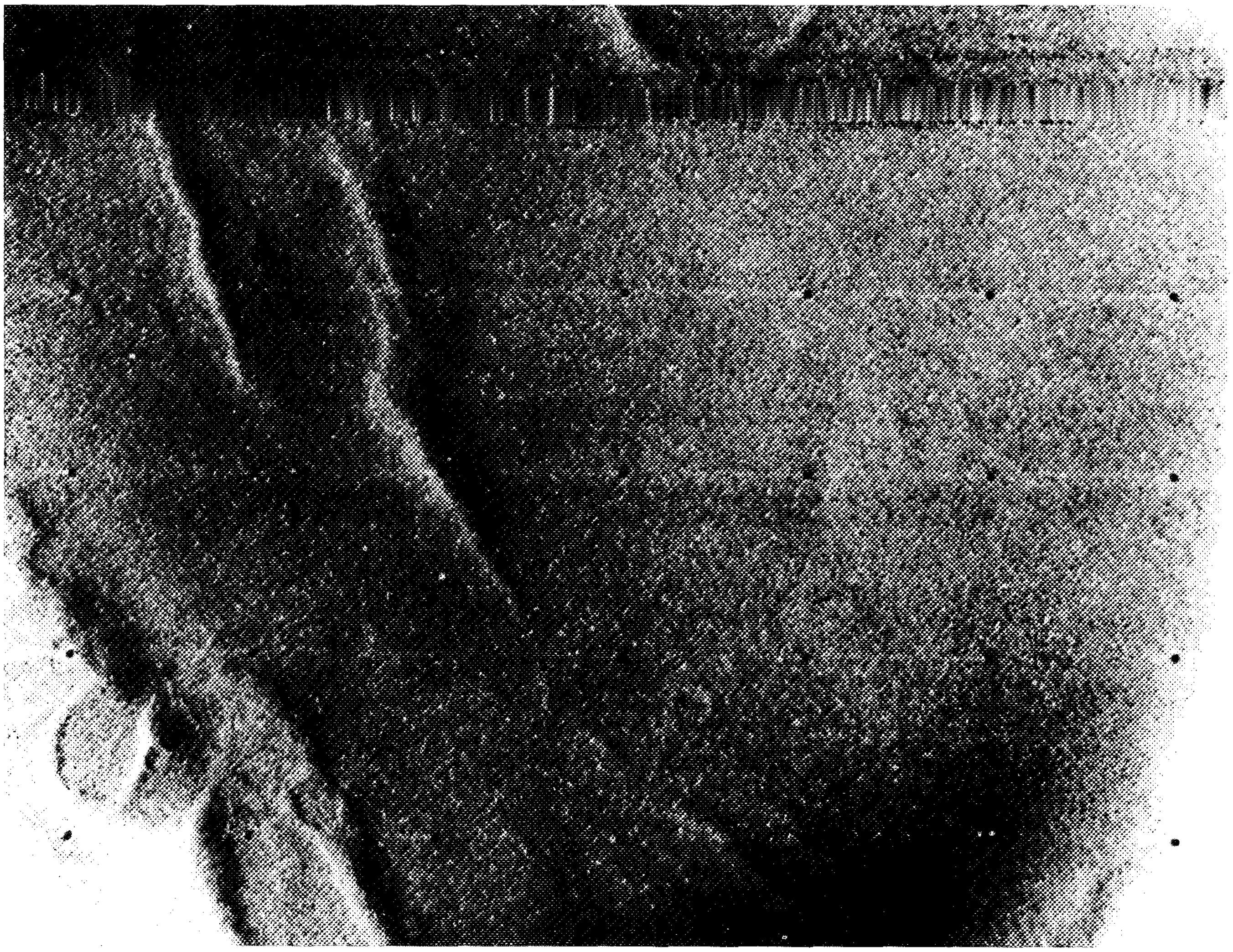


7N23 (opposite) includes much of Noachis. Craters seen here do not appear to differ significantly from those in Mariner 6 pictures. At bottom is an enhanced photometric version of 7N23.

7N24 (above) reveals more flat-bottomed craters.

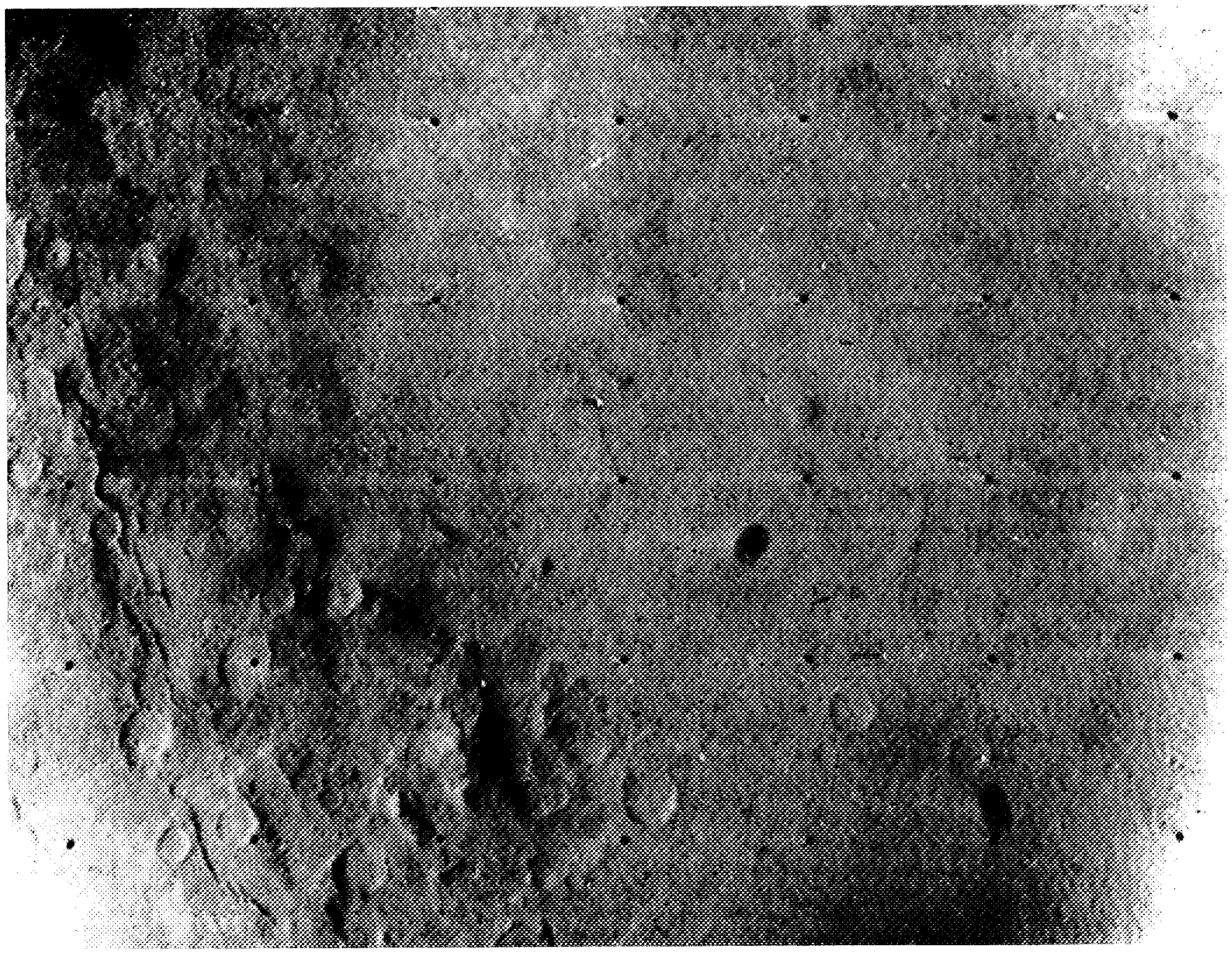


Enhanced photometric version

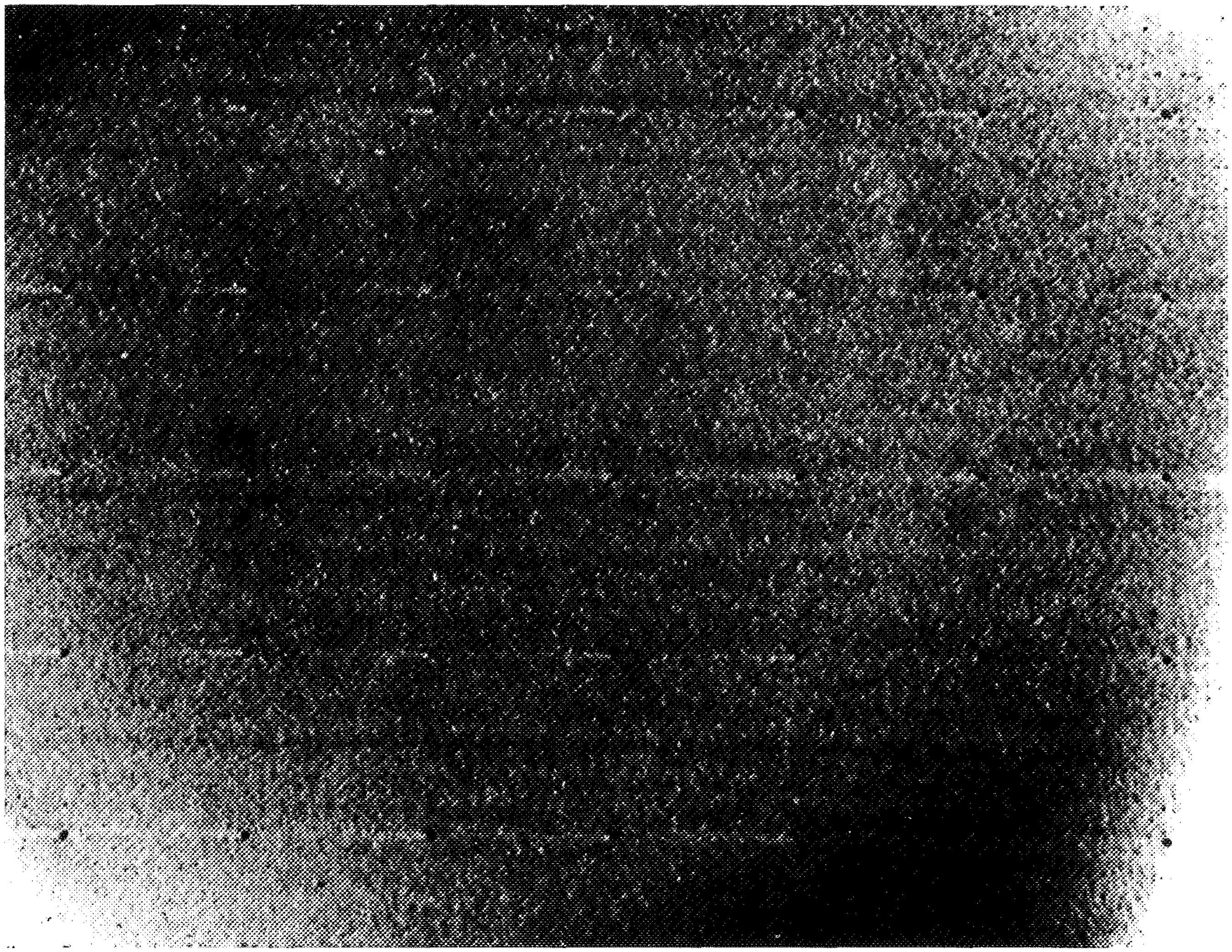


7N25 (opposite) offers an interesting view of the transitional area between cratered terrain and Hellas. The diagonal ridges in the upper right corner characterize a gentle downward slope to the lower floor of Hellas, in the extreme corner. At bottom is an enhanced photometric version of 7N25.

7N26 (above) is a high-resolution picture of these ridges and shows an otherwise largely smooth surface. Notice that the ridges appear to predate the craters in the lower left corner because the craters, like those seen in 7N25, interrupt the ridges and are apparently not controlled by the ridges.

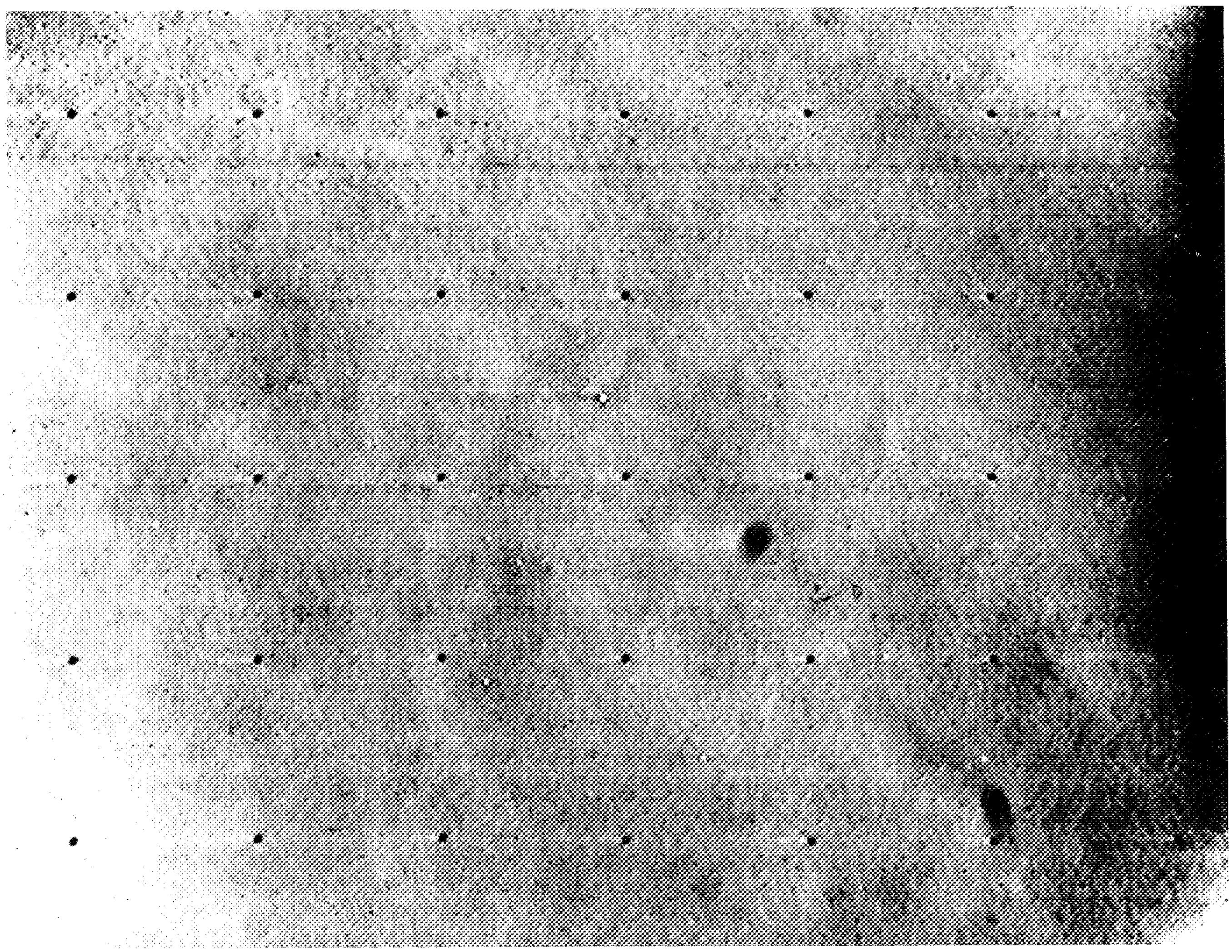


Enhanced photometric version

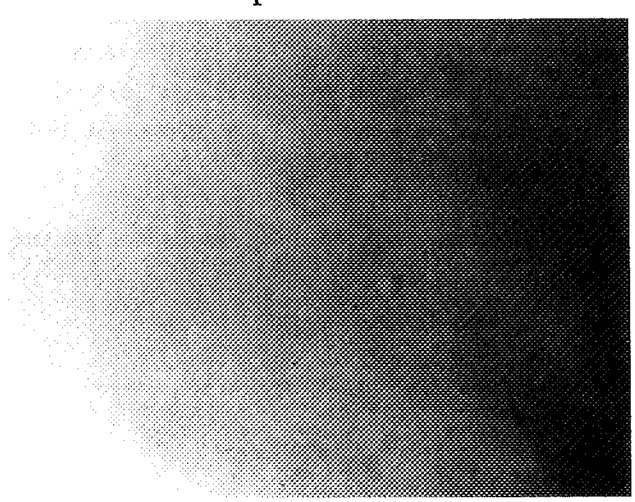


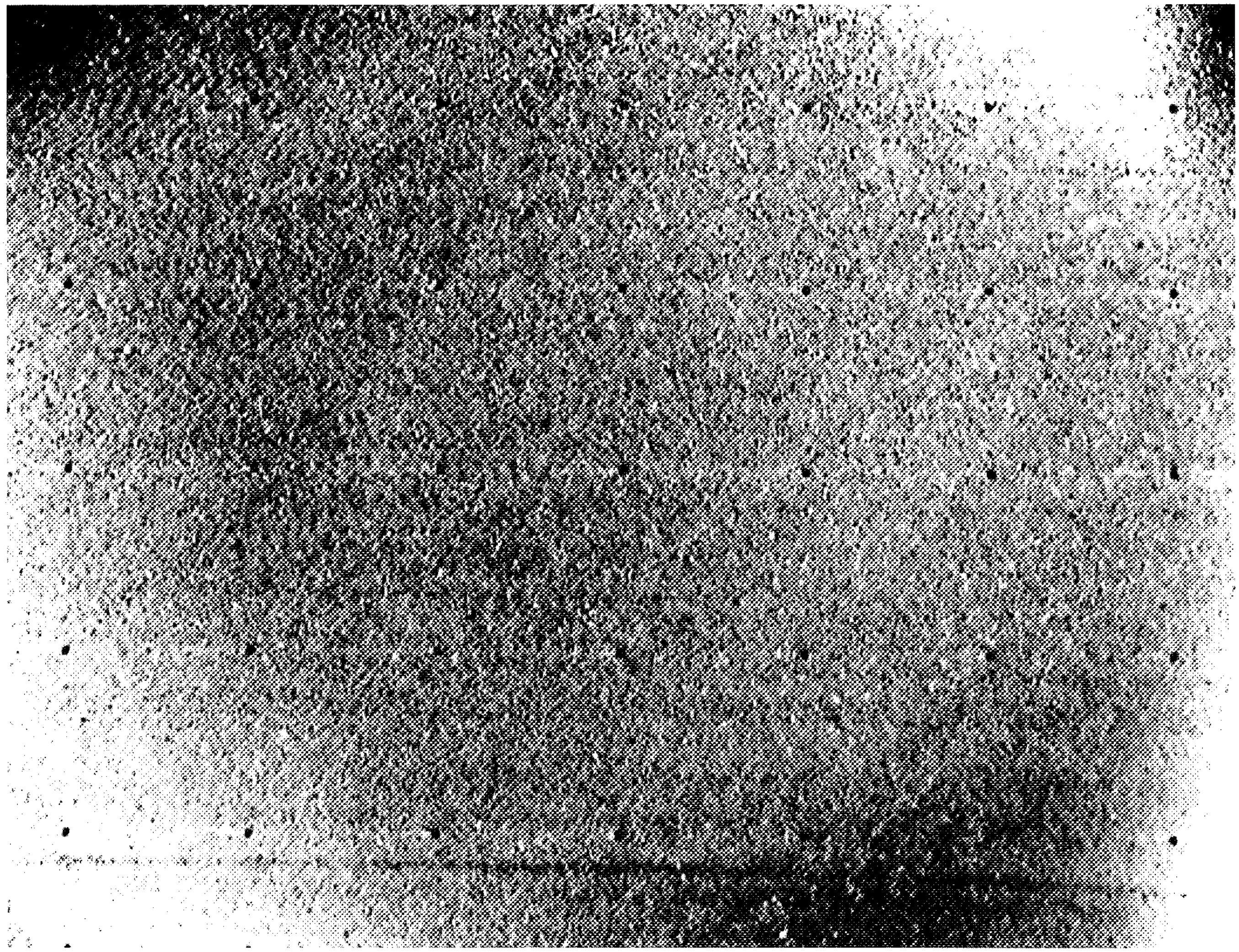
7N27 (opposite) shows the distinctively featureless floor of Hellas. Three craters are visible near the western boundary, but none are clearly identified further into Hellas. Apparently, some process is operating, or has operated, in Hellas which either prevents the formation of craters or erases such craters as they form. At bottom is an enhanced photometric version of 7N27.

7N28 (above) is evidence of the lack of visible features at a resolution of approximately 500 meters.



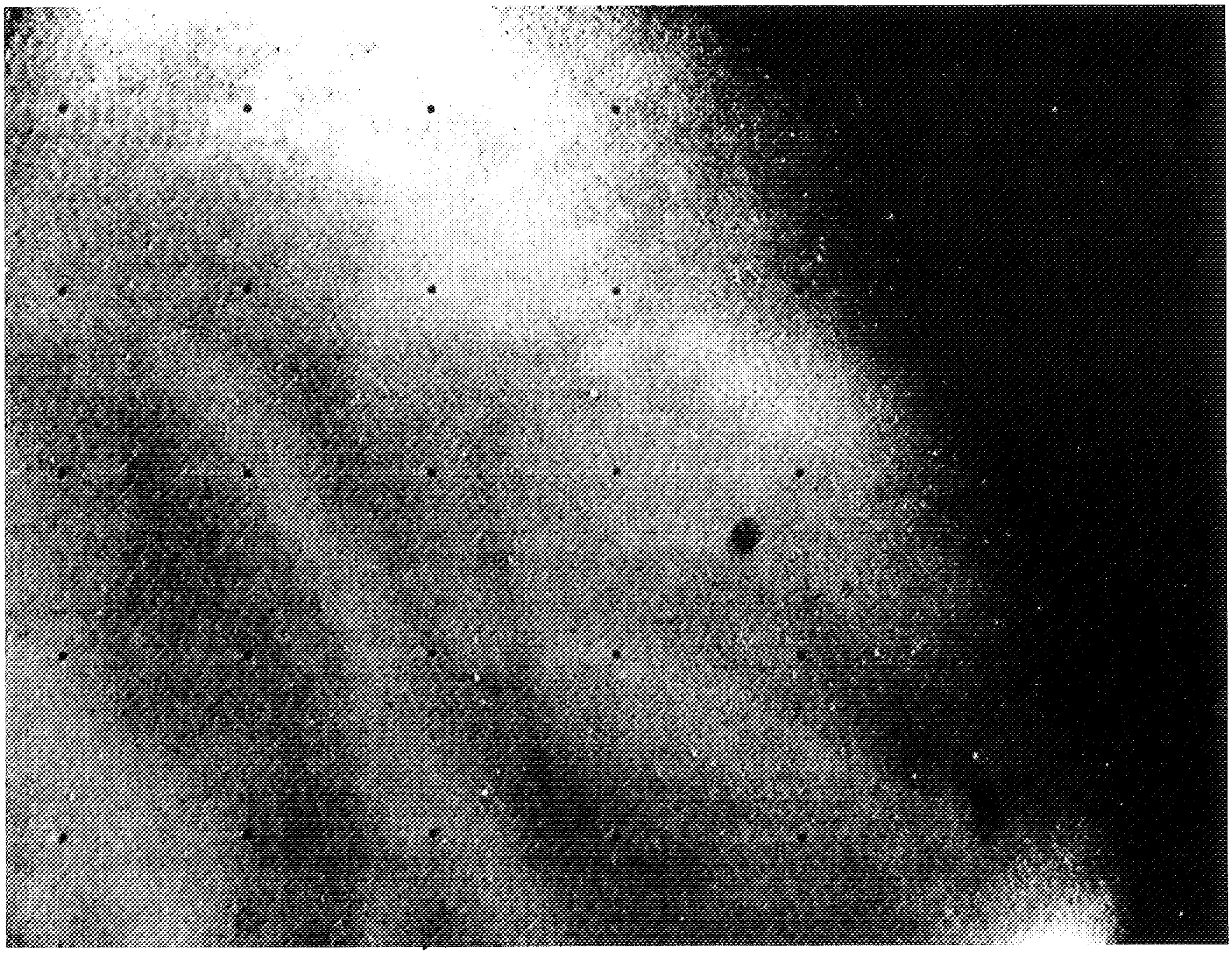
Enhanced photometric version



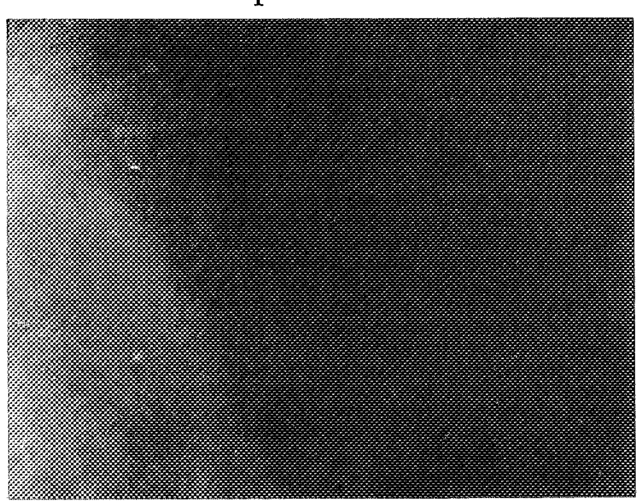


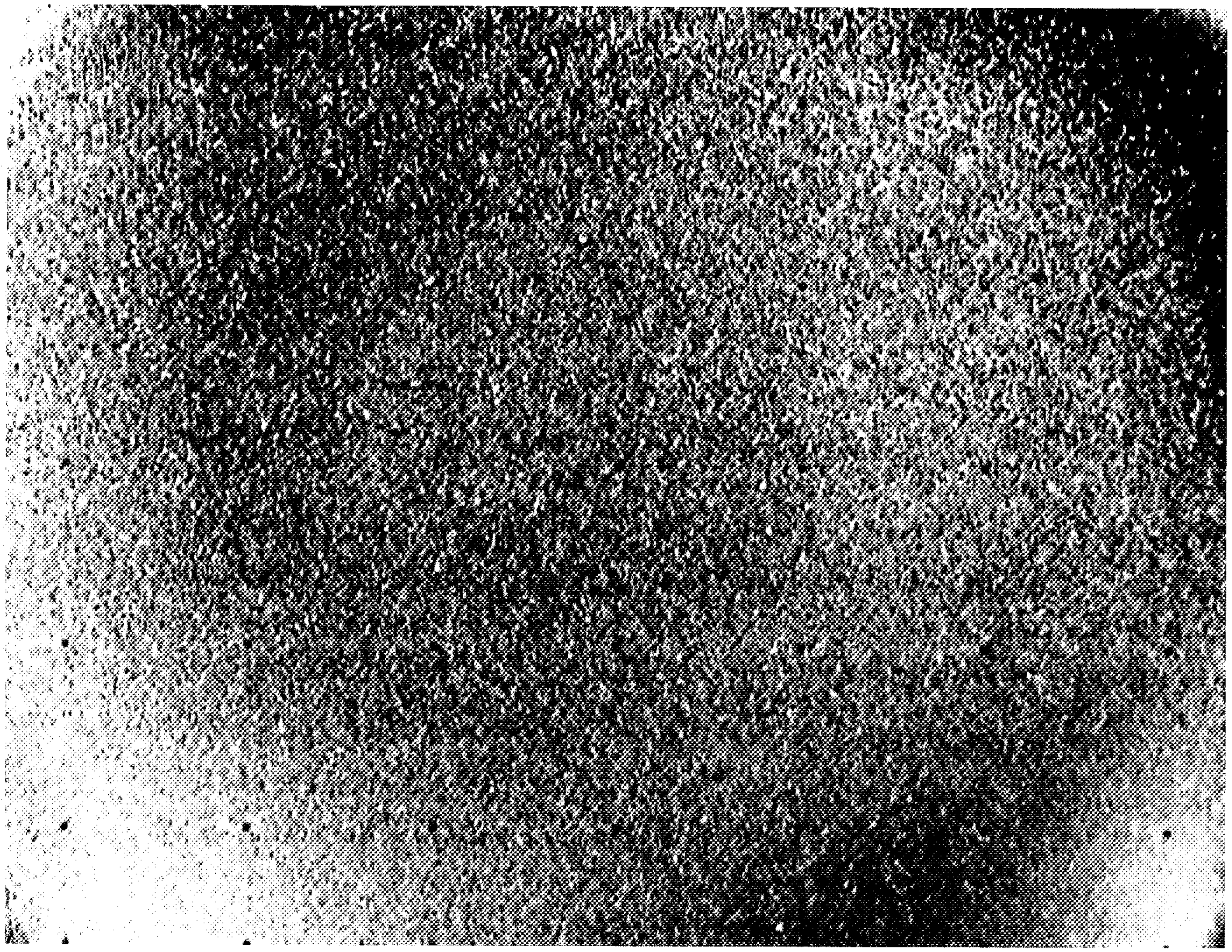
7N29 (opposite) covers more of the Hellas floor. At bottom is an enhanced photometric version of 7N29.

7N30 (above) supports the evidence of 7N28.



Enhanced photometric version





7N31 (opposite) shows that even at the very low solar elevation angle of 8 degrees there are no identifiable features. At bottom is an enhanced photometric version of 7N31.

7N32 (above), like 7N31, shows the lack of identifiable features on the floor of Hellas.

CHAPTER 5

Summary

Since the seventeenth century, Mars has captivated man's imagination. From rudimentary knowledge, man has imagined that Mars, of all the planets, most closely resembles Earth and is perhaps capable of supporting life. Mariner 4 abruptly reversed these visions and suggested that perhaps Mars, heavily cratered and lacking Earth's dense atmosphere and strong magnetic field, more closely resembled the Moon. The Mariner 6 and 7 flights have finally revealed a unique Martian character, distinctly different from that of either the Earth or the Moon.

Martian crater shapes and size distributions differ significantly from the lunar counterparts. Chaotic terrain appears unlike anything recognized on either the Moon or the Earth; and featureless terrain has no lunar equivalent. Dramatic Polar Cap pictures reveal long ridges and irregular depressions of unknown nature and origin. Clearly, the handiwork of uniquely Martian phenomena is evidenced on the surface.

Tenuous, patchy layers of haze are seen in the atmosphere above local regions of Mars. Mars' larger moon, Phobos, is found to be the darkest object yet identified in the solar system.

Finally, Earthlings' views of Martian "life" have undergone major evolution. Lowell's canal-constructing race can finally be abandoned. However, this does not eliminate the possibility that simpler microbial life may have developed; nor does it diminish the importance of learning whether life of any kind has ever existed or presently exists on the planet. In this connection, Dr. Norman Horowitz has warned ". . . . it should be noted that if Mars is to be a testing ground for our notions about the origin of life, we must avoid using these same notions to disprove in advance the possibility of life on the planet."

These 200 Mariner 6 and 7 pictures, taken in a brief span of 8 days, have told us much about our planetary neighbor and have raised many new questions whose answers await the discoveries of future missions.

Bibliography

Glasstone, S., *The Book of Mars*, NASA-SP-179. National Aeronautics and Space Administration, Washington, D.C., 1968.

Leighton, R. B., et al., "Mariner 6 and 7 Television Pictures: Preliminary Analysis," *Science*, Vol. 166, No. 3901, pp. 49–67, October 3, 1969.

Leighton, R. B., et al., "The Mariner 6 and 7 Pictures of Mars," Special Supplement, *Journal of Geophysical Research*, January 1971.

Mariner-Mars 1964, Final Project Report, NASA SP-139. National Aeronautics and Space Administration, Washington, D.C., 1967.

Mariner-Mars 1969, A Preliminary Report, NASA SP-225. National Aeronautics and Space Administration, Washington, D.C., 1969.

Slipher, E. C., *The Photographic Story of Mars*, Sky Publishing Corporation, Cambridge, Massachusetts, 1962.

Acknowledgments

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Appendix

FAR ENCOUNTER PHOTOREFERENCE TABLE

Picture number	Shutter direction	Range, km	Phase angle, °	Sub-spacecraft point Longitude, °W	Sub-spacecraft point Latitude	Kilometers/ pixel[a]
6F1	Bottom	1,244,221	21	100	−6	34.0
6F2	Bottom	1,228,388	21	109	−6	33.4
6F3	Bottom	1,212,556	21	117	−6	32.9
6F4	Bottom	1,196,724	21	126	−6	32.5
6F5	Top	1,180,281	21	136	−6	32.1
6F6	Top	1,164,448	21	145	−6	31.7
6F7	Top	1,148,615	21	153	−6	31.3
6F8	Top	1,132,782	21	162	−6	30.8
6F9	Bottom	1,116,342	21	172	−6	30.4
6F10	Bottom	1,100,507	21	181	−6	30.0
6F11	Bottom	1,083,790	21	190	−6	29.5
6F12	Top	1,068,232	21	199	−6	29.0
6F13	Top	1,052,399	21	208	−6	28.6
6F14	Top	1,036,568	21	217	−6	28.2
6F15	Top	1,020,733	21	226	−6	27.8
6F16	Bottom	1,004,291	21	235	−6	27.3
6F17	Bottom	988,457	21	244	−6	26.8
6F18	Bottom	972,624	21	253	−6	26.4
6F19	Top	956,181	21	262	−6	26.0
6F20	Top	940,347	21	271	−6	25.6
6F21	Top	924,514	21	280	−6	25.2
6F22	Top	908,679	21	289	−6	24.7
6F23	Bottom	892,236	21	298	−6	24.3
6F24	Bottom	876,402	21	307	−6	23.8
6F25	Bottom	860,568	21	316	−6	23.4
6F26	Bottom	844,733	21	325	−6	23.0
6F27	Top	828,289	21	334	−6	22.6
6F28	Top	812,455	21	343	−6	22.1
6F29	Top	796,619	21	352	−6	21.7
6F30	Bottom	780,175	21	1	−6	21.2
6F31	Bottom	764,339	21	10	−6	20.8
6F32	Bottom	748,454	21	19	−6	20.4
6F33	Bottom	732,667	21	28	−6	19.9
6F34	Bottom	568,196	21	120	−6	15.4
6F35	Bottom	540,171	21	136	−6	14.7

[a]6F1–33 and 7F0–67 are 480 pixels in width.
6F34–49 and 7F69–93 are 960 pixels in width.

FAR ENCOUNTER PHOTOREFERENCE TABLE (Contd)

Picture number	Shutter direction	Range, km	Phase angle, °	Sub-spacecraft point		Kilometers/ pixel[a]
				Longitude, °W	Latitude	
6F36	Top	512,753	21	151	−6	13.9
6F37	Top	484,723	21	167	−6	13.1
6F38	Bottom	457,301	21	182	−6	12.4
6F39	Bottom	429,267	21	198	−6	11.6
6F40	Bottom	401,840	21	213	−6	10.9
6F41	Bottom	401,231	21	214	−6	10.9
6F42	Bottom	376,849	21	227	−6	10.2
6F43	Bottom	352,463	21	241	−6	9.5
6F44	Bottom	328,075	21	255	−6	8.8
6F45	Top	304,293	21	268	−6	8.2
6F46	Top	279,898	21	282	−6	7.5
6F47	Top	255,498	21	295	−7	6.9
6F48	Top	231,092	21	309	−7	6.2
6F49	Top	206,680	21	322	−7	5.5
7F0	Top	1,844,034	22	50	−4	50.3
7F1	Bottom	1,720,371	22	121	−4	46.9
7F3	Top	1,697,072	22	134	−4	46.3
7F4	Bottom	1,685,722	22	141	−4	46.0
7F5	Top	1,674,371	22	147	−4	45.7
7F6	Bottom	1,663,021	22	154	−4	45.3
7F7	Top	1,651,670	22	160	−4	45.0
7F8	Bottom	1,640,320	22	167	−4	44.7
7F9	Bottom	1,628,371	22	173	−4	44.4
7F10	Top	1,617,023	22	180	−4	44.1
7F11	Bottom	1,605,671	22	186	−4	43.8
7F12	Top	1,594,321	22	193	−4	43.5
7F13	Bottom	1,582,971	22	199	−4	43.2
7F14	Top	1,571,621	22	206	−4	42.9
7F15	Top	1,559,673	22	213	−4	42.5
7F16	Bottom	1,548,323	22	219	−4	42.2
7F17	Top	1,536,973	22	226	−4	41.9
7F18	Bottom	1,525,623	22	233	−4	41.6
7F19	Top	1,514,167	22	239	−4	41.3
7F20	Bottom	1,502,923	22	246	−4	41.0
7F21	Bottom	1,490,977	22	252	−4	40.7
7F22	Top	1,479,626	22	259	−4	40.4
7F23	Bottom	1,468,279	22	265	−4	40.1

FAR ENCOUNTER PHOTOREFERENCE TABLE (Contd)

Picture number	Shutter direction	Range, km	Phase angle, °	Sub-spacecraft point		Kilometers/ pixel[a]
				Longitude, °W	Latitude	
7F24	Top	1,453,533	22	272	−4	39.8
7F25	Bottom	1,445,577	22	278	−4	39.4
7F26	Top	1,433,630	22	285	−4	39.1
7F27	Top	1,422,281	22	292	−4	38.8
7F28	Bottom	1,410,931	22	298	−4	38.5
7F29	Top	1,399,581	22	305	−4	38.2
7F30	Bottom	1,388,233	22	311	−4	37.9
7F31	Top	1,376,882	22	318	−4	37.6
7F32	Top	1,364,937	22	325	−4	37.3
7F33	Bottom	1,353,586	22	331	−4	37.0
7F35	Bottom	1,199,474	23	60	−4	32.8
7F36	Top	1,184,540	23	68	−4	32.4
7F37	Top	1,169,009	23	77	−4	31.9
7F38	Bottom	1,154,076	22	86	−4	31.5
7F39	Bottom	1,138,545	22	95	−4	31.1
7F40	Top	1,123,613	23	103	−4	30.7
7F41	Top	1,108,081	23	112	−4	30.3
7F42	Top	1,092,551	23	121	−4	29.9
7F43	Bottom	1,077,617	23	130	−4	29.5
7F44	Bottom	1,062,086	23	139	−4	29.0
7F45	Top	1,047,152	23	147	−4	28.6
7F46	Top	1,031,621	23	156	−4	28.2
7F47	Bottom	1,016,687	23	165	−4	27.8
7F48	Bottom	1,001,156	23	174	−4	27.3
7F49	Bottom	985,625	23	183	−4	26.9
7F50	Top	970,691	23	191	−4	26.5
7F51	Top	955,160	23	200	−4	26.1
7F52	Bottom	940,225	23	209	−4	25.7
7F53	Bottom	924,693	23	218	−4	25.3
7F54	Top	909,759	23	226	−4	24.8
7F55	Top	894,227	23	235	−4	24.4
7F56	Top	878,695	23	244	−4	24.0
7F57	Bottom	863,760	23	253	−4	23.6
7F58	Bottom	848,227	23	261	−4	23.2
7F59	Top	833,292	23	270	−4	22.8
7F60	Top	817,760	23	279	−4	22.4
7F61	Bottom	803,248	23	287	−4	22.0

FAR ENCOUNTER PHOTOREFERENCE TABLE (Contd)

Picture number	Shutter direction	Range, km	Phase angle, °	Sub-spacecraft point		Kilometers/ pixel[a]
				Longitude, °W	Latitude	
7F62	Bottom	787,291	23	296	−4	21.5
7F63	Top	772,355	23	305	−4	21.1
7F64	Top	756,821	23	314	−4	20.7
7F65	Top	741,287	23	323	−4	20.3
7F66	Bottom	726,351	23	331	−4	19.9
7F67	Bottom	710,816	23	340	−4	19.4
7F69	Bottom	535,132	23	81	−4	14.6
7F70	Bottom	514,811	23	93	−4	14.0
7F71	Top	495,087	23	104	−4	13.5
7F72	Top	474,764	23	116	−4	12.9
7F73	Bottom	455,037	23	127	−4	12.4
7F74	Top	435,309	23	138	−4	11.9
7F75	Top	414,982	23	150	−4	11.3
7F76	Bottom	395,251	23	161	−4	10.8
7F77	Bottom	374,920	23	173	−4	10.2
7F78	Top	355,185	23	184	−4	9.7
7F79	Bottom	335,449	23	195	−5	9.1
7F80	Bottom	315,112	23	207	−5	8.6
7F81	Top	295,370	23	218	−5	8.0
7F82	Bottom	275,625	22	230	−5	7.5
7F83	Bottom	255,279	22	241	−5	6.9
7F84	Top	235,527	22	252	−5	6.4
7F85	Top	215,173	22	264	−5	5.8
7F86	Bottom	195,412	22	275	−5	5.3
7F87	Top	175,645	22	286	−5	4.8
7F88	Top	155,273	22	298	−6	4.2
7F89	Top	150,478	22	300	−6	4.0
7F90	Bottom	145,084	22	304	−6	3.9
7F91	Bottom	140,288	22	306	−6	3.7
7F92	Top	134,892	22	309	−6	3.6
7F93	Top	130,095	22	312	−6	3.5

NEAR ENCOUNTER PHOTOREFERENCE TABLE

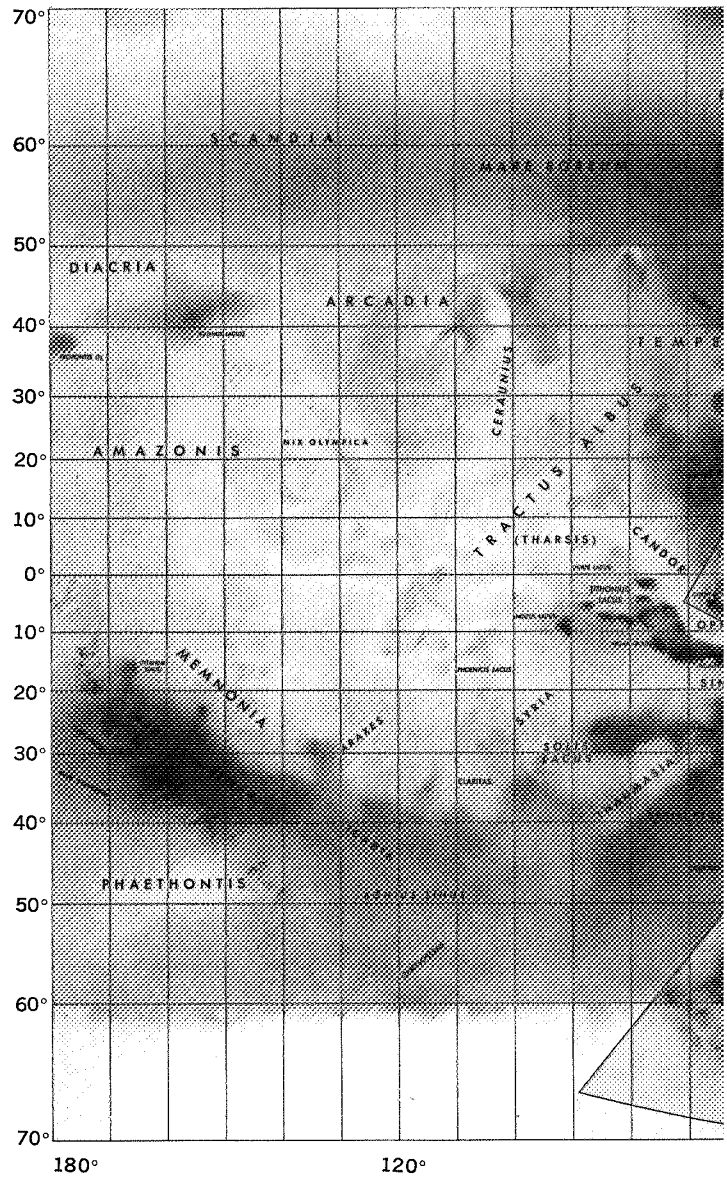
Picture number	Shutter or filter	Data at center of picture						Picture dimension on surface, km	
		Slant range, km	Phase angle, °	Solar elevation angle, °	Viewing angle, °	Longi-tude, °W	Latitude, °	Horizontal	Vertical
6N1[a]	Blue	6621	44	88	45	53	−6	—	1292
6N2	Top	7389	52	71	70	67	4	551	143
6N3	Green	6598	52	83	57	56	−2	—	1324
6N4	Bottom	6159	52	85	51	50	−5	238	118
6N5	Red	5699	52	79	42	43	−8	2283	1127
6N6	Top	5355	52	73	37	37	−10	162	103
6N7	Green	5030	51	66	30	31	−13	1492	990
6N8	Bottom	4778	52	61	25	26	−14	128	92
6N9	Blue	4930	51	49	41	14	0	1511	1228
6N10	Top	4727	52	44	39	10	−1	123	111
6N11	Green	4541	51	39	37	4	−3	1177	1124
6N12	Bottom	4428	52	35	38	0	−3	109	107
6N13	Red	4331	52	29	40	354	−4	1090	1130
6N14	Top	4903	80	71	62	37	−13	253	94
6N15	Green	4404	80	60	50	26	−16	2202	865
6N16	Bottom	4105	80	52	42	18	−17	123	79
6N17	Blue	3865	80	44	34	10	−18	1270	756
6N18	Top	3746	80	38	31	4	−16	105	73
6N19	Green	3617	80	31	25	357	−17	983	718
6N20	Bottom	3546	80	24	21	351	−16	91	69
6N21	Red	3501	80	20	17	345	−16	889	697
6N22	Top	3498	80	14	15	340	−15	86	69
6N23	Green	3522	80	8	15	334	−14	880	706
6N24	Bottom	3584	80	3	18	328	−13	88	71
7N1[a]	Blue	8725	37	79	44	9	−5	—	1767
7N2[a]	Top	9766	43	58	75	13	20	—	201
7N3	Green	9118	44	67	67	59	12	—	2144
7N4	Bottom	8492	44	75	59	5	4	401	162
7N5	Red	7995	44	82	52	3	−2	—	1598
7N6	Top	7552	44	88	46	359	−7	269	144
7N7	Green	7136	44	85	41	356	−12	3143	1406
7N8	Bottom	6774	44	80	36	353	−17	203	130
7N9	Blue	6443	44	74	31	350	−21	1989	1272

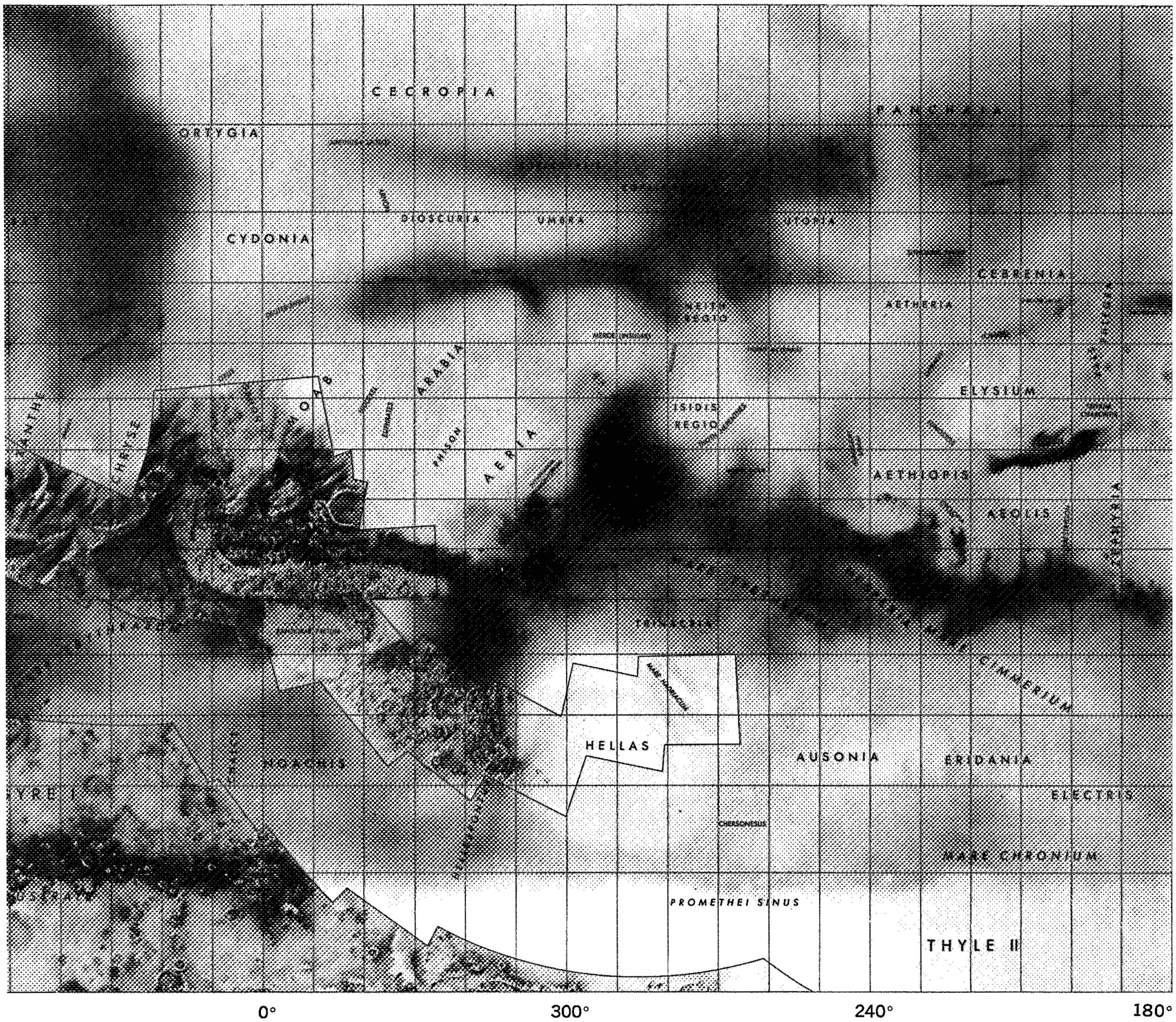
[a]For this limb picture, the picture center was not on the planet. Therefore, the data given here is for the point at the center of the right edge of the frame.

NEAR ENCOUNTER PHOTOREFERENCE TABLE (Contd)

Picture number	Shutter or filter	Data at center of picture						Picture dimension on surface, km	
		Slant range, km	Phase angle, °	Solar elevation angle, °	Viewing angle, °	Longitude, °W	Latitude, °	Horizontal	Vertical
7N10	Top	6693	35	39	48	33	−54	168	190
7N11	Green	6381	35	38	45	27	−57	1650	2025
7N12	Bottom	6095	35	36	43	21	−61	149	159
7N13	Red	5886	35	34	43	17	−65	1512	1690
7N14	Top	5662	35	31	42	9	−68	142	143
7N15	Green	5495	35	28	43	1	−71	1484	1513
7N16	Bottom	5318	35	25	43	349	−74	141	132
7N17	Blue	5195	35	21	45	334	−77	1549	1394
7N18	Top	5069	35	18	46	314	−77	148	124
7N19	Green	5013	35	13	49	291	−78	1837	1356
7N20	Bottom	4971	35	8	53	269	−75	172	124
7N21	Red	5337	80	76	66	354	−21	—	1066
7N22	Top	4818	80	66	56	346	−28	210	92
7N23	Green	4431	80	57	47	339	−34	1951	868
7N24	Bottom	4154	80	49	40	331	−38	132	80
7N25	Blue	3938	80	43	34	324	−42	1218	773
7N26	Top	3778	80	36	29	316	−44	104	73
7N27	Green	3656	80	31	24	308	−46	989	723
7N28	Bottom	3679	80	24	28	298	−41	94	77
7N29	Red	3633	80	19	26	291	−41	925	779
7N30	Top	3636	80	13	27	284	−39	89	78
7N31	Green	3660	80	8	28	277	−38	915	811

NASA has prepared this map of Mars from the Mariner 1969 television pictures. Far encounter pictures provided the basis for most of the map, but near encounter data was used for areas of near encounter coverage. To most dramatically present the Martian topography, the cartographers used maximum-definition near encounter pictures in their work. Since this data, unlike the far encounter data, is not photometrically accurate, there is an obvious mismatch at the boundaries between areas drawn from far encounter pictures and those drawn using near encounter data. This maximum definition data has also caused Meridiani Sinus to appear much less prominent than it actually is and has caused the spurious dark band along the edge of the polar cap. However, this map shows many features previously unmapped and locates other features more accurately than was previously possible.





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