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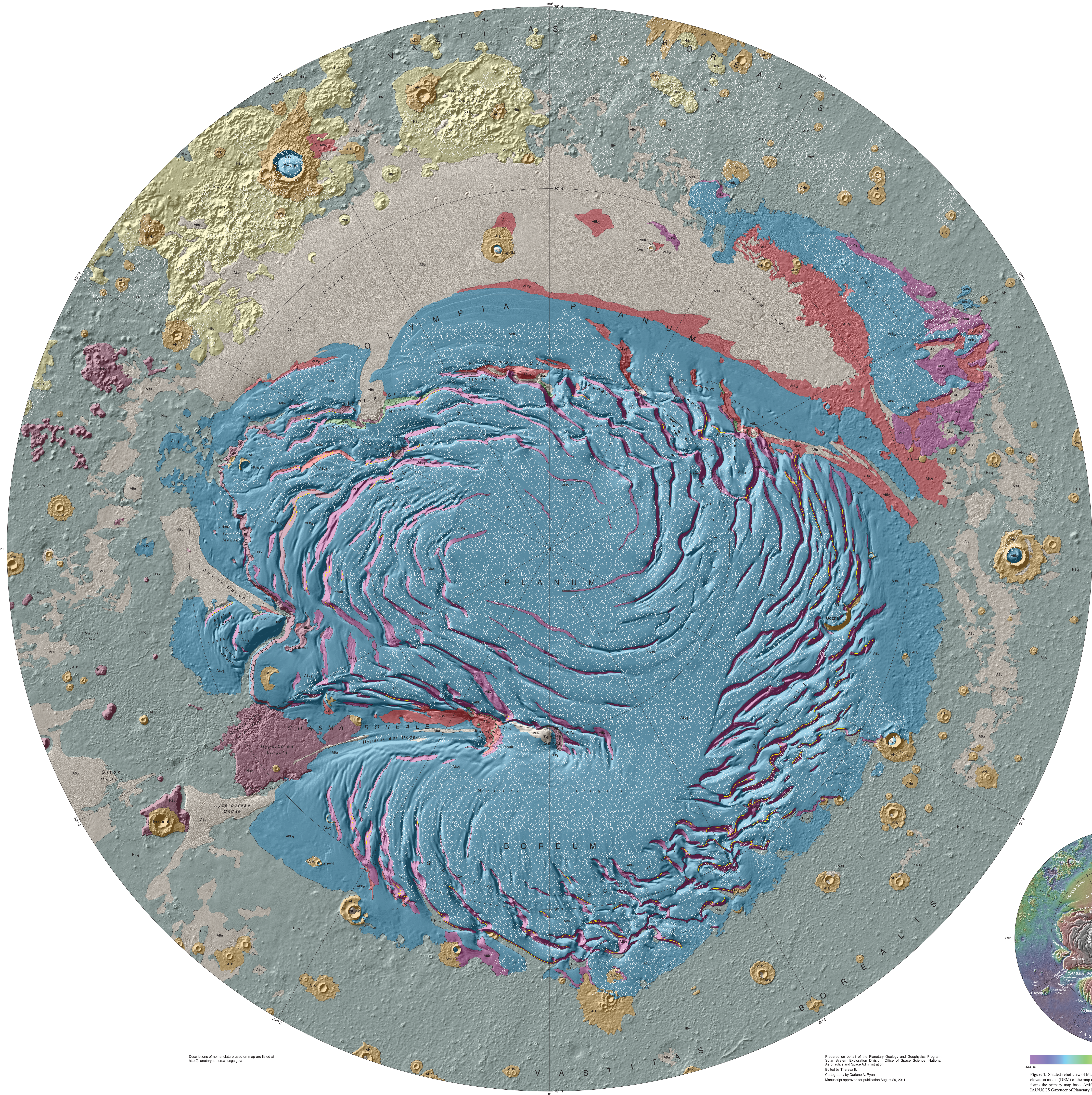
National Aeronautics and Space Administration

Scientific Investigations Map 3177
Atlas of Mars: North Polar Region
Pamphlet accompanies map



Descriptions of nomenclature used on map are listed at http://planetarynames.wr.usgs.gov/

Geologic Map of the North Polar Region of Mars

By
Kenneth L. Tanaka and Corey M. Fortezzo
2012

SCALE 1:2 000 000 (1 mm = 2.00 km) AT LAT 80° N.
SCALE 1:2 204 836 (1 mm = 2.20 km) AT LAT 75° N.

POLAR STEREOGRAPHIC PROJECTION
Planetocentric latitude and east longitude coordinate system

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

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CORRELATION OF MAP UNITS

AGE — EPOCH — BOREALIS PROVINCE (PLANUM BOREUM UNITS; CIRCUMPOLAR PLAINS UNITS) — CRATER MATERIAL — NON-SEDIMENTARY POLAR GEOLOGIC EVENTS

AMAZONIAN — Late: residual ice; ABb_3; undae unit ABu; ABb_2
AMAZONIAN — Middle: ABb_1; ABb_c; episodic mantle material
AMAZONIAN — Early
HESPERIAN: HBb_r; Scandia region unit HBs; Vastitas Borealis interior unit HBv_i
Crater material: AHc

Non-sedimentary polar geologic events:
- Erosion of unit perhaps during higher obliquity
- Erosion of units results in dune fields during possible higher obliquity
- Accumulation of lithic particles and ice cementation result in unit
- Troughs and scarps eroded into units ABb_c and ABb_1; Jojutla impact
- Polar ice deposited in meter-thick layers; erosion in lower sequences on outer parts of Planum Boreum result in unconformities (interior black lines)
- Accumulation of sand and interbeds of ice result in unit ABb_c
- Mantles episodically cover plains; when impacted and later removed they form pedestal craters
- Polygonal troughs form in plains and lower part of unit HBb_r forming Hyperborea Lingula
- Erosion of unit HBb_r and related plains material forms Rupes Tenuis, Chasma Boreale marginal scarps, and pedestal craters on the unit; Boola, Escorial, Crotone impacts
- Scandia region resurfacing: mud diapirism and volcanism and gypsum generation instigated by Alba Patera magmatism forms unit HBs and HBb
- Waning of catastrophic outflow channel activity that results in upper deposits of unit HBv_i; compaction and local volatile release from unit HBv_i

DESCRIPTION OF MAP UNITS

Unit symbol	Unit Name and Definition	Additional characteristics*	Interpretation
	PLANUM BOREUM UNITS		
ABb_3	**Planum Boreum 3 unit**—Forms as many as 6 to 8 layers each several meters thick of moderately high or variable albedo having knobby margins and diffuse interlayer boundaries; moderate surface ice abundance	Covers most of Planum Boreum, including some pole-facing trough walls, and scattered outlier mesas of Olympia, Abalos, and Tenuis Mensae. Mostly thinly mantled by bright residual ice. Local unconformities occur within unit. Locally cut by grabens and pits along low ridges and scarps above western Olympia Rupēs	Late Amazonian nearly pure water ice with small dust concentration except for thin surficial dust lags; likely undergoing thermokarst degradation and eolian erosion, particularly on unit margins
ABb_2	**Planum Boreum 2 unit**—Forms low-albedo material; layers evident in places; low ice abundance. As much as several tens of meters thick	Covers parts of floors and slopes of Chasma Boreale, Olympia Cavi and Rupēs and nearby troughs, and margins of Gemina Lingula east of Chasma Boreale. Variably hummocky and bumpy surface. Locally includes possible cut-and-fill structures	Late Amazonian dusty to sandy eolian mantle derived largely from Planum Boreum cavi and rupēs units
ABb_1	**Planum Boreum 1 unit**—Finely layered, high-albedo in upper part and moderate-albedo in lower part; moderate ice content. Locally exceeds 1000 m in thickness. Includes bright horizontal reflectors and local discontinuities in SHARAD radar data	Forms much of upper Planum Boreum and scattered patches in the surrounding plains; exposed mainly in southward-facing scarps; unit may exceed 1500 m thickness near north pole. Exposures typically include sequences of dozens to hundreds of even layers mostly meters thick (interrupted by a few prominent, thicker layers); lower sequences polygonally fractured. Local internal unconformities commonly with dark surfaces, particularly in lower, outer parts of Planum Boreum. Marked by arcuate patterns of troughs and undulations and dissected by Chasma Boreale. Sparsely cratered by impacts tens to a few hundred meters in diameter. Displays cross-hatched fracturing within 10 to 12 kilometers of 43-km-diameter Udzha crater	Middle to Late Amazonian atmospherically precipitated and transported ice and dust perhaps deposited during episode of overall lower obliquity and originating from lower latitude sources; alternating layers may result from cyclic climatic and depositional conditions. Glacial deformation not apparent but brittle contraction cracks and possible subsurface faults beneath troughs evident. Exposed surfaces may be partly covered by dust mantle
ABb_c	**Planum Boreum cavi unit**—Dark and light even to irregular layers typically meters thick; local cross bedding; overall low water ice abundance. Locally reaches a couple hundred meters in thickness	Lines lower, steep walls of Olympia, Boreum, and Tenuis Cavi, northern Olympia Planum, Chasma Boreale, and depression in western Abalos Mensa. Light-toned layers typically form prominent ledges marked by polygonal fractures spaced meters apart, whereas dark layers less fractured and more friable and disaggregated into dark sands, ripples, and dunes	Middle to Late Amazonian poorly indurated sandy weathered basalt fines deposited by wind, interbedded with ice-rich layers. Sandy material may originate from erosion of Planum Boreum rupēs and Scandia units. Occurrence may be spotty, within former wind-sheltered hollows carved within Planum Boreum rupēs unit. Perhaps generated during a mostly high-obliquity epoch
HBb_r	**Planum Boreum rupēs unit**—Evenly layered; >20 layers total exposed, each ~10 to 100 m thick; likely high ice content. Diffuse and moderately reflective in MARSIS and SHARAD data. Locally 1000 m thick along Rupes Tenuis	Forms much of the basal section of the main lobe of Planum Boreum, particularly along Rupes Tenuis and lower parts of Olympia Rupēs and Cavi; also forms low (<300 m thick) Hyperborea Lingula plateau covering the base of Chasma Boreale; likely forms plateau underlying Escorial crater ejecta and perhaps material of Abalos Colles. Layer margins commonly form knobs and rounded, concave-upward plates. Superposed by several multi-kilometer-diameter craters including Boola and Crotone	Early to Late Hesperian, ice-laden, fine-grained deeply eroded but presently indurated deposits. Generally undeformed except for polygonal graben network that cuts lower section of unit making up Hyperborea Lingula and Hyperboreus Labyrinthus
	CIRCUMPOLAR PLAINS UNITS		
ABu	**Undae unit**—Includes dunes typically tens to hundreds of meters across and tens to more than 100 m high, as well as rippled and bumpy mantle material commonly between and surrounding dunes. Low albedo in defrosted, summertime images and bright (warm) in THEMIS daytime infrared images; low ice abundance	Forms broad, irregular patches encircling much of Planum Boreum; locally confined within subtle topographic traps and craters; most pronounced dune fields include Olympia Undae and other areas within and south of Chasma Boreale (Hyperborea and Abalos Undae) that appear to be made up of individual and chains of barchan dune forms. High abundance of Type 2 TES spectral type; OMEGA data indicate overall signature of hydration plus gypsum concentrated on upper parts of Olympia Undae	Late Amazonian ergs of wind-blown, weathered basaltic silt and sand, locally rich in gypsum and other hydrated minerals. Originates mostly from local erosion of Planum Boreum cavi unit and some Planum Boreum 2 unit, particularly from west- to south-facing cavi-wall outcrops and buried surfaces in eastern Olympia Planum. Dunes largely inactive at present; likely active during higher obliquity episodes, particularly > 4–5 million years ago
HBv_i	**Vastitas Borealis interior unit**—Vast, moderately cratered plains-forming deposits	Typically marked by scattered higher albedo bumps ~1 to several kilometers across. South of Chasma Boreale and around western Scandia Tholi and Cavi in some of the lowest elevation plains marked by a polygonal network of shallow trough segments tens of meters deep, a few hundred to 2000-m wide and several kilometers long. Also contains scattered circular depressions up to tens of kilometers in diameter. Unit largely obscured by recent thin mantle deposits	Early to Late Hesperian sediments of outflow channels that dissect highlands thousands of kilometers south of map area. Pervasively altered and deformed during Late Hesperian by compaction, mud volcanism, and other periglacial processes involving subsurface volatiles. Scattered bumps may be degraded, infilled crater forms
HBs	**Scandia region unit**—Forms singular and chained subcircular to irregular complexes of domical hills of Scandia Tholi and Cavi tens to a few hundred kilometers across and tens to hundreds of meters in relief	Larger hill complexes have interior and surrounding depressions (Scandia Cavi) tens to hundreds of meters deep and a few narrow sinuous ridges a couple kilometers wide and tens of kilometers long. Many tholi bounded by shallow moats within surrounding Vastitas Borealis interior unit. Wrinkle ridges in adjacent Vastitas Borealis units disappear in Scandia region unit. Unit largely obscured by recent thin mantle deposits	Early to Late Hesperian sedimentary and cryoclastic volcanism may have formed much of unit and attendant collapse structures, perhaps instigated by Alba Patera magmatism. Unit may be deeply eroded
	CRATER MATERIAL		
AHc	**Crater material**—Forms crater rims and bowls and surrounding blankets tens of meters above subjacent units. Outcrops >15 km across mapped	Blankets vary considerably and are missing in some cases and include thin ones with ramparts and extensive, smooth, thick ones (of so-called "pedestal craters"). See table 4 for descriptions of crater types distinguished by geomorphologic and geologic characteristics	Late Hesperian to Amazonian ejecta resulting from larger impacts

*Mineral and ice compositional data are from CRISM, OMEGA, and TES data and reflect surface compositions generally indicative in high albedo regions of ice and dust and in low albedo regions of basaltic and perhaps andesitic or altered basaltic lithologies that may include zeolites, silica glass, and minor amounts of clay minerals; eastern Olympia Undae also include gypsum signatures (Bandfield, 2002; Wyatt and others, 2004; Langevin and others, 2005; Tanaka and others, 2008; Horgan and others, 2009).

EXPLANATION OF MAP SYMBOLS

- **Contact**—Dashed where approximate; dotted where gradational
- **Graben**
- **Unconformity**
- **Residual ice**

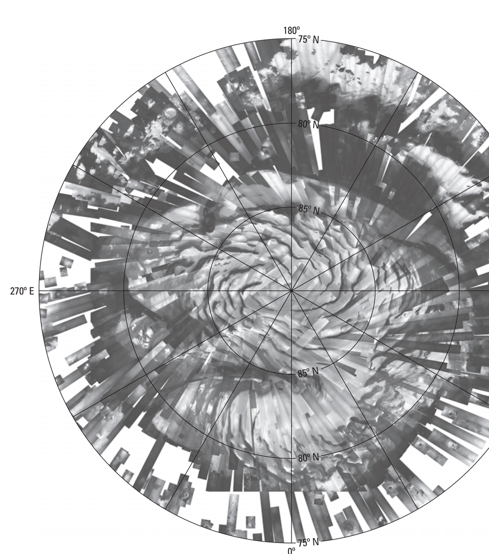

Figure 2 (right). Mars Reconnaissance Orbiter (MRD) Context Camera (CTX) image mosaic (constructed at 6.2 m/pixel; version provided here is 24 m/pixel due to size) of the Planum Boreum region of Mars in Polar Stereographic projection. The mosaic includes ~1400 images from the testing, primary, and extended mission phases. The Planum Boreum set has ~99% coverage with images from orbits T02 thru B03, but excludes orbits P13 thru P19 because of obscuration due to presence of the polar hood. The circumpolar plains tile set has ~70% coverage and includes images from all orbits with those from P13 thru P19 used as background images. The mosaic is not controlled, but it is sufficiently georeferenced to the MOLA topographic model such that in most places the mosaic's spatial accuracy is adequate for mapping at 1:2,000,000 scale. Images are not tone matched; however, the residual ice layer on Planum Boreum provides fairly consistent pixel values on which to stretch the individual images and the tiles, resulting in a useful, but not photometrically balanced, product.

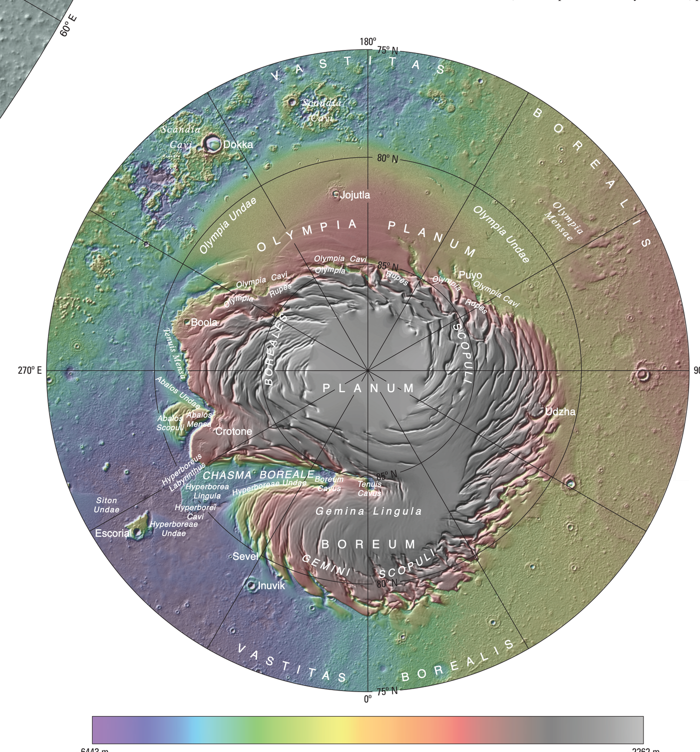

Figure 1. Shaded-relief view of Mars Global Surveyor (MGS) Mars Orbiter Laser Altimeter (MOLA) digital elevation model (DEM) of the map region (230 m/pixel; also version at 115 m/pixel used in mapping), which forms the primary map base. Artificial illumination is from upper left. Geographic features are from the IAU/USGS Gazetteer of Planetary Nomenclature (http://planetarynames.wr.usgs.gov/).

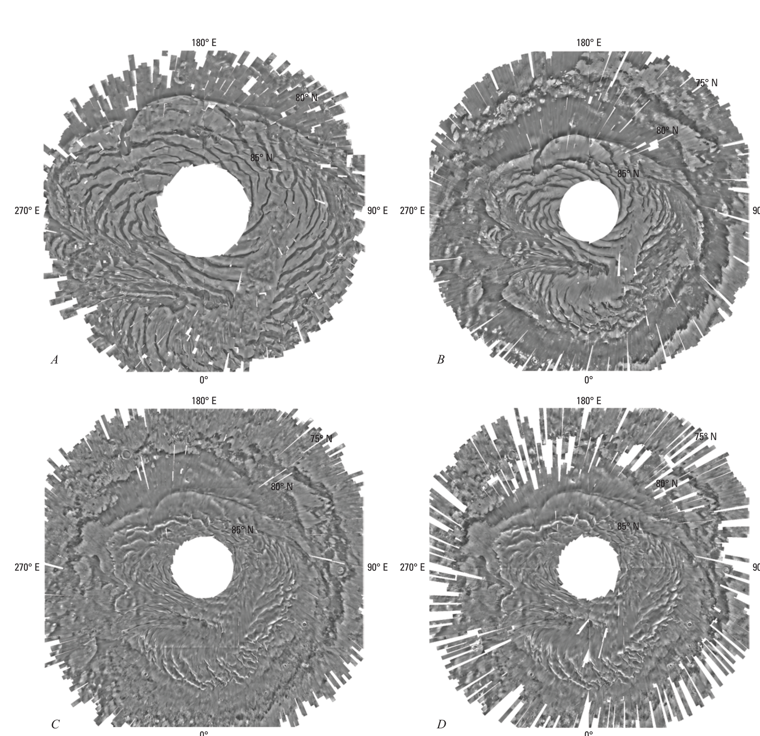

Figure 3 (right). Mars Odyssey (ODY) mission Thermal Emission Imaging System (THEMIS) visual-range image mosaics of the Planum Boreum region in Polar Stereographic projection (courtesy of P.R. Christensen, Arizona State University). The mosaics are at half the spatial resolution of the original images, which were obtained at full (18 m/pixel) and half instrument resolution. *A*, Summertime images at 36 m/pixel north of lat 80° N. *B*, Summertime images at 72 m/pixel north of lat 75° N. *C*, Springtime images at 36 m/pixel north of lat 75° N. *D*, Springtime images at 72 m/pixel north of lat 75° N.

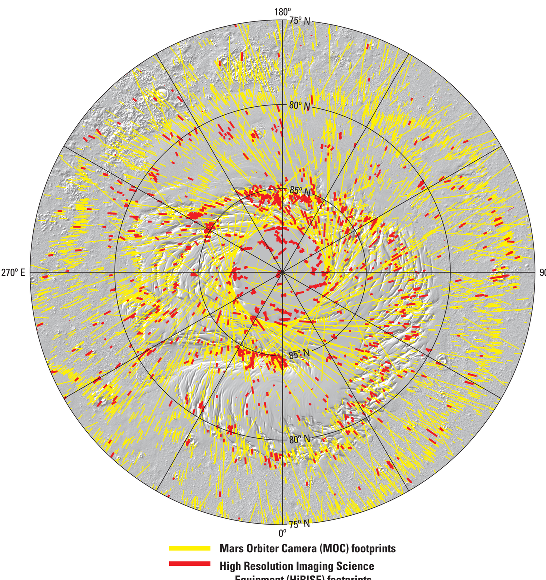

Figure 4. Plot showing locations of Mars Global Surveyor (MOC) (>3 m/pixel) and Mars Reconnaissance Orbiter (HiRISE) (25 cm/pixel) images in the map region obtained during all seasons and released as of May 2009, on a background showing the topography in shaded relief based on the MOLA DEM.

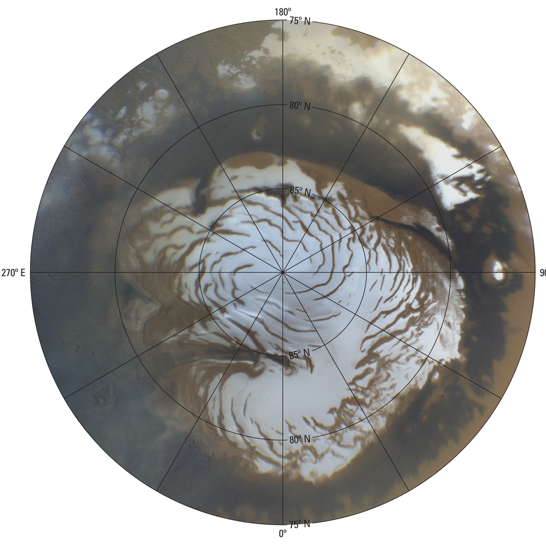

Figure 5. Composite mosaic of three color images acquired by the Mars Reconnaissance Orbiter Mars Color Imager (MARCI) on October 16th of 2006 during Martian northern summer, solar longitude, $L_s = 121°$. The MARCI frames are blended with a MOLA shaded relief (~230 m/pix) to enhance topographic features, which are somewhat muted by atmospheric haze in the color images. The image shows the region north of lat 72º N. at ~1000 m/pixel. The color is derived from three spectral bands acquired at 425 nm, 550 nm, and 600 nm. We mapped the high-albedo residual ice using this mosaic. Additional color units shown in Tanaka and others (2008) include beige-colored dust, low-albedo basaltic sand, and mixtures of low- and moderate-albedo materials with sparse residual ice.

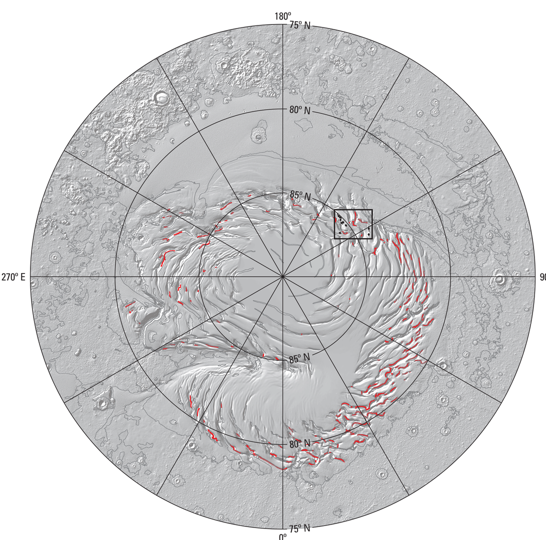

Figure 6. Map of unconformities (red lines) and grabens (black lines with balls in box) in Planum Boreum 1 unit and Planum Boreum 3. Background shows the topography in shaded relief based on the MOLA DEM as well as unit contacts.

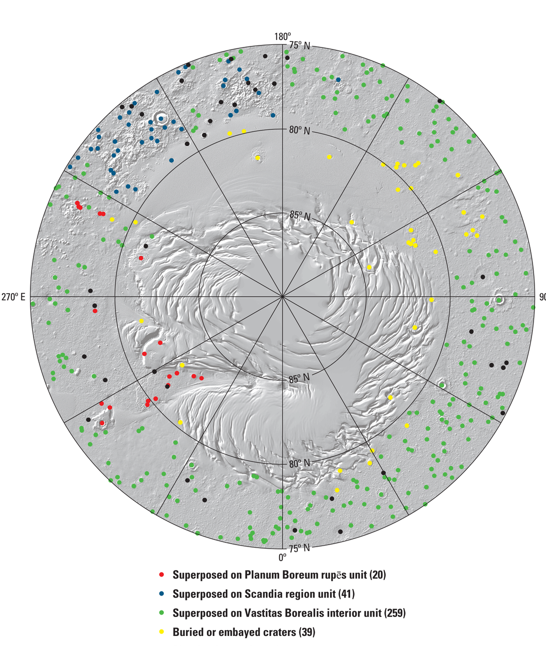

Figure 7. Plot showing the distribution of impact craters > 2 km in diameter in the map region (see table 4 regarding morphologic and other characteristics). These include craters used in crater statistics (table 2 and fig. 8).

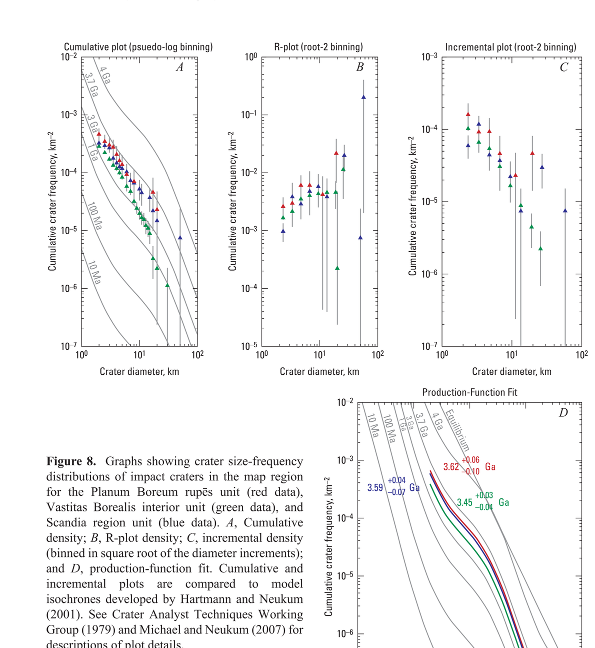

Figure 8. Graphs showing crater size-frequency distributions of impact craters in the map region for the Planum Boreum rupēs unit (red data), Vastitas Borealis interior unit (green data), and Scandia region unit (blue data). *A*, Cumulative density; *B*, R-plot density; *C*, incremental density (binned in square root of the diameter increments); and *D*, production-function fit. Cumulative and incremental plots are compared to model isochrones developed by Hartmann and Neukum (2001). See Crater Analyst Techniques Working Group (1979) and Michael and Neukum (2007) for descriptions of plot details.