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MARS

AS VIEWED BY MARINER 9

A Pictorial Presentation by the Mariner 9 Television Team and the Planetology Program Principal Investigators

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Preface

Mariner 9 was launched from Kennedy Space Center on May 30, 1971. A midcourse maneuver on June 5 placed its aiming point so close to Mars that no additional course correction was necessary. The spacecraft was successfully inserted into Mars orbit on November 14 at 00:15:29 GMT, becoming the first manmade object to orbit another planet.

Initiated in 1968, the Mariner Mars 1971 Program had called for two spacecraft to orbit Mars during the 1971 opportunity, one in a high inclination orbit and the other in a low inclination orbit. After Mariner 8 was lost during launch on May 9, the operational strategy was changed to an intermediate inclination orbit to achieve maximum scientific return from a single orbiter. The objective of the mission was to explore Mars from orbit for a period of time sufficient to observe a large fraction of the surface and to examine selected areas for dynamic changes. Imagery of the surface was to be obtained as well as significant data on the atmosphere and surface characteristics.

Eleven Principal Investigators were concerned with the six experiments carried by Mariner 9:

Television—H. Masursky (team leader), U.S. Geological Survey, Flagstaff; G. Briggs, Jet Propulsion Laboratory; G. De Vaucouleurs, University of Texas; J. Lederberg, Stanford University; B. Smith, New Mexico State University.

Ultraviolet spectroscopy—C. Barth, University of Colorado.

Infrared spectroscopy—R. Hanel, NASA Goddard Space Flight Center.

Infrared radiometry—G. Neugebauer, California Institute of Technology.

S-band occultation—A. Kliore, Jet Propulsion Laboratory.

Celestial mechanics—J. Lorell (team leader), Jet Propulsion Laboratory; I. Shapiro, Massachusetts Institute of Technology.

The spacecraft was approaching Mars, when telescopes on Earth revealed that a planetwide dust storm had broken out and was totally obscuring its surface. From November to mid-December only faint markings appeared on the surface of Mars and sometimes a diffuse feature with a series of billowing dust waves on its lee side. The last picture taken before orbital insertion had shown four curious dark spots aligned in a T-shaped pattern, and it was theorized that they might be high-standing parts of an otherwise obscured planet. This area was monitored repeatedly during the course of the storm, and as successive pictures showed more and more detail it became clear to the science team that these were the summit areas of enormous volcanoes protruding through the top of the dust cloud. By the end of December it appeared that the dust storm was diminishing and that the planetary mapping sequences could soon begin.

From January 1972 onward, every week was punctuated by new and startling discoveries. First there were the enormous volcanoes standing as much as 15 miles above the average surface, each one about the size of

Arizona. Then, totally unanticipated, immense canyons appeared, including a great equatorial chasm more than ten times the size of the U.S. Grand Canyon. The canyons proved to have eroded walls, and in addition numerous dendritic tributaries extended back from the canyon walls, suggesting that water erosion may have played a role in sculpturing the surface of Mars some time in its past. Yet it was known from previous flyby missions that atmospheric and surface temperature conditions are such as to prevent liquid water from existing in adequate quantity at the present time. For this reason the science team was astounded by the apparent evidences of erosion, and then by the discovery of non-canyon-related sinuous channels that had all the earmarks of dry river valleys. Eroded cliffs appeared, as well as wind-erosion features and large dune masses. It is difficult to convey the sense of high excitement that pervaded the scientific investigators as the newly perceived character of our sister planet began to unfold.

Soon it became apparent that almost all generalizations about Mars derived from Mariners 4, 6, and 7 would have to be modified or abandoned. The participants in earlier flyby missions had been victims of an unfortunate happenstance of timing. Each earlier spacecraft (except in part for Mariner 7, which had returned startling pictures of the south polar regions) had chanced to fly by the most lunar-like parts of the surface, returning pictures of what we now believe to be primitive, cratered areas. Given a difference of as little as six hours in arrival times of any of these earlier spacecraft (each of which had spent many months in transit), an entirely different view of Mars would have resulted. It was almost as if spacecraft from some other civilization had flown by Earth and chanced to return pictures only of its oceans.

Mars moved behind the Sun in early August 1972, and the spacecraft could no longer be commanded from Earth. At this point in the mission nearly all the planet had been mapped with the low resolution camera, and about 2 percent of its surface covered by the high resolution camera, specially targeted over points of high scientific interest. In addition, the waning of the south polar cap had been examined in detail, and the layered and pitted deposits in these regions extensively pictured. At an altitude of 1650 km the resolution of the TV camera system was about 1 km for the low resolution camera and about 100 m for the high resolution camera.

When Mars came out from behind the solar corona on October 12, so that scientific operations with the orbiter could be resumed, mapping coverage of the northern latitudes was completed and the northern polar regions examined in detail. After a lifetime in space of 516 days, the Mariner 9 spacecraft ran out of attitude-control gas and tumbled out of control on October 27, 1972, almost one year after it had been inserted into Mars orbit.—J. F. McCauley, H. F. Hipsher, and R. H. Steinbacher.

Contents

1
Introduction

Although the dust storm delayed the start of systematic mapping, it afforded an unparalleled opportunity to examine its effects on the surface and atmosphere of Mars. Pictures of the limb were taken showing that dust reached the enormous elevation of about 70 km (43 mi.). Gradually features emerged through the haze. At first only the dimly shining south polar cap and four dark spots could be seen. One of the dark spots had been noted during the dust storms of 1924 and 1956 by astronomers. Under normal conditions this feature appears as a bright white spot, Olympus Mons. The other three spots lay in the area where periodic brightenings called the "W-cloud" have often appeared. As the storm gradually subsided and the atmosphere cleared, the four spots turned out to be high mountains with craters at their summits. Olympus Mons appeared as an immense shield volcano 24 km high with long finger-shaped lava flows on its flanks — the largest volcanic pile ever photographed. Later a great plateau became visible, sloping to the east from the volcanoes. On it appeared a bright stripe that later turned out to be a great equatorial chasm.

The more than 7300 pictures acquired from Mariner 9 indicate that Mars is more varied and dynamic than previously inferred. Although impact craters are common, only a few small craters show continuous ejecta blankets and well developed rays. Most small craters, however, exhibit degraded, irregular ejecta blankets. About half the surface consists of ancient cratered terrain surrounding large impact basins. The largest circular feature, Hellas Planitia, is almost twice the size of the largest basin on the Moon, Mare Imbrium. Argyre Planitia is ringed by radially and concentrically textured mountainous terrain, similar to the lunar multi-ringed impact basins such as Imbrium and Orientale. The remainder of the surface is covered by younger volcanic rocks and volcanoes. These rise as much as 25 km above the mean level of extensive lava plains deposits, some of which contain windblown or possibly fluviatile deposits that are sedimentary in origin. The single volcanic edifice of Olympus Mons, which rises high above the floor of Amazonis Planitia, is almost three times the width and height of the largest of the Hawaiian volcanoes, Mauna Loa. Three other large volcanoes lie along the Tharsis ridge. The volcanoes with summit calderas have fresh flows on their slopes and appear to be relatively young. These volcanic vents provide a plausible source for much of the carbon dioxide and water in the atmosphere. The great equatorial chasm or canyon system, Valles Marineris, comparable in size to the East African Rift Valley system, is as much as 6 km deep and greater than 5000 km long, the distance from Los Angeles to New York City. It terminates in a complexly faulted plateau to the west, and in large patches of chaotic terrain to the east.

Emerging from the northern plateau lands, a complex array of broad sinuous channels descends into a regionally depressed area. Large fluvial channels begin in this chaotic terrain — possibly from episodic melting of permafrost — and seem to flow northward into the Chryse Planitia lowland. The channels merge on the border of the flat, low Chryse area; here the channel floors show multiple braided features and streamlined islands. It has been proposed that the collapse of these rocks and formation of large-scale landslides may be caused by melting of permafrost.

Other large sinuous channels with many tributaries have no obvious sources. Small dendritic channel networks abound in the equatorial regions and imply possible rainfall. Many of the basin floors are underlain by lava flows having lobate fronts, and are inferred to be basaltic from the form of the flows, ridges, and broad, low mare-type domes that characterize their surface.

The polar regions are covered by glacio-eolian layered rocks that appear to be still forming under the present climatic regime. Older massive deposits are being eroded, pitted, and etched into troughs around the margins of the poles. Young layered deposits resembling thin laminae overlie the etch-pitted unit. The individual thin layers appear to be cyclical deposits. High velocity wind is stripping the surface and forming deflation hollows. A nantle of windblown debris, presumably derived from hese circumpolar zones, thins toward the equator. These leposits smoothly blanket a subdued cratered terrain and partially fill its craters. The south and north polar regions iave apparently acted as sediment or dust traps throughut much of Mars history.

Both eolian erosional features such as yardangs wind eroded ridges) and depositional features such as unes have been identified in the equatorial region. One une field, about 130 km long, lies on the floor of a rater. Wind erosional and depositional processes are active, as seen by numerous changes in the albedo patterns that were monitored after the clearing of the planetwide dust storm. Redistribution of deposits of silt and clay particles reveals dark, irregular markings and light and dark tails emanating from topographic obstacles. The light tails appear to be wind-deposited material; the dark tails appear to be mostly wind-scoured zones. Throughout the mission clouds of various patterns composed of CO_2 ice crystals, water ice crystals, and local wind raised dust clouds were observed.

The temperature measurements and cloud patterns led to interpretations of the planetwide atmospheric circulation pattern, which in turn could be compared with the bright and dark surface markings that also indicate wind directions. Changes in the surface patterns were monitored on a periodic basis. During this time the dark markings that had been observed from Earth telescopes for more than a hundred years gradually reappeared after having been obscured by the storm deposits.

The retreats of both the north and south polar ice caps were observed closely. The carbon dioxide and possibly some water ice retreated by sublimation, revealing layered deposits formed by glacial-like processes, and a belt of etched pitted terrain surrounding the polar ice-cap region. The hollows may be formed by wind erosion, for the winds at the margins of the polar caps have a very high velocity on Mars, as they do on Earth in Antarctica and near the Greenland ice cap.

The spacecraft ceased functioning when it ran out of attitude-control gas after 349 days in orbital operation. It succeeded its design lifetime by almost a factor of four, and its observations exceeded all science goals. Mariner 9 data will greatly assist planning for the Viking flights to Mars in 1975–76 that involve landing spacecraft on the surface of Mars to search for life. — H. Masursky and B. A. Smith

2
Giant Volcanoes of Mars

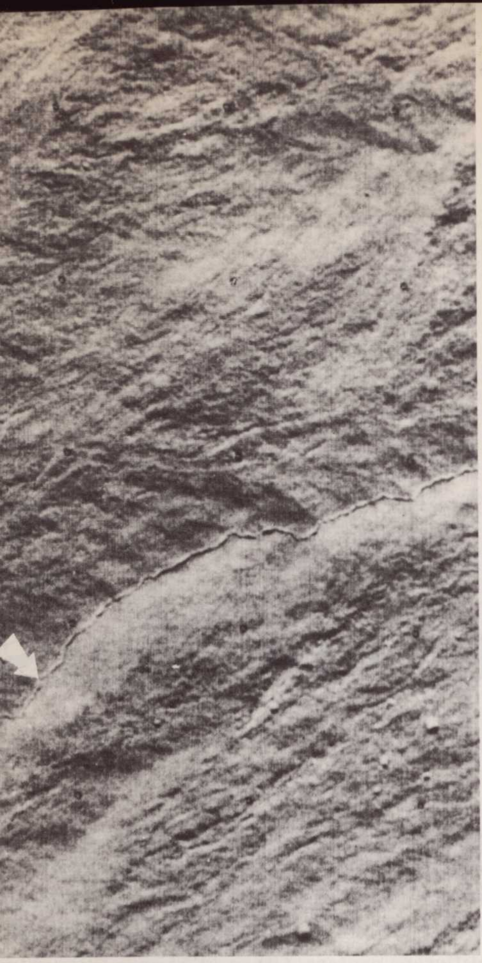
Recognition of prominent volcanic features on Mars was one of the first and most significant results of the flight of Mariner 9. During the fully developed dust storm, the only surface features clearly visible outside the polar areas were four dark spots in the Amazonis-Tharsis region. As the atmosphere cleared, those spots were seen to be the central calderas of four enormous shield volcanoes. Subsequent photography of other parts of the planet revealed more volcanic features, indicating that volcanism played a major role in the evolution of Mars. Past volcanic activity includes formation of extensive plains units, and building of the tremendous shield volcanoes and numerous smaller dome-like structures.

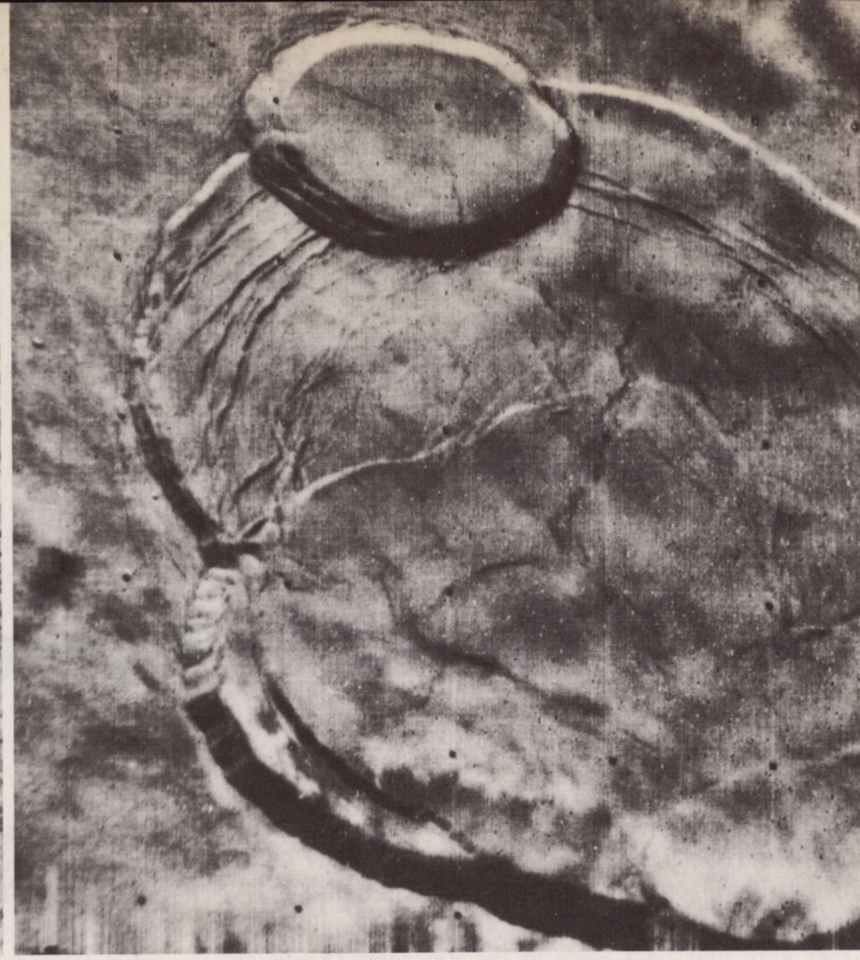
Most of the volcanic features except the plains are in the regions of high elevation. The three shield volcanoes, the Tharsis Montes, lie on a broad ridge which is 3 to 5 km above the mean level of the martian surface. Olympus Mons, the largest of the volcanic shields, lies on the western flank of this ridge. Olympus is 500 km wide and rises 29 km above the surrounding plain. The Tharsis Montes, Ascraeus, Pavonis, and Arsia Mons are each about 400 km across and, although smaller than Olympus Mons, may reach the same elevation above the mean level of Mars because of their location on a ridge. In comparison, the largest volcano on Earth, Mauna Loa in Hawaii, is approximately 200 km wide and rises about 9 km above the sea floor.

All shield volcanoes have roughly circular outlines and central summit depressions. Arsia Mons, Pavonis Mons, and an Elysium shield, Albor Tholus, have simple craters at their summits. Olympus Mons and Ascraeus Mons have complex craters as a result of successive collapses around different centers. Other volcanoes, differing from shield volcanoes in that they are smaller and simple, are properly termed domes or tholi.

The shields and domes are the most spectacular aspects of martian volcanism, but the plains on Mars may be volumetrically more significant. High resolution pictures of the plains commonly show long, low, lobate scarps (possible flow fronts) that strongly resemble features in Mare Imbrium on the Moon. By analogy with the lunar maria and terrestrial flow fronts, the plains are probably largely volcanic in origin.

In many places the cratered surface appears to be partly or wholly covered by younger plains-forming materials. In some areas only the small craters are buried, in others even the largest craters are buried entirely or show only subdued impressions. Such effects could result from eolian deposition, but volcanic activity also appears to have been widespread and products of this activity also may cover part of the cratered surface. Both volcanic plains and circular constructional features are found within the densely cratered province. Thus, although the most spectacular volcanic features occur in sparsely cratered regions, the entire planet may have been affected by volcanism. — M. H. Carr





(20°N, 135°W; MTVS 4133–96)

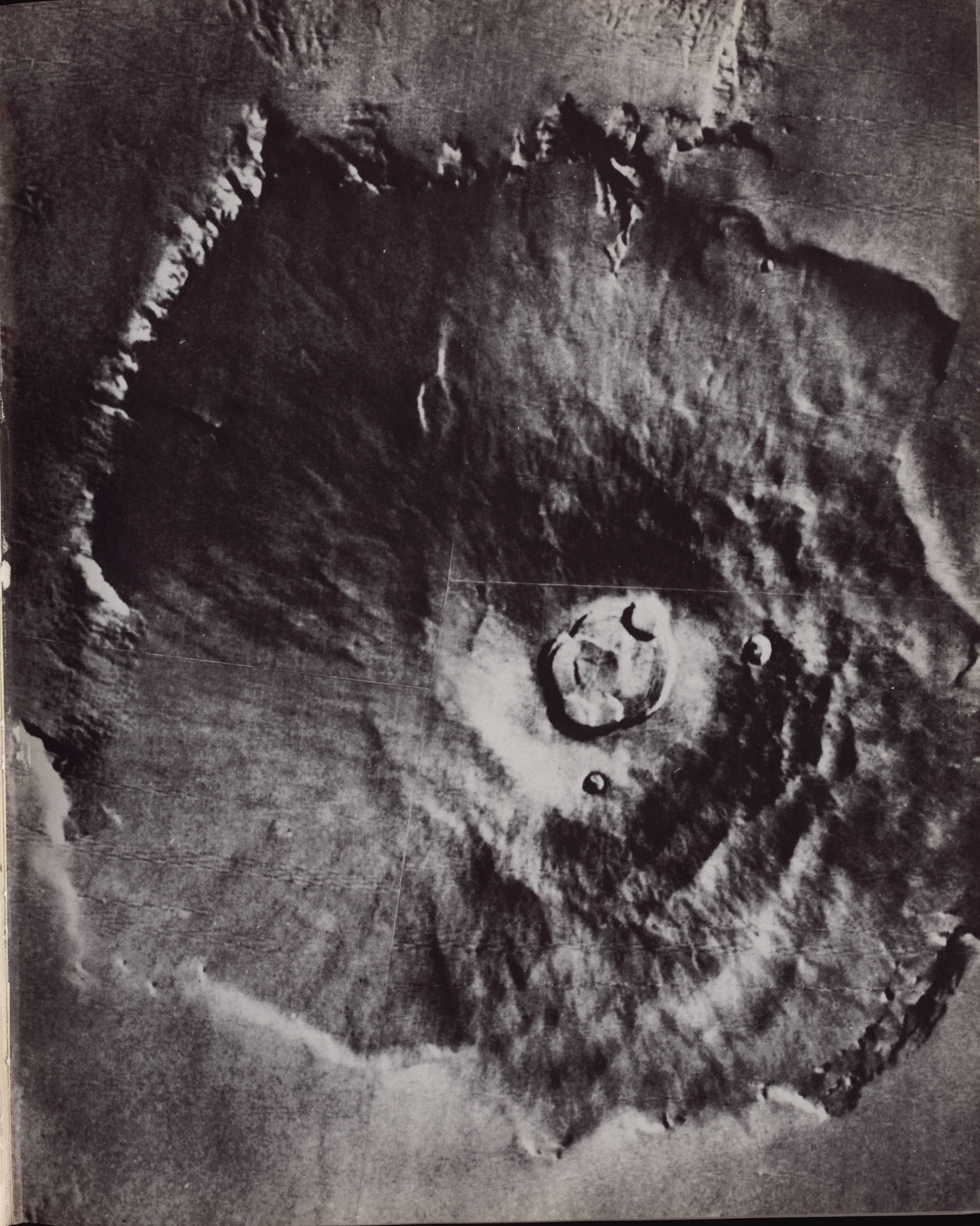
Long lava flows (above left) are visible in this photograph of the northwest flank of Olympus Mons (resolution, about 100 m). Many show natural levees such as occur along the margins of many terrestrial lava flows. The most prominent ridge has a channel (arrow) 250 m wide along 36 km of its crest that is inferred to be a lava channel. Lava flows of this form are characteristic of basaltic eruptions in the Hawaiian and Galapagos Islands on Earth.—H. Masursky

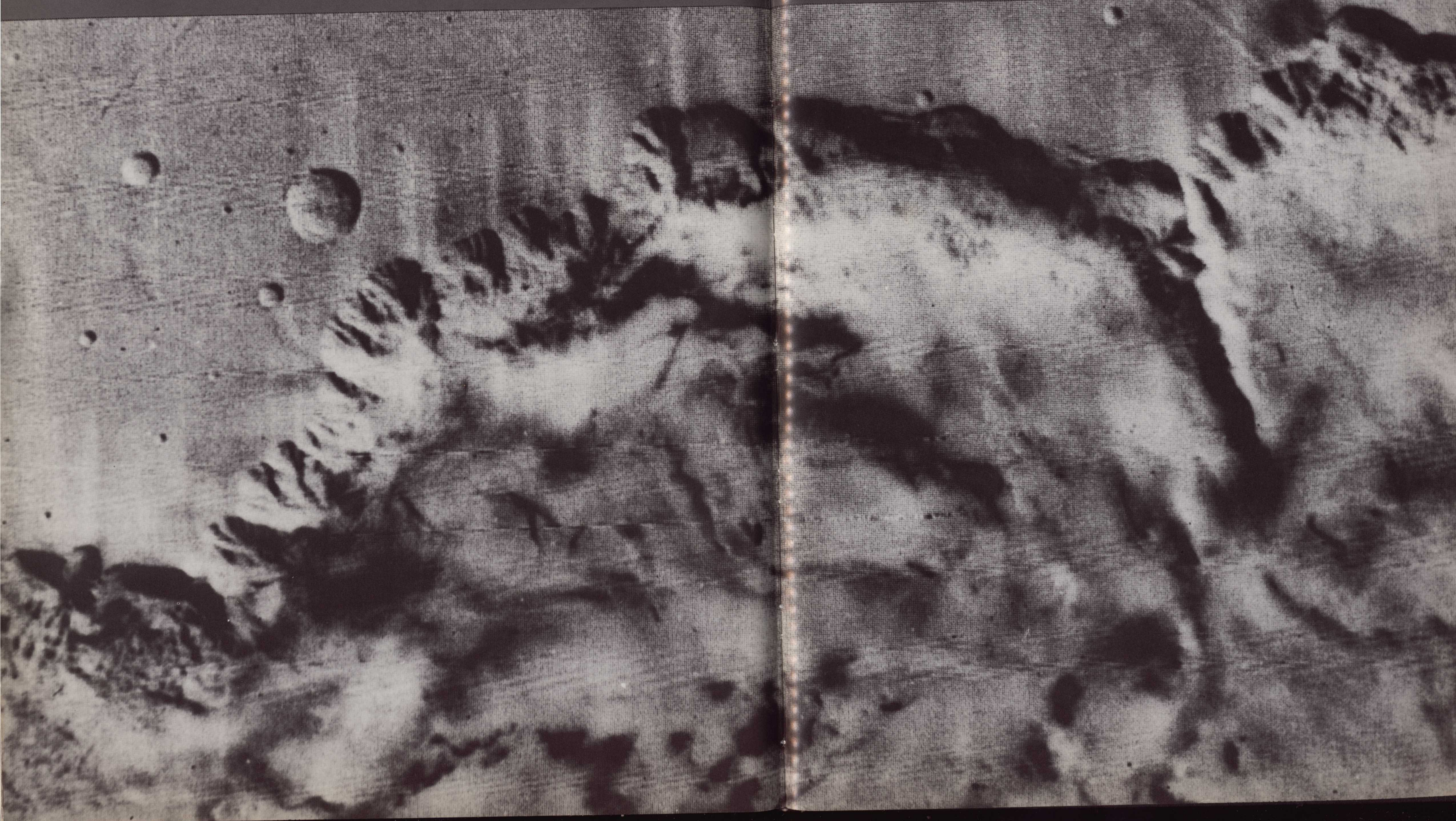
(18°N, 133°W; MTVS 4265–52)

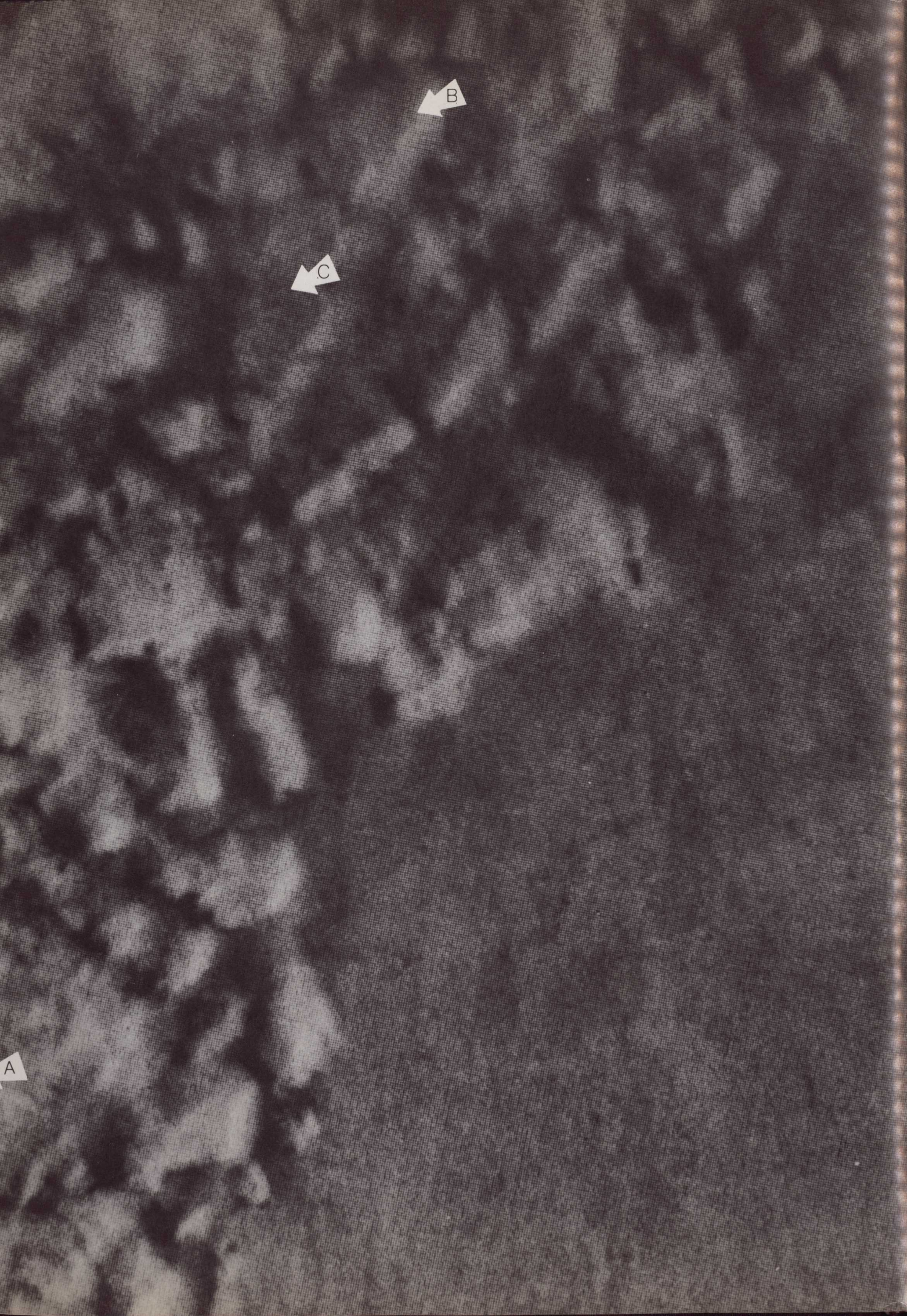
The central caldera (above right) on Olympus Mons shows a structure of intersecting collapse depressions and concentric fractures. The inward collapse of the caldera floor is evident from the terrace pattern that steps toward the caldera center, a pattern similar to terrestrial volcanic calderas. The smaller, youngest, collapse pit (top center), is about 30 km across.—H. Masursky

(18°N, 133°W)

Photomosaic of Olympus Mons (facing page), the largest of the Mars volcanic mountains. The volcanic structure is 500 km across and about 29 km high, with a complex summit caldera about 70 km across. These dimensions make it the largest volcanic structure known. It is much larger than the island of Hawaii, which (on the ocean floor) at 200 km across and 9 km high is the largest volcanic pile on the Earth. The scarp around the base of Olympus Mons stands 1 to 4 km high and may have been produced by wind erosion. Originally the volcanic pile probably graded smoothly into the surrounding plain.—H. Masursky







(34°S, 177°W; IPL 1422/174345)

Rugged hills, 0.5 to 8 km across, rise abruptly from a smooth, lightly cratered plain. A small cone (A) may be a volcano, and other hills may be volcanic domes. The straight valleys which separate some hills, escarpments (B), and flat hilltops (C) indicate formation of this hilly terrain by crustal fracturing and subsequent erosion.—J. H. Howard III and J. F. Woodruff

(23°S, 241°W; IPL 311/210101)

A low resolution view (right), about 400 km across, of a region in the Hesperia Planum shows numerous parallel, light streaks associated with craters. A credible explanation of such an array of long parallel streaks emanating from craters is that fine, bright dust, transported into craters in the waning stages of the dust storm, was subsequently blown out by high velocity winds having a prevailing direction. In any case the streaks must point downwind, and are natural wind direction indicators.—C. Sagan

(10°S, 107°W; IPL 1108/150842)

An area in Tharsis (below), about 160 km across, characterized by an assortment of bright streaks showing strong evidence of an eolian streak stratigraphy. No variation in the configuration of these streaks was observed during the Mariner 9 mission.—C. Sagan