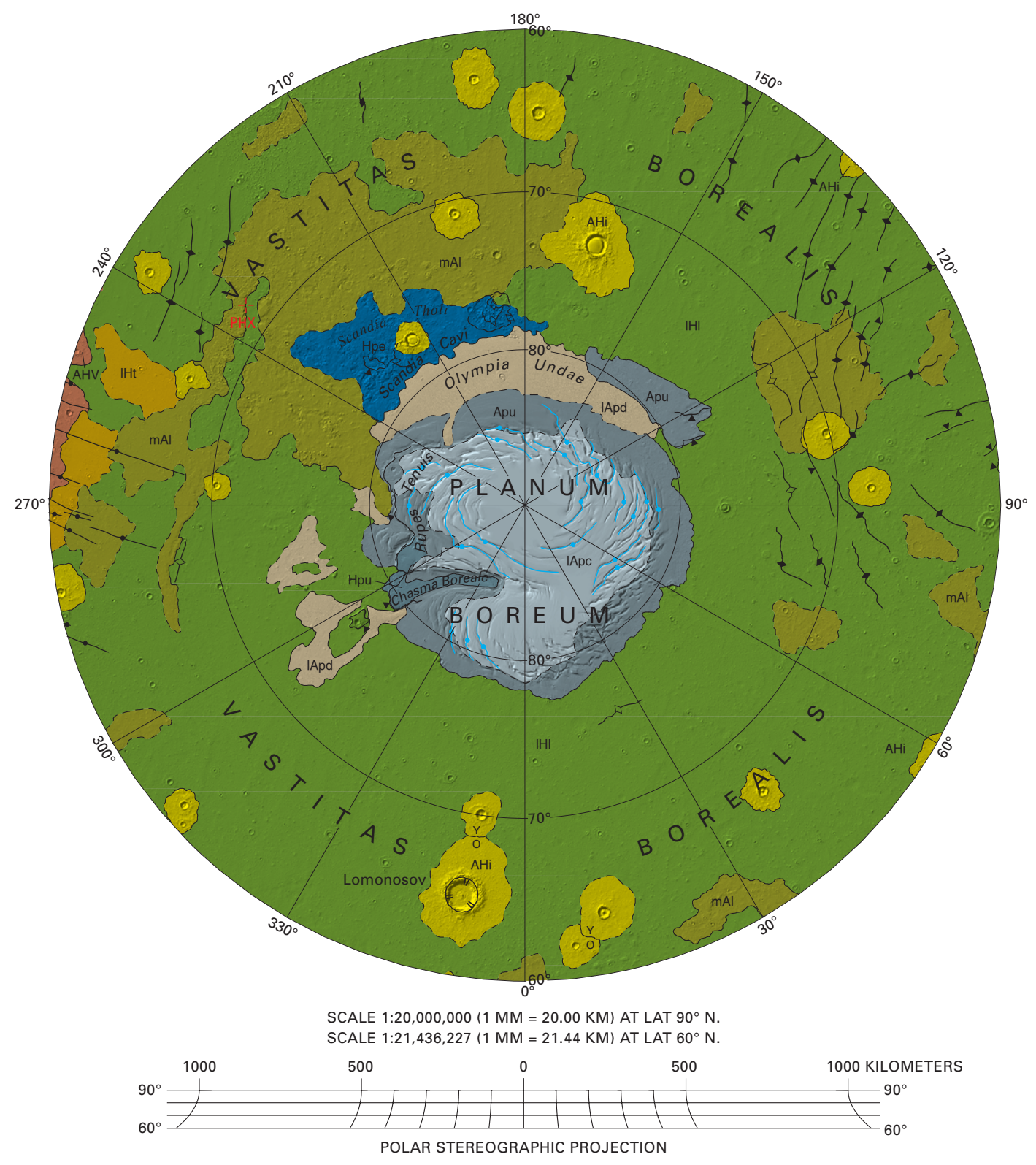
U.S. Department of the Interior
U.S. Geological Survey

Prepared for the
National Aeronautics and Space Administration

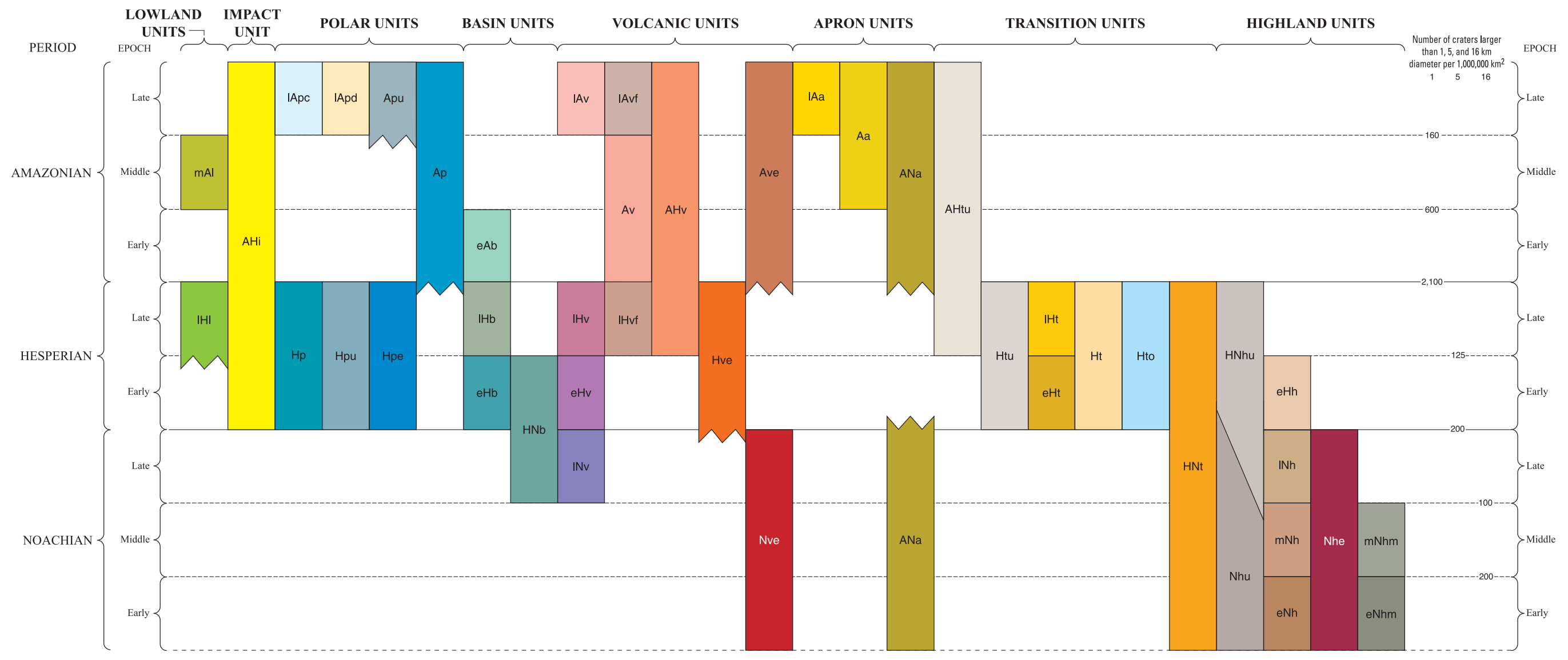
Scientific Investigations Map 3292
Pamphlet accompanies map

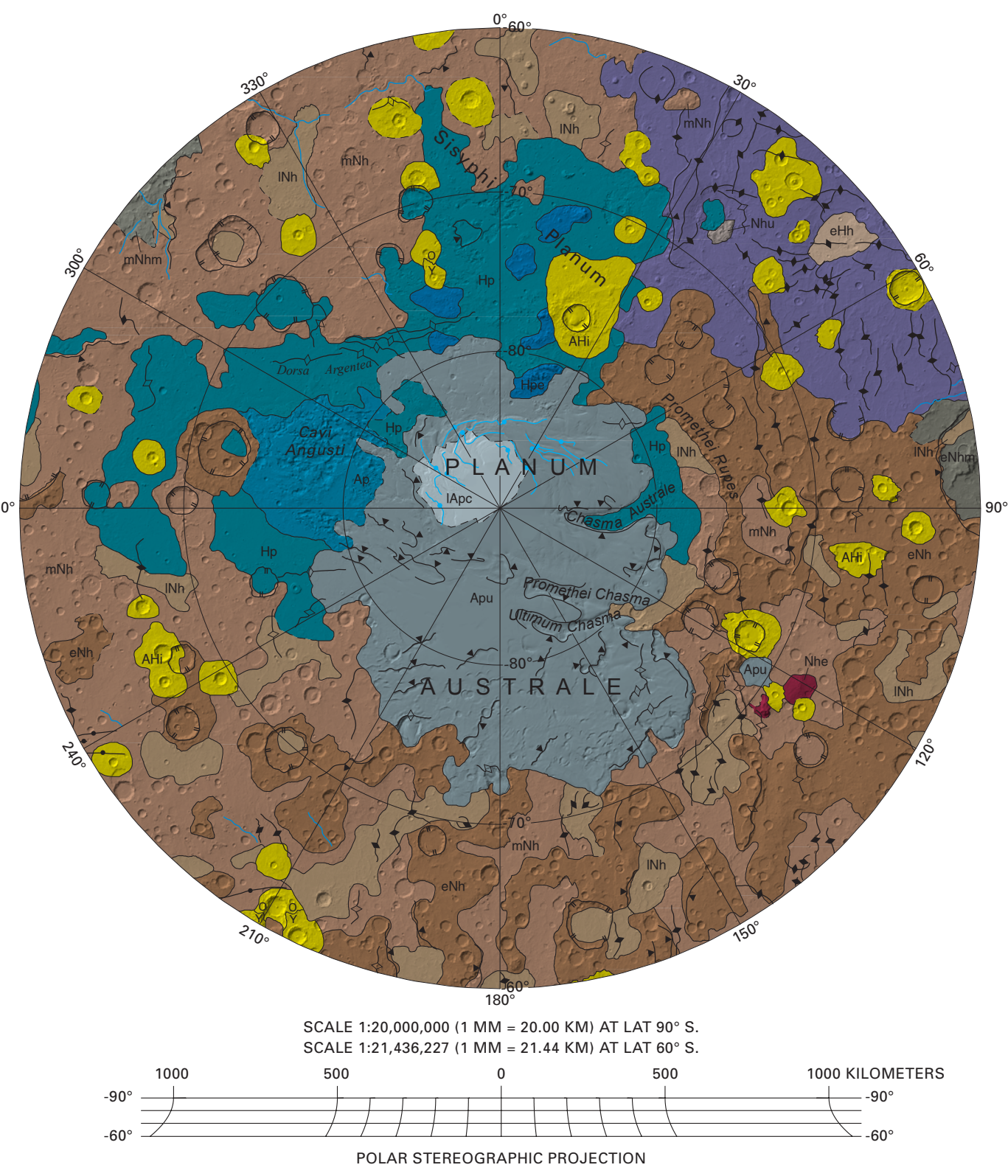


NORTH POLAR REGION

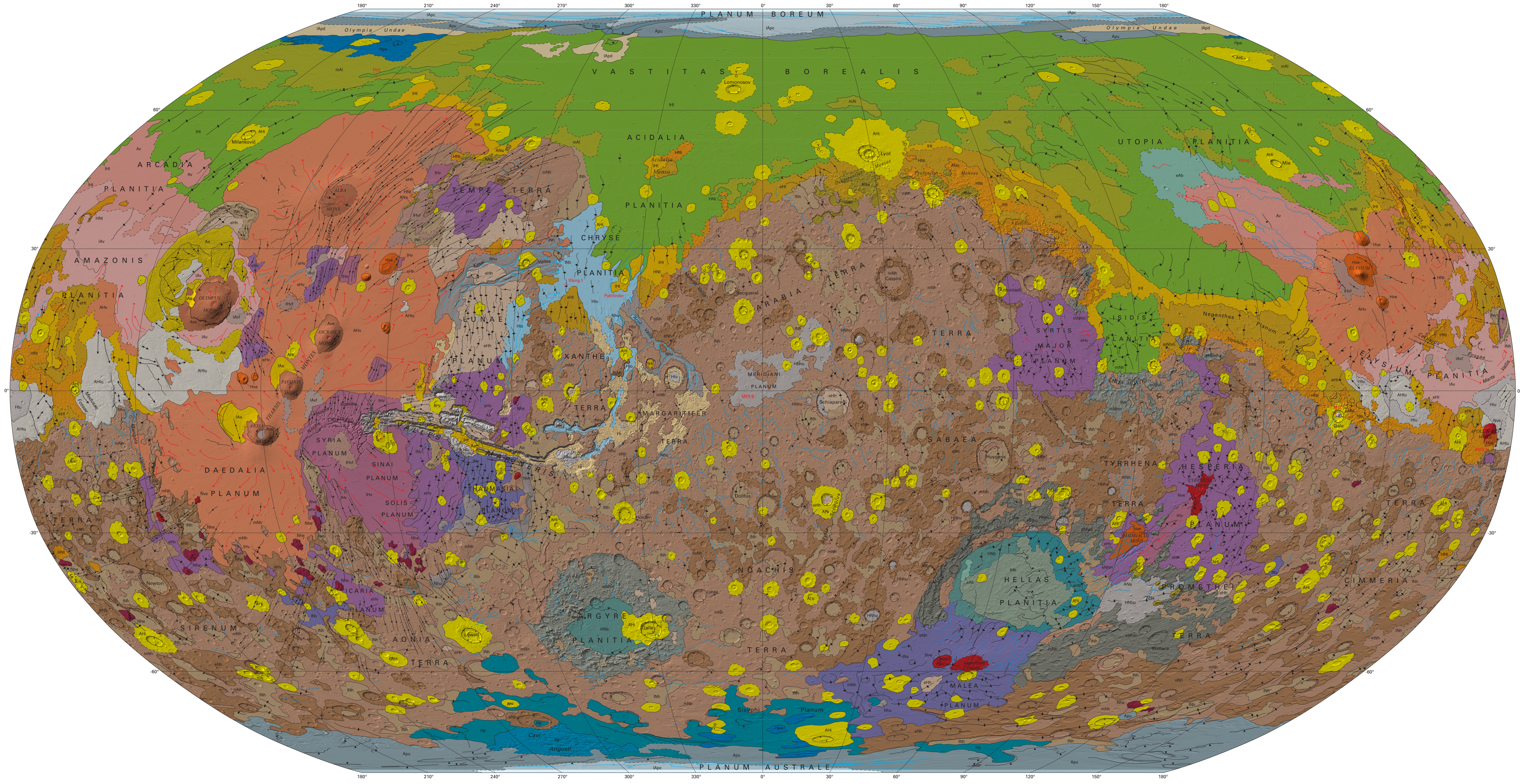
CORRELATION OF MAP UNITS

[Cumulative crater-densities for epoch boundaries at 1, 5, or 16 km diameters are from Werner and Tanaka (2011); see table 1 for model absolute-ages for the epoch boundaries. Map unit ages are resolved to nearest epoch; hachured box edges indicate possible, extended durations. The determinations rely on both stratigraphic relations as documented in the Description of Map Units and crater size-frequency distributions provided in tables 2, 3, and D1 and by other workers as referenced in the Geologic History section. See Age Determinations section of text for methodology discussion. Determination of ages from crater densities is complicated by the geologic history of the unit of interest, including size-dependent degradation and resurfacing, such that different crater diameter ranges (and the associated N(1), N(5), and N(16) values) may provide different age estimates for a given geologic unit; see tables 2 and D1 for examples of formation and resurfacing ages for some localities]





SOUTH POLAR REGION



SCALE 1:20,000,000 (1 MM = 20.00 KM) AT LAT ±38°

ROBINSON PSEUDOCYLINDRICAL PROJECTION WITH POLE LINE

For clarity, only representative physiographic names are shown on the map. The full list of IAU-approved nomenclature and descriptions thereof are listed at http://planetarynames.wr.usgs.gov/

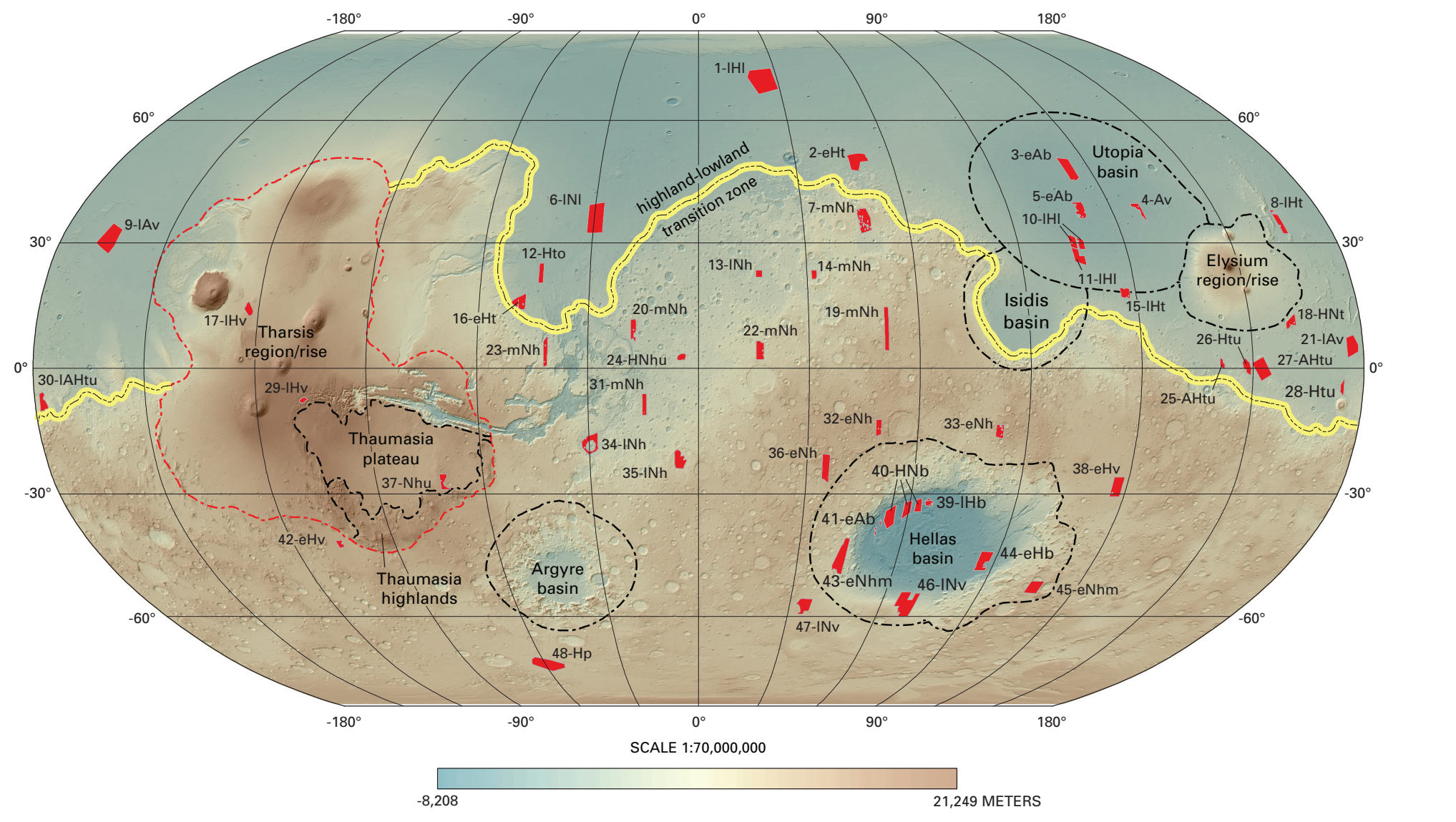


Figure 1. Topography of Mars showing (1) numbered locations of detailed crater counts for some units (red areas; see table 2 for crater count data and Platz and others (2013) for detailed discussion of results) and (2) extents of informally named geographic features (dashed lines). (Mars Orbiter Laser Altimeter digital elevation model; see pamphlet for description.)

EXPLANATION OF MAP SYMBOLS

[For each feature type, typical morphologies and process origins are indicated. See the "Global Structure Digital Attribute Table" in the GIS database for additional information on preservation state (fresh, subdued, partly buried, and buried) and width (broad, >10 km; narrow, <10 km)]

- **Contact**—Solid where certain, dashed where approximate, concealed, or gradational; internal contacts mark where superposition relations identify "y" (younger) and "o" (older) divisions
- **Wrinkle ridge**—Ridge, sinuous, crenulated; tectonic contraction
- **Graben**—Trough, linear or sinuous, en echelon; tectonic extension
- **Channel**—Trough, sinuous, floor sloping downhill, dendritic branching or anastomosing; fluvial erosion
- **Scarp**—Sinuous, crenulated or scalloped; erosional, also tectonic or volcanic
- **Lobate flow**—Lobate flow axis and trend; volcanic flow
- **Crater rim**—Circular ridge and (or) scarp, associated inner depression and outer apron; impact
- **Ridge**—Simple form; erosional or volcanic
- **Spiral trough**—Arcuate, deeper at lower elevations, asymmetrical in cross section, equator-facing steeper slope; ablation due to wind and insolation
- **Outflow channel**—Long, wide, sinuous channel floors, often braided with bars and islands along the reach; catastrophic flooding, local collapse, and mass wasting
- **Yardangs**—Parallel, narrow, linear to curvilinear ridges, some areas showing multiple orientations; eolian erosion
- **Pit-crater chain**—Linear series of circular to semicircular, isolated to overlapping pits, typically associated with a trough, collapse associated with tectonic activity
- **Rille**—Sinuous, steep-sided trough, narrows in down-slope direction; volcanic erosion and possible collapse
- **Caldera rim**—Ovoid scarp, outlines single or multiple coalesced partial to fully enclosed depression(s); volcanic collapse, related to effusive and possibly explosive eruptions
- PHX **Landing sites**—Locations of landed spacecraft. Labels include Viking 1 (Viking 1 Lander), Viking 2 (Viking 2 Lander), Pathfinder (Mars Pathfinder-Sojourner), MER A (Mars Exploration Rover A–Spirit), MER B (Mars Exploration Rover B–Opportunity), PHX (Phoenix Lander), MSL (Mars Science Laboratory–Curiosity)

Geologic Map of Mars

By

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DESCRIPTION OF MAP UNITS

[Note: Unit groups and labels are discussed in pamphlet. Unit definitions include morphologic character, infrared brightness or albedo (where diagnostic), nature of stratification (if observed), and typical unit thickness (where top and bottom of unit identified and assuming flat-lying materials; measured or estimated using MOLA elevation data). Additional characteristics include location, complete record of observed superposition relations with other map units (except with unit AHi, which displays complex age relations with other units), and other secondary and (or) local characteristics and associations including morphologies, spectrally based compositional information, and radar-sounding properties. See Geologic Summary in pamphlet for further discussion of map units, including references; tables 2 (locality numbers) and 3 and fig. 1 for crater-density data; and tables 6 and 7 for comparison with Viking-based, global mapping units]

LOWLAND UNITS

[Materials occupying northern lowlands (mostly –5,000 to about –4,000 m in surface elevation; low kilometer-scale surface roughness)]

UNIT LABEL	UNIT NAME AND DESCRIPTION (coordinates of center(s) of type area(s) and, where available, counting localities (fig. 1 and table 2))	ADDITIONAL CHARACTERISTICS	INTERPRETATION
mAl	**Middle Amazonian lowland unit**—Hummocky to undulating; grades into fields of knobs. Internally stratified. Tens of meters thick. (lat 51.43° N., long 118.45° E.)	Distributed within Vastitas Borealis and other northern plains; makes up the platforms of nearby pedestal-crater forms and perhaps whorled, low-relief ridge systems (thumbprint terrain, unmapped). Superposes units Av, AHv, eAb, lHl, lHt, Hpe, Hve, HNt, eHt, lNh, and mNh; underlies unit lApd; relation with unit Apu unclear	Ice-rich loess. Periglacial modification formed thumbprint terrain
lHl	**Late Hesperian lowland unit**—Planar to undulating; lobate and troughed marginal areas in places. Hundreds of meters to kilometers thick. (lat 21.40° N., long 118.20° E.; localities 1, 6, 10, 11)	Continuous across most of the northern plains. Embays units lHt, Hto, eHt, eHv, HNt, lNh, mNhm, and mNh; superposed by units AHv, Av, eAb, Apu, mAl, lAv, and lApd; temporal relation to units Hpe and Hpu unclear. Contains hundreds of superposed pedestal-crater forms, thumbprint terrain, topographically subdued wrinkle ridges, and narrow grabens northeast of Alba Mons	Fluvial/lacustrine/marine and colluvial sediments sourced from circum-lowland outflow channels and bounding highland terrains; likely intercalated with and underlain by lava and volcaniclastic rocks. Pervasively modified and obscured by periglaciation, sedimentary diapirism, and particulate mantling

IMPACT UNIT

UNIT LABEL	UNIT NAME AND DESCRIPTION	ADDITIONAL CHARACTERISTICS	INTERPRETATION
AHi	**Amazonian and Hesperian impact unit**—Craters with rims and surrounding blankets; some include single to multi-lobed blanket forms, dense secondary crater chains, and (or) central peak or pit. Blanket thicknesses of meters to a few hundred meters. (lat 23.17° N., long 207.77° E.)	Global occurrence. Superposes Noachian units; other unit superposition relations diverse. High kilometer-scale surface roughness; crater floors may be smooth to rough	Upturned, ejected, and brecciated target rocks and sediments, with local areas of impact melt. Post-impact mass-wasting and fluvial-lacustrine and eolian infill of craters common

POLAR UNITS

[Mostly ice, dust, and other fines at polar latitudes; north polar outcrops occur within the northern lowlands and south polar outcrops are within the southern highlands. Some of the units have a relatively low dielectric constant consistent with water ice and water ice and dust mixtures]

UNIT LABEL	UNIT NAME AND DESCRIPTION	ADDITIONAL CHARACTERISTICS	INTERPRETATION
lApc	**Late Amazonian polar cap unit**—Hummocky and pitted at meter (northern cap) to hundreds of meter (southern cap) scales. Very high albedo except on pit floors. Mostly <2 m (northern cap) to <10 m (southern cap) thick. (lat 83.00° N., long 317.85° E. and lat –86.04° N., long 291.81° E.)	Thinly caps parts of Planum Boreum and Planum Australe. Superposes units Apu and Hpu. Location of unit margin varies and south polar surface pits enlarge seasonally and annually	Residual ice (H_2O in northern cap and mainly CO_2 in southern cap) with dust lags trapped in north polar pits. Margins and surface of unit actively changing due to ice accumulation and ablation
lApd	**Late Amazonian polar dunes unit**—Mounds with barchan-like, linear, and other dune morphologies. Low albedo. Marked by meter-scale ripples. Mounds typically tens to hundreds of meters across and tens of meters high. (lat 81.21° N., long 217.34° E.)	Surrounds Planum Boreum. Superposes units mAl, lHl, Hpe, and most of Apu. Includes spectral detections of sulfates, including gypsum	Wind-blown sand organized into variety of dune forms owing to variable wind activity and permafrost development
Apu	**Amazonian polar undivided unit**—Plateaus hundreds of kilometers across at both poles. Moderate to high albedo. Meters-thick layers; some internal unconformities; local lower, mostly low-albedo deposits unevenly bedded or crossbedded. Exceeds 1,000 m thickness in places. (lat 80.97° N., long 0.00° E. and lat –83.15° N., long 64.91° E.)	Forms Planum Australe and upper part of Planum Boreum. Superposes units lHl, Hp, Hpe, Hpu, lNh, mNh, eNh, and most of Ap; overlain by unit lApc and, except for youngest part, by unit lApd. Tens-of-meters-thick layers in radargrams; modified by systems of spiral and aligned troughs	Water ice with minor amounts of dust intermixed and as lags; local lower sequences made up of frozen dunes with interbedded ice layers
Ap	**Amazonian polar unit**—Plains-forming deposit. Relatively low radar dielectric constant. As much as 1,000 m thick. (lat –76.62° N., long 287.50° E.)	Occurs in vicinity of Cavi Angusti, near Planum Australe. Superposes outcrops of units Hp and eNh; mostly post-dated by unit Apu. Extensively and deeply pitted by Cavi Angusti	Dominantly water ice and minor lithic fines; pits may be thermokarst forms produced in part by magmatism
Hp	**Hesperian polar unit**—Plains-forming deposits marked by narrow sinuous, anabranching ridges and irregular depressions. Relatively low radar dielectric constant. Hundreds of meters thick. (lat –77.78° N., long 332.51° E.; locality 48)	Surrounds Planum Australe. Superposes units lNh, lNv, mNh, and eNh; gradational with unit Hpe; overlain by units Ap and Apu. Bumpy surface at meter scale	Water-ice sheets as indicated by dielectric constant, perhaps emplaced by cryovolcanism or from atmospheric precipitation. Covered by thin, periglacially deformed mantling deposit
Hpu	**Hesperian polar undivided unit**—Plateau-forming deposits. Decameter-thick layers. Relatively low radar dielectric constant. Locally >1,000 m thick. (lat 80.28° N., long 302.72° E.)	Forms base of main lobe of Planum Boreum, including Rupes Tenuis and mouth of Chasma Boreale. Moderately low radar dielectric constant. Overlain by units Apu, lApd, and lApc; stratigraphic relation to unit lHl uncertain. Lower sequences locally cut by polygonal troughs; contains local pedestal crater forms	Roughly equal proportions of water ice and lithic fines, possibly emplaced during lowland flooding events or by eolian activity. Deeply eroded but armored by impact material; lower sequence troughed likely due to compaction
Hpe	**Hesperian polar edifice unit**—Shields and cones having summit and flank depressions in polar regions. Relatively low radar dielectric constant. Hundreds of meters thick. (lat 75.94° N., long 206.23° E. and lat –75.96° N., long 341.69° E.)	Forms Scandia Tholi and Sisyphi Tholus. Gradational with units Hp and lHl; overlain by units mAl, Apu, and lApd. Rugged texture	Cryovolcanic or sedimentary or igneous volcanic, ice-rich constructs. Highly degraded by mass wasting and (or) sublimation

BASIN UNITS

[Low-lying deposits (mostly –7,000 m to slightly above –3,000 m surface elevation; low kilometer-scale surface roughness) occurring in and around Hellas, Argyre, and Utopia Planitiae]

UNIT LABEL	UNIT NAME AND DESCRIPTION	ADDITIONAL CHARACTERISTICS	INTERPRETATION
eAb	**Early Amazonian basin unit**—Plains-forming deposits on basin floor; hummocky and troughed textures. Variable daytime IR brightness. Thickness <100 m in most places. (lat 37.44° N., long 111.17° E.; localities 3, 5, 41)	Occurs in central Utopia Planitia and western Hellas Planitia. Superposes units lHl, lHb, and HNb; gradational with units Av and AHv; superposed by unit mAl. Marked by wrinkle ridges in Hellas Planitia	Lacustrine and (or) sheet-flood deposits. Perhaps modified by compaction and thermokarst
lHb	**Late Hesperian basin unit**—Plains-forming deposits on basin floor. Finely layered in places. Hundreds of meters thick. (lat –40.80° N., long 64.00° E.; locality 39)	Covers central Hellas Planitia. Superposes units eHb, HNb, and lNv; embayed by unit eAb. Complex, rugged surface marked by scarps and ridges; largely bounded by marginal scarp	Ice-rich eolian, lacustrine, and (or) volcanic air-fall deposits. Margins eroded and back-wasted
eHb	**Early Hesperian basin unit**—Plains-forming deposit. Several hundred meters thick along contact with unit HNb. (lat –37.95° N., long 78.84° E.; locality 44)	Covers eastern margins of Hellas Planitia. Superposes units HNb, lNh, lNv, and mNh; gradational with unit HNhu; overlain by unit lHb. Marked by crosscutting systems of wrinkle ridges and local valleys	Basin fill of eolian, lacustrine, and (or) volcanic origin. Modified by fluvial dissection. Tectonically contracted
HNb	**Hesperian and Noachian basin unit**—Low-lying, plains-forming deposit. Relatively low daytime IR brightness in Hellas Planitia. Thickness at least hundreds of meters. (lat –33.53° N., long 59.53° E.; locality 40)	Forms Argyre and western Hellas Planitiae. Embays units mNh, mNhm, and eNhm; gradational with unit lNv; overlain by units eHb, lHb, and eAb. Marked by wrinkle ridges and sinuous ridges	Basin fill of eolian, lacustrine, and (or) volcanic origin. Tectonically contracted. Sinuous ridges in Argyre Planitia interpreted as inverted fluvial landforms or eskers

VOLCANIC UNITS

[Lava flows and pyroclastic deposits forming volcanoes. Flow fields erupted from fissures and centralized vents; may include local pyroclastic deposits. Most occurrences are likely basaltic, based on rheologic properties estimated from morphologic measurements. Lava plains display low kilometer-scale surface roughness]

UNIT LABEL	UNIT NAME AND DESCRIPTION	ADDITIONAL CHARACTERISTICS	INTERPRETATION
lAv	**Late Amazonian volcanic unit**—Planar deposits containing lobate scarps that extend hundreds to more than 1,000 km; sinuous troughs, ridges, and platy textures common; low-relief, shield-like edifices rare. Meters to tens of meters thick. (lat 26.27° N., long 192.67° E.; localities 9, 21)	Covers Amazonis Planitia, southern Elysium Planitia, Marte Vallis, periphery of Olympus Mons, and northeast of Ceraunius Fossae. Superposes units Aa, Av, AHv, AHtu, AHi, lHv, lHl, lHt, Htu, eHv, eHt, eHh, HNt, lNh; gradational with unit lAvf and youngest parts of units Ave and AHv. Impact craters and tectonic features sparse. Contains local roughness and albedo variations	Largely unmodified flood lavas, including lava channels and other morphologies; sourced from fissures and shields
lAvf	**Late Amazonian volcanic field unit**—Flows each typically tens of kilometers long extending from shields and fissure vents as much as tens of kilometers across. Meters to at least tens of meters thick. (lat –2.13° N., long 253.85° E.)	Occurs in central parts of Tharsis rise and at Cerberus Fossae. Superposes units Aa, lHv, eHv, HNt, and most of AHv; gradational with unit lAv and youngest parts of units Ave and AHv. Impact craters and tectonic features sparse	Largely unmodified lava flows and vents; vents and flows not differentiated at map scale
Av	**Amazonian volcanic unit**—Rugged, hummocky, and pitted fields of irregular, poorly defined flows forming plains hundreds to more than 1,000 km across. Tens of meters or more thick. (lat 34.82° N., long 135.11° E.; locality 4)	Covers eastern Utopia and northern Amazonis Planitiae. Superposes units lHl and HNt and adjacent parts of unit AHv; gradational with unit eAb; overlain by units lAv, mAl, and Aa northwest of Olympus Mons. Subdued wrinkle ridges	Lava and perhaps volcaniclastic flows from Elysium Mons and unknown source northwest of Olympus Mons
AHv	**Amazonian and Hesperian volcanic unit**—Stacked, gently sloping lobate flows meters to tens of meters thick and hundreds of kilometers long. Variable daytime IR brightness in places. Cumulative thicknesses reach hundreds of meters to several kilometers. (lat –22.76° N., long 242.33° E.)	Forms bulk of the Tharsis and Elysium rises. Locally, superposes units lHl, Hve, Ht, eHh, eHt, HNt, lNh, mNh, Nhu, and eNh; gradational or interfingering with units lAvf, Ave, eAb, AHtu, lHt, lHvf, lHv, and eHv; overlain by units Av, mAl, lAa, and lAv. Low crater density in central part of Tharsis rise, moderate density elsewhere	Flood lavas and large lava flows, undifferentiated, sourced from regional fissure and vent systems. Highly variable ages of individual flows, although generally younger in central parts of Tharsis rise
lHv	**Late Hesperian volcanic unit**—Lobate flows, meters to tens of meters thick and tens to hundreds of kilometers long; forms patches hundreds to more than a thousand kilometers across. Variable daytime IR brightness in places. Hundreds of meters or more total thickness. (lat –18.84° N., long 256.12° E.; localities 17, 29)	Distributed occurrence in Tharsis region, southwestern Hesperia Planum, and Orcus Patera. Superposes units eHv, eHh, lNh, Nhu, Nhe, Nve, mNh, eNh, and eNhm; gradational with units lHvf and Hve; overlain by units AHv, AHtu, ANa (Amazonian part), Aa, lAv, and lAvf. Largest patch in Syria Planum region deeply dissected by troughs and grabens of Noctis Labyrinthus and Noctis Fossae	Flood lavas and large lava flows, undifferentiated, sourced from regional fissure and vent systems
lHvf	**Late Hesperian volcanic field unit**—Patches hundreds of kilometers across of lobate flows typically meters thick and tens of kilometers long emanating from low shields and fissure vents kilometers to tens of kilometers across. Hundreds of meters or more total thickness. (lat –12.31° N., long 257.63° E.)	Distributed occurrence in Syria Planum, western Tempe Terra, southwest of Ceraunius Fossae, western Elysium Mons, and Orcus Patera. Superposes units eHh, HNt, lNh, mNh; gradational or interfingers with units lHv, Hve, and AHv; overlain by unit ANa (Amazonian part). Locally modified by troughs and fissures	Volcanoes and lava flows
eHv	**Early Hesperian volcanic unit**—Planar deposits meters to tens of meters thick and tens to hundreds of kilometers across; lobate scarps common. Variable daytime IR brightness in places. Hundreds of meters or more total thickness. (lat –25.34° N., long 279.97° E.; localities 38, 42)	High plains within and near Tharsis rise, Syrtis Major and Hesperia Plana, and Gusev crater. Superposes units HNt, HNhu, lNv, lNh, Nhu, Nhe, Nve, mNh, mNhm, eNh, and eNhm; gradational with units eHt, eHh, Ht, and Hve; overlain by units Hto, lHv, lHt, lHl, AHv, AHtu, lAv, and lAvf. Marked by wrinkle ridges	Flood lavas, undifferentiated, sourced from regional fissure and vent systems. Tectonically contracted
lNv	**Late Noachian volcanic unit**—Planar deposits meters to tens of meters thick and tens to hundreds of kilometers across; lobate scarps sparse and indistinct. Variable daytime IR brightness in places. Hundreds of meters or more total thickness. (lat –55.89° N., long 67.99° E.; localities 46, 47)	Occurs in Malea and Thaumasia Plana, Icaria Fossae area, and east of Hellas Planitia. Superposes units Nhe, mNh, eNh, and eNhm; gradational with units lNh, HNb, Nhu, and Nve; overlain by units eHv, eHh, eHb, lHb, Hp, HNt (Hesperian part), AHv, and Aa. Includes some degraded craters; marked by wrinkle ridges	Degraded lava and volcaniclastic flows. Tectonically contracted
Ave	**Amazonian volcanic edifice**—Shield-like edifices hundreds of kilometers across; made up of lobate flows meters to tens of meters thick and tens to hundreds of kilometers across. Edifices several to more than ten kilometers high. (lat 18.89° N., long 225.86° E.)	Forms Olympus, Alba, Ascraeus, Pavonis, and Arsia Montes. Younger part superposes units Aa and AHtu; gradational with units lAvf, and AHv; overlain by unit lAa. Deformed by summit calderas tens to >100 km wide and circumferential scarp systems	Volcanic edifices composed of lava flows and possible volcaniclastic rocks. Deformed by summit collapse from magma withdrawal and gravity spreading of flanks

UNIT LABEL	UNIT NAME AND DESCRIPTION (coordinates of center(s) of type area(s) and, where available, counting localities (fig. 1 and table 2))	ADDITIONAL CHARACTERISTICS	INTERPRETATION

VOLCANIC UNITS—Continued

[Lava flows and pyroclastic deposits forming volcanoes. Flow fields erupted from fissures and centralized vents; may include local pyroclastic deposits. Most occurrences are likely basaltic, based on rheologic properties estimated from morphologic measurements. Lava plains display low kilometer-scale surface roughness]

UNIT LABEL	UNIT NAME AND DESCRIPTION	ADDITIONAL CHARACTERISTICS	INTERPRETATION
Hve	**Hesperian volcanic edifice unit**—Shield-like edifices several tens to hundreds of kilometers across; made up of lobate flows meters to tens of meters thick and tens to hundreds of kilometers across, as well as dissected layers tens of meters thick. As much as few kilometers thick. (lat 24.65° N., long 146.80° E.)	Occurs at Tharsis and Elysium rises, Hadriacus Mons, and Apollinaris Mons south flank. Superposes unit eNhm; gradational with units lHv, lHvf, lHt, lHl, eHv, and HNt (Hesperian part); overlain by unit AHv. Some outcrops have summit calderas tens of kilometers across; some radiating valleys	Volcanic edifices composed of different combinations of lava flows and pyroclastic and volcaniclastic deposits. Modified by summit collapse from magma withdrawal and fluvial dissection in places
Nve	**Noachian volcanic edifice unit**—Shield-like edifices several tens to hundreds of kilometers across; lobate flow morphologies indistinct or absent. As much as few kilometers thick. (lat –8.11° N., long 174.50° E.)	Occurrences include Amphitrites and Peneus Paterae, Tyrrhenus Mons, northern Apollinaris Mons, and southern Tharsis rise. Gradational with units lNv, mNh, eNh, and HNt (Noachian part); overlain by units HNt (Hesperian part), eHv, lHv, Hve, Htu, AHtu, and AHv. Heavily cratered; some outcrops have summit depressions tens of kilometers across; marked by irregular scarps and ridges; some radiating valleys	Volcanic edifices composed of different combinations of lava flows, pyroclastic deposits, and volcaniclastic deposits sourced from degraded shields. Domed and fractured by local intrusions. Tectonically contracted

APRON UNITS

UNIT LABEL	UNIT NAME AND DESCRIPTION	ADDITIONAL CHARACTERISTICS	INTERPRETATION
lAa	**Late Amazonian apron unit**—Concentrically ribbed, knobby lobes extending as much as 500 km from shield-like edifices. Meters (or less) to tens-of-meters thick. (lat 4.33° N., long 243.07° E.)	Covers northwest peripheries of Tharsis and Olympus Montes. Superposes units Aa, Ave, and AHv. Craters sparse; underlying lobate flows only moderately subdued by distal parts of unit	Drop moraines left by cold-based glaciers
Aa	**Amazonian apron unit**—Lobes bounded by scarps tens to hundreds of kilometers across, marked by transverse ridges few kilometers wide and tens of kilometers long; linear grooves in places. As much as 1,000 m thick. (lat –8.04° N., long 281.80° E. and lat 30.17° N., long 214.65° E.)	Surrounds Olympus Mons and covers parts of walls and floors of Valles Marineris. Superposes units Av, lHt, lHv, eHh, Ht, Htu, lNh, lNv, and Nhu; overlain by units lAv, lAa, lAvf, AHtu, and youngest part of Ave	Landslide and gravity-spreading deposits derived from flanks of Olympus Mons and walls of Valles Marineris
ANa	**Amazonian and Noachian apron unit**—Irregular knobs and mesas tens of kilometers across and aprons extending tens of kilometers from them. Aprons hundreds of meters thick. (lat –43.22° N., long 26.66° E.)	Occurs in Deuteronilus and Protonilus Mensae and east of Hellas Planitia. Noachian part gradational with units HNt, lNh, mNh, and eNhm and overlain by unit AHi. Amazonian part embays units AHv, lHv, lHvf, lHt, eHv, eHt, HNhu, lNh, mNh, and eNhm; gradational with HNt (Hesperian part). Aprons sparsely cratered, locally grooved and pitted, and in places display low-radar-dielectric constant	Ice-rich Amazonian materials derived from air-fall and mass-wasting erosion and transported by mass flow and underlying, relict Noachian highland materials. Modified by thermokarst processes

TRANSITION UNITS

[Materials occupying highland/lowland marginal zones and dissected areas of highland terrain (mostly just above –4,000 to –1,000 m surface elevation). Mass-wasting, sedimentary, and possibly volcanic origins likely. Units may include knobs and mesas of highland materials too small to map separately]

UNIT LABEL	UNIT NAME AND DESCRIPTION	ADDITIONAL CHARACTERISTICS	INTERPRETATION
AHtu	**Amazonian and Hesperian transition undivided unit**—Irregularly shaped plateaus hundreds to more than one thousand kilometers across. Locally layered. Hundreds of meters to ~3,000 m thick. (lat –2.37° N., long 240.33° E.; localities 25, 27, 30)	Occurs along highland/lowland boundary from Olympus Mons to southwestern Elysium Planitia and as one small outcrop west of Kasei Valles. Superposes units Aa, Ave, lHv, lHt, eHv, eHt, Htu, HNt, Nve, mNh, and eNh; interfingers with unit AHv; overlain by unit lAv. Marked by dense linear ridges, grooves, and scarps hundreds of meters wide and tens of kilometers long; includes subdued and pedestal-crater forms	Fine-grained eolian sediments and (or) pyroclastic air-fall deposits. Linear ridges and grooves form yardangs
Htu	**Hesperian transition undivided unit**—Irregular plateaus hundreds of kilometers across. Layered. Hundreds of meters to kilometers thick. (lat –6.41° N., long 156.42° E; lat –6.17° N., long 286.05° E.; localities 26, 28)	In southern Elysium Planitia along highland/lowland boundary and within and east of Valles Marineris. Superposes units Nhu, Nve, mNh, and eNh; gradational with units eHt, Hve, and HNt (Hesperian part); overlain by units lHt, Ht, Hto, AHtu, Aa, and lAv. Includes hydrated sulfate spectral signatures; fluted slopes in places. Linear ridges, anabranching sinuous ridges, and wrinkle ridges common	Fine-grained eolian sediments and (or) pyroclastic air-fall deposits. Modified by fluvial dissection and eolian erosion. Linear ridges and grooves form yardangs. Tectonically contracted. Channels mostly inverted. Altered by acidic weathering in places
lHt	**Late Hesperian transition unit**—Plains-forming deposits, relatively smooth; includes small knobs and mesas of Noachian and perhaps younger material. May be tens to hundreds of meters thick. (lat 18.13° N., long 117.11° E.; localities 8, 15)	Occurs along highland/lowland boundary, near Phlegra Montes, on and alongside Valles Marineris and on several crater floors, and at Acidalia Mensa and southeast of Hesperia Planum. Superposes units eHt, eHv, eHh, Htu, HNt, Nhu, mNh, mNhm, and eNh; gradational with unit Hve; interfingers with unit AHv, overlain by units Hto, lHl, AHtu, Aa, mAl, lAv, and younger part of ANa. Moderate density of wrinkle ridges; dense branching valleys near Echus Chasma	Mass-wasting, fluvial/lacustrine, and possibly other sedimentary materials and volcanic rocks in places. Tectonically contracted
eHt	**Early Hesperian transition unit**—Plains-forming deposits, undulating to moderately rugged; includes scattered low knobs and mesas of Noachian highland material. May be tens to hundreds of meters thick. (lat 13.38° N., long 116.70° E.; localities 2, 16)	Abutting the highland/lowland boundary, Arcadia and southwestern Amazonis Planitiae, and Acidalia Mensa. Superposes units lNh, Nhu, mNh, mNhm, and eNh; gradational with units Htu, HNt (Hesperian part), and eHv; overlain by units Ht, Hto, lHl, lHt, AHv, AHtu, mAl, lAv, and younger part of ANa. Moderate density of wrinkle ridges	Mass-wasting, fluvial/lacustrine, and other sedimentary materials and possibly volcanic rocks in places. Tectonically contracted
Ht	**Hesperian transition unit**—Knobs, mesas, and intervening aprons and plains within highland canyons and chaotic terrain. Hundreds of meters thick. (lat 1.75° N., long 325.45° E.)	Occurs in topographic lows in Xanthe and Margaritifer Terrae and north of Valles Marineris. Superposes units eHt, eHh, eHv, lNh, mNh, Nhu, and eNh; gradational with unit Hto; overlain by units Htu, lHt, AHv, and Aa	Mixture of sediments and blocks of broken up, mass-wasted, and collapsed materials
Hto	**Hesperian transition outflow unit**—Plains deposits in places dissected by tens-of-kilometers-wide anabranching channel systems. Relatively bright in nighttime IR in Maja Valles. Meters to at least tens of meters thick. (lat 19.33° N., long 326.45° E.—Mars Pathfinder landing site; locality 12)	Covers Chryse Planitia, eastern Lunae Planum, and canyons in Xanthe and Margaritifer Terrae. Superposes units AHv, lHt, eHh, eHv, eHt, lNh, mNh, Nhu, and eNh; gradational with unit Ht; overlain by unit lHl	Outflow channel fluvial and debris-flow deposits from catastrophic erosion of highland rocks; islands of underlying bedrock exposed
HNt	**Hesperian and Noachian transition unit**—Knobs, mesas, and intervening aprons and plains. May be tens to hundreds of meters thick. (lat 10.96° N., long 111.71° E.; locality 18)	Occurs adjacent to Noachian highland materials along highland/lowland boundary except in lowlands east of Elysium rise and near Acidalia Mensa. Noachian part gradational with units eNh, mNh, mNhm, lNh, Nve, and Noachian part of ANa. Hesperian part superposes units lNv, Nve, Nhe, Nhu, mNh, mNhm, and eNh; gradational with units eHt, eHh, Htu, Hve, and Amazonian part of ANa; overlain by units eHv, lHt, lHl, lHvf, AHtu, AHv, AHi, Av, mAl, lAv, and lAvf. Marked by predominantly north-south-oriented wrinkle ridges	Noachian impact breccias, sediments, and volcanic deposits with intervening aprons of Hesperian mass-wasted materials. Tectonically contracted

HIGHLAND UNITS

[Materials forming densely cratered midland and highland areas (generally ~3,000 m to 5,000 m in surface elevation, down to less than –6,000 m in Hellas Planitia; high kilometer-scale surface roughness). Dominated by complex admixtures of impact, sedimentary, and volcanic rocks]

UNIT LABEL	UNIT NAME AND DESCRIPTION	ADDITIONAL CHARACTERISTICS	INTERPRETATION
HNhu	**Hesperian and Noachian highland undivided unit**—Mound forming. Light toned in visible images. Layered. Hundreds of meters to several kilometers thick. (lat 5.97° N., long 2.33° E.; locality 24)	Occurs on Meridiani Planum, in some highland craters, and east of Hellas Planitia. Superposes units eHh, lNh (except gradational east of Hellas Planitia), mNh, eNh, and eNhm; gradational with unit eHb; overlain by units eHv and ANa (Amazonian part). Includes hydrated sulfate spectral signatures	Undifferentiated, friable (likely fine grained) sedimentary, volcanic, and impact rocks. Altered by weathering
Nhu	**Noachian highland undivided unit**—Forms canyon walls and some high plains and channel floors. Layered. Hundreds of meters to several kilometers thick in exposures. (lat –25.80° N., long 288.53° E.; locality 37)	Occurs in Valles Marineris walls; in eastern Thaumasia and Malea Plana; and along Kasei, Ares, and Mangala Valles. Gradational with units lNh, lNv, mNh, and eNh; overlain by units eHh, eHv, eHt, Hp, Htu, Ht, Hto, HNt (Hesperian part), lHv, lHt, AHv, and Aa. Marked in places by wrinkle ridges and valleys	Undifferentiated friable sedimentary, impact, and volcanic materials. Tectonically contracted in places
eHh	**Early Hesperian highland unit**—High plains-forming, relatively smooth outcrops extending hundreds of kilometers. May be hundreds of meters thick. (lat 15.88° N., long 293.44° E.)	Occurs on plateaus surrounding Tharsis rise and in scattered highland lows. Superposes units lNh, lNv, Nhu, mNh, mNhm, eNh, and eNhm; gradational with units eHv and HNt (Hesperian part); overlain by units HNhu (in Schiaparelli crater), Hto, lHv, lHvf, lHt, AHv, Aa, and lAv. Knobby, wrinkle-ridged, and dissected in places	Undifferentiated impact, volcanic, eolian, fluvial/lacustrine materials. Locally degraded and (or) deformed
lNh	**Late Noachian highland unit**—Mostly plains forming, rugged in places. May be hundreds of meters thick. (lat –20.74° N., long 354.35° E.; localities 13, 34, 35)	Occurs commonly in highland depressions, as well as sparsely in higher-elevation parts of the lowlands. Superposes units mNh, mNhm, eNh, and eNhm; gradational with units lNv, Nhu and HNt and ANa (Noachian parts); overlain by units HNhu, eHv, eHh, eHt, eHb, Hp, Ht, Hto, lHl, lHv, lHvf, AHv, Apu, Aa, and lAv. Locally marked by grabens or wrinkle ridges	Undifferentiated impact, volcanic, fluvial, and basin material. Lightly to heavily degraded and (or) deformed
mNh	**Middle Noachian highland unit**—Uneven to rolling topography; high-relief outcrops that extend hundreds to thousands of kilometers. Commonly layered in crater walls. May be hundreds of meters to more than a kilometer thick. (lat –47.17° N., long 349.33° E.; localities 7, 14, 19, 20, 22, 23, 31)	Extensive in the equatorial to southern highlands. Superposes units eNh and eNhm; gradational with units mNhm, Nhu, Nhe, Nve, and HNt and ANa (Noachian parts); overlain by units lNh, lNv, HNt (Hesperian part), HNhu, HNb, eHb, eHv, eHh, eHt, Hp, Ht, Hto, Htu, lHl, lHv, lHvf, ANa, AHtu, AHv, Apu, mAl, and lAv. Heavily cratered and marked by locally dense valleys, grabens, and wrinkle ridges	Undifferentiated impact, volcanic, fluvial, and basin materials. Moderately to heavily degraded
eNh	**Early Noachian highland unit**—Rugged, very high relief outcrops extending hundreds of kilometers. Thickness commonly exceeds a few kilometers but ill-defined. (lat –20.74° N., long 354.35° E; localities 33, 36)	Covers large parts of equatorial and southern highlands but sparse surrounding Argyre basin, in Arabia Terra, and near highland/lowland boundary. Gradational with units HNt (Noachian part), Nhu, Nhe, Nve, mNhm, and eNhm; overlain by mNh, lNh, lNv, HNhu, HNt (Hesperian part), eHv, lHv, lHt, Hp, Hto, AHv, AHtu, AHi, Apu. Densely cratered; marked by broad, linear and irregular scarps and ridges	Undifferentiated impact, volcanic, fluvial, and basin materials. Heavily degraded; tectonically deformed in places
Nhe	**Noachian highland edifice unit**—Irregular edifices marked by troughs and peaks. As much as a few kilometers thick. (lat –34.72° N., long 214.85° E.)	Occurs in southern highlands mostly lat 30° to 70° S., especially south of Tharsis region. Gradational with units HNt, lNh, mNh and eNh; overlain by units lNh, lNv, HNt (Hesperian part), eHv, lHv, and AHv. Densely cratered and marked by scarps and ridges	Mainly undifferentiated, degraded volcanic materials. Heavily degraded and tectonically modified
mNhm	**Middle Noachian highland massif unit**—High-relief massifs tens of kilometers across separated by broad linear troughs and valleys. Kilometers thick. (lat –44.48° N., long 307.54° E.)	Surrounds Argyre and part of Isidis Planitiae. Gradational with units mNh, eNh, and HNt (Noachian part); overlain by units lNh, HNb, HNt (Hesperian part), eHh, eHt, eHv, lHt, and lHl. Heavily cratered; dissected by grabens and valleys in places	Ancient, degraded crustal rocks uplifted by large, basin-forming impacts. Dissected by basin-related fault structures and erosional valleys
eNhm	**Early Noachian highland massif unit**—Forms high-relief massifs tens of kilometers across separated by broad linear troughs and valleys. Kilometers thick. (lat –26.00° N., long 63.24° E.; localities 43, 45)	Forms annulus around most of Hellas Planitia. Gradational with units eNh and ANa (Noachian part); overlain by units mNh, lNh, lNv, HNb, HNhu, eHv, Hve, and lHv. Heavily cratered; dissected by valleys in places	Primitive, degraded crustal rocks uplifted by large, basin-forming impact. Dissected by basin-related fault structures and erosional valleys