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ATLAS OF MARS: MTM 25047 AND 20047 QUADRANGLES

GEOLOGIC MAP OF THE MTM 25047 AND 20047 QUADRANGLES, CENTRAL CHRYSE PLANITIA/VIKING 1 LANDER SITE, MARS

By

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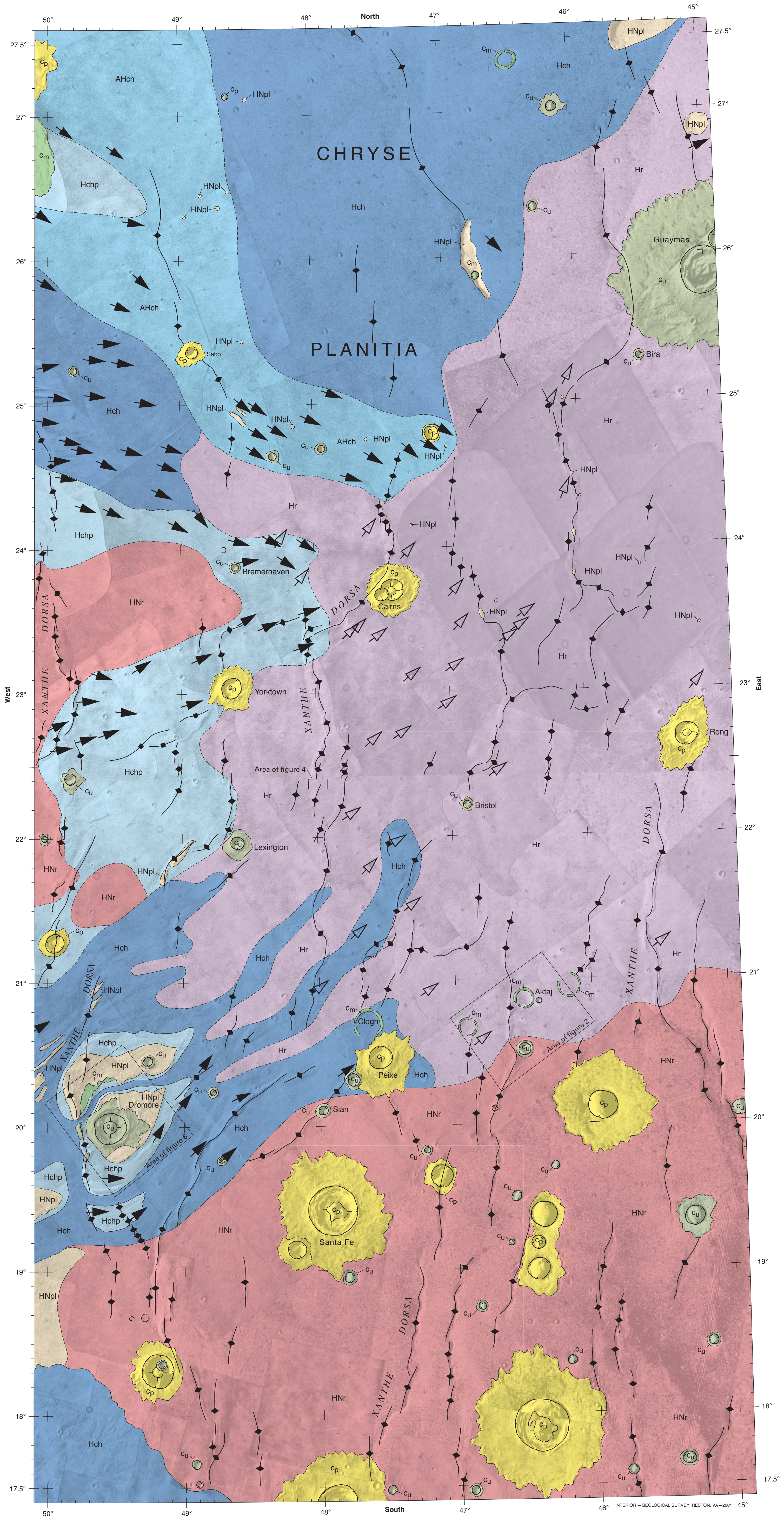

SCALE 1:1 004 000 (1 mm = 1.004 km) AT 50° LONGITUDE
TRANSVERSE MERCATOR PROJECTION

20 0 20 40 60 80 100
KILOMETERS

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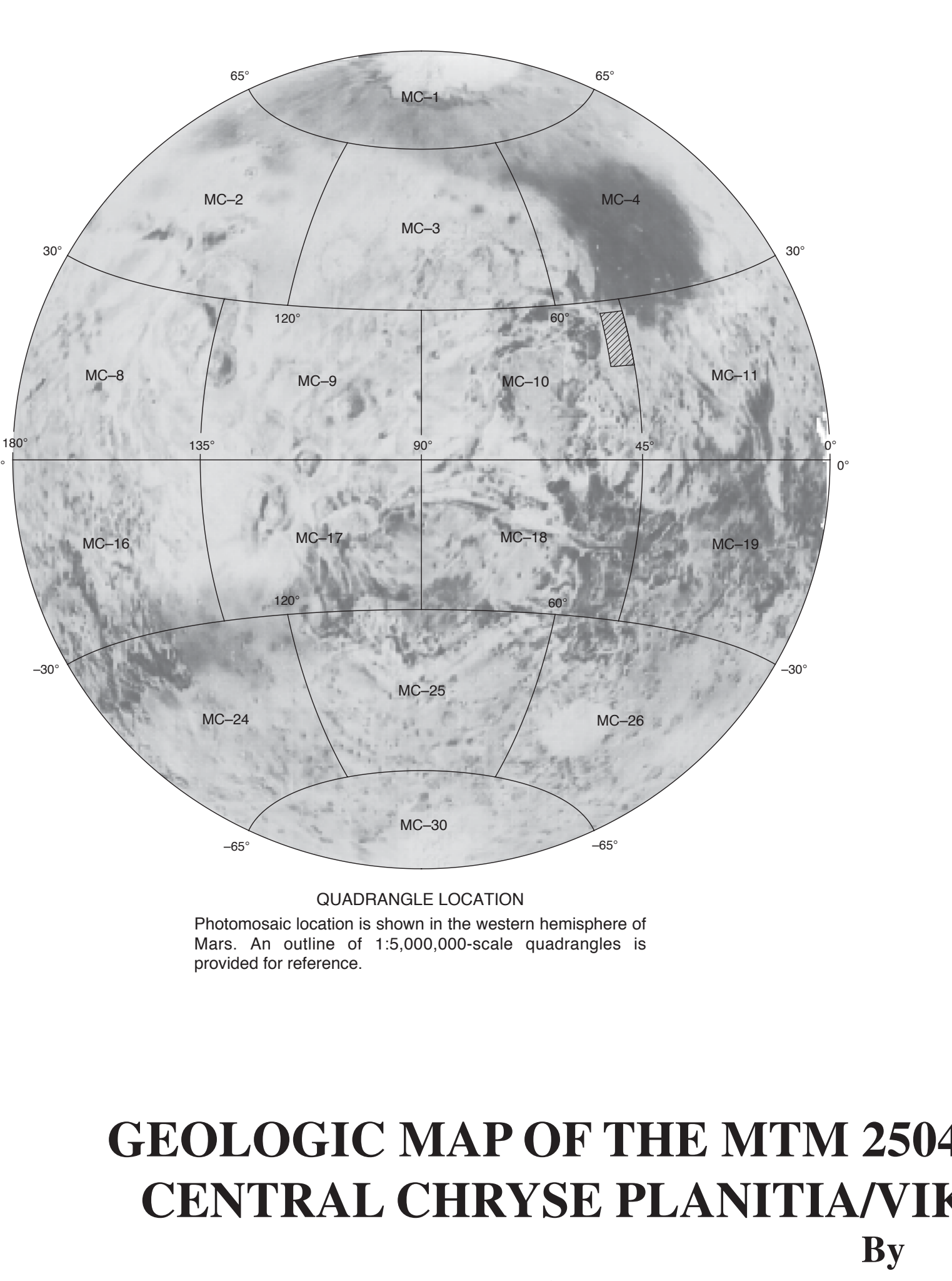
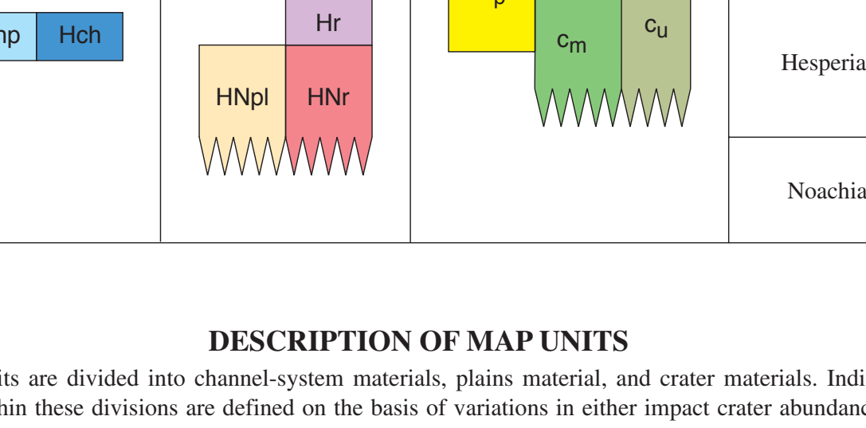


QUADRANGLE LOCATION
Photomosaic location is shown in the western hemisphere of Mars. An outline of 1:5,000,000-scale quadrangles is provided for reference.

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

[Map units are divided into channel-system materials, plains material, and crater materials. Individual units within these divisions are defined on the basis of variations in either impact crater abundance (for the ridged plains units), or on the basis of variations in scale and type of modifications of the preexisting surfaces (for channel-related units)]

CHANNEL MATERIAL

[Channels and valleys primarily in the western half of the map area sculpted from preexisting plains surfaces by fluvial erosion associated with Maja Vallis and Kasei Vallis. Isolated plateaus occur both in the west and east]

AHch **Younger channel floor material**—Relatively smooth plains forming channel floor of Kasei Vallis. Determined from mapping farther west (Scott, 1993) to be the latest channel unit within the Chryse outwash unit material: Embays and cuts channel unit (Hch) from earlier depositional stages of Kasei Vallis and Maja Vallis. In this map area it is relatively smooth, bears few impact craters, occurs largely as the terminus of the Kasei outwash units, and is locally characterized by longitudinal grooves, scour marks, and small streamlined bars. *Interpretation:* Distal end of scour and fill associated with outwash from Kasei Vallis

Hchp **Channel flood-plain material**—Forms smooth, low-lying plains adjacent to grooved channel units (Hch and AHch). Forms terraces and slopes adjacent to remnant islands of ridged plains units and in places surrounds areas of channel floor unit (Hch). *Interpretation:* Flood-plain unit indicating high-water overflows from main channels of early flood events. Emplaced at approximately the same time as channel floor unit (Hch). Local evidence for direction of flow is indicated with closed arrow symbol. Channeled plains stand higher than late ridge plains because they represent older terraces

Hch **Older channel floor material**—Striated and terraced floor of Maja Vallis outflow channels. Characterized by parallel, linear striations, ridges, and troughs; includes sculpted mare-type ridges and craters with streamlined ejecta patterns and outer rim slopes. Deep troughs around islands of older cratered plateau surfaces (unit Hcrp). Near its eastern distal ends characterized by discontinuous sinuous, streamlike small channels. Appears to thin eastward and either cuts or overlaps late ridged plains (Hr_2). *Interpretation:* Formed by erosion and fluvial sculpting and deposition of a preexisting plains surface during catastrophic outflow of water from termini of Maja Vallis. Locally marks the extreme reaches of visible effects associated with catastrophic outwash. Small interior channels represent post-flood residual drainage. Local evidence for direction of flow is indicated with closed arrow symbol

PLAINS AND PLATEAU MATERIAL

[Forms relatively low relief and low elevation surfaces within the Chryse Planitia basin; locally altered to variable extents by aeolian deposition and erosion and impact cratering, and deformed regionally by wrinkle-ridge formation. Plains units occur throughout the map area]

Hr **Younger ridged plains material**—Smooth plains occurring within the central area of map characterized locally by partially filled craters, and subdued and discontinuous mare-type ridges. Characterized in particular by isolated knobs and flat-topped and faceted relief features. These are particularly prominent on the crests of mare-type ridges. The cumulative number of craters is less on younger ridged plains material than on older ridged plains material (HNr). Channels and scours are not present at the Viking Lander 1 site, but occur within 30 km to the west and southeast. At small scale the surface at the Viking Lander 1 site is characterized physically by a bimodal population of rocks averaging several tens of centimeters in size and intervening fine-grain soils. Pits generally less than 1 cm in diameter are locally common in many rocks. Chemical analysis of soils by X-ray fluorescence indicate mafic composition similar to soil composition at Viking Lander 2 site in Utopia Planitia. *Interpretation:* Basaltic plains unit veneered to undetermined depth by sediments derived from outwash channels, and modified by small impact craters and aeolian deposition of fine-grained materials. Knobs appear confined to the lowest areas of Chryse basin and are interpreted to have formed in a standing water body formed at the time of catatrosphic outwash. The knobs may have formed as wave-cut benches on local relief features

HNr **Older ridged plains material**—Plains characterized by prominent and continuous mare-type ridges striking north-south. One of the few regional surfaces where there is no evidence for channeling, erosion or significant filling and degradation of impact craters. Crater abundance is greater than on younger ridged plains material. Primary modification has been by impact craters and eolian deposition of fine-grained materials. This is the basal unit within map area. *Interpretation:* Basaltic plains unit. Represents older surface that has elsewhere been covered by late sediments associated with outflow channels

HNpl **Undivided plateau material**—Isolated plateaus or flat-topped ridges, generally less than a few kilometers in length. These occur either in the floors of major outflow channels and bear "streamlined" forms or occur as isolated minor mesalike features along the crests of larger mare-type ridges in the lower, eastern regions of Chryse Planitia. *Interpretation:* Remnants of the upper surface of either the older or younger ridged plains (HNr or Hr) formed as a result of deep erosion and scour around local obstacles during catastropic outflow, or as wave-cut benches cut into local topopgraphic highs and ridges in a regional standing body of water

CRATER MATERIAL

[Impact crater rims, interiors, and ejecta. Only craters with diameters of five kilometers or greater are mapped. Impact craters occur throughout the map area. Differences in general preservation of crater morphological characteristics in this area due to variations in relative erosion rates as a result of localized outwash channeling]

c_p **Material of pristine craters**—Impact craters characterized by narrow and sharp-crested rims, radial striae in ejecta aprons, associated discontinuous ejecta patterns, and complex hummocky interior floors

c_m **Material of modified craters**—Impact craters characterized by a discontinuous rim and filled or partially filled interior floors, or extensive channeling of surrounding ejecta patterns

c_u **Undivided crater material**—Impact craters characterized by raised rims, rough and hummocky ejecta aprons, and rough interior floors

Contact—Dashed where approximately located, short dashed where inferred, queried where uncertain

Ridge crest

Furrow or valley—Faint linear to arcuate and discontinuous depression tracing course of small drainage channels

Crater rim—Showing crest

Buried crater rim—Showing crest; elevated interior floor

Dome or central peak—Hachures point downslope

Area of channelized erosion and scouring—Arrow points in direction of interpreted flow

Area of eolian transport—Arrow points in direction of air flow as interpreted from dark and bright streaks trailing impact craters

Viking Lander 1 site

INTRODUCTION

This map uses Viking Orbiter image data and Viking 1 Lander image data to evaluate the geologic history of a part of Chryse Planitia, Mars. The map area lies at the termini of the Maja and Kasei Valles outwash channels and includes the site of the Viking 1 Lander. The photomosaic base for these quadrangles was assembled from 98 Viking Orbiter frames comprising 1204 pixels per line and 1056 lines and ranging in resolution from 20 to 200 m/pixel. These orbital image data were supplemented with images of the surface as seen from the Viking 1 Lander, one of only three sites on the martian surface where planetary geologic mapping is assisted by ground truth.

SETTING AND BACKGROUND

The map area is on the southwest interior slope of Chryse Planitia, a basin-shaped embayment of low elevation on the northern margins of the cratered highlands (fig. 1). The Chryse basin is interpreted to be an ancient and heavily modified multi-ring impact basin (Schultz and others, 1982) initially filled and resurfaced by widespread emplacement of flood basaltic lava in a manner probably similar to mare basin filling on the Moon (Wilhelms, 1987). Fluvial events occurred much later or over a much greater period of time.

The surface of Chryse Planitia is a part of the widespread plains material surface (Scott and Tanaka, 1986; Rotto and Tanaka, 1995) of generally low elevation and intermediate age (Hesperian) that covers much of the northern hemisphere of Mars. The basin is bounded by higher elevation terrains of Lunae Planum on the west, Arabia Terra on the east, and Xanthe Terra on the south. Maja and Kasei Valles outflow channels on the west and Shalbatana Vallis on the southeast drain from the surrounding higher elevations and empty into central Chryse Planitia. The Viking Lander site was chosen originally in part because evidence for past water there; where these channels appear to converge supported one of the primary goals of the Viking program, the life sciences experiments. The relatively low regional relief and the uncomplicated regional geology of the plains in this region also assured, in principle, that there were few obvious hazards for a lander.

The regional geology was interpreted at the close of the Viking mission to reflect basaltic flood lava filling an ancient basin and overlain, or possibly interbedded (Milton, 1974; Greeley and others, 1977; Scott and Carr, 1978; Theilig and Greeley, 1979; Arvidson and others, 1989; Rotto and Tanaka, 1995; Tanaka, 1997), with sediments deposited by the Kasei and Maja Valles fluvial outwash channels. Kasei Valles, northwest of the Viking 1 Lander, has been interpreted to reflect several catastrophic outwash events rather than a single short-lived flood (Scott, 1993; Tanaka and Chapman, 1992). Mapping by Rice and De Hon (1996) in the area immediately to the west of the south half of this map identified two main channels from which catastrophic outflows were directed out onto Chryse Planitia, Maumee and Maja Valles. The most recent outflow across the site of the Viking Lander appears to have come from these two channels. On the basis of stratigraphic relations, Maja Valles is considered to be the later of these two channels to be formed in the overall sequence of outwash channels (Rice and De Hon, 1996).

In orbiter images of the region, outflow channels appear to converge near the lander site. The lander is situated 60 km north and east from the easternmost detectable evidence of outwash channel erosion, but direct evidence for fluvial deposits or erosion in the surface in lander image data is equivocable. Several hypotheses, outlined by Mutch and others (1976), for the origin of the surface at the landing site remain applicable: (1) The surface consists of fluvial materials deposited as a result of outwash from the Maja and Kasei Valles outflow channels on a basaltic lava plain. This interpretation agrees broadly with results of previous mapping at scales of 1:5,000,000 and 1:15,000,000 (Milton, 1974; Greeley and others, 1977; Scott and Carr, 1978; Theilig and Greeley, 1979; Scott and Tanaka, 1986; Rotto and Tanaka, 1995) and is the simplest interpretation consistent with the broad evidence. The main difficulty with this interpretation is that no direct evidence exists for sedimentary emplacement of materials at the Viking 1 Lander site. However, the landforms at meter scales that are indicative of deposition in catastrophic floods are not well known. (2) Chryse Planitia is mostly volcanic, but the fluvial materials that were deposited are relatively smooth and consist of only slightly reworked indigenous rock. (3) Volcanism was the latest event, and the interior of the Chryse basin was flooded with lava flows younger than the channeling (see also, Arvidson and others, 1983). (4) Channel deposits are younger but did not reach the landing site, and the surface is entirely preexisting lava flows similar to lunar mare. On the basis of initial geologic mapping at the time of the Viking mission, none of these hypotheses could be excluded.

Additional attempts to interpret the geology in the vicinity of the Viking 1 Lander have been made since the conclusion of the Viking mission. Garvin and others (1981) analyzed quantitative indicators of rock shape and compared these results with shapes characteristic of different sedimentary environments on Earth. They concluded that fluvial erosion and modification of the near-field surface boulders can be neither demonstrated nor refuted. More recently Craddock and others (1997) discuss geomorphic evidence for fluvial erosion based on the shape and orientation of topographic swells near the Viking 1 Lander.

Sharp and Malin (1984) concluded on the basis of the observations cast from the perspective of field geologists that the surface rock morphology at the Viking 1 Lander site includes several examples of possible breccias, as well as some vesicular and dense volcanic rocks. They also noted that the rocks of the Viking 1 Lander site differ from those seen in Utopia Planitia at the Viking 2 Lander site, where vesicular and dense volcanic rocks appear to be more common.

STRATIGRAPHIC UNITS

Material units mapped within this area range from Upper Noachian/Lower Hesperian to Lower Amazonian in age. These units overlie structures associated with an earlier Chryse impact basin structure and its associated topography. The basal map unit within this area, older ridged plains material (unit HNr), is characterized primarily by many distributed and relatively uneroded impact craters and by numerous, well-developed linear to sinuous mare-type wrinkle ridges. Older ridged plains material lies on a regional topographic surface that slopes from the highlands of Xanthe Terra northward and eastward down toward the center of the Chryse basin. It is distinguished from the younger ridged plains material (unit Hr) by (1) topographically more prominent and more continuous ridges, (2) surfaces devoid of evidence for channeling, erosion or scouring, and (3) greater cumulative number and diameters of impact craters (table 1).

The transition from erosion to deposition may occur within this map area. Evidence for channel scouring mapped by Rice and De Hon (1996) and by Scott (1993) within Maja and Kasei Valles, respectively, diminishes from west to east across Chryse Planitia. As a result, geologic contacts in the map area are more gradational than those farther west and likely reflect the overall diminished effects of outwash from west to east as water emerged from the mouths of Maja and Kasei Valles.

The younger ridged plains material is a more sparsely cratered and smoother surface than the older ridged plains material. Ghost crater rings and residual rims of craters (unit c_m), particularly along the southern contact between younger ridged plains material and older ridged plains material imply deep burial of an earlier surface. The surface of the older ridged plains material appears to have been inundated by either sedimentary deposits or lava flows that now form the younger ridged plains material (fig. 2). Crater counts within younger ridged plains material indicate a dearth of craters smaller than 10 km diameter relative to older ridged plains material (fig. 3). This relation is consistent with an interpretation that the older ridged plains surface was buried to a depth of ~300 m with a later material. This depth is based on the amount of material necessary to fill the interiors and bury the rims of impact craters less than 10 km in diameter with typical martian rim-height to diameter ratios (Pike and Davis, 1984).

Both the younger and older ridged plains materials are interpreted by analogy with the ridged mare plains material on the Moon (Plescia and Golombek, 1986; Watters, 1988) to be generally flat lying material of regionally uniform mechanical properties deformed by tectonic shortening of a few percent over broad areas. Crustal shortening responsible for the mare-type ridges may have arisen from compressional stresses peripheral to the Tharsis region (hoop stresses) and compressive stresses radial with respect to the center of Chryse basin (Chicarro and Schultz, 1985; Watters, 1993). Because ridges may accumulate strain over long geologic periods of time, the smaller size of ridges in the younger ridged plains material compared with ridges developed on the older ridged plains material may reflect a shorter time period over which strain has continued to accumulate over buried ridges. Estimates of younger ridged plains material thickness of several hundred meters exceed the measured heights of typical wrinkle ridges (Plescia and Golombek, 1986), so the complete burial of existing ridges may have occurred. This complete burial is consistent with evidence for continued small amounts of deformation that occurred on northeast-southwest-oriented wrinkle ridges crossing late channel floors (Rice and De Hon, 1996) stratigraphically closer to younger ridged plains than to older ridged plains.

Viking 1 Lander is located along one of these mare-type ridges at an offset between two short ridge segments (fig. 4). The north-south strike of ridges throughout the older ridged plains material is evidence for an east-west sense of shortening. A secondary, or topographically less prominent set of ridges, trends northeast and formed more recently. Many ridges predate catastrophic outflow channels, but some small finely crenulated ridges formed subsequent to channeling (Rotto and Tanaka, 1995). These crenulated ridges occur along the strike of preexisting ridges, implying that movement along ridges continued throughout the duration of channeling events in which successively smaller ridges tend to develop on the crests of earlier ridges. A long-lived cumulative growth and development may characterize mare-type ridge topography in general (Aubele, 1988), in which successively smaller ridges tend to develop on the crests of earlier ridges. An analogous situation is the development of large displacement faults on Earth which do not form in single events, but instead grow over long periods of time by the gradual accumulation of many small displacements.

Undivided plateau material (unit HNpl) occurs in two principal settings, either along the crest of prominent wrinkle ridges (fig. 5) or on the floors of outflow channels (fig. 6). Possible origins of undivided plateau material along the crest of ridges include: (1) scattered topographic remnants of the older ridged plains material as a result of large-scale erosion during channel floor formation, or (2) wave-cut benches and scarps resulting from a regional stand of water (Parker and others, 1993) acting on local topographic highs and ridges of easily eroded younger ridged plains material.

Channel flood-plain material (unit Hchp) is a continuation of material from the west and follows the definition of Rice and De Hon (1996). Channel flood-plain material forms the slopes and terraces of local streamlined mesas bearing perched craters. These mesas mark earlier, high stands of water that caused scours and possible deposition (overbank deposits). A clear example of this type of landform occurs around the undivided plateau material of Dromore crater (lat 20° north and long 49.8° west). Many tablelike surfaces also occur astride wrinkle ridges within the channeled flood-plains material suggesting the effects of local streamlining of preexisting wrinkle ridges. Channel flood-plain material occurs principally at two localities along the western margin of the map area, in association with Kasei and Maja Valles. Striations are interpreted as resulting from erosive scouring and channeling during catastrophic flooding from Maja and Kasei Valles eastward toward the topographic low of Chryse Planitia and across the preexisting younger ridged plains material.

Younger and older channel floors materials (units AHch and Hch, respectively) are similar in appearance but differ in their stratigraphic positions (Scott, 1993). Older channel floor material dominates in the Xanthe Dorsa region along the west edge of the map area. Farther east, where this unit contacts the younger ridged plains material (unit Hr), the older channel floor material bifurcates into many fingers defined largely by swathlike tracks of streamlined bedforms and courses of aligned hummocks. Younger channel floor material includes striated and grooved material on the floors of the main channels within Maja and Kasei Valles where they continue from the west.

Xanthe Dorsa, a series of north-south-oriented wrinkle ridges, created transient damming that caused local ponding of outflow from Maja Valles immediately west of Dromore crater. The plains surface in the region immediately west of Xanthe Dorsa is unusually smooth and featureless as might occur from local deposition of sediments from an ephemeral lake. Once spillover occurred across Xanthe Dorsa, outflow coursed around Dromore crater (fig. 6) and out onto Chryse Planitia where it either (1) deposited the younger ridged plains material, or (2) cut and scoured the younger ridged plains material.

The youngest materials (not mapped) are locally discontinuous wind streaks, particularly on the ridged plains materials. Regional patterns of wind streaks are associated mostly with small impact craters. Local patterns of wind-driven fine materials are visible in Viking 1 Lander images of the surface as small dunes and drifts largely in the lee of cobbles and blocks. The orientations indicate emplacement by southwesterly winds (Mutch and others, 1976). Both the regional and local lander observations of wind streaks also agree with measurements made by the lander meteorology experiment, which indicate strong, recurring (diurnal), early morning winds (Hess and others, 1977) flowing from southwest to northeast down the regional slope to the basin center.

IMPACT CRATERS

Three classes of impact craters are identified on the basis of degree of preservation. Modified craters (unit c_m) are characterized by a discontinuous rim and filled, or partially filled, interior floors (fig. 2), Pristine craters (unit c_p) are distinguished by relatively narrow and sharply crested rims, radial striae in ejecta aprons, associated discontinuous ejecta patterns, and complex hummocky interior floors. Undivided craters (unit c_u) have raised rims, rough and hummocky ejecta aprons, and rough interior floors. Modified craters are interpreted to have developed largely by fluvial erosion and deposition. These crater types are used in lieu of a standard three-fold division relative to crater age because dfferences in the crater preservation within Chryse Planitia may not be a simple function of crater age. For example, some pristine craters distal from fluvial materials may represent impact craters protected from fluvial events, whereas a crater of the same age within a fluvial material unit may have been extremely eroded and degraded by the flooding events. In contrast, some pristine craters within fluvial material units are likely to be relatively young.

OUTCROP-SCALE OBSERVATIONS FROM VIKING 1 LANDER

The Viking 1 Lander (Mutch Memorial Station), near the boundary between the MTM 20047 and 25047 quadrangles, is located on the younger ridged plains material within a left-stepped offset between north-south oriented mare-type ridge segments of Xanthe Dorsa (fig. 4) (Morris and Jones, 1980; U.S. Geological Survey, 1980, 1982a,b; Craddock and Zimbelman, 1989).

Observations by the Viking 1 Lander at centimeter to meter scales (fig. 7) identified two sizes of material on the surface: (1) pebble-, cobble-, and block-sized rocks (8 mm to 30 cm), and (2) soils, drifts, and cemented or cohesive fine-grained (0.1 to 10 m) materials (Mutch and others, 1977). The surface is dominated by moderately angular, equidimensional, knobby, and some pitted blocks. These blocks are embedded within fine-grained surficial material and clumped, or cloddy, fine-grained, and dusty material of eolian origin (Mutch and others, 1977; Binder and others, 1977; Sharp and Malin, 1984; Arvidson and others, 1983,1989; Garvin and others, 1981; Moore and Jakosky, 1989). Chemical analysis of loose, fine surface material at the Viking 1 Lander site (Clark and others, 1982) indicated a mafic provenance for the parental materials of the surface fines. No actual rock fragments were analyzed, only soils. The compositions of the soils were similar at both Lander 1 and 2 sites, implying the fines, or a significant portion of the fines, may be more representative of globally distributed wind-emplaced and (or) atmospheric fallout rather than derived from local materials. Spectral modeling of Viking 1 Lander images by Adams and others (1986) supports a relatively simple local lithology consisting of one unweathered rock type, coarse soil derived from this rock, and palagonitelike dust. If the substrate is basaltic, as some of the more vesicular-appearing rocks in the lander field of view might suggest, the primary morphology has been modified or buried (Aubele and Crumpler, l987).

Several studies have examined the size distribution of rocks within the field of view (Binder and others, 1977; Garvin and others, 1981; Moore and Jakosky, 1989; Moore and Keller, 1991; Crumpler, 1996; Golombek and Rapp, 1997, 1995). Rocks constitute between a few percent to several percent of the surface area. The rocks at the Viking 1 Lander site are diverse in morphology but consistent with the types of materials expected from subaerial and fluvial deposition of materials reworked from a surface previously disturbed by impact cratering and rock fragmentation. In particular, rocks derived from highland terrains up the regional topographic gradient on the south and southwest margins of Chryse basin could account for many of the granular, crystalline, and potentially brecciated rocks seen at the Viking 1 Lander site.

The basal unit for this region, older ridged plains material, may have been emplaced through lava flooding (Craddock and others, 1997; Crumpler, 1997) analogous to mare plains emplacement inside impact basins on the Moon. The ease with which this material was eroded to form isolated plateau material (unit HNpl), particularly within outwash channels suggests that some of the older ridged plains material consists of sediments that accumulated early in the basin history. Several lines of reasoning outlined above imply that the younger ridged plains material is entirely sedimentary material emplaced during catastrophic flooding events from Kasei and Maja Valles; however, little direct evidence exists in lander image data for this interpretation. The younger ridged plains material is either sediment from Maja Valles or lava flows emplaced unconformably on the eroded surface of the older ridged plains material.

In addition to the hypotheses noted by Mutch and others (1976), scenarios for the origin of the surface at the Viking 1 Lander site include the following: (a) Outwash flowed across the lander site, but the effects of outwash were inhibited because variations in the topographic relief of the pre-flood surface influenced the pattern of erosion. (b) Surface scouring was inhibited where the water entered abruptly into a static and deep water-filled basin (for example, Parker and others, 1989; Baker and others, 1991); the eastern contact of channeled flood-plains material with the younger ridged plains material would mark the approximate west edge of a basin-filling body of water. (c) The local geology of the Viking 1 Lander site along the crest of a mare-type ridge may not be representative of the plains material surface elsewhere.

The younger ridged plains material and the floors of outflow channels, the location of the younger ridged plains material at the termini of outflow channels, and the burial of preexisting topography in the younger ridged plains material in the topographic bottom of the Chryse basin, are all consistent with simple erosion of material from the basin margins and deposition of that material within the Chryse basin during catastrophic outflow or flood event. The decrease in evidence for erosion from west to east is likewise consistent with the gradual transition from erosion on the west to deposition on the east (fig. 8). The distribution of the small, steep-sided knobs in the east half of the map area within the lowest part of the Chryse basin, mapped here as undivided plateau materials, is consistent with wave-cut margins of isolated relief features, such as mare ridges, but no geomorphic evidence exists for shorelines elsewhere within the southern parts of Chryse Planitia.

Evidence for fluvial emplacement of the surface in lander images (rounded rocks, gullies, and gravel bars) is absent despite the large-scale regional evidence. Large-scale, long-wavelength topography bears the primary evidence for channel erosion and is preserved because nothing has eroded it at that scale. Widespread impact crater gardening and erosion of the surface at meter scales possibly is responsible for the disparity between local Viking 1 Lander observations and more regional Viking Orbiter observations.

GEOLOGIC HISTORY

Central Chryse Planitia developed in an early impact basin that was resurfaced with early plains lavas and subsequently modified by fluvial and impact processes (fig. 8). Following plains volcanism, fluvial runoff from the surrounding highlands contributed sediments that yielded additional plains-forming materials. These sediments discontinuously buried some early mare-type ridges that developed on the plains material throughout the Hesperian and as late as the Early Amazonian in places. Mare-type ridges resulted in the formation of the north-south striking Xanthe Dorsa and northeasterly oriented ridges within the basin-filling units. Following the initiation of mare-type ridge deformation, catastrophic outflows of water from Maja Valles to the west and Kasei Valles to the northwest scoured and incised the plains material and ridges of central Chryse Planitia. Both channel systems are associated with a system of scours and striations that converge on the Viking 1 Lander site. At about this time, the material on which the Viking Lander is situated (younger ridged plains material) was emplaced. The younger ridged plains material buried large areas of older ridged plains material. Included in this burial process were impact craters up to 10 km in diameter superimposed on the older ridged plains material. Therefore, the depth of the younger ridged plains material is estimated to be several hundred meters. Because this surface lies at the termini of two of the largest outflow channels on Mars, the younger ridged plains material is interpreted as a sedimentary deposit of catastrophic fluvial origin (fig. 8).

Local Viking 1 Lander observations are inconclusive regarding the process responsible for emplacing the younger ridged plains material. Morphologic evidence for the process of emplacement has been destroyed at centimeter to meter scales by prevalent impact gardening of the surface. On the basis of mapping shown here, the lineations associated with channeling become discontinuous and finger out around the east and south margins of the younger ridged plains material. Therefore, evidence for flooding is not detected because of the relative absence of significant high-energy flow environment indicators at the surface originally.

The latest deposition and erosion is marked by numerous local drifts and dunes near the lander site and by eolian streaks at impact craters regionally. The shape and orientation of drifts at the Viking 1 Lander site are in accordance with dominantly southwesterly winds. The eolian streaks are similar in orientation to the orientation of fluvial scour patterns because both have followed regional topographic gradients toward the center of Chryse basin.

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Table 1. *Cumulative crater densities and inferred surface ages for geologic units within Chryse Planitia.*

Geologic Unit	N(D=2 km)[1]	N(D=5 km)[1]	Area (/km^2)	Image No	System[2]
HNpr	840±172	289±101	2.83x10^4	897A22	N(2): L. Hesperian N(5): U. Noachian
Hpr	200±56	129±45	6.45x10^4	[1:500K map]	N(2): L. Amazonian N(5): L. Hesperian
Hch	171±90	69±57	2.09x10^4	825A41	N(2): L. Amazonian N(5): U. Hesperian

(1) N is the total number of craters counted within the indicated image area. Crater densities reported are the number of craters larger than diameter D per 10^6 km^2.
(2) Relative ages based on age boundaries of Tanaka (1986).

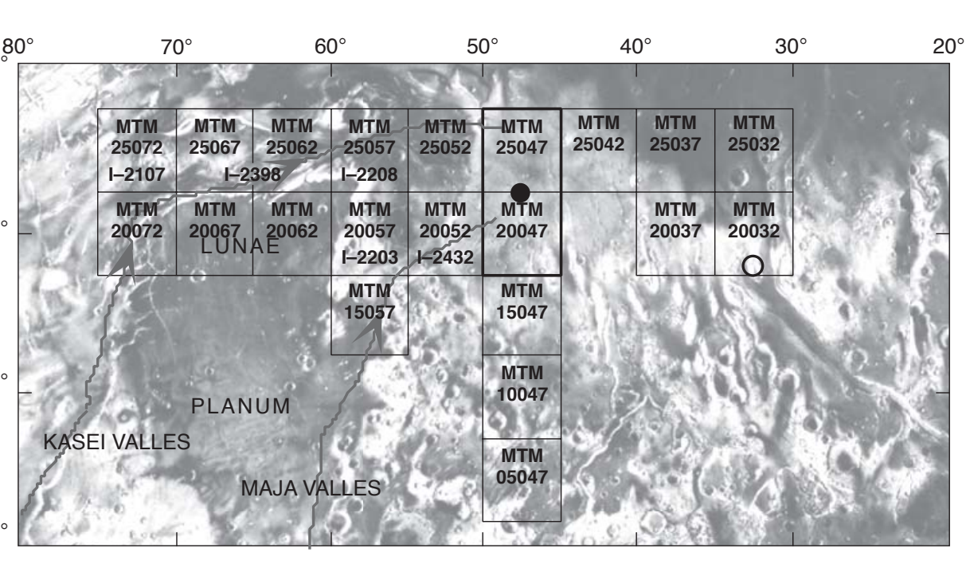

Figure 1. Location of map area (bold outline) in relation to large nearby outflow channels. Major outflow channels Maja Valles and Kasei Valles terminate near the center of map area. Boxes represent areas of Mars Transverse Mercator (MTM) 1:500,000-scale base maps (indicated by center latitude and longitude), I–number indicates published 1:500,000-scale geologic maps. Also shown are Viking 1 Lander (1976) site (solid dot) and Mars Pathfinder (1997) site (open dot). Base map from U. S. Geological Survey (1991).

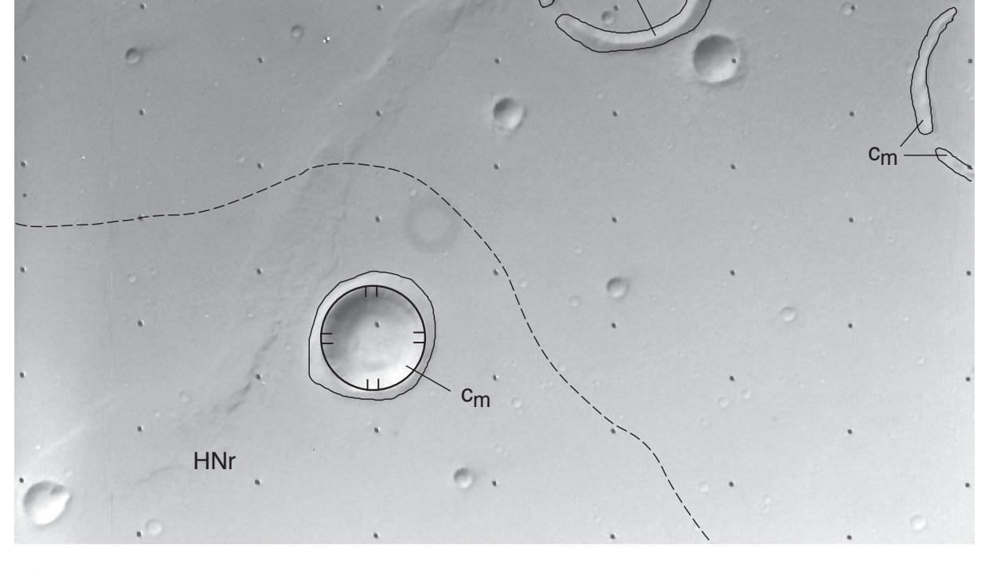

Figure 2. Craters partially buried by younger materials and example of ridges forming younger ridged plains material (unit Hr) [Viking image 020A89]. Contact (dashed line) between younger ridged plains and older ridged plains is transitional in this region, where unit Hr thins and laps onto unit HNr. Image width is 50 km.

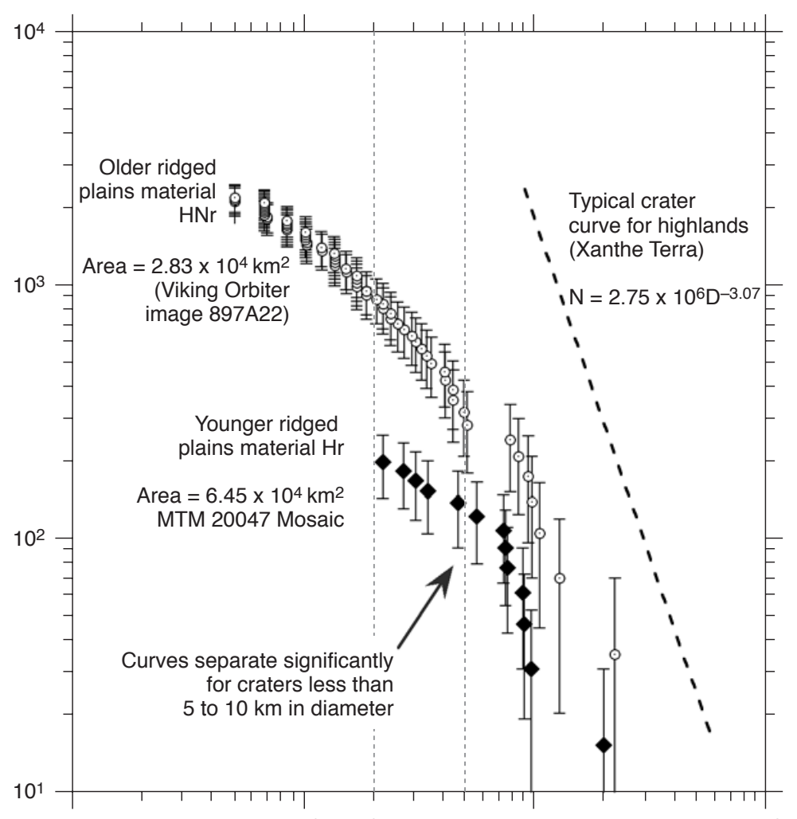

Figure 3. Cumulative number of impact craters for plains materials within map area. A break in slope of the impact crater distribution curve indicatives that there has been relative removal or burial of craters less than 10 km in diameter during formation of the younger ridged plains material. This diameter corresponds to craters less than 300 m deep and yields a maximum thickness of the burying materials.

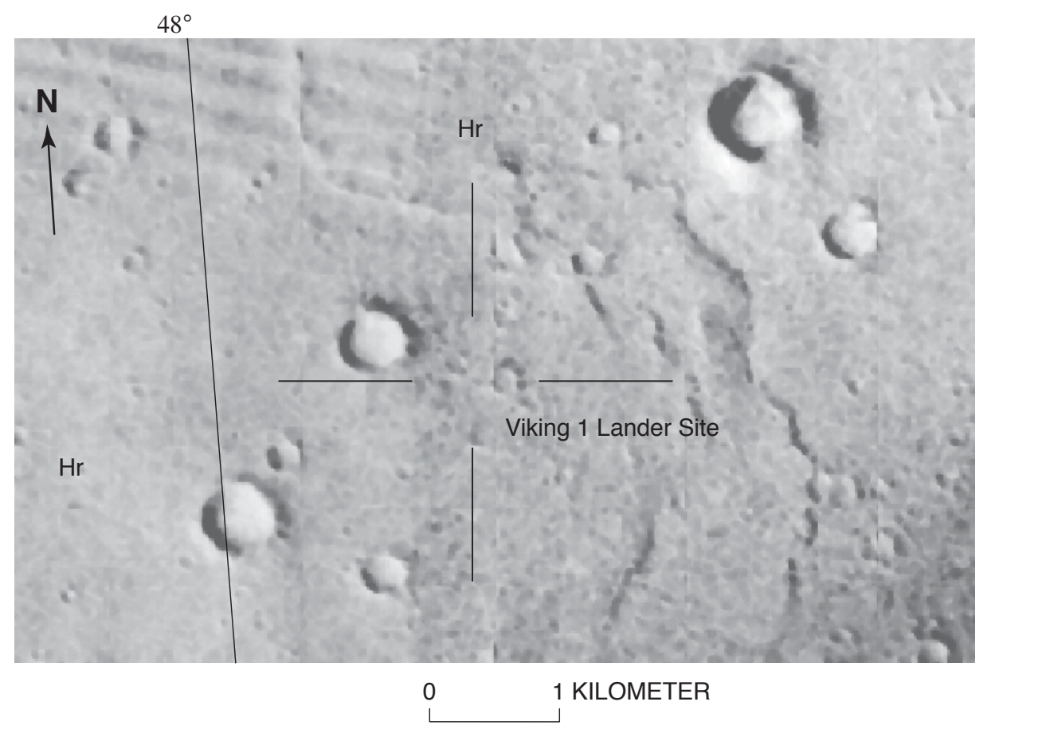

Figure 4. Highest resolution Viking images of the Viking 1 Lander site. Lander is situated between the ends of two small mare-type wrinkle ridges that form a segment of a much larger ridge. This surface, dominated by mare type ridges and featureless expanses, is typical of younger ridged plains unit (unit Hr) which covers the lower reaches of Chryse basin [Viking image 020A71]. Image width, 4 km by 11 km. Location of Lander 1 indicated by tick marks.

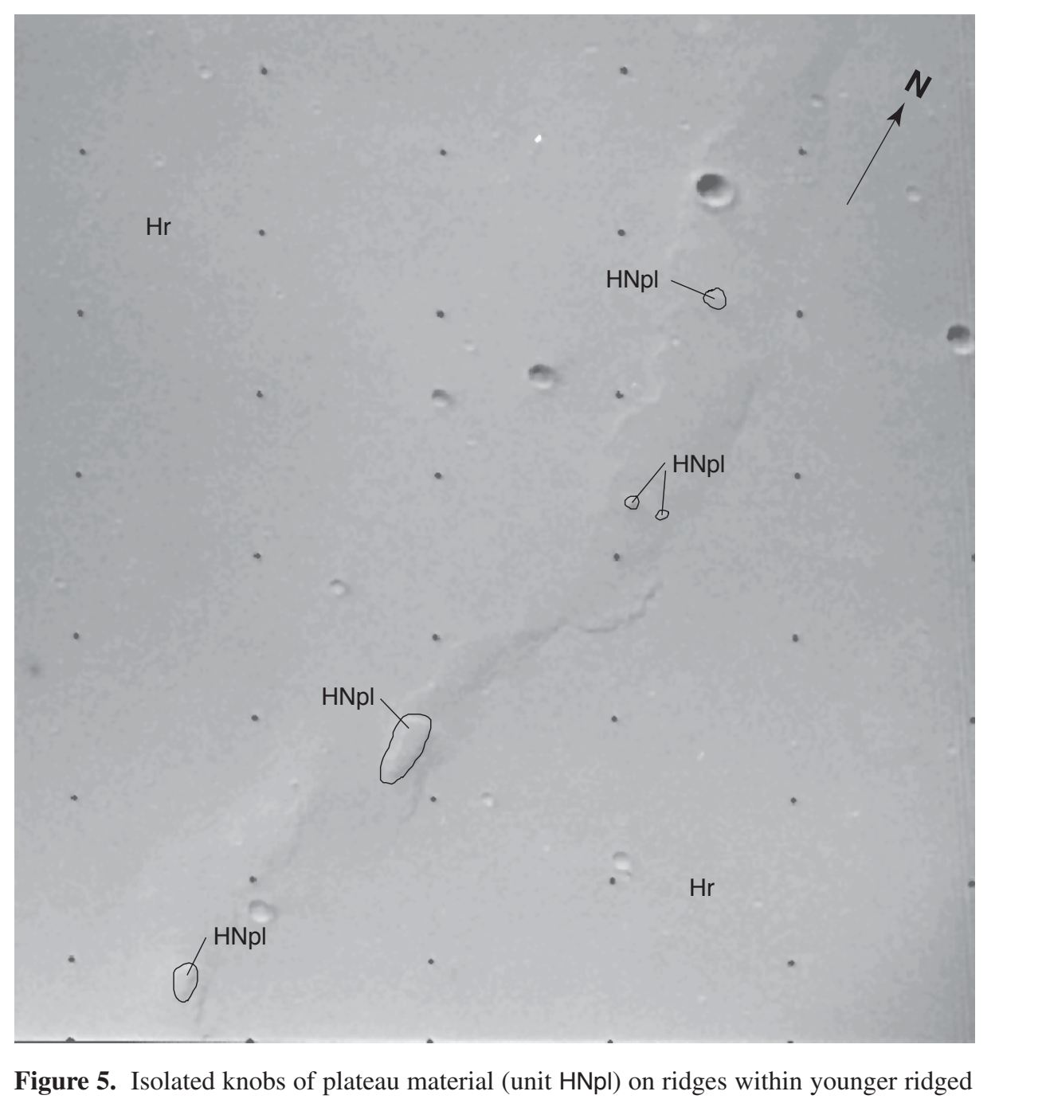

Figure 5. Isolated knobs of plateau material (unit HNpl) on ridges within younger ridged plains material (unit Hr) [Viking image 10A03]. Knobs are interpreted to be either topographic erosional remnants of an older material protruding through a thin overlying material or wave-cut benches (Parker and others, 1993) in easily eroded sediments conformably draped over wrinkle ridges. Image width is 30 km.

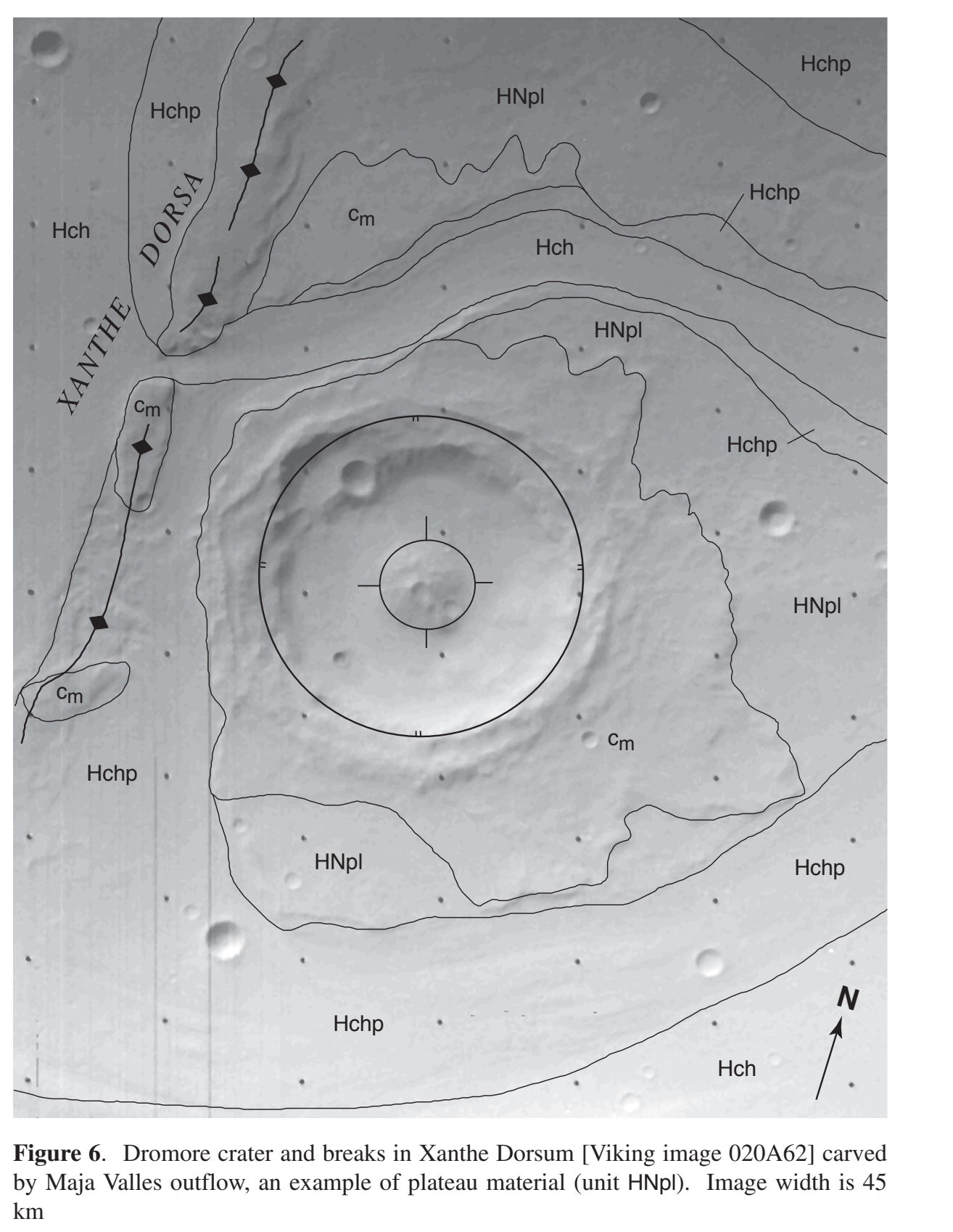

Figure 6. Dromore crater and breaks in Xanthe Dorsum [Viking image 020A62] carved by Maja Valles outflow, an example of plateau material (unit HNpl). Image width is 45 km

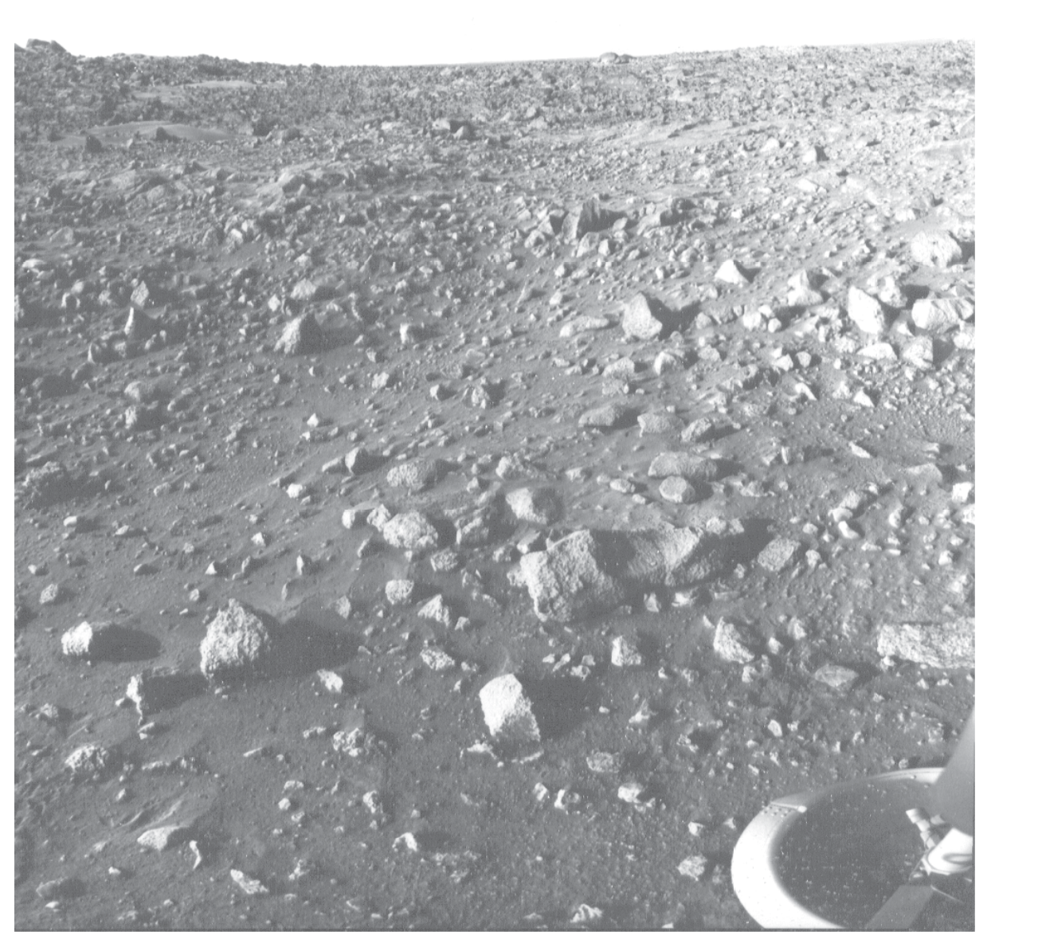

Figure 7. Early morning surface image of younger ridged plains material (unit Hr) from Lander 1, camera 2 perspective. Direction of view is to the south. Rounded or otherwise obvious fluvially modified rock shapes are not present. Angular and elongate rock in the near field and just to the right of center is 40 cm long. Local eolian drift materials (light patches in upper left) and dunes are oriented north-northeast in agreement with regional eolian markings (shown as open arrows on map), which imply southwesterly regional winds. Blocks on horizon at upper left are on the west rim of an impact crater visible in figure 4. (From part of mosaic of Viking 1 Lander images 12A03–108 and 12A112–124).

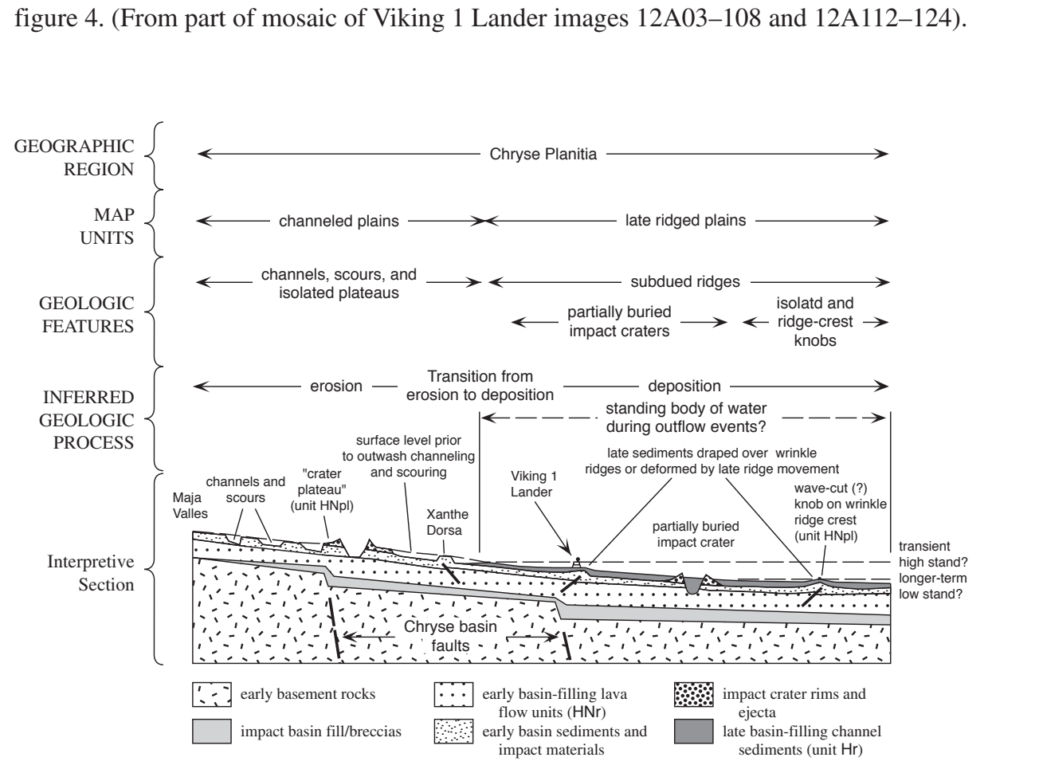

Figure 8. Summary sketch and generalized regional geologic cross section from west to east across map area in the vicinity of Viking 1 Lander. Hypothetical section shown includes elements of several possible sections all of which are oriented approximately southwest to northeast across northern half of MTM 20047.

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