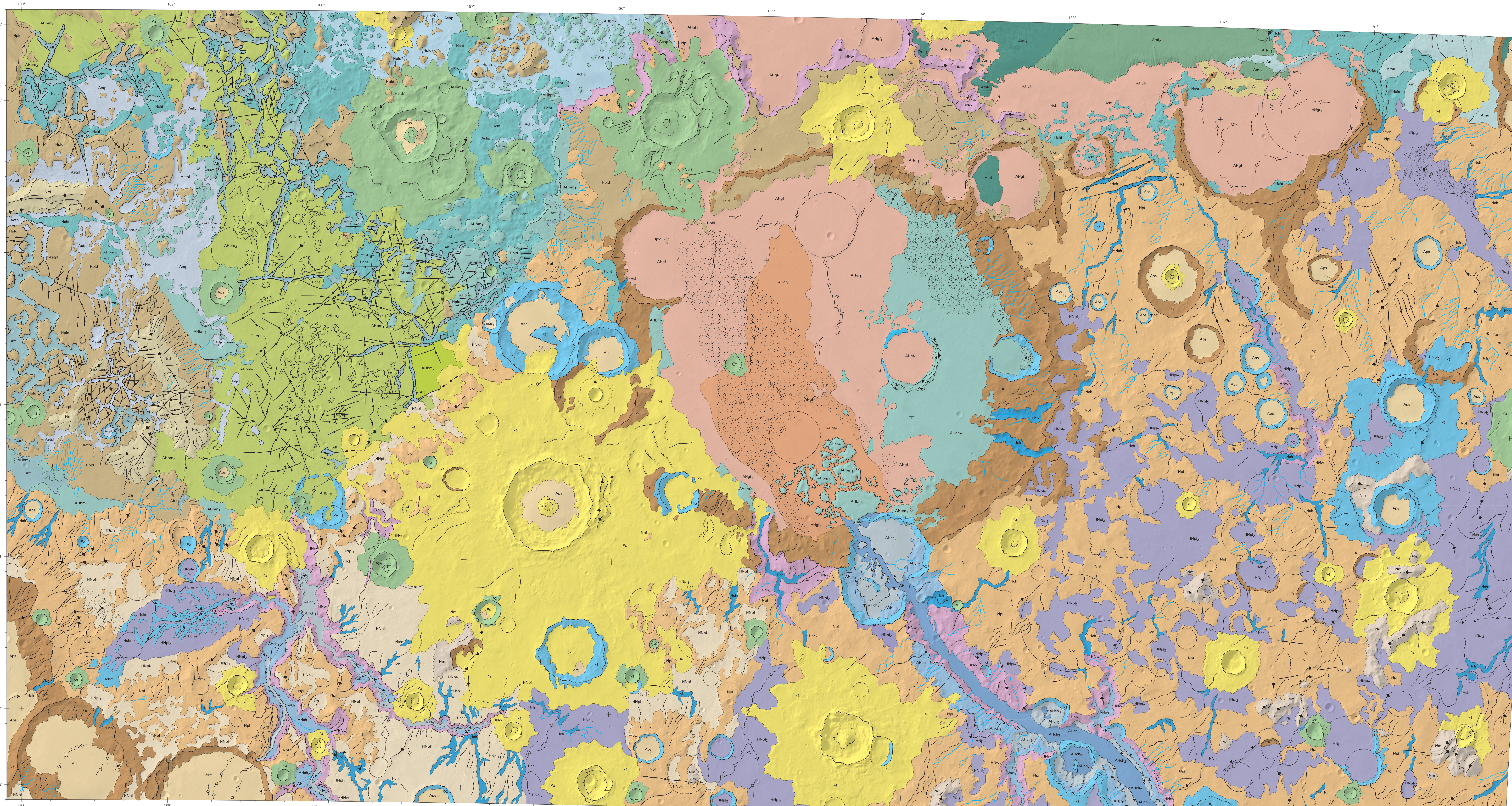

SCALE 1:502 000 (1 mm = 502 m) AT 190° LONGITUDE
TRANSVERSE MERCATOR PROJECTION

10 0 10 20 30 40 50 60 70 80 90 100
KILOMETERS

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

Edited by Derrick D. Hirsch; cartography by Darlene A. Casebier and Hugh F. Thomas

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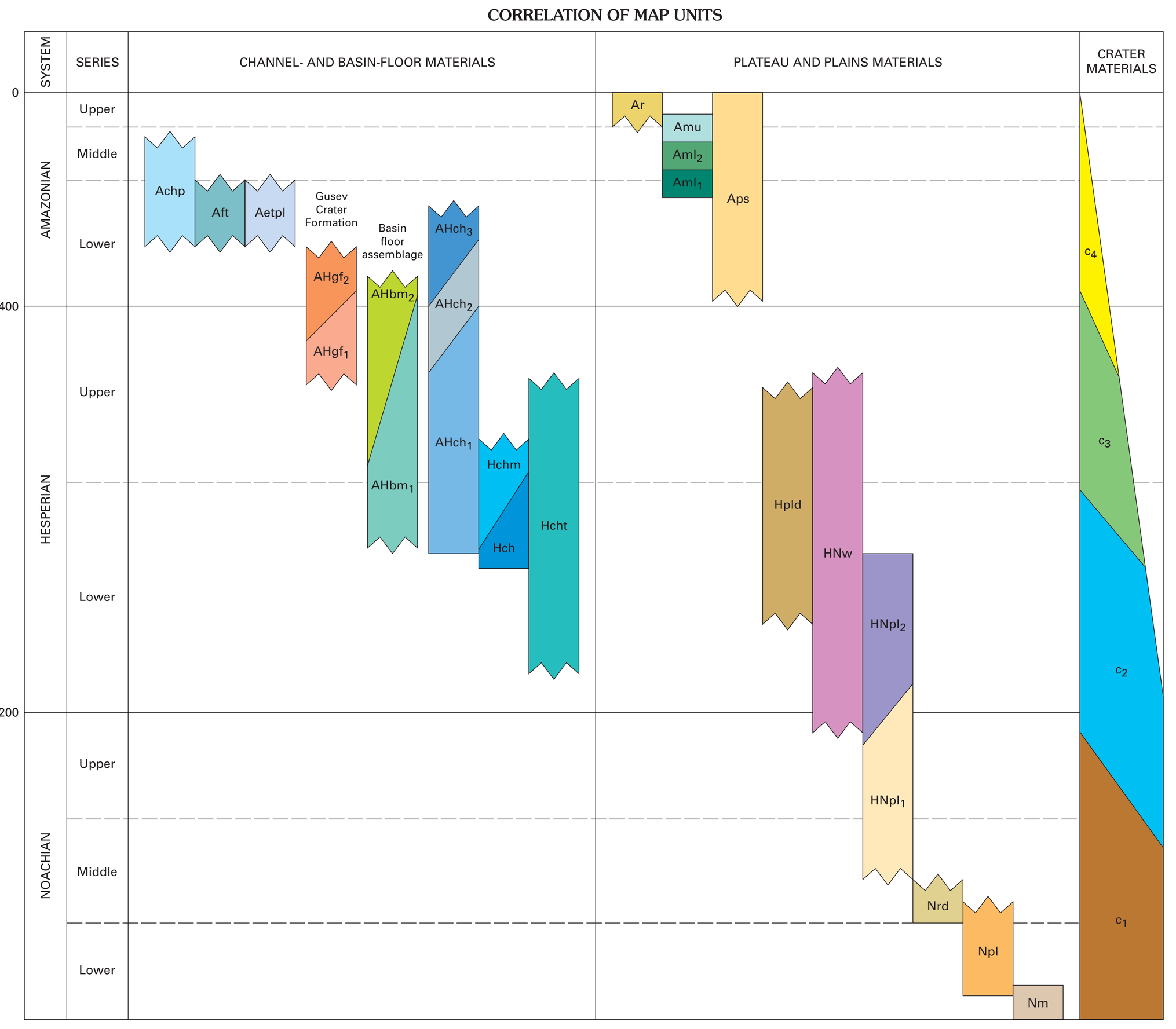
CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

[Relative ages are listed for some units based on cumulative densities of craters whose diameters are greater than 2 km, normalized to 10^6 km^2; ages for others established by stratigraphic relations]

CHANNEL- AND BASIN-FLOOR MATERIALS

Achp **Fluvial plains material**—Forms smooth surfaces that embay hills and plateaus of chaotic terrain material (unit Hcht) west and southwest of Apollinaris Patera. Albedo mottled to low. Type area: lat 12.9° S., long 186.2° W. *Interpretation*: Fluvial deposits associated with latest flooding from Ma'adim Vallis and sapping processes within de Vaucouleurs west of Gusev crater

Aft **Fretted terrain material**—Forms floors of channels in far western part of map area. Channels are slightly sinuous, flat-floored, and intersecting, with each segment being about 10–12 km long and about 2–3 km wide. Channel floors are smooth and rounded against the walls. Type area: lat 14.1° S., long 190° W. *Interpretation*: Channel floor material possibly formed from sapping erosion due to melting of ice from geothermal heating along faults. Unit later mantled by windblown material

Aetpl **Etched plains material**—Forms numerous hills, mesas, and streamlined features through the erosion of units Hpld and $AHbm_1$. Type area: lat 14° S., long 189° W. *Interpretation*: Unit formed by water erosion from geothermal melting of ground ice and sapping erosion by ground water

Gusev Crater Formation

$AHgf_2$ **Member 2 of Gusev Crater Formation**—Forms smooth surfaces along western half of Gusev at mouth of Ma'adim Vallis. Material has distinct lobate boundary and is superposed on unit $AHgf_1$. Type location: lat 15° S., long 185° W. *Interpretation*: Fluvio-lacustrine sediments and debris flow materials formed during the most recent stage of the Ma'adim Vallis flooding into Gusev crater

$AHgf_1$ **Member 1 of Gusev Crater Formation**—Forms smooth surfaces with some extensive ridges in northern and eastern parts of unit in western two-thirds of Gusev crater floor. Variable albedo. Unit appears lower in elevation than the rugged surface on the floor of Gusev ($AHbm_1$). Type area: lat 15° S., long 185° W. *Interpretation*: Fluvio-lacustrine deposits within and north of Gusev crater

Basin Floor Assemblage

$AHbm_2$ **Basin floor unit 2**—Forms extensive area of de Vaucouleurs center. Surface is complicated by densely clustered, rounded hills. Local, narrow, fracture networks form polygonal hillocks. Mottled albedo. *Interpretation*: Fluvio-lacustrine deposits, accompanied by glaciation, tectonic fractures, sublacustrine collapse, and ground-ice decay. Slightly sloping hills possibly resulted from piling ice-sheet fragments and distal sediments from Durius Valles

$AHbm_1$ **Basin floor unit 1**—Forms rugged surface with small hills of a few hundred meters across. Moderate albedo. Located in the eastern one-third of Gusev crater floor and within de Vaucouleurs west of Gusev. Type area: lat 14.9° S., long 183.7° W. *Interpretation*: Fluvio-lacustrine sediments formed during wide-spread ponding inside Gusev and de Vaucouleurs by flooding from Ma'adim Vallis and Durius Valles

Channel Materials

$AHch_3$ **Young channel floor material**—Forms smooth surface on the floor of Ma'adim Vallis. Mixed albedo. Channel floor material bounded by terraces, especially in the northern parts of the vallis. Type area: lat 17.5° S., long 182.3° W. *Interpretation*: Youngest channel deposits of Ma'adim Vallis mantled by veneer of modern aeolian materials

$AHch_2$ **Intermediate channel floor material**—Forms lower level terrace along Ma'adim Vallis and floor of Durius Valles. Mixed albedo. Type area: lat 17.5° S., long 182.2° W. and lat 17° S., long 188.2° W. *Interpretation*: Intermediate-age channel sediments resulting from intravalley depositional processes and modified by mass wasting

$AHch_1$ **Old channel floor material**—Forms upper level terraces within Ma'adim Vallis and Durius Valles. Surface of unit more eroded than surface of $AHch_2$ and $AHch_3$. Mixed albedo. Type area: lat 17.5° S., long 182.2° W. and lat 17° S., long 188.2° W. *Interpretation*: Oldest channel sediments resulting from earliest intravalley depositional processes; modified by erosion

Hchm **Channeled mesa material**—Forms deposit on $HNpl_2$ unit at head of channels; material forms branchlike system of linear, plateaulike mesa features. Type area: lat 16.4° S., long 189° W. *Interpretation*: Ancient deltaic deposits formed on the surface of a glacial sheet or a frozen lake. After sublimation of ice, deltaic deposit remained as positive relief feature (Kuzmin and others, 1997). Alternatively, structures might have formed as delta deposits on floor of ancient lake and were later subjected to headward erosion by some sapping channels

Hch **Oldest channel material**—Forms smooth surface within depressions and degraded channels cut into old cratered plains, subdued cratered plains, and modified cratered plains units (units Npl, $HNpl_1$, $HNpl_2$, respectively). Type area: lat 15.7° S., long 180.2° W. *Interpretation*: Floor deposits of degraded channels of Ma'adim Vallis formed during the Hesperian

Hcht **Chaotic terrain material**—Occurs in northeastern part of map area and within de Vaucouleurs west of Gusev crater. Unit forms densely spaced hills and mesas that become more broken up and smaller toward Apollinaris Patera. Fluvial plains material (unit Achp) embays the hills and plateaus of the unit. Type area: lat 12.7° S., long 186.7° W. *Interpretation*: Plains material eroded by flood waters from Ma'adim Vallis and Durius Valles and deeply dissected by geothermal heating associated with Apollinaris Patera

PLATEAU AND PLAINS MATERIALS

Ar **Ridged material**—Occurs in low area; one occurrence only (lat 12.8° S., long 181.8° W.). Linear crests form corrugated surface on member 1 of Gusev Crater Formation (unit $AHgf_1$) in northeastern part of map area. *Interpretation*: Sand dunes resulting from deflation of lithofacies 1 and 2 of the Lower Member of the Medusae Fossae Formation (units Aml_1 and Aml_2)

Amu **Upper Member of Medusae Fossae Formation**—Forms a smooth, flat to rolling surface, in places sculptured by grooves. Type area: lat 12.5° S., long 180.4° W. *Interpretation*: Thick deposits of pyroclastic material interbedded with aeolian deposits (Scott and Tanaka, 1986)

Aml_2 **Lithofacies 2 of Lower Member of Medusae Fossae Formation**—Forms relatively flat sheets in northern part of map area. Surfaces are smooth and gently rolling, rugged, and in places ridged and grooved. Sparsely cratered. Type area: lat 12.5° S., long 182.5° W. *Interpretation*: Plains material with grooves and yardangs on the base of welded and nonwelded ash-flow tuffs (Scott and Tanaka, 1982, 1986), eroded by multidirectional winds

Aml_1 **Lithofacies 1 of Lower Member of Medusae Fossae Formation**—Forms a smooth surface with a grooved surface pattern. Surface is more eroded than lithofacies 2 of lower member of Medusae Fossae Formation (unit Aml_2). Type area: lat 12.5° S., long 183.4° W. *Interpretation*: Welded ash-flow tuffs (Scott and Tanaka, 1982, 1986)

Aps **Bright and smooth plains material**—Smooth surfaces with sparse narrow ridges on floors of some craters. Unit represents a modification of floors of c_1 and c_2 craters. High to moderate albedo. Type area: lat 13.4° S., long 183.3° W. *Interpretation*: Mostly fluvial-lacustrine, mass wasting, and aeolian deposits

Hpld **Dissected plains material**—Forms a generally smooth and finely pitted surface with some grooves and network-valley patterns west and immediately north of Gusev crater at the contact with the crater rim. Network-valley patterns vary in appearance, those in the western part of the map area are straight and rarely adjoin; those in the central part form second-order tributary patterns. Low to high albedo. Type area: lat 13.3° S., long 186.2° W. *Interpretation*: Ancient volcanic plains deposits, eroded by fluvial processes

HNw **Undivided wall material**—Occurs on steep slopes within the plateau and walls of valles. Discrimination of the material is complicated by shadow and glare due to exposure of different slopes to illumination. High to moderate albedo. Type area: lat 16.5° S., long. 183.7° W. *Interpretation*: Series of plateau-forming rocks, thought to be composed of megaregolith material and ancient lava, interbedded and covered with fluvial and aeolian sediments of Noachian and Hesperian age

$HNpl_2$ **Modified cratered plains material**—Forms a cratered surface south and southeast of Gusev crater. Surface shows moderate topographic relief. Unit differs from old cratered plains and subdued cratered plains materials (units Npl and $HNpl_1$, respectively) in exhibiting fewer craters, valley networks, and a smoother surface. Type area: lat 17° S., long 185° W. *Interpretation*: Material deposited during last stages of ponding outside of lower reaches of Ma'adim Vallis

$HNpl_1$ **Subdued cratered plains material**—Forms cratered terrain southwest of Gusev crater. Unit is cut by Durius Valles, which debouches at de Vaucouleurs west of Gusev. Surface is smooth and subdued (for example, it shows impact ejecta superimposed by other materials). Small (1–2 km) craters are common. Surface is cut by some grooves and valley networks. Unit differs from old cratered plains material (unit Npl) in having fewer grooves and wider valley networks and in being less rugged and more uniform in elevation. Low to moderate albedo. Type area: lat 16.5° S., long 187.5° W. *Interpretation*: Ancient crustal material that has been modified by fluvial processes and impact cratering. Could be deposits from widespread flooding along Ma'adim Vallis and Durius Valles

Nrd **Degraded rim material**—Forms rugged curvilinear ridges having sharp central crests. Grooves and fractures extend perpendicular to the crest down the flanks on one segment of the ridge. Type area: lat 14.9° S., long 189° W. *Interpretation*: Rim material of ancient impact crater or possible volcanic constructs superposed on older terrain

Npl **Old cratered plains material**—Forms widespread plains east of Gusev crater and immediately adjacent to Ma'adim Vallis on both sides of the channel. Surface has been cut by grooves, fractures, and valley networks. Grooves and fractures are present at local topographic highs, and some terminate in smooth low-lying areas. Valleys are of first and second order. Unit is heavily modified by impact craters. Ma'adim Vallis and its tributaries cut the unit. Terrain appears more rugged and eroded than the subdued and modified cratered plains materials (units $HNpl_1$ and $HNpl_2$, respectively). It is also different from these units in being higher in elevation and more densely cratered. Moderate albedo. Type area: lat 14.1° S., long 181° W. *Interpretation*: Ancient crustal material. Rugged appearance is partly due to erosion of impact crater ejecta. Surface is interpreted to have been eroded by water, owing to the presence of valley networks and groove patterns. Unit related to the most widespread episode of flooding outside Ma'adim Vallis

Nm **Mountainous material**—Forms ridges 10–70 km long throughout map area. Some have grooves extending perpendicular to ridge crest. High albedo. Type area: lat 12.5° S., long 187.5° W. *Interpretation*: Ancient uplifted crustal material that has been embayed by younger material

CRATER MATERIALS

[Materials of impact craters with rim diameters larger than 3 km]

c_4 **Fresh crater material**—Superposed on all Amazonian and older units; fresh ejecta blankets generally well preserved

c_3 **Slightly degraded crater material**—Crater morphology similar to younger Amazonian crater materials, but is smoother and in places embayed by Amazonian-age deposits. Characterized by moderately preserved crater ejecta and rim material. Crater floors may show evidence of resurfacing or aeolian deposits

c_2 **Moderately degraded crater material**—Craters are more eroded than c_3 crater material. Ejecta blankets only partly preserved, being largely buried or eroded. In most cases, crater rims are degraded and partly filled by deposits from volcanic, aeolian, and fluvio-lacustrine processes

c_1 **Intensely degraded crater material**—Oldest crater material, preserved mainly as rim or interior slope deposits of former craters. Ejecta blanket and most outer rim slopes eroded or buried. Rim crest very sinuous and less distinct than c_2 crater material

Contact—Dashed where approximately located or gradational; dotted where buried

Fault or graben—Bar and ball on downthrown side

Wide ridge (>1 km wide)—Symbol on ridge crest

Narrow ridge (<1 km wide)—Symbol on ridge crest

Terrace—Line marks top of slope, barb points downslope

Scarp—Hachures point downslope; dashed where buried

Narrow channel

Groove

Depression—Dashed where approximate

Crater rim—Showing crest where preserved and defined

Degraded crater rim—Showing crest

Buried crater rim—Showing crest

Central peak of impact crater

Lobate scarp—Hachures at top of scarp point downslope

Detached lobe—Interpreted as landslide or debris flow deposits

Low albedo smooth material—Interpreted as aeolian material

Erosional boundary—Erosion increases in direction of arrow

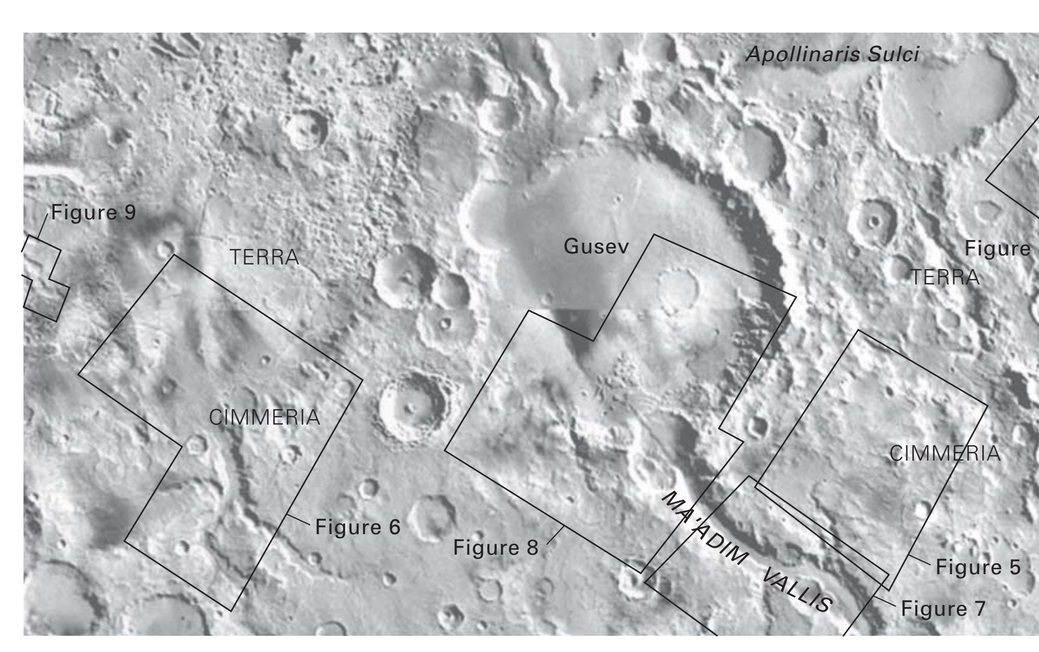


Figure 1. General view of Gusev crater–Ma'adim Vallis map area. Boxes show locations of figures 4 through 9, which illustrate various morphologies within map area.

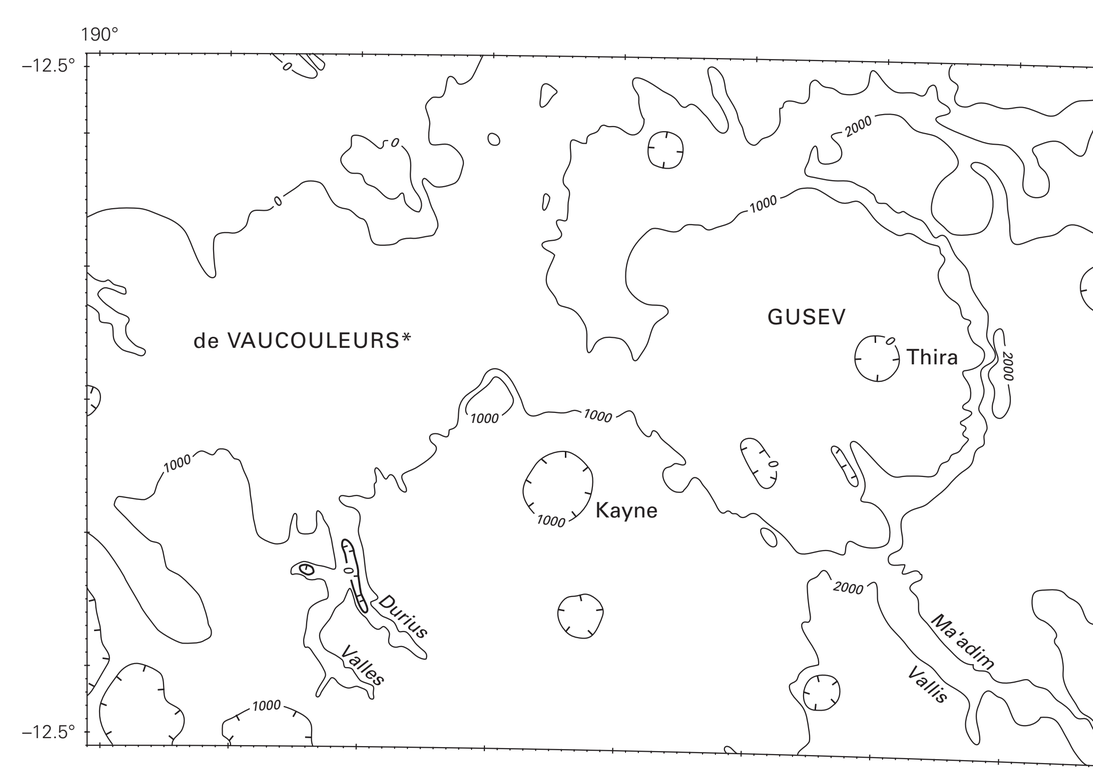


Figure 2. Index map showing location and topographic structure of Gusev crater–Ma'adim Vallis region. Linear depression that joins Gusev crater with de Vaucouleurs west of crater is distinctly visible. Surface in this region trends downhill from southeast to northwest (U.S. Geological Survey, 1991a, b). Contour interval 1000 m. Asterisk indicates name is provisional and has not been approved by the International Astronomical Union.

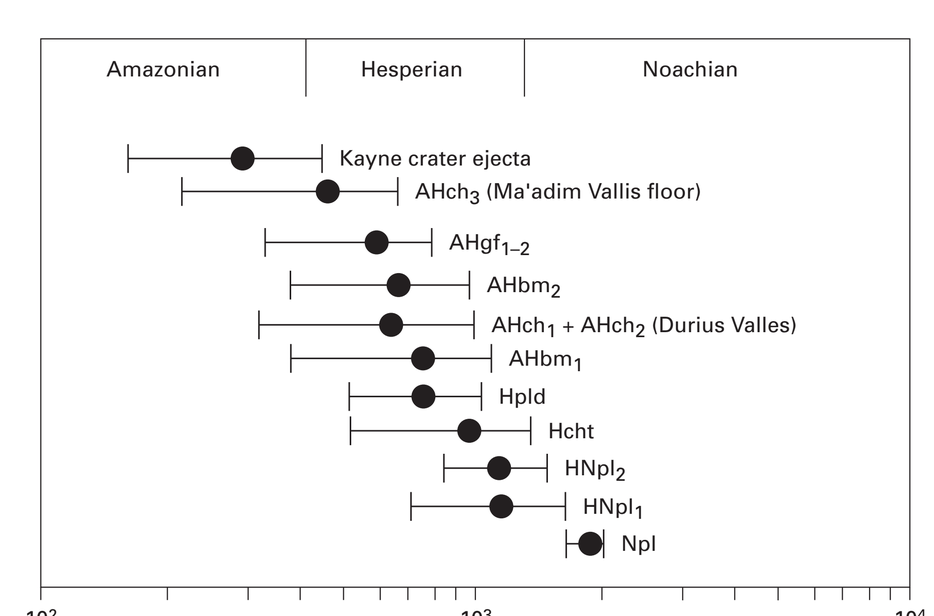


Figure 3. Cumulative densities of craters more than 2 km in diameter per 10^6 km^2 for selected geologic units of Gusev crater–Ma'adim Vallis region. Accuracy of crater statistics are limited by areal restriction of units.

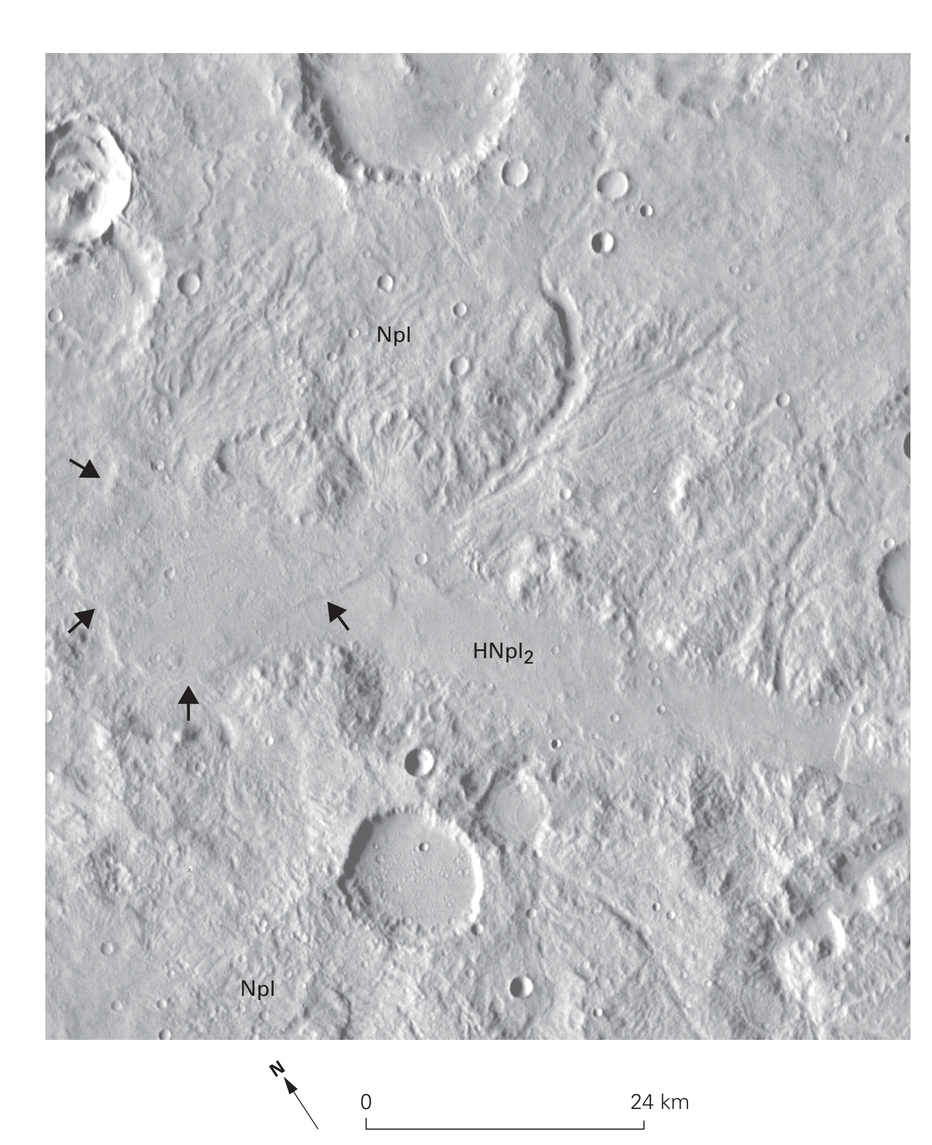


Figure 4. Oldest highland plain (unit Npl) is superposed by Hesperian–Noachian flood sediments (unit $HNpl_2$). A system of small channels was cut into the walls of the elongated depression and debris flow (indicated by arrows) materials superposed on surface of unit $HNpl_2$. Viking Orbiter image 436S07.

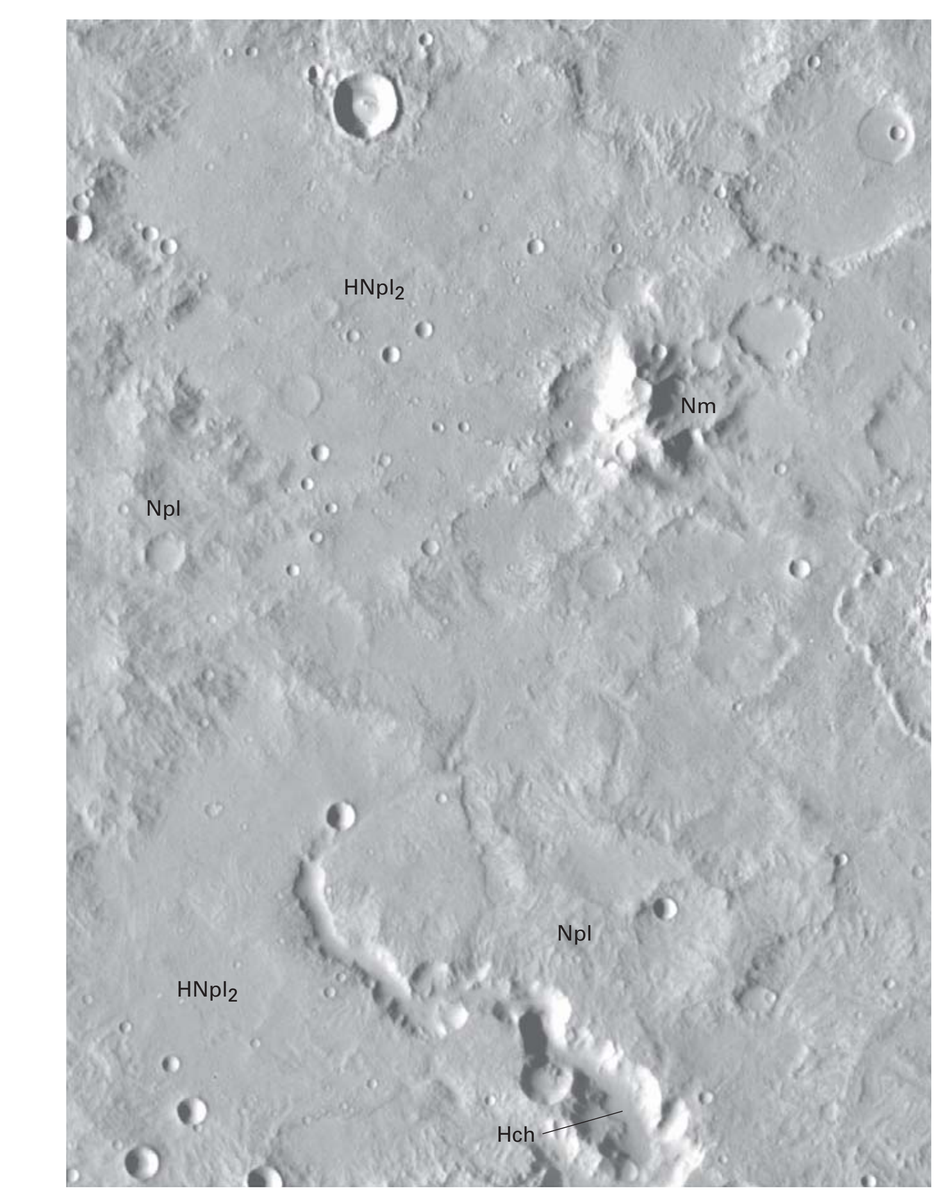


Figure 5. Hesperian–Noachian flood plain (unit $HNpl_2$) was formed by flooding of separate depressions within highland plateau (units Npl and Nm) and was drained later by a paleochannel system (unit Hch). Viking Orbiter images 435S10, 434S13.

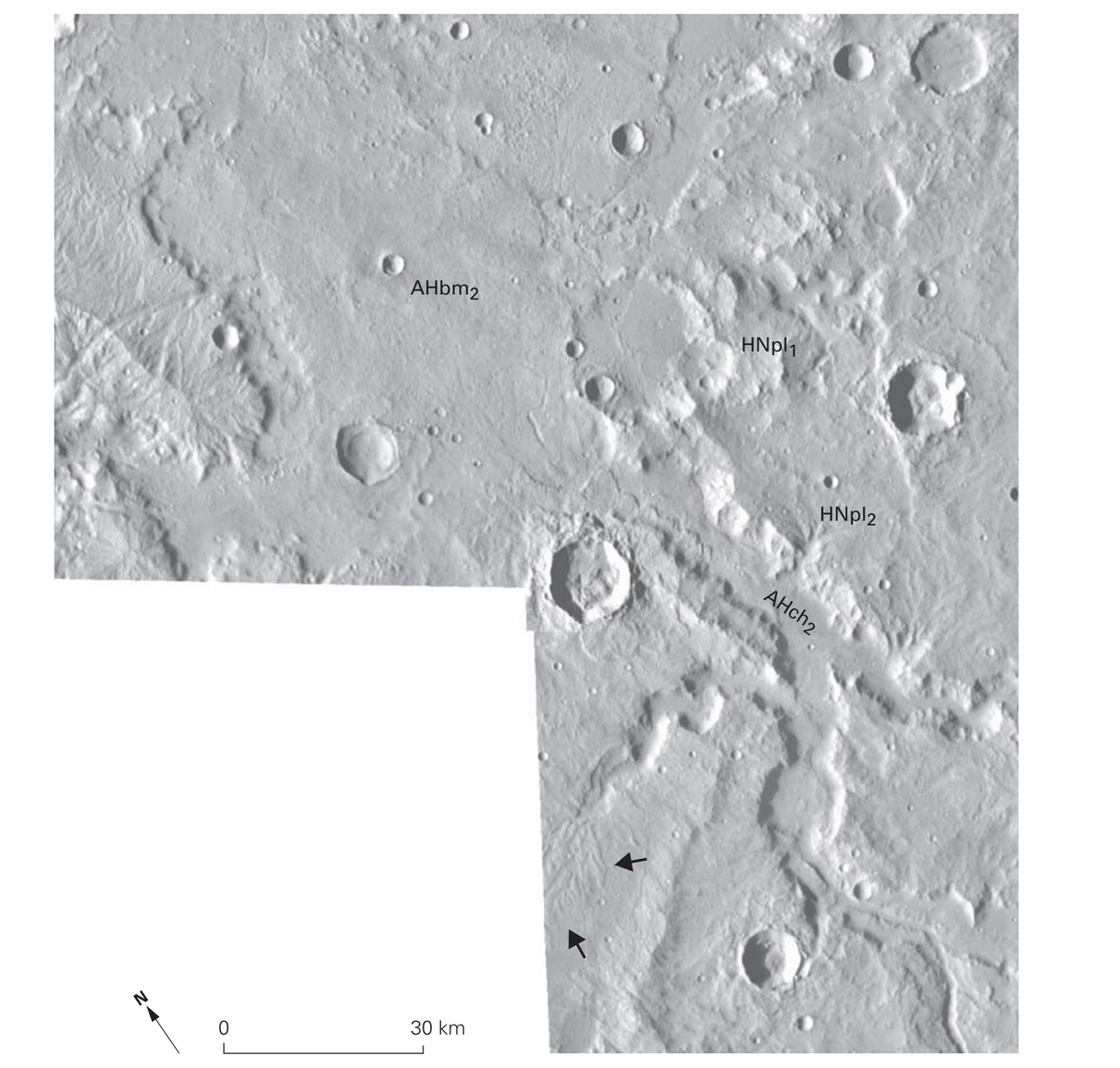


Figure 6. Hesperian deltaic deposits (unit Hchm, indicated by arrows) near lower reaches of Durius Valles (unit $AHch_2$), which eroded cratered plains materials (units $HNpl_1$ and $HNpl_2$) and flowed into de Vaucouleurs (unit $AHbm_2$). Deltaic deposits (arrows) were dissected by headward erosion of distributary channels of western valles. Viking Orbiter images 432S06, 432S08, 431S13.

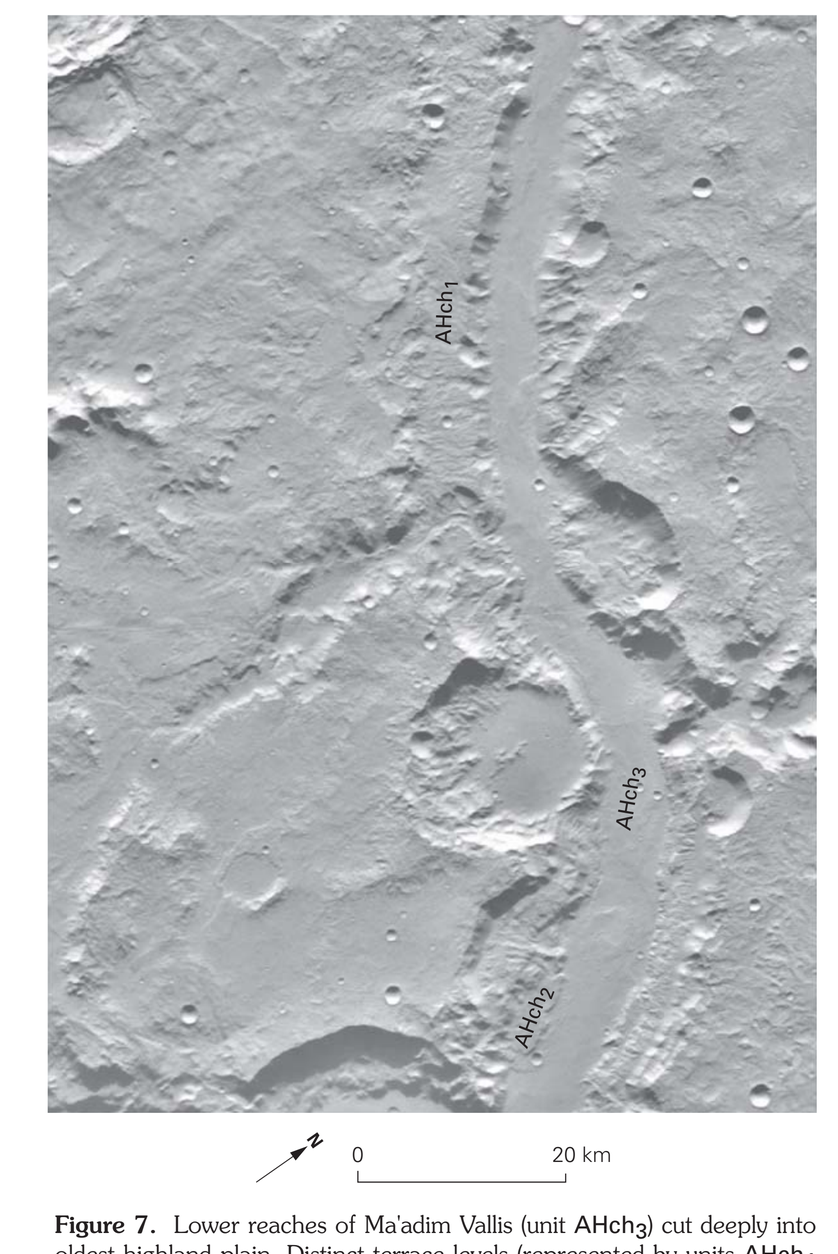


Figure 7. Lower reaches of Ma'adim Vallis (unit $AHch_3$) cut deeply into oldest highland plain. Distinct terrace levels (represented by units $AHch_1$ and $AHch_2$) and deeply cut tributaries complicate the sides of main vallis. Viking Orbiter images 434S12, 434S14.

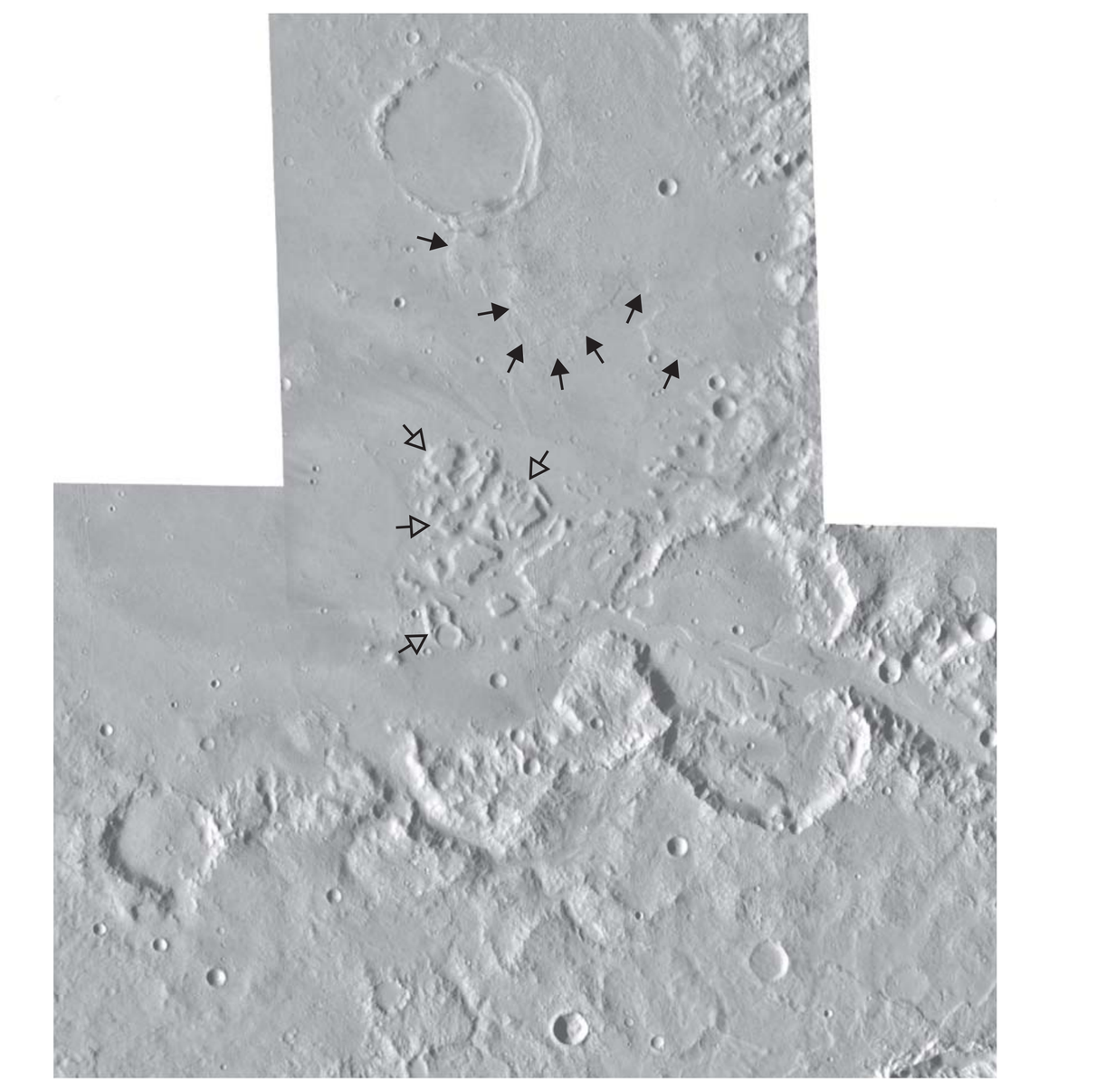


Figure 8. Location where Gusev crater rim was breached by Ma'adim Vallis. Vallis deltaic material formed mesas (open arrows) on southern crater floor. Distinct erosional contact between sediments of latest ponding stages (smooth plain) and older fluvio-lacustrine deposits (rough, knobby surface) is marked by solid arrows. Viking Orbiter images 434S08–10.

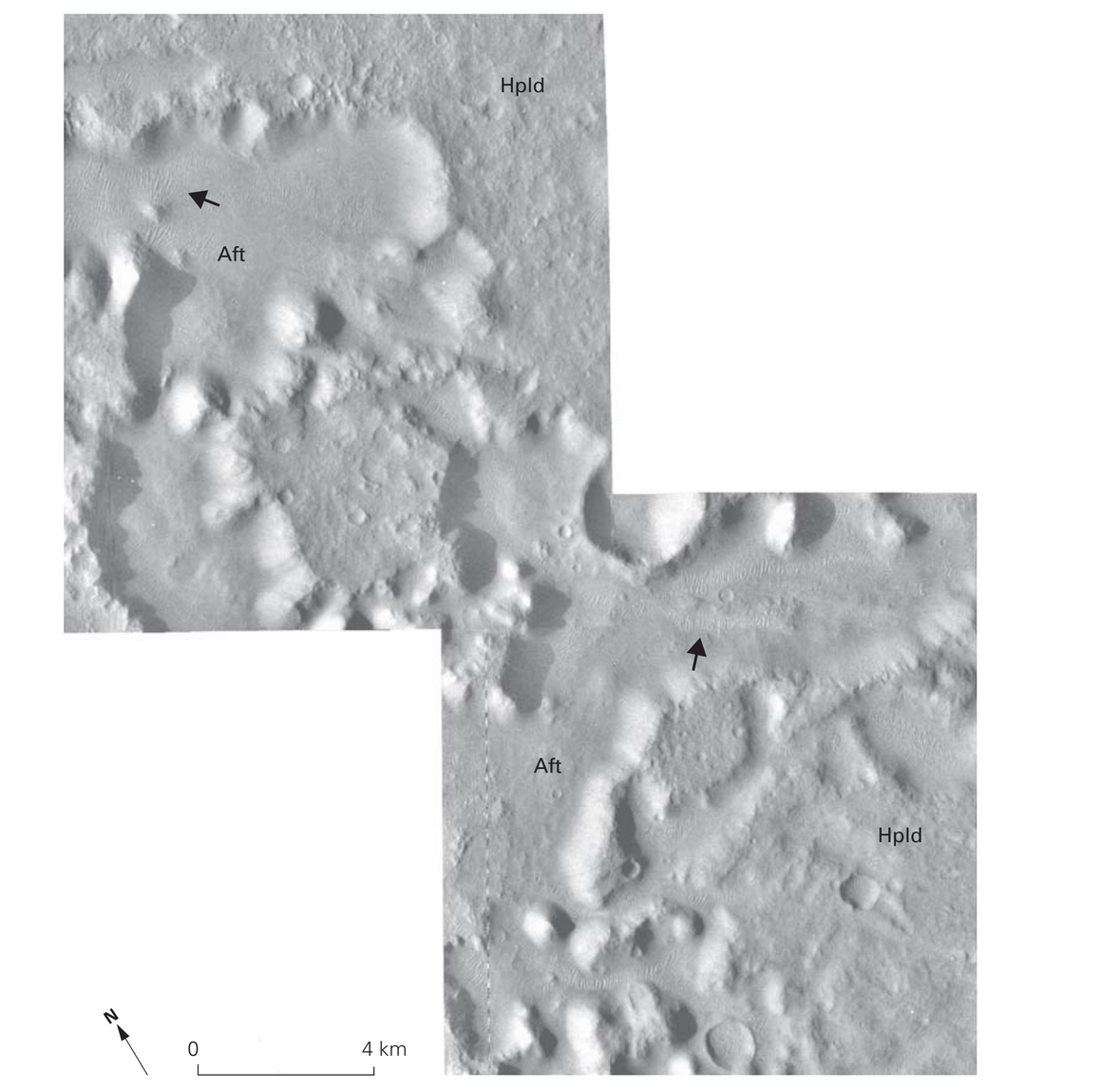
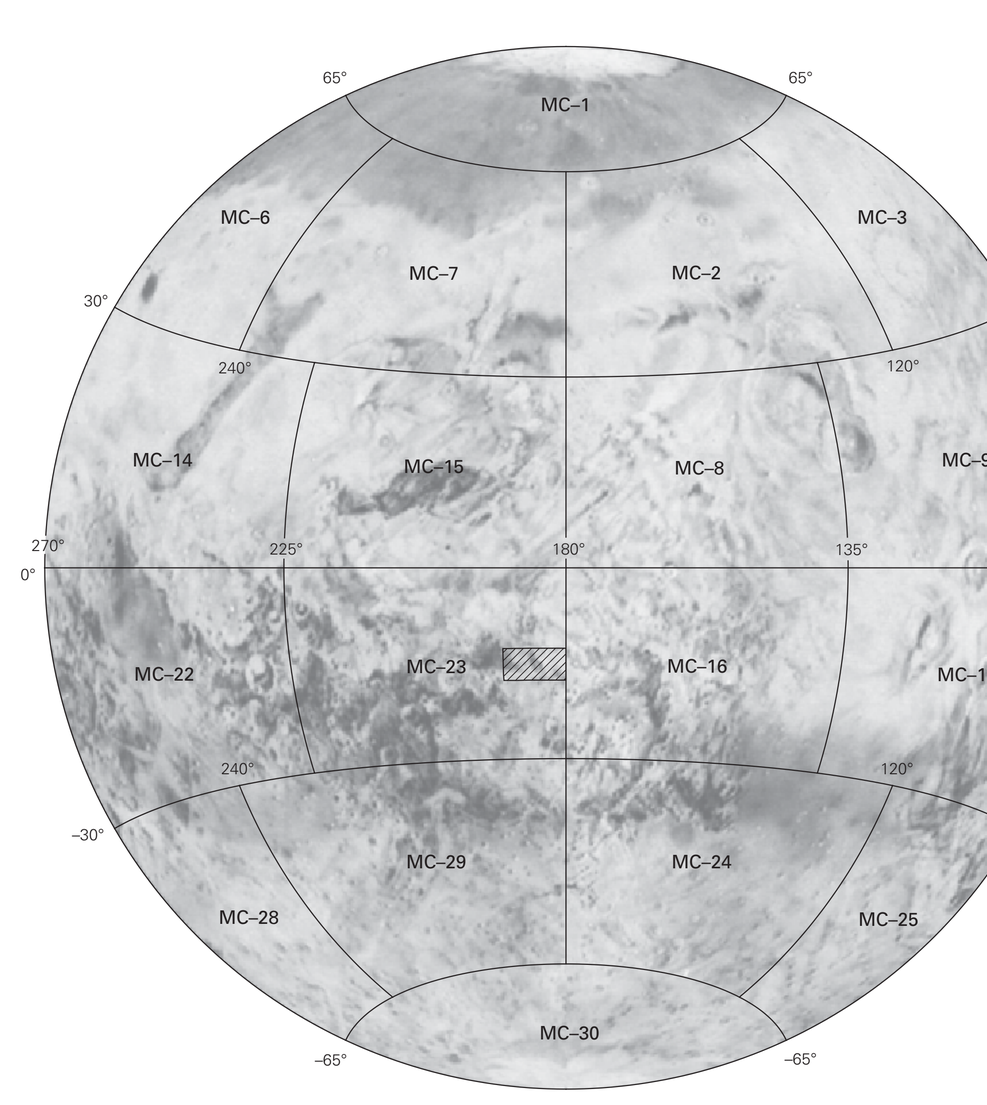


Figure 9. High-resolution images (~11 m/pixel) of fretted terrain (unit Aft) within Hesperian dissected plains material (unit Hpld). Surface of fretted terrain material is mantled by modern aeolian material which forms a system of ripplelike, transverse dunes (arrows). Viking Orbiter images 763A11, 763A12.



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.

GEOLOGIC MAP OF THE MTM –15182 AND MTM –15187 QUADRANGLES, GUSEV CRATER–MA'ADIM VALLIS REGION, MARS

By

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