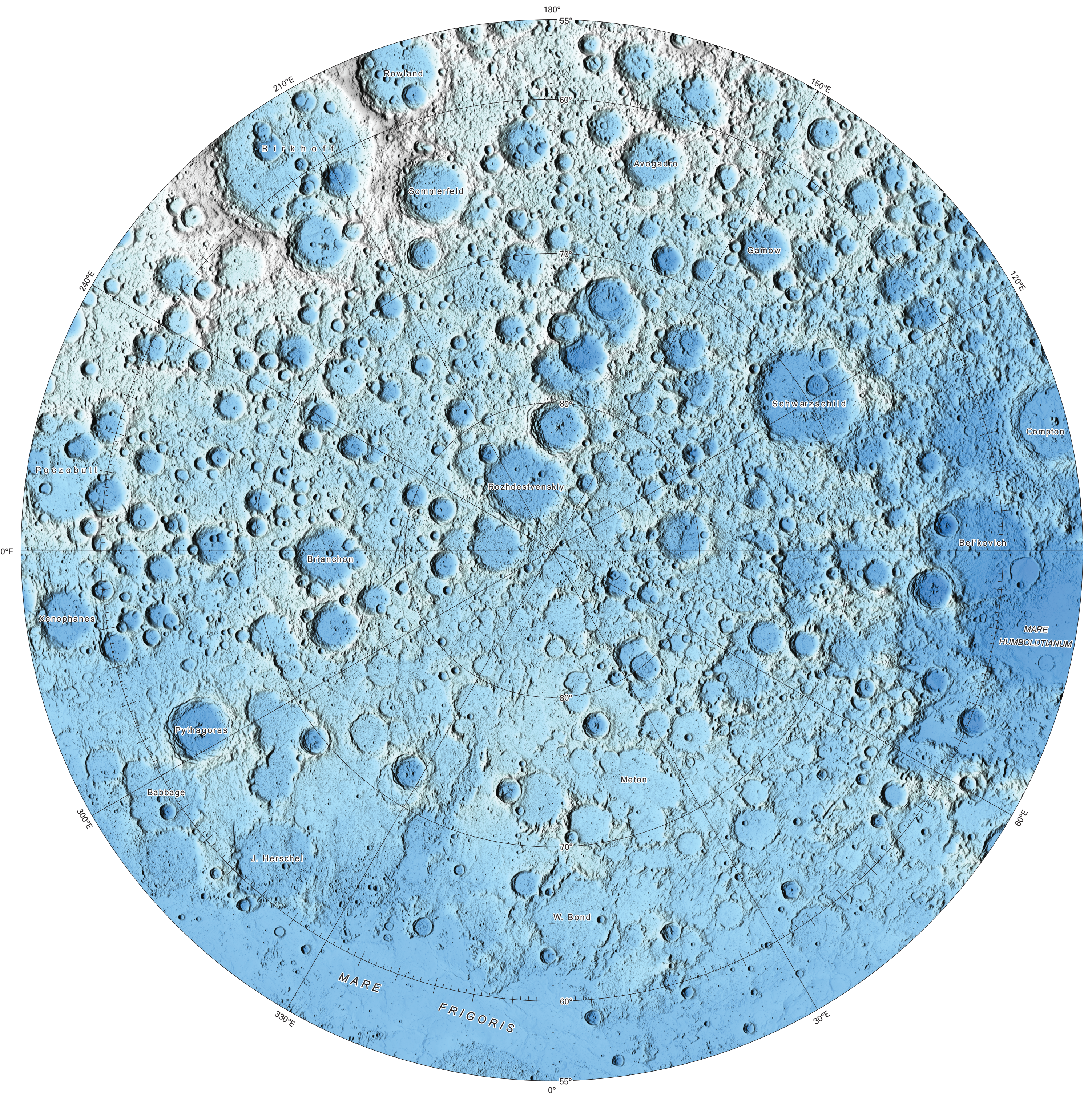
U.S. Department of the Interior
U.S. Geological Survey

Prepared for the
National Aeronautics and Space Administration

Scientific Investigations Map 3316
Sheet 2 of 2



SCALE 1:6 078 683 (1 mm = 6.078683 km) AT 90° LATITUDE
POLAR STEREOGRAPHIC PROJECTION

NORTH POLAR REGION

MAP DESCRIPTION

This map is based on data from the Lunar Orbiter Laser Altimeter (LOLA; Smith and others, 2010), an instrument on the National Aeronautics and Space Administration (NASA) Lunar Reconnaissance Orbiter (LRO) spacecraft (Tooley and others, 2010). The image used for the base of this map represents more than 6.5 billion measurements gathered between July 2009 and July 2013, adjusted for consistency in the coordinate system described below, and then converted to lunar radii (Mazarico and others, 2012). Elevations were computed by subtracting the lunar reference radius of 1737.4 kilometers (Lunar Reconnaissance Orbiter Project Lunar Geodesy and Cartography Working Group, 2008; Archinal and others, 2011) from the surface radius measurements. Thus elevation values are the distance above or below the reference sphere. The average accuracy of each point after crossover correction is better than 20 meters (m) in horizontal position and ~1 m in radius (Mazarico and others, 2012). For the Mercator portion, these measurements were converted into a digital elevation model (DEM; Neumann and others, 2011) using Generic Mapping Tools software (Wessel and Smith, 1998), with a resolution of 0.015625 degrees per pixel, or 64 pixels per degree. In projection, the pixels are 473.8 m in size at the equator. Gaps between tracks of 1–2 km are common, and some gaps of as much as 4 km occur near the equator. DEM points located in these gaps were filled by interpolation (Smith and others, 2011). For the polar portion, the LOLA elevation points were used to create a DEM at 240 meters per pixel. The high and low elevations noted on the map and listed on the scale bar are approximate.

PROJECTION

The Mercator projection is used between latitudes ±57°, with a central meridian at 0° longitude and latitude equal to the nominal scale at 0°. The Polar Stereographic projection is used for the regions north of the +55° parallel and south of the –55° parallel with a central meridian set for both at 0° and a latitude of true scale at +90° and -90° respectively. The adopted spherical radius used to define the map scale is 1737.4 km (Lunar Reconnaissance Orbiter Project Lunar Geodesy and Cartography Working Group, 2008; Archinal and others, 2011).

COORDINATE SYSTEM

The LOLA data were initially referenced to an internally consistent inertial coordinate system, derived from tracking of the LRO spacecraft. By adopting appropriate values for the orientation of the Moon as defined by the International Astronomical Union (IAU; Archinal and others, 2011), these inertial coordinates were converted into the planet-fixed coordinates (longitude and latitude) used on this map. The coordinate system defined for this product is the mean Earth/polar axis (ME) system, sometimes called the mean Earth/rotation axis system. The ME system is the method most often used for cartographic products of the past (Davies and Colvin, 2000). Values for the orientation of the Moon were derived from the Jet Propulsion Laboratory Developmental Ephemeris (DE) 421 planetary ephemeris (Williams and others, 2008; Folkner and others, 2008; 2009) and rotated into the ME system.

Longitude increases to the east and latitude is planetocentric as allowed in accordance with current international and NASA standards (Lunar Reconnaissance Orbiter Project Lunar Geodesy and Cartography Working Group, 2008; Archinal and others, 2011). The intersection of the lunar equator and prime meridian occurs at what can be called the Moon's "mean sub-Earth point." The concept of a lunar "sub-Earth point" derives from the fact that the Moon's rotation is tidally locked to the Earth. The actual sub-Earth point on the Moon varies slightly due to orbital eccentricity, inclination, and other factors, so a "mean sub-Earth point" is used to define the point on the lunar surface where longitude equals 0°. This point does not coincide with any prominent crater or other lunar surface feature (Lunar Reconnaissance Orbiter Project Lunar Geodesy and Cartography Working Group, 2008; Archinal and others, 2011).

MAPPING TECHNIQUES

To create the topographic base image, the original DEM that was produced by the LOLA team in the Simple Cylindrical projection with a resolution of 64 pixels per degree, was projected into the Mercator and Polar Stereographic pieces. A shaded relief map was generated from each DEM with a sun angle of 45° from horizontal and a sun azimuth of 270°, as measured clockwise from north with no vertical exaggeration. The DEM values were then mapped to a global color look-up table, with each color representing a range of 1 km of elevation. These two files were then merged and scaled to 1:10,000,000 for the Mercator part, and 1:6,078,683 for the two Polar Stereographic parts with a resolution of 300 pixels per inch. The two projections have a common scale at ±56° latitude.

NOMENCLATURE

Names on this sheet are approved by the IAU. Only larger features shown. For a complete list of the IAU-approved nomenclature for the Moon, see the Gazetteer of Planetary Nomenclature at http://planetarynames.wr.usgs.gov.

ACKNOWLEDGMENTS

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REFERENCES

Archinal, B.A. (Chair), A'Hearn, M.F., Bowell, E., Conrad, A., Consolmagno, G.J., Courtin, R., Fukushima, T., Hestroffer, D., Hilton, J.L., Krasinsky, G.A., Neumann, G.A., Oberst, J., Seidelmann, P.K., Stooke, P., Tholen, D.J., Thomas, P.C., and Williams, I.P., 2011, Report of the IAU Working Group on cartographic coordinates and rotational elements—2009: Celestial Mechanics and Dynamical Astronomy, v. 109, no. 2, p. 101–135, doi: 10.1007/s10569-010-9320-4.

Davies, M.E., and Colvin, T.R., 2000, Lunar coordinates in the regions of the Apollo landers: Journal of Geophysical Research, v. 105, no. E8, p. 20,277–20,280.

Folkner, W.M., Williams, J.G., and Boggs, D.H., 2008, The planetary and lunar ephemeris DE 421: Jet Propulsion Laboratory Memorandum IOM 343R-08-003, 31 p., at ftp://ssd.jpl.nasa.gov/pub/eph/planets/ioms/de421.iom.v1.pdf.

Folkner, W.M., Williams, J.G., and Boggs, D.H., 2009, The planetary and lunar ephemeris DE 421: Interplanetary Network Progress Report 42-178, 34 p., at http://ipnpr.jpl.nasa.gov/progress_report/42-178/178C.pdf.

Lunar Reconnaissance Orbiter Project Lunar Geodesy and Cartography Working Group, 2008, A standardized lunar coordinate system for the Lunar Reconnaissance Orbiter and lunar datasets: Lunar Reconnaissance Orbiter Project and Lunar Reconnaissance Orbiter Project Lunar Geodesy and Cartography Working Group White Paper, v. 5, at http://lunar.gsfc.nasa.gov/library/LunCoordWhitePaper-10-08.pdf.

Mazarico, E., Rowlands, D.D., Neumann, G.A., Smith, D.E., Torrence, M.H., Lemoine, F.G., and Zuber, M.T., 2012, Orbit determination of the Lunar Reconnaissance Orbiter: Journal of Geodesy, v. 86, no. 3, p. 193–207.

Neumann, G.A., 2011, Lunar Reconnaissance Orbiter Lunar Orbiter Laser Altimeter reduced data record and derived products software interface specification, version 2.42, LRO-L-LOLA-4-GDR-V1.0, NASA Planetary Data System (PDS), at http://imbrium.mit.edu/DOCUMENT/RDRSIS.PDF

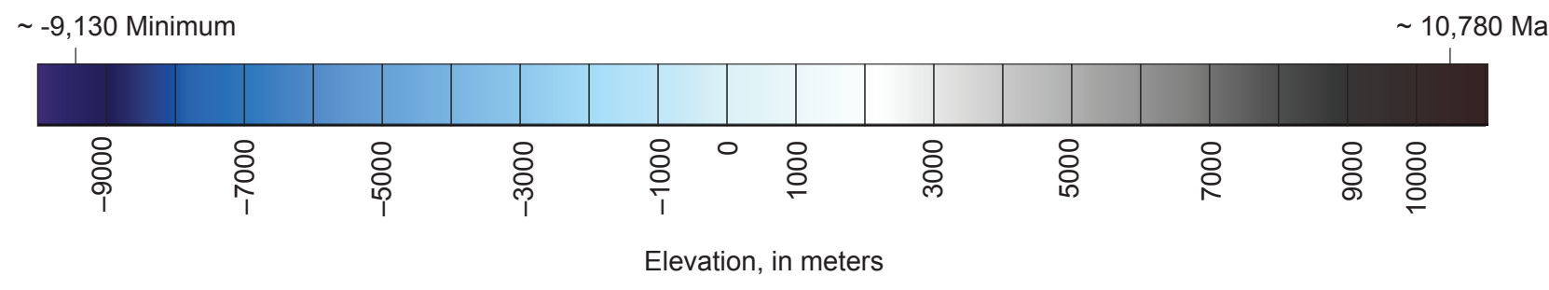
Smith, D.E., Zuber, M.T., Neumann, G.A., Lemoine, F.G., Mazarico, E., Torrence, M.H., McGarry, J.F., Rowlands, D.D., Head, J.W., III, Duxbury, T.H., Aharonson, O., Lucey, P.G., Robinson, M.S., Barnouin, O.S., Cavanaugh, J.F., Sun, X., Liiva, P., Mao, D., Smith, J.C., and Bartels, A.E., 2010, Initial observations from the Lunar Orbiter Laser Altimeter (LOLA): Geophysical Research Letters, v. 37, no. L18204, doi:10.1029/2010GL043751.

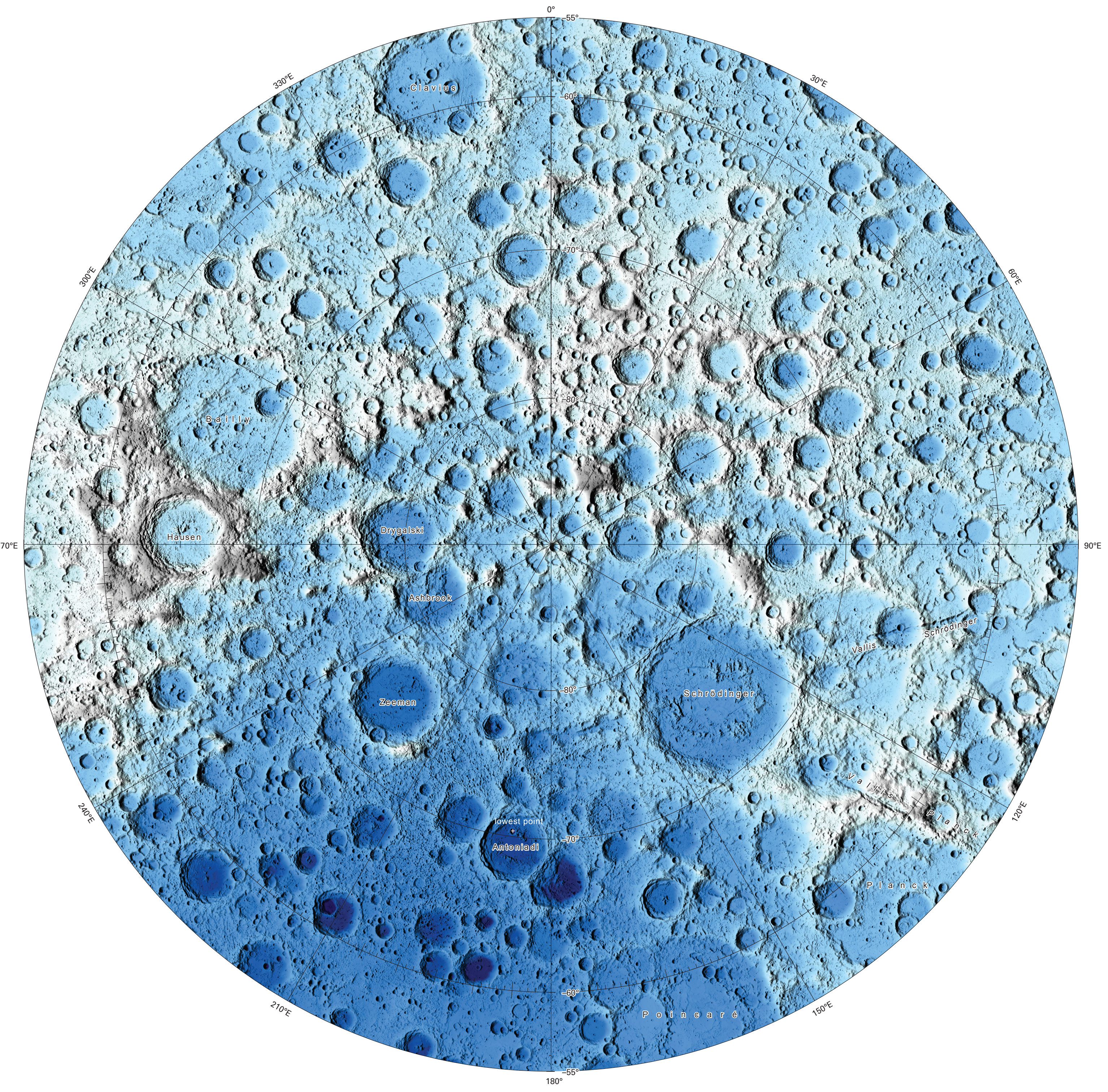
Smith, D.E., Zuber, M.T., Neumann, G.A., Mazarico, E., Head, J.W., III, Torrence, M.H., and the LOLA Science Team, 2011, Results from the Lunar Orbiter Laser Altimeter (LOLA)—global, high-resolution topographic mapping of the Moon [abs.]: Lunar Planetary Science Conference XLII, Woodlands, Tex., Abstract 2350.

Tooley, C.R., Houghton, M.B., Saylor, R.S., Peddie, C., Everett, D.F., Baker, C.L., and Safdie, K.N., 2010, Lunar Reconnaissance Orbiter mission and spacecraft design: Space Sciences Review, v. 150, no. 1, p. 23–62, doi:10.1007/s11214-009-9624-4.

Wessel, P., and Smith, W.H.F., 1998, New, improved version of Generic Mapping Tools released: Eos, Transactions of the American Geophysical Union, v. 79, no. 47, p. 579.

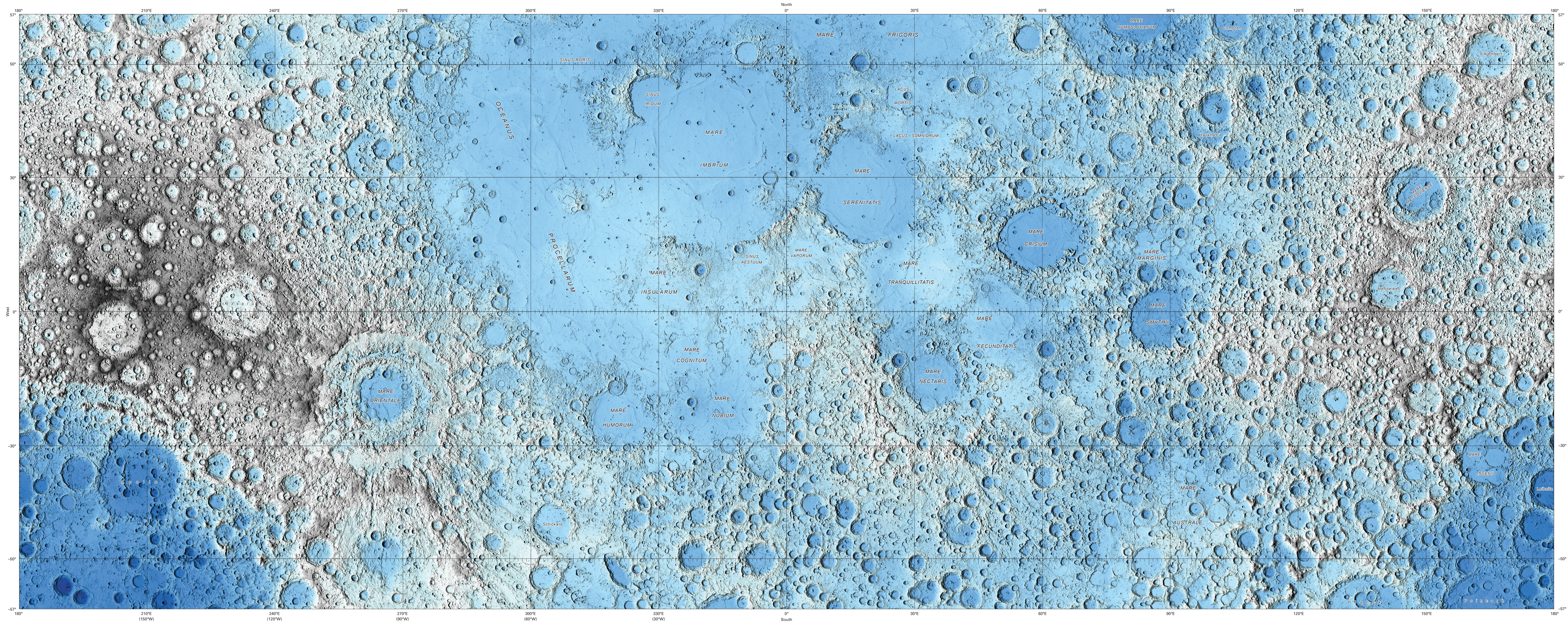
Williams, J.G., Boggs, D.H., and Folkner, W.M., 2008, DE421 Lunar orbit, physical librations, and surface coordinates: Jet Propulsion Laboratory Interoffice Memorandum IOM 335-JW,DB,WF-20080314-001, at ftp://ssd.jpl.nasa.gov/pub/eph/planets/ioms/de421_moon_coord_iom.pdf.





SCALE 1:6 078 683 (1 mm = 6.078683 km) AT -90° LATITUDE
POLAR STEREOGRAPHIC PROJECTION

SOUTH POLAR REGION



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

SCALE 1:10 000 000 (1 mm = 10 km) AT 0° LATITUDE
MERCATOR PROJECTION

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Edited by Kate Jacques; digital cartography by Vivian Nguyen

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Topographic Map of the Moon

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