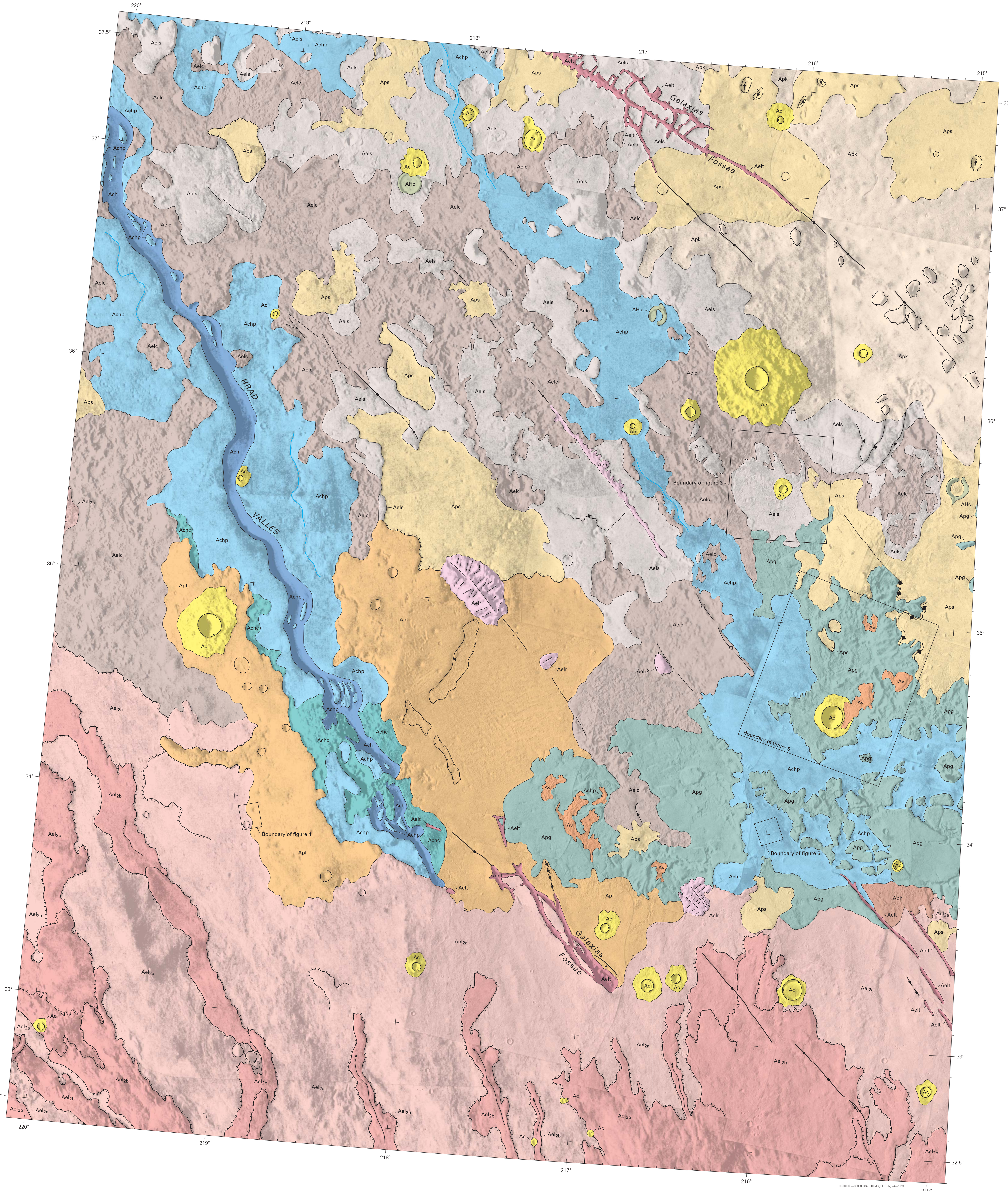
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Prepared for the
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

ATLAS OF MARS
1:500,000 GEOLOGIC SERIES
GALAXIAS REGION
M 500k 35/217 G, 1999
MAP I-2579



Prepared on behalf of the Planetary Geology Program, Solar System Exploration Division, Office of Space Science, National Aeronautics and Space Administration

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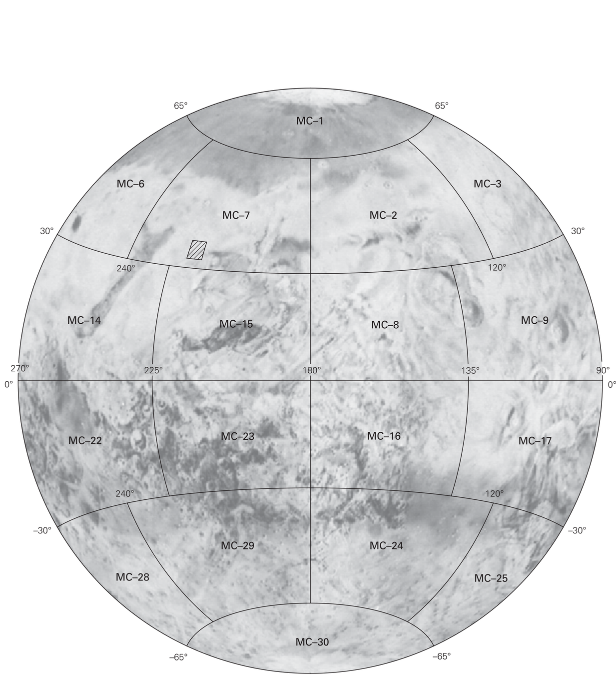
SCALE 1:502 000 (1 mm = 502 m) AT 210° LONGITUDE
TRANSVERSE MERCATOR PROJECTION

KILOMETERS



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

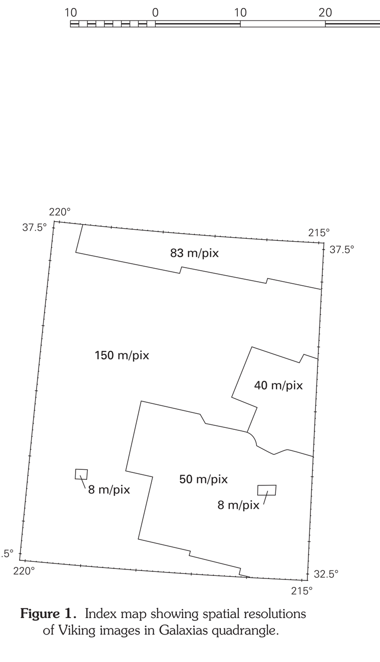


Figure 1. Index map showing spatial resolutions of Viking images in Galaxias quadrangle.

CORRELATION OF MAP UNITS

DESCRIPTION OF MAP UNITS

Interpretation that this material is locally derived sediment moved by gravity, wind, or water. Some or all of the smooth plains material may represent lacustrine deposition in lakes.

... and intervening narrow ravines. The coarse member is described by Tanaka and others (1992) as flows that are thicker and more rugged than the smooth material. These materials have been interpreted as huge lahar deposits (Christiansen and Greeley, 1981; Christiansen, 1989), erosional plains material (Mouginis-Mark, 1985), pyroclastic flows (Tanaka and Scott, 1987), and jökulhlaup deposits (Chapman, 1994). A nonvolcanic origin for the coarse member is suggested by De Hon and Mouginis-Mark (1990) and De Hon (1992).

The physical position of the smooth member overlying the coarse member would suggest by superposition that the smooth member is younger than the coarse member. For this interpretation to be true, the scattered, discontinuous outcrops of the smooth member would either represent local deposits or the existing materials must be remnants of a much more widespread unit that has been removed by erosion. A mechanism for widespread erosion on Mars is not recognized at this time.

The topographic and stratigraphic position and the distribution of smooth and coarse members in this area suggest an alternate interpretation to the volcanic origin. Aligned pits within the smooth member and rugged embayments along the edge of the smooth member may be incipient stages of formation of the coarse member at the expense of the smooth member. The coarse member is interpreted here as a degradational remnant of the smooth material (and perhaps other materials) modified by karst, thermokarst, or surface water erosion (De Hon, 1992).

In the Galaxias quadrangle, Elysium lava flows are divided into two mapping units. These divisions are locally identifiable. We make no claim to their significance in other areas of the Elysium region. The oldest flow material (unit Ael_{2a}), characterized by degraded lobate scarps, covers much of the southern third of the map. This material may be pyroclastic flows or it may be simply lava flows with or without slight compositional variation from the superposed, more pristine, lobate flows of member 2b (unit Ael_{2b}). Member 2b is characterized by elongate tongues having fresh-appearing lobate scarps and lava channels.

Galaxias Fossae consist of a system of open fissures at the northern edge of the Elysium lavas and in the northern part of the quadrangle. Materials exposed in the fissure are mapped as the trough member of the Elysium Formation (unit Aelt, Tanaka and others, 1992). The trough member consists of slope and floor material produced by mass wasting as well as fluvial materials moved short distances by water on the floor of the fissure.

A unique hill of rugged material (unit Aelr) stands above the plains in mid-quadrangle. The ridged and gullied flanks of the hill provide evidence that the material is easily eroded and may be friable volcaniclastic material or that erosion has exposed dikes radiating from an intrusive body. The ridge has been interpreted to be a moberg hill, a type of sub-ice volcano (Anderson, 1992; Chapman, 1994). Smaller, smooth-surfaced mounds are found to the southeast of this feature, and a long ridge of similarly ridged and gullied flanks lies to the northeast. These hills and the ridge appear to be structurally controlled, as they occur along a major fracture trend.

Channel systems of probable fluvial origin occur as channel material (unit Ach) of wall and floor deposits of Hrad Vallis, as flood-plain material (unit Achp), and as chaotic channel material (unit Achc). Channel material occurs in a 4-km-wide channel of low sinuosity. Material of the flood plains flanks the channel and forms the floor of a 25- to 45-km-wide outer valley. Slumped and collapsed walls near the head of Hrad Vallis form chaotic terrain that may have blocked the channel at one time but was reopened by renewed discharge from the source fissure. At least two generations of fluid release are identified for Hrad Vallis by Mouginis-Mark (1985), and the fluted plains material possibly was formed as mud flows during these episodes.

Fluted plains material (unit Apf) near the head of Hrad Vallis may be a lahar deposit originating from Hrad Vallis (Christiansen, 1989) or Galaxias Fossae or both. The fluted plains material contains several, shallow depressions approximately 1 km in diameter (Mouginis-Mark, 1985) that may be maar craters or, more likely, partly buried impact craters. High-resolution images from Viking appear to show these depressions partly mantled by overlying materials. Some of these depressions have concentric inner rings (fig. 4). If these are impact craters, the fluted plains material has sufficient thickness (greater than 200 m) to bury the rim crest of 1.5-km-diameter craters. Concentric craters may be an indication of a shallow stratigraphic horizon. West of Hrad Vallis the mudflow partially buries material of the Elysium Formation.

Hilly plains material (unit Aph) is expressed as closely spaced hills having less than 1 km basal diameters. This material, near the east edge of the quadrangle (lat 33.7° N., long 215.2°), is much more widespread in the adjacent Hecates quadrangle to the east. This small-scale hilly material appears to be formed by degradation of surface materials of the polygons of the grooved terrain on which it lies.

Breakup of Elysium lavas (mostly unit Ael_{2a}) into polygonal blocks is mapped as grooved plains material (unit Apg) along the north edge of the Elysium lava flows (Tanaka and others, 1992). Grooved plains material is made up of large, smooth-surfaced polygons (5 to 30 km across) separated by 1- to 3-km-wide, flat-floored troughs. Removal of ground-ice or liquefaction of material beneath Elysium lavas is likely responsible for removal of support and downslope migration of polygonal blocks that make up grooved terrain (Sharp, 1973; Carr and Schaber, 1977; Mouginis-Mark and others, 1984; De Hon, 1992). Well developed east of the Galaxias quadrangle, the polygons become degraded and obscured by surface mantling as the material is traced westward and northward. In the Galaxias quadrangle grooved material grades northward into coarse and smooth members of the Elysium Formation or materials of the smooth plains that apparently bury it. In the region east of this quadrangle, grooved terrain grades northward to become buried beneath knobby plains material. Knobs may be mantled erosional remnants of high-standing polygons of the grooved terrain.

Knobby plains material (unit Apk) extends into the northeastern part of the map area and is better developed farther east. This material forms smooth surfaces of rolling topography broken by small to moderate-size, widely spaced, rounded knobs with basal diameters of 2 to 10 km. Knobby plains material is part of the enigmatic northern plains materials that have curvilinear ridges which may be strand lines from former standing bodies of water (Parker and others, 1989). In many areas on Mars these materials are associated with paleochannels (Scott and Underwood, 1991). The knobby plains material was probably emplaced as a mantling layer over an irregular surface. The unit may be composed of interbedded sedimentary material of local origin and materials of eolian, aqueous, or volcanic origins. The knobs may represent buried remnants of polygons formed from a once continuous layer of Elysium lavas, such as member 2a of the Elysium Formation, or they may be remnants of older material found in nearby Phlegres Montes (Scott and Carr, 1978; Greeley and Guest, 1987).

Smooth plains material (unit Aps) forms extensive lowland plains and occurs on the floors of some topographic basins. The location of smooth plains material in closed depressions lends support to an interpretation that this material is locally derived sediment moved by gravity, wind, or water. Some or all of the smooth plains material may represent lacustrine deposition in lakes.

Vermicular terrain material (unit Av) is found in the southeastern part of the quadrangle (lat 34.7° N., long 215.5°) superposed on portions of grooved terrain and craters. The material is characterized by small, closely spaced, subparallel ridges on moderate slopes and downhill from slopes (fig. 5). The ridges are perpendicular to slopes, and they develop greatest continuity at the base of slopes. This material is assumed to be formed by mass wasting and downslope movement of slope materials (Mouginis-Mark, 1985). Mass wasting in this region may be accentuated by an ice-rich substrate that allows rubble to creep downslope and develop a series of parallel "push up ridges."

CRATERS

Most craters within the region are less than 5 km in diameter and are morphologically fresh appearing Amazonian craters (unit Ac). Amazonian craters have sharp rim crests and have either radial striations on their ejecta blankets or well-preserved, continuous, lobate ejecta deposits surrounding the parent crater. Some craters possess lobate deposits having distal ramparts characteristic of craters believed to have formed in volatile-rich targets (Carr and others, 1977), whereas others have radially scoured ejecta deposits that may be caused by atmospheric effects (Schultz and Gault, 1979). Secondary crater fields are scarce. The largest craters in this area have diameters of only 6 km. The ejecta blanket of one of these craters, on grooved plains material, is characterized by the same vermicular texture as the surrounding terrain (fig. 5). A few craters, which are partly buried by Amazonian plains-forming material, have uncertain stratigraphic bases. These craters are designated as Amazonian and Hesperian crater material (unit AHc) on the basis of their degree of degradation and burial of outer rim material.

STRUCTURE

The dominant structural trend follows the regional slope (inferred from the direction of the channels) and is roughly radial to Elysium Mons. Fissures, grabens, and faults trend northwest. This trend is accentuated by parallel alignment of other linear features, such as the long axis of the rugged ridge material, other ridges, valleys, closed depressions, and flow lobes. Some faults are younger than smooth plains material, but at least one fault is buried by it.

Galaxias Fossae consist of a system of parallel and aligned fissures trending northwest in the southern part of the map area and a 300-km-long fissure trending west-northwest in the northern part of the region. In the south, Galaxias Fossae consist of a bifurcated fissure complex 5 to 7 km wide and 45 km long. Several smaller, 1- to 2-km-wide, fissures occur near the east edge of the quadrangle. In the north, Galaxias Fossae consist of two 1- to 2-km-wide parallel fissures having scalloped sides. Erosion has cut alcoves into the walls to produce many right angle, short, cross valleys. Galaxias Fossae appear to have enlarged original fissures by slumping and backwasting of the walls. In the larger fissures, material from the walls was redistributed by water flowing along the floor of the fissure.

Small hillocks, 1 to 3 km in basal diameter and a few hundred meters high, occur within smooth plains material in the northern part of the quadrangle. These hillocks, smooth surfaced at Viking resolutions, have convex upward flanks and are topped by pits or troughs. Whether these hillocks are small versions of the much larger dome of rugged ridge material is uncertain. The hillocks are smaller and not situated along identifiable faults or fracture traces. They resemble pingos or breached volcanic cones. If they are pingos, they have not collapsed by decay of the ice core and, therefore, would indicate the continued presence of water-ice.

CHANNEL AND HYDROLOGIC HISTORY

Water and, perhaps, ice play important roles in the shaping of landforms in this region. Many water-cut channel systems are associated with the north and northwest distal edge of the Elysium volcanic pile. These outflow channels were cut by water derived from the subsurface by less catastrophic releases than the channels associated with the Chryse Basin. Much of the water appears to have found its way to the surface at fissures and along the basal contact of the Elysium lavas. Although it is common to think in terms of water being released by volcano-ice interaction, it is just as likely that the ground-water system was pressure driven by the weight of the Elysium volcanic pile. In addition, the smooth member of the Elysium Formation may have contained connate water. Dewatering may have led to significant degradation of those materials and may have supplied local lakes.

Hrad Vallis and an unnamed flood plain (from about lat 34° N., long 216° to lat 37° N., long 218°) are the two prominent drainage courses in the region. Both drainages trend north-northwest parallel to the dominant structural trend of fissures, faults, and lineaments. In addition, scour marks and channeling indicate that the floor of Galaxias Fossae carried small volumes of flowing water.

Hrad Vallis begins as a fissurelike depression that is locally associated with chaotic terrain. The valley has a well-defined, incised, low sinuous channel flanked by a broad, paired terrace of flood-plain material along much of its course in this quadrangle. The channel continues to the northwest for more than 500 km into Utopia Planitia. The flood plain is only found along the upper 175 km of the channel. Slumping along the walls of the valley has left small islands within the channel. A few cut-off loops attest to an earlier period of channeling before the present channel was fully established. However, extensive scars of meander loops are not apparent.

East of Hrad Vallis a broad, flat-floored, irregular depression floored by flood-plain material reaches from the southeastern part of the quadrangle to beyond the north-central border. Although lacking a narrow channel throughout its length, the depression has a smooth floor with some minor scour and channeling marks ,which indicate that it has carried water. The valley heads at a 10-km-diameter depression along the southern limit of the Elysium Planitia lava flows (lat 33.7° N., long 216.2°), but water was probably released into the valley along the edge of the adjacent grooved terrain. A delta and levee complex (fig. 6) leads from the basin into the drainage course (Mouginis-Mark, 1985). Locally, the waters on the flood plain embayed isolated blocks of the grooved terrain.

Although the morphology of upper Hrad Vallis is superficially similar to terrestrial mid- to late-stage valley development, there are problems with any attempt to explain the origin of the valley in terms of normal, sequential valley development by running water. The channel is sinuous, but it is not meandering. Within this quadrangle the channel is found within a wide, flat-floored valley, but the channel is responsible neither for carving the valley nor for planation of the valley floor. Rather, the flat-floored outer valley appears to have formed first, and then the channel was cut into the floor of the valley at a later time (De Hon, 1992).

The origin of the Hrad Vallis broad, outer valley and the flat-floored valley to the east is not clear. The walls of the outer valley are irregular, and the valley does not appear to be cut by simple overland flow. Both valleys may have incorporated earlier formed, flat-floored, closed basins localized along structural trends that were later flooded and connected by short channels cut by spillover as the basins filled to capacity (De Hon, 1992). The discharge pattern appears to have been controlled by the regional structural trends of the area. Galaxias Fossae, Hrad Vallis, and numerous ridges and enigmatic structures such as the rugged ridge material lie along the same northwest trend. In particular, the elongate structures of rugged ridge material could be the site of an abortive additional outflow event. Gullying caused by water release may have cut the scalloped flanks.

Ridges less than one kilometer wide occur along the edge of the smooth plains material parallel to its contact with polygonal plains material in the eastern part of the area (fig. 5). The origin of these features is also in doubt. They may be shoreline dunes or ice-pushup ridges along the shore of an ice-capped paleolake.

GEOLOGIC HISTORY

In this region, the interplay of volcanism, near-surface volatiles, and surface runoff is evident. The presence of subsurface ice as permafrost and the possibility of standing water in small and large lakes is inferred. Resurfacing by late-stage volcanism and active surfical processes (erosion by ice degradation and water runoff and deposition from water and mass wasting) has largely erased evidence of early periods of high impact rates. Most of the geologic activity recorded by stratigraphic units and by modification of the surface is Early Amazonian in age. Members 2a and 2b of the Elysium Formation were emplaced as lava flows from Elysium Mons volcano. Multiple episodes of clastic deposition took place because of sedimentary or volcaniclastic processes that may have been initiated by ground warming associated with the Elysium Mons volcanic activity. The smooth member of the Elysium Formation was subsequently degraded by dewatering or runoff (or both) to produce coarse-textured surface expression of the coarse member.

Following emplacement of materials of the Elysium Formation, dewatering and degradation of water-ice-rich sedimentary or volcaniclastic materials underlying Elysium lava flows resulted in the formation of polygonally grooved material and fissure material. Grooved plains material shows a progressive degradation in which originally well-defined polygons are degraded to irregular, blocky materials having faint hints of the original polygonal pattern. In the northeastern part of the region, isolated mesas and buttes of degraded grooved material were mantled by material of undetermined origin. In the central part of the region, rugged ridge materials of possible volcanic origin were emplaced along regional fracture trends.

Mudflows followed by large-volume water releases are preserved within the floor of Hrad Vallis, and numerous smaller aqueous discharges were evidently associated with Galaxias Fossae and the grooved plains material. Mudflows and water apparently were discharged from these sources at a time that postdates the emplacement of lava flows from Elysium Mons.

Smooth plains material deposited on the floor of irregular basins was probably emplaced by mass wasting, fluvial, and lacustrine processes. Mass wasting continues to modify the topography by creep in loose surface rubble. Much of the grooved material and channel material appear to have experienced the creep of surface material that created the ridged terrain paralleling topographic highs.

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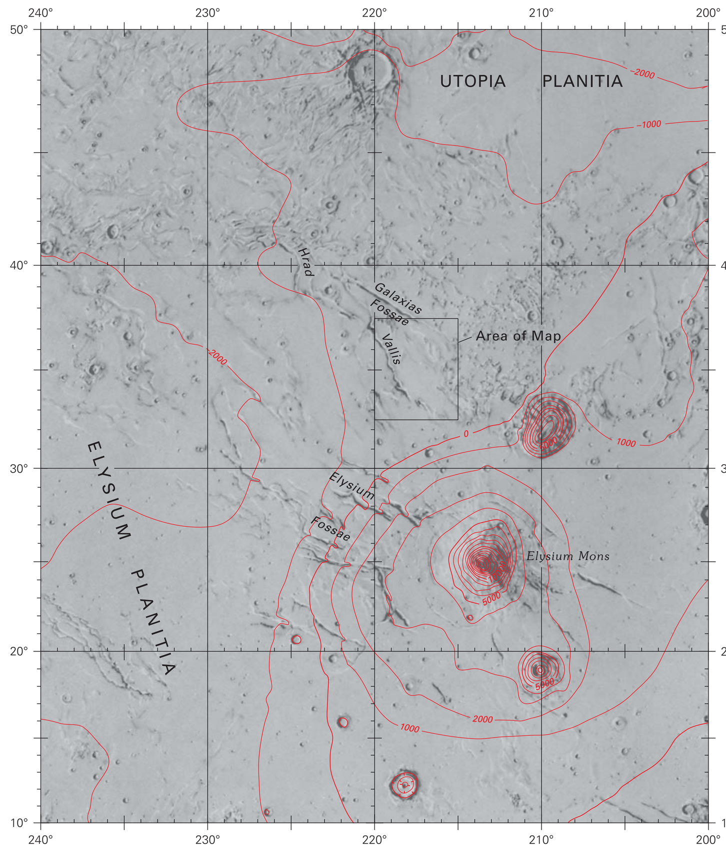

Figure 2. Topographic map of Elysium region, Mars (U.S. Geological Survey, 1989). Galaxias quadrangle is on a broad spur of the northern flank of Elysium rise. Contour interval 1,000 m.

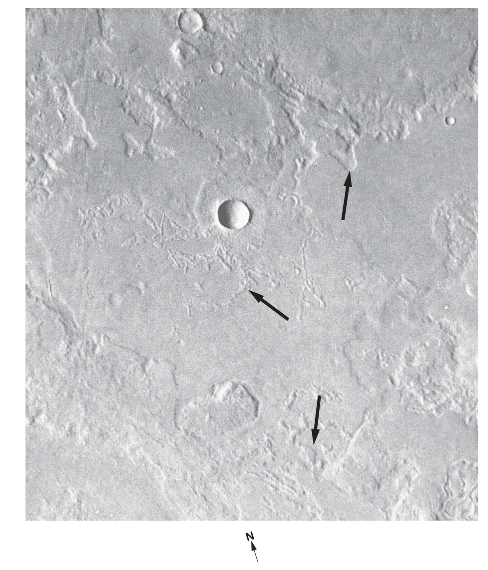

Figure 3. Pitted surface of smooth member of Elysium Formation.

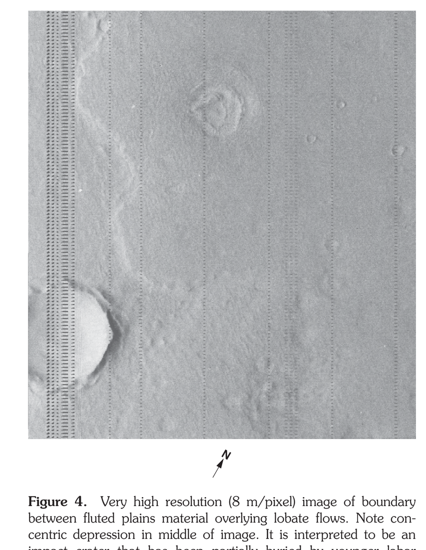

Figure 4. Very high resolution image of boundary between fluted plains material and other flows.

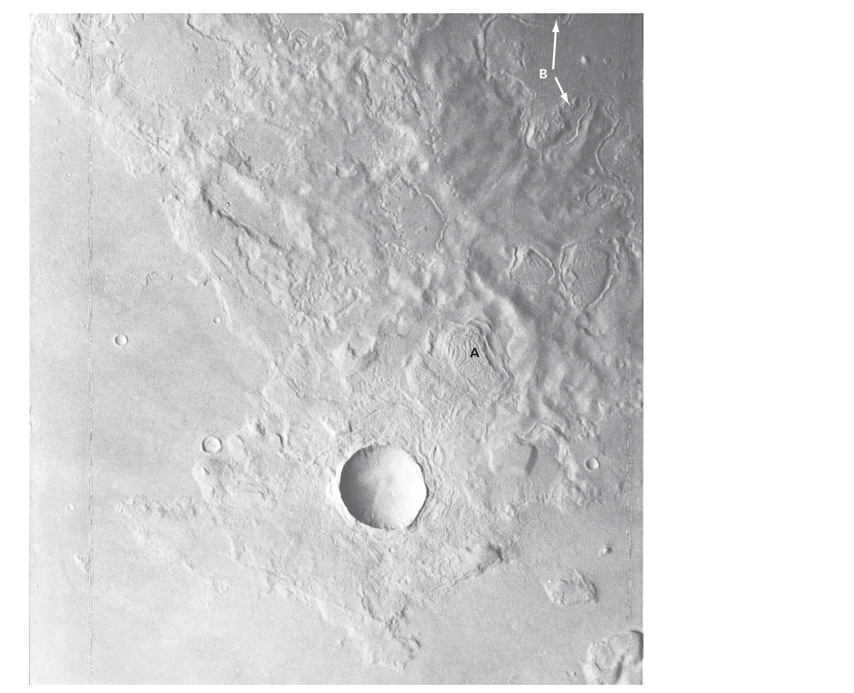

Figure 5. Impact crater on grooved plains.

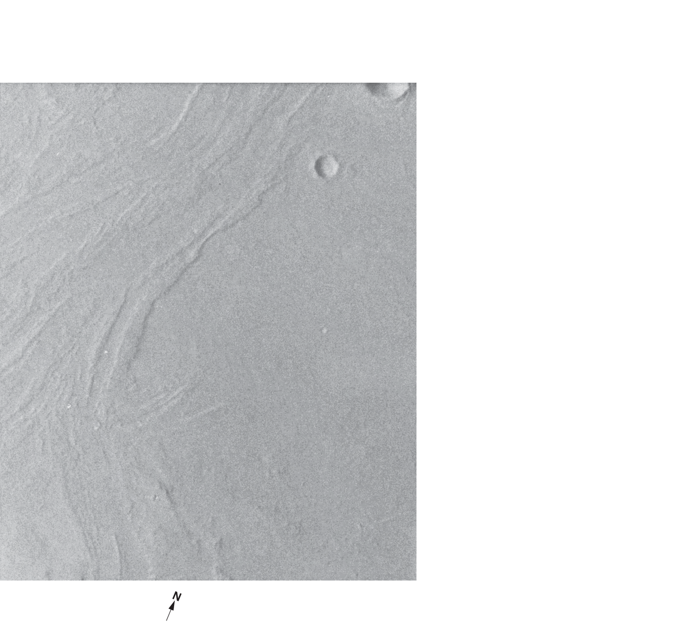

Figure 6. At very high resolution image on floor of catchment area east of Hrad Vallis.

GEOLOGIC MAP OF THE GALAXIAS QUADRANGLE (MTM 35217) OF MARS

By René A. De Hon, Peter J. Mouginis-Mark, and Eugene E. Brick

1999