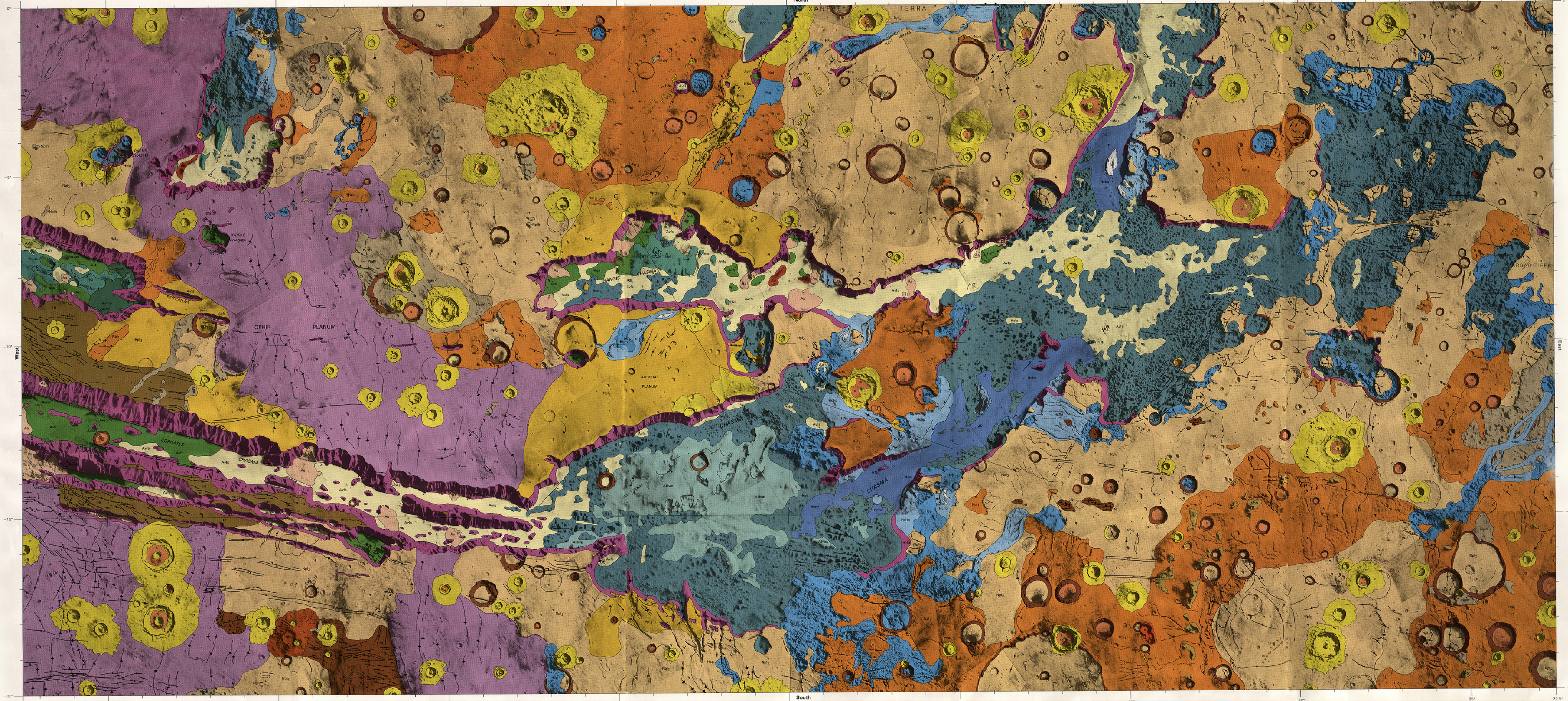
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

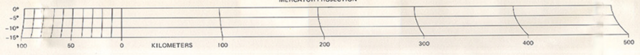
Prepared for the
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

ATLAS OF MARS
1:2,000,000 GEOLOGIC SERIES
VALLES MARINERIS REGION
M2M -10/45 G, 1991
MAP I-2010 (SHEET 2 OF 2)



Base from U.S. Geological Survey, 1979, Controlled photomosaic of the Coprates northeast quadrangle of Mars (MC–18NE); U.S. Geological Survey, 1979, Controlled photomosaic of the Coprates southeast quadrangle of Mars (MC–18SE); U.S. Geological Survey, 1981, Controlled photomosaic of the Margaritifer Sinus northwest quadrangle of Mars (MC–19NW); and U.S. Geological Survey, 1979, Controlled photomosaic of the Margaritifer Sinus southwest quadrangle of Mars (MC–19SW). U.S. Geological Survey Miscellaneous Investigations Series Maps I–1208, 1184, 1381, and 1209.

SCALE 1:2000000 (1mm ≈ 2km) AT −27.3°
MERCATOR PROJECTION

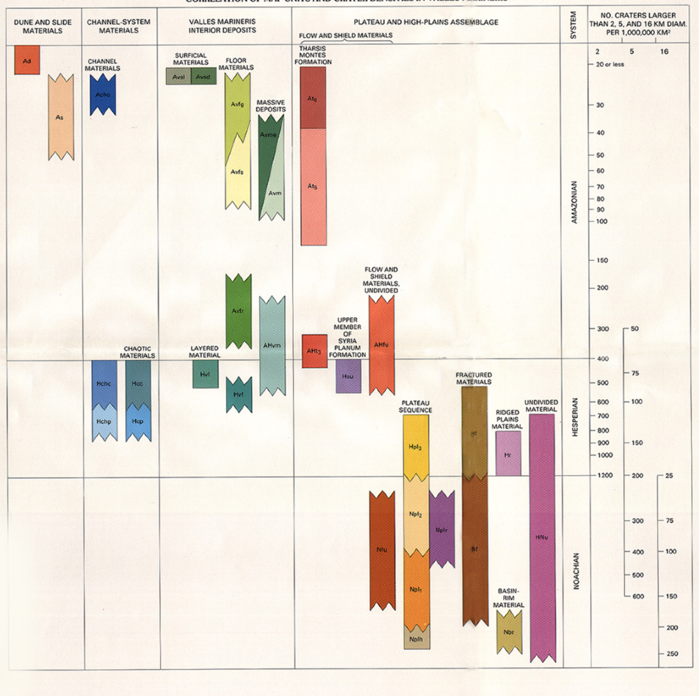


Prepared on behalf of the Planetary Geology Program, Solar System Exploration Division, Office of Space Science, National Aeronautics and Space Administration, under contract W-15,814

Compilation dates: 1983–1986

Manuscript approved for publication, September 14, 1988

CORRELATION OF MAP UNITS AND CRATER DENSITIES IN VALLES MARINERIS



DESCRIPTION OF MAP UNITS

[Map units were selected on the basis of morphology, stratigraphic position, and inferred origin. They are grouped according to geographic and geologic associations. Many of the units in the plateau and high-plains assemblage were established previously by 1:15,000,000-scale mapping (Scott and Tanaka, 1986). The densities of craters greater than 2, 5, and 16 km per 10^6 km² are given in table 1 for units on which reliable crater counts could be obtained]

DUNE AND SLIDE MATERIALS

[Recent dunes and slides derived from local rocks]

Ad **Dune material**—Forms generally dark patches of complex, kilometer-size ridges on floors of Melas, Juventae, and Gangis Chasmata; no superposed craters discernible. *Interpretation:* Active barchan and transverse dunes consisting of reworked surficial material

As **Slide material**—Occurs mainly along base of chasma walls and on their floors throughout canyon system; overlaps most other units; surfaces pristine, sparsely cratered. Slides range in size from 40 km² to 7,500 km² and runout is as long as 100 km (Lucchitta, 1978a, 1979). First recognized by Sharp (1973); mapped as part of chaotic and chasma-floor materials by McCauley (1978); largest slides mapped by Scott and Tanaka (1986). Two facies of slide material recognized; they form (1) jumbled blocks and ridges near and aligned parallel to canyon walls; surfaces are hummocky, rough; (2) smoother material, commonly in vast aprons extending tens of kilometers; marked by concentric and longitudinal ridges and troughs. *Interpretation:* Hummocky material consists of rotated slide blocks capped by resistant plateau material. Smoother material is once-fluid slides composed of impact breccia underlying plateau material; concentric ridges formed by compression, longitudinal ridges by differential flow. Long slide lengths achieved by gas or water fluidization or thixotropic flow

CHANNEL-SYSTEM MATERIALS

[Channel materials interpreted as deposited by running water, chaotic material as formed by surface collapse due to removal of ground ice. Previous mapping (McCauley, 1978; Saunders, 1979; Scott and Tanaka, 1986) did not distinguish between plateau and chasma occurrences. Units are sparsely cratered]

Acho **Channel material of Ophir Chasma**—In central part of chasma; varied albedo; local longitudinal striations. *Interpretation:* Deposit of debris-laden flow released by landslides from chasma walls

Hchc **Chasma channel material**—In Capri and Eos Chasmata; displays longitudinal striations and streamlined bars. Channels smooth and as wide as 80 km, commonly head from chasma chaotic material, cut plateau channel material. Unit covered by smooth floor material (unit Avfs) in places. North of map region, unit fills channels that cut ridged plains material and is buried by flows from Tharsis Montes. *Interpretation:* Stream-carved plateau deposits and material transported and deposited by flowing water; water formed striations on channel floors and streamlined islands

Hcc **Chasma chaotic material**—Forms large knobs and mesas in Juventae, Capri, Eos, and other chasmata. In eastern Eos Chasma, knobs have aligned linear sides. Partly buried by smooth floor material (unit Avfs) and, in Eos Chasma, by older massive material (unit AHvm); grades into undivided material (unit HNu) and plateau chaotic material along chasma margins. *Interpretation:* Eroded materials of plateau sequence; deep collapse due to discharge of ground water at chasma floor level; alignment of knob sides due to structural control

Hchp **Plateau channel material**—Forms grooved, high-standing channel floors in Capri and Eos Chasmata and anastomosing channel floors on highland surface near Juventae, Gangis, and Eos Chasmata. Channels originate in plateau chaotic material; truncated by deep chasmata; incised into plateau materials; contain streamlined bars. *Interpretation:* Stream-carved plateau deposits and material transported and deposited by flowing water

Hcp **Plateau chaotic material**—In craters, in heads of high channels, and adjacent to chasmata; forms mosaic of small mesas and knobs capped at places by plateau-sequence materials; surfaces of mesas at about same elevation as adjacent plateau surfaces. Grades into plateau units and chasma and chaotic materials. *Interpretation:* Plateau material collapsed by ground-water discharge at shallow depths

VALLES MARINERIS INTERIOR DEPOSITS

[McCauley (1978) and Scott and Tanaka (1986) divided the material within the chasmata into two units: layered and floor materials. Here they are divided into ten units on the basis of morphology, albedo, layering, and stratigraphic position. Dune, slide, and channel materials also occur within Valles Marineris, but because they are common in other areas and settings on Mars as well, they are excluded from this group]

Surficial materials—Form small patches throughout the central chasma region that partly bury canyon floors and walls and overlie other interior deposits. No craters observed

Avsl **Light surficial material**—On floors and in alcoves of Tithonium, Ius, Melas, and Candor Chasmata; in places near patches of dark material (unit Avsd). Thin, low relief, high albedo; occurrences on canyon floors are smooth. *Interpretation:* Volcanic or eolian material from local sources

Avsd **Dark surficial material**—Along base of walls in Candor and Coprates Chasmata and on floors of other chasmata; low albedo; commonly overlies fresh-appearing fault scarps and extends from them into gullies above and below. *Interpretation:* Mafic volcanic material erupted along faults, partly redistributed by wind

Hvl **Layered material**—In most large chasmata. Thick sequence of alternating layers of light and dark material; 10 to 15 layers observed in places. Individual layers tens of meters thick in Juventae Chasma to perhaps hundreds of meters thick in Hebes and Gangis Chasmata; traceable laterally for tens of kilometers. Unit forms irregular mesas commonly separated from plateau but locally abutting it in Candor and Ophir Chasmata; mesas approach elevation of plateau in Hebes and Candor Chasmata. Few craters. Some outcrops highly fluted; some form groups of yardangs. *Interpretation:* Volcanic or lacustrine material deposited after formation of chasmata. Less resistant layers fluted or eroded into yardangs by wind (or perhaps by water in Juventae Chasma); more resistant layers cap mesas

Floor materials—Thin deposits on chasma floors; few craters

Avfg **Grooved floor material**—Occurrences in eastern Noctis Labyrinthus and at Candor Chaos; many irregular troughs and pits. *Interpretation:* Alluvial deposits collapsed or contracted by removal of water or ice

Avfs **Smooth floor material**—Widespread in chasmata. Low relief; high albedo. Partly buries channel materials and fills hollows in chasma chaotic material; found between mesas of layered material in Candor Chasma; mantles much of floors of Coprates Chasma, Oudemans crater, and grabens of Noctis Labyrinthus; buried in places by slide materials. Intergrades with grooved floor material and younger massive material. *Interpretation:* Alluvial deposits from local sources and eolian material

Avfr **Rough floor material**—Throughout canyon system; rough surface, varied albedo. *Interpretation:* Rubble and debris eroded from canyon walls; locally may be eolian mantle burying possible landslides or rugged landforms

Hvf **High floor material**—In places in central chasma region; forms terraces above base of chasma walls. Surfaces smooth to rough; relief and elevation higher than other floor materials; faulted in Melas Chasma. *Interpretation:* Older floor material left high by lowering of adjacent canyon floors

Massive deposits—Thick unlayered deposits; few craters

Avme **Etched massive material**—In central chasmata. Varied albedo, rough pitted and grooved surface; locally appears to overlie layered material. *Interpretation:* Volcanic or eolian deposits pitted and etched by wind

Avm **Younger massive material**—In Tithonium Chasma and central chasmata. Smooth, undulatory surface; moderate albedo. In Tithonium Chasma has lobate form and overlies floor and slide materials; in Candor Chasma overlies and embays layered material. *Interpretation:* Ash-fall or volcanic-flow deposits or eolian material eroded from older interior deposits

AHvm **Older massive material**—In Eos Chasma. High albedo, high relief, undulatory surface, locally fluted. Resembles smooth floor material (unit Avfs), but has much higher relief and greater thickness; draped over chasma chaotic material. *Interpretation:* Ash-fall or ash-flow deposits or eolian material; flutes eroded by wind

PLATEAU AND HIGH-PLAINS ASSEMBLAGE

[Includes ancient and intermediate-age units of moderate to high elevation that surround Valles Marineris canyon system]

Flow and shield materials

[Materials forming vast plains and shields of Syria Planum, Tharsis Montes, and other areas. Units distinguished by lobate scarps, pit-crater chains, and conical and domal mountains having summit depressions. Materials interpreted to be lava flows and volcanoes]

Tharsis Montes Formation—Includes large shields and associated flows of Tharsis Montes. Members 1, 2, and 4 (Scott and Tanaka, 1986) not present in map region.

At6 **Member 6**—Adjacent to Pavonis Mons and northern Claritas Fossae. Forms smooth plains with patchy albedo pattern in places; few craters; lobate scarps observed on high-resolution images; cut by few fractures; embays grabens, depressions, and fractured materials of northern Claritas Fossae. *Interpretation:* Youngest lava flows of Pavonis Mons

At5 **Member 5**—Widespread in westernmost map region; forms plains with lobate scarps; high albedo south of Pavonis Mons; low crater density. Overlies upper member of Syria Planum Formation; embays Noctis Fossae, Noctis Labyrinthus, and Claritas Fossae. *Interpretation:* Lava flows of Tharsis Montes; high albedo caused by thin eolian mantle

AHt3 **Member 3**—Forms surface of Pavonis Mons. Consists of overlapping, long, narrow flows; pitted; cut by concentric graben-bounding faults. *Interpretation:* Lava flows erupted from summit caldera and flanks of Pavonis Mons; pits formed by collapse of lava conduits; grabens formed by lithospheric flexure as result of loading

Syria Planum Formation—Lower member (Scott and Tanaka, 1986) not present in map region.

Hsu **Upper member**—In Syria and Sinai Plana and north of Noctis Labyrinthus. Varied albedo, moderately cratered; embays and partly buries fractured materials but is itself cut by a few fractures; impacted by Oudemans crater (100 km in diameter). On Syria Planum, flow lobes emanate from small volcanoes (unit AHfu). *Interpretation:* Lava flows of Syria Planum; erupted from summit area of Syria Planum and from local fractures

Flow and shield materials, undivided

AHfu **Younger flow and shield material, undivided**—In western map region, particularly near crest of Syria Planum. Makes up flows from fracture on Noctis Labyrinthus floor and small conical hills; areas too small for reliable crater counts. *Interpretation:* Volcanoes and lava flows

Nfu **Older flow and shield material, undivided**—West of Nectaris Fossae. Forms conical mountain about 70 km in diameter displaying radial channels and summit depression, heavily cratered, embayed by subdued cratered material of plateau sequence. *Interpretation:* Material of ancient volcano

Plateau sequence

[Moderately to heavily cratered highland units]

Hpl3 **Smooth unit**—Mainly in Hebes Chasma, north of "Coprates rise," and on Aurorae Planum. Flat, relatively featureless; many partly buried, few superposed craters; a few scarps and grabens present north and south of Gangis Chasma; locally fractured; grades into younger fractured and ridged plains material and subdued cratered unit; fills channellike depression north of Gangis Chasma. *Interpretation:* Probably a complex of eolian, volcanic, and alluvial materials

Npl2 **Subdued cratered unit**—Extensive in eastern canyon region. Forms smooth, moderately cratered plains in intercrater and intracrater areas of rugged, heavily cratered highlands; embays older crater rims; varied albedo; rare flow fronts; common low ridges and scarps trending north; east-trending grabens cross unit in places; locally grades into ridged plains material, plateau chaotic material, and cratered unit. *Interpretation:* Dominantly lava flows and eolian material; in "Ladon basin" possibly flood-plain deposits from Ladon Valles

Npl1 **Cratered unit**—Generally extensive in east half of map region. Forms rough, irregular surface cut by small channels and fractures; high density of degraded to relatively fresh craters. *Interpretation:* Volcanic materials and impact breccia emplaced throughout region during heavy impact bombardment; channels of probable fluvial origin

Nplh **Hilly unit**—Mainly northeast of Valles Marineris in eastern canyon province. Forms knobs, mesas, and broad areas that rise above surrounding materials; densely cratered; most exposures and scarps north of Coprates Chasma aligned northeast. *Interpretation:* Volcanic materials, impact breccia, and possibly other older crustal materials; high elevations caused by tectonic uplift

Nplr **Ridged unit**—Southwest of Melas Chasma. Resembles ridged plains material but ridges generally larger, more sinuous, and more randomly oriented; areas between ridges rough and fractured; moderately cratered. Embayed by ridged plains material; overlies older fractured material. *Interpretation:* Lava flows erupted from local fractures; ridges produced by volcanic and tectonic processes

Fractured materials

Hf **Younger fractured material**—Adjacent to chasmata and at Noctis Labyrinthus. Forms relatively smooth, raised surfaces of moderate relief; exhibits faults and collapse depressions generally aligned with large canyons; wrinkle ridges present at Nia Fossae. Moderately cratered. *Interpretation:* Probably lava flows. Faults caused by crustal extension; collapse depressions formed by withdrawal of subsurface water or ice. Modified ridged plains material at Nia Fossae.

Nf **Older fractured material**—At Noctis, Claritas, and Nectaris Fossae and in small patches throughout canyon region. Similar to younger fractured material but more rugged, and cratering and dense fracturing have destroyed primary morphologic characteristics. *Interpretation:* Probably impact breccia and volcanic materials

Other materials

Hr **Ridged plains material**—Throughout central canyon region, particularly at Lunae and Ophir Plana and adjacent to Nectaris Fossae. Forms extensive smooth plains marked by long, parallel, linear to sinuous wrinkle ridges resembling those of lunar maria; ridges trend generally north, are tens of kilometers apart and as much as 100 km long, and intersect canyon walls in places. Moderately cratered; flow lobes rare; cut by chasmata. Overlies Noachian materials in eastern part of map region; underlies Syria Planum Formation in western part. *Interpretation:* Low-viscosity lava flows; source fissures possibly buried. Ridges may be tectonic or volcanic features

Nbr **Basin-rim material**—Forms scattered, high-standing, rugged mountains as much as 40 km across that surround 600-km-diameter "Ladon basin" in eastern canyon province (fig. 1). Originally mapped as mound material (Saunders, 1979). *Interpretation:* Ancient crustal material uplifted by faulting when impact basin formed

HNu **Undivided material**—In Noctis Labyrinthus, Valles Marineris, and eastern canyons. Forms rugged mountains and knobs and walls of canyons and depressions. Some canyon walls are smooth and show crude layering in places; other walls are interrupted by spurs and gullies or tributary canyons. Rare craters. Previously mapped as slope and bedrock material (Masursky and others, 1978; McCauley, 1978). *Interpretation:* Basement, plateau sequence, fractured, and ridged plains materials exposed by faulting, collapse, erosion, and sapping

Contact—Dashed where approximately located or gradational

Fault or narrow graben—Bar and ball on downthrown side of fault; dotted where partly buried. Queried faults shown on cross sections are interpreted as rift faults

Possible wrench fault—Arrows show sense of offset

Wrinkle ridge

Scarp—Barb points downslope

Depression

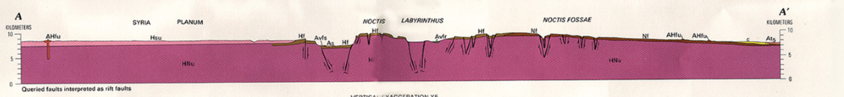
Small channel—May be fluvial or volcanic

Streamlined bar or island on channel floor—May be erosional or depositional

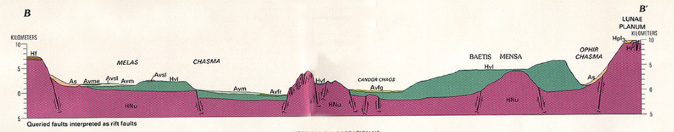
High-albedo patches—Interpreted as thin eolian mantle

Impact crater materials—Symbol c denotes crater rim and apron materials; yellow if superposed, brown if partly buried. May include rim crest (hachured) and central peak (inner circle). Symbol s and orange color denote smooth floor; floor material may be eolian or volcanic fill. Symbol cs denotes secondary craters outside crater aprons. Materials of craters smaller than 10 km in rim diameter not mapped

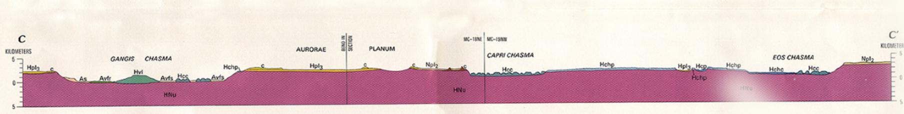
Rim crest of buried impact crater



VERTICAL EXAGGERATION X5
CROSS SECTION IN THE NOCTIS LABYRINTHUS PROVINCE (MC-17NE, SHEET 1)



VERTICAL EXAGGERATION X5
CROSS SECTION IN THE VALLES MARINERIS PROVINCE (MC-18NW, SHEET 1)



VERTICAL EXAGGERATION X5
CROSS SECTION IN THE EASTERN CANYON PROVINCE (MC-18NE AND 19NW)

GEOLOGIC MAP OF THE VALLES MARINERIS REGION, MARS

(EAST HALF)

By
Nanci E. Witbeck, Kenneth L. Tanaka, and David H. Scott

1991