Color-coded Topography and Shaded Relief of the Lunar Hemispheres

A new 3 sheet map

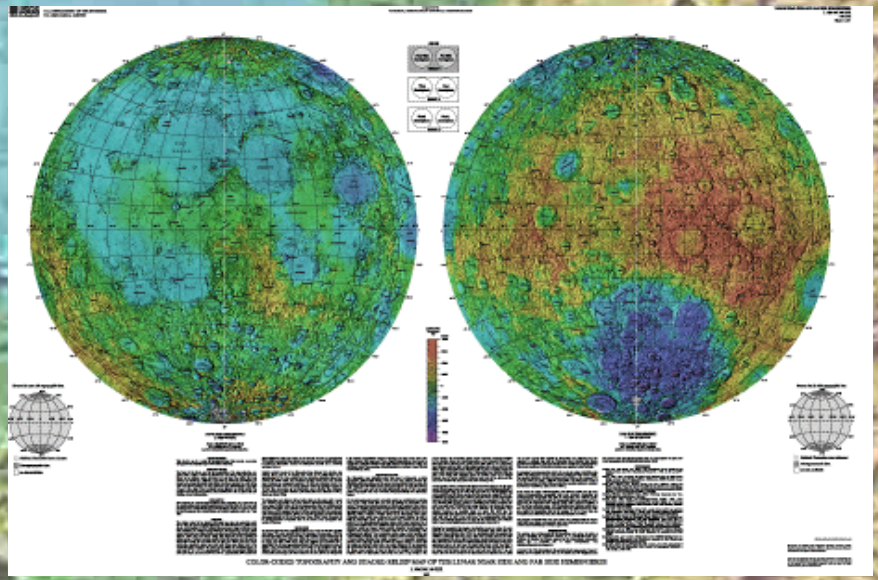
February 2002

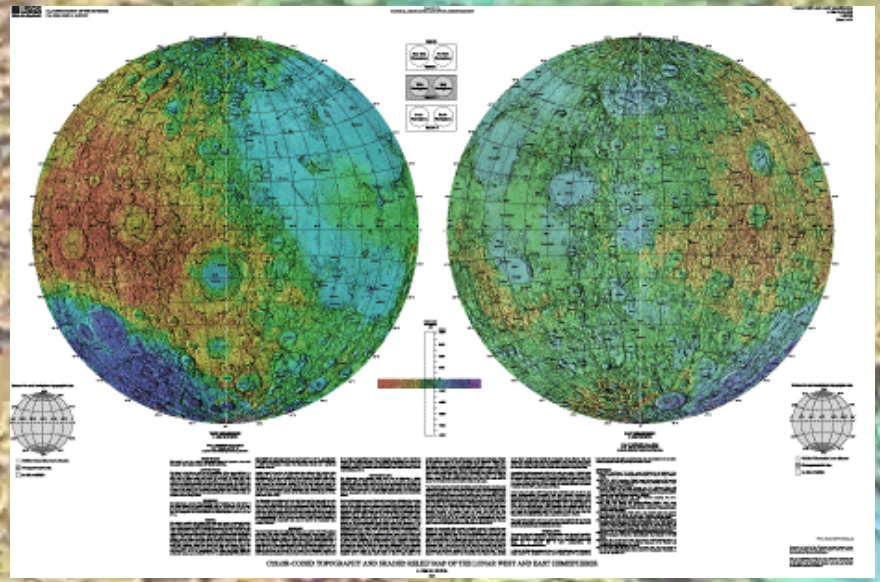
Overview of Presentation

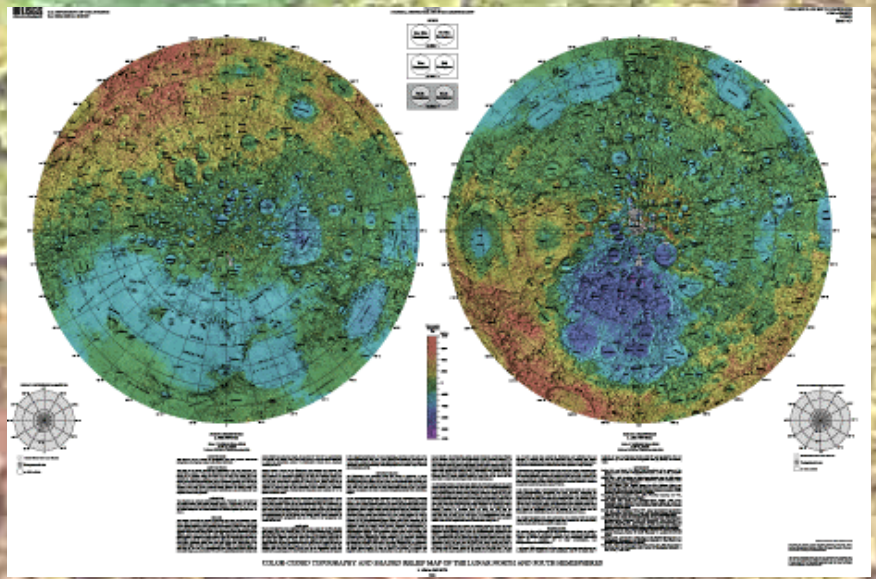
- Description of maps
- Description of layers
- Status

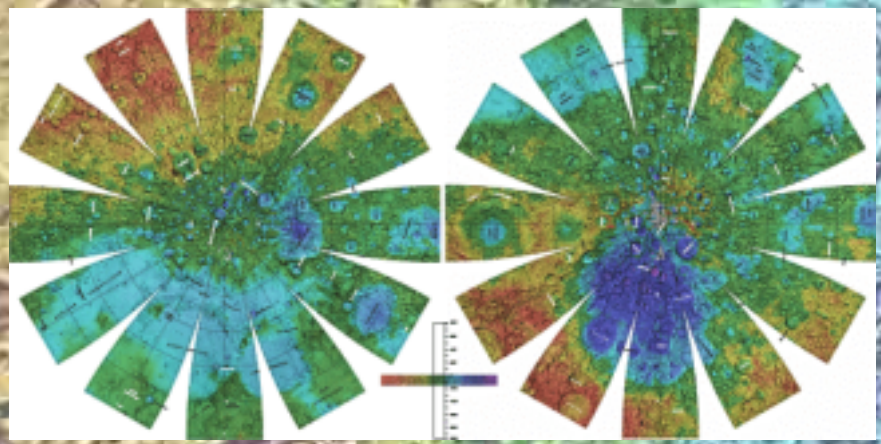
Description of maps

- 3 sheets with 2 hemispheres per sheet
- Set of lunar gores for globes







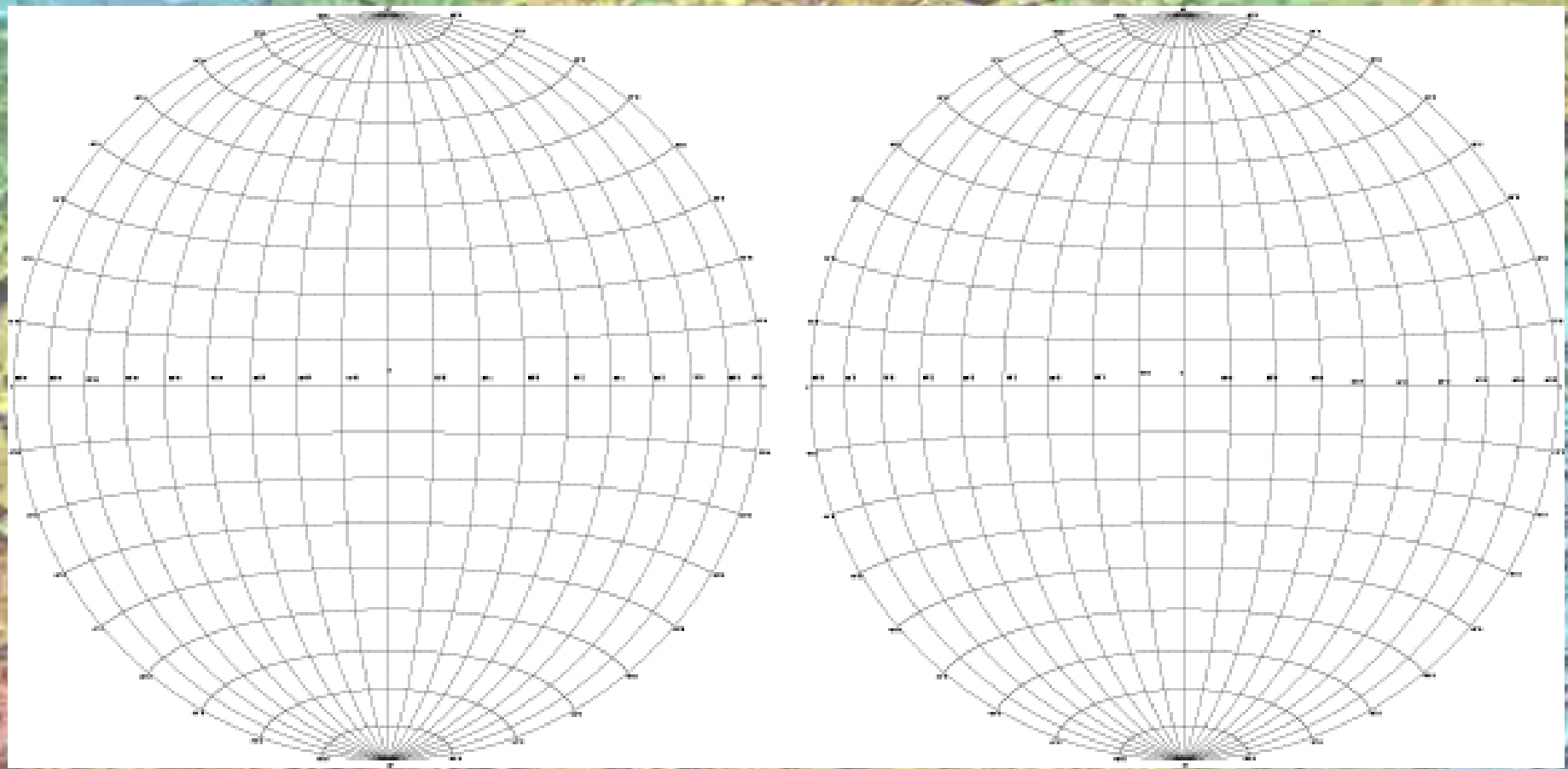


Grid and Coordinates Layers

1 Layer

Bonnie Redding, Mark Rosiek

PICS, Illustrator



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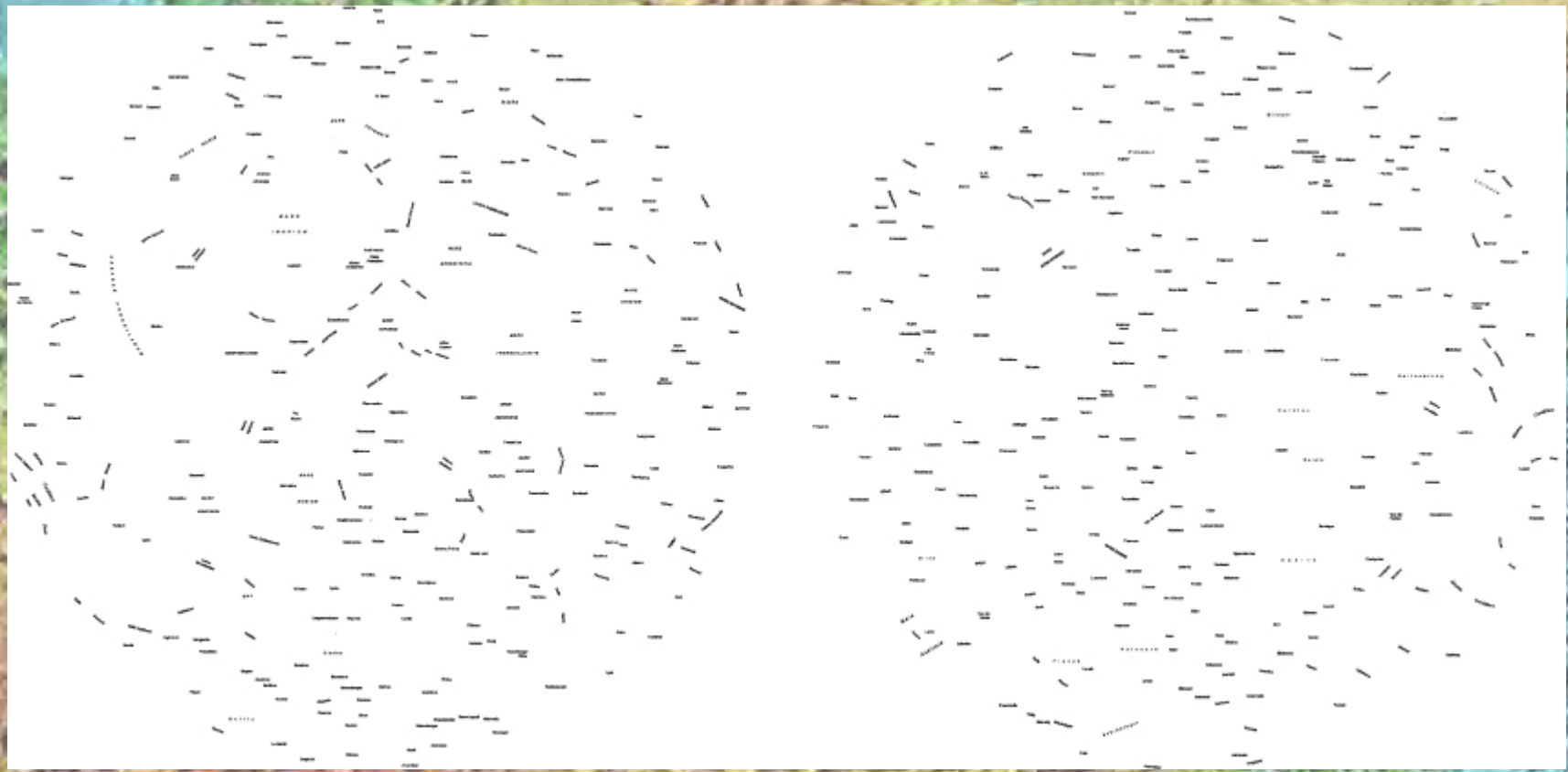
Nomenclature

2 layers – one for each hemisphere

Jennifer Blue

Illustrator Program

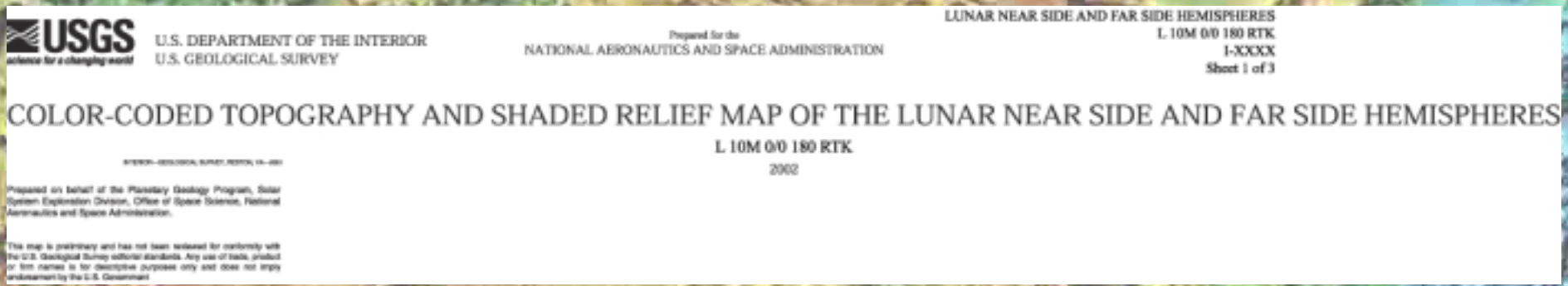


Standard Text

1 Layer

Bonnie Redding

Illustrator



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

Prepared for the
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

LUNAR NEAR SIDE AND FAR SIDE HEMISPHERES
L 10M 0/0 180 RTK
I-XXXX
Sheet 1 of 3

COLOR-CODED TOPOGRAPHY AND SHADED RELIEF MAP OF THE LUNAR NEAR SIDE AND FAR SIDE HEMISPHERES

L 10M 0/0 180 RTK

2002

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

This map is preliminary and has not been reviewed for conformity with the U.S. Geological Survey editorial standards. Any use of trade, product or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government

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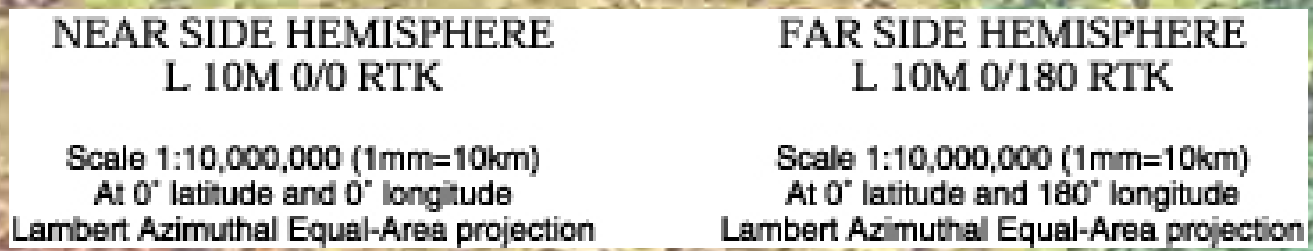
Titles

1 layer

Mark Rosiek

Illustrator



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Notes on base

1 layer

Mark Rosiek

Microsoft Word

NOTES ON BASE

This sheet is one in a series of topographic maps that presents color-coded topographic data digitally merged with shaded relief data.

ADOPTED FIGURE

The figure for the Moon, used for the computation of the map projection, is a sphere with a radius of 1737.4 km (Seidelmann and others, 2001). Because the Moon has no surface water, and hence no sea level, the datum (the 0-km contour) for elevations is defined as the radius of 1737.4 km. Coordinates are based on the mean Earth/polar axis (M.E.) coordinate system; the Z axis is the axis of the Moon's rotation, and the X axis is the mean Earth direction. The center of mass is the origin of the coordinate system (Davies and Colvin, 2000). The equator lies in the x-y plane and the prime meridian lies in the x-z plane with east longitude values being positive.

PROJECTION

The projection is Lambert Azimuthal Equal Area Projection. The scale factor at the central latitude and central longitude point is 1:10,000,000. For the near side hemisphere the central latitude and central longitude point is at 0° and 0°. For the polar side hemisphere the central latitude and central longitude point is at 0° and 180°.

CONTROL

The original control for the shaded relief maps was based on horizontal control tied to either the Lunar Positional Reference of 1974 (Schimerman, 1975) or the Apollo control system of 1970. Positional discrepancies as large as 25 km at map scale existed in the original shaded relief base. To improve the accuracy, digital shaded relief data were aligned with a mosaic produced from Clementine images (Eliason, 1997, Isbell and others, 1997). This alignment process consisted of matching points of features that were visible in both the shaded relief data and the Clementine mosaic. To accomplish this, the files were divided into three areas: north pole, equatorial region, and south pole. They were aligned first in the equatorial region and then in the polar regions. Within the equatorial region, an area from 60° S. to 60° N., encompassing 1,080 points were picked. Within the north polar region, an area from 61° N. to 90° N., approximately 1908 points were picked. Within the south polar region, an area from 57° S. to 90° S., approximately 1130 points were picked. These points were used to warp the shaded relief map to match the Clementine mosaic. The Clementine mosaic has a positional accuracy of 600 m.

Vertical control is based on the Clementine laser altimeter that collected data between 79° S. and 81° N. spacing was based on the orbits track and is approximately 60 km at the equator and less elsewhere. Elevation values were collected at 79,048 points. The along-track spacing reflect over every smooth terrain surface an along-track spacing of 30 km was achieved, while the instrument lost track over some rough highland terrain, the spacing degraded to 100 km. The across-track by the Clementine laser altimeter. The estimated vertical accuracy of points collected by the Clementine laser altimeter is 130 m. (Smith and others 1997).

The Clementine laser altimeter did not collect data over the lunar north or south poles, therefore topographic data were collected photogrammetrically to fill in theses gaps. Vertical control, for the photogrammetric data, was established by using the Clementine laser altimeter data at the outer edge of theses circular polar areas, and the imagery was used to bridge control data for the central part of the circle (Rosiek and others, 2001). The expected precision of points collected photogrammetrically is 180 m. (Rosiek and others, 1999). Further discussion of the photogrammetric topographic data can be found in the topographic data section of this note.

IMAGE BASE

The shaded relief data were originally published as a series of 1:5 million shaded relief maps. This series included three U.S. Geological Survey maps 1:1216-S, Shaded Relief Map of the Lunar Far Side, 1969; I-1284-A, Shaded Relief Map of the Lunar Near Side, 1980; and I-2276, Sheet 2 of 2, Shaded Relief Map of the Lunar Near Side, 1992. These data were digitized and mosaicked into a single digital file. An area approximately 400,000 km² near the south pole was not visible in any pre-Clementine images and is blank on the published map. The digitized relief data were revised on the basis of the Clementine mosaic and recast Earth based imagery to show features in the area. Errors are still present in the original interpretations of lunar morphology and these errors exist in the warped shaded relief map base. These original interpretations were based on nearly dark, semispherical fabricated by highly oblique solar incidence angles and distortions created in generating orthophotographs from oblique images (Pearlman and Arvidsman, 2001).

TOPOGRAPHIC DATA

The Clementine laser altimeter points were used to triangulate a global topographic gridded digital terrain model for the lunar surface. Because the altimeter points were sparse near the poles and non-existent near the poles, the polar regions from this digital terrain model were clipped and only data between 79.5, and 151N, were used in the final digital terrain model. To fill in the polar regions, topographic data were collected photogrammetrically from Clementine images.

For the photogrammetric project, horizontal control was established by selecting scenes of thin mosaic points that were used in building the Clementine global mosaic. These points provided estimates for latitude and longitude values and no estimate for elevation values. Vertical control was established by using the global topographic gridded digital terrain model developed from the Clementine laser altimeter points to estimate elevation values for the Clementine match points. Clementine match points were selected to tie two images together in order to build the Clementine global mosaic. To improve the geometry of the control network for the photogrammetric project match points were chosen in areas of image that contained the point. Additional points were selected to have four well-distributed points per image, where possible. Analytical aerotriangulation, a weighted least squares process, is used to solve for all the parameters in the photogrammetric project. These parameters include image sensor position and angles; latitude, longitude, and elevation of match points; and image coordinates of match points. During the solution, weights assigned to a panoramic-camera exterior values with high weight are held to the original estimate or values with low weight are allowed to float and a new value determined for the parameter. The parameters with the most error in their original estimate for their values are the image sensor angles, so they are given a low weight. The latitude and longitude values of Clementine match points are given a high weight as the solution holds to the Clementine global mosaic horizontal coordinates. Weights for the elevation values are varied depending on the horizontal distance to a Clementine laser altimeter point; match points within 3000 m of a Clementine laser altimeter point are given a high weight; match points between 3000 m and 8000 m from a Clementine laser altimeter point are given a medium weight; and match points greater than 8000 m from a Clementine laser altimeter point are given a low weight. This weighting allows the vertical control to be bridged between areas of known vertical control—the outer part of the circle—and the areas void of control—the inner part of the circle over the poles.

The Clementine mission collected both oblique and vertical images over the polar regions; these images form stereo pairs that can be used photogrammetrically to collect topographic data. In the north pole region (90° N. to 65° N. latitude) topographic data were collected from 667 stereo models. Topographic data were collected within each stereo model with a post spacing of 1 km in the x and y direction. This spacing resulted in 1,427,824 points being collected in the north pole region and 1,734,872 points being collected in the south pole region. On average, over the area that data were collected, the Clementine laser altimeter collected an elevation value every 374 km². Each of the photogrammetric data collected an elevation value for every every 1.3 km² in the north pole and 1.3 km² in the south pole. The photogrammetric data were merged and vertically transformed to align with the Clementine laser altimeter data to form the final digital terrain model (Rosiek and others, 2001).

Merging the topographic data required an iterative process to reduce the error between the photogrammetric data and the topographic data derived from the Clementine laser altimeter data. At first the photogrammetric topographic data exhibited a systematic dish-step error, in that stereo models closer to the poles had a systematic bias to be lower than stereo models farther from the poles. When this bias was removed the resulting digital terrain model had a bowl-shape appearance with a low spot near the pole. Each stereo model was fitted to remove the bowl-shape for stereo models in the north pole area this was 500 m. for degree and for stereo models in the south pole area this was 1 km. per degree. To fit the stereo models to the Clementine laser altimeter data an initial set of stereo models that overlaid the Clementine laser altimeter data was adjusted to vertically align with the Clementine laser altimeter data. Stereo models that overlaid the previously adjusted stereo models were adjusted further. this process continued until all stereo models were adjusted to align vertically.

In analyzing the photogrammetric data for the north pole region 1,189,858 points (83% of the data) occur on two or more stereo models. For 80% of those points, the standard deviation in elevation is between 24 and 469 m., with a mean of 184 m., in the south pole region, 1,350,349 points (75% of the data) occur on two or more stereo models. For 80% of these points, the standard deviation in elevation is between 13 and 386 m., with a mean of 160 m.

In the north pole region 1,076 Clementine laser altimeter points are in the area where photogrammetric topographic data were collected. Comparing the photogrammetric topographic data with the Clementine laser altimeter points shows that for the north pole region the topographic data is an average of 48 m. higher than the Clementine laser altimeter points, with a standard deviation of 118 m. In the south pole region, 1,078 Clementine laser altimeter points are in the area where photogrammetric topographic data were collected. For the south pole region the topographic data is an average of 183 m. lower than the Clementine laser altimeter points, with a standard deviation of 100 m.

The merged topographic data were color-coded and combined with the shaded relief data. Areas where no topographic data were collected are not color-coded, and the shaded relief image is shown as gray scale.

NOMENCLATURE

The number, size and placement of last annotations were chosen to provide a general orientation of conspicuous features on a 1:10,000,000-scale map. Features are labeled with names approved by the International Astronomical Union (for a complete list of lunar nomenclature, see http://planetarynames.wr.usgs.gov/).

L 1091 SC 180 FITC Abbreviation for Moon; 1:10,000,000 map; center of maps: 0° latitude and 0° longitude for near side, and 0° latitude and 180° longitude for far side; Shaded relief (R) with topographic data and nomenclature (T) and color-coded topographic data (K) (Dowling and Rosiek, 1992).

REFERENCES

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.

Eliason, E.M., 1997, Production of Digital Image Models using the ISIS system [abs.], in Lunar and Planetary Science Conference XXVIII: Houston, Lunar and Planetary Institute, p. 331-332.

Isbell, C.E., Eliason, E.M., Becker, Tammy, Lee, E.A., McEwen, Alfred, and Soderblom, Hoyt, 1997, The Clementine Mission--An archive of a Digital Image Model of the Moon [abs.], in Lunar and Planetary Science Conference XXVIII: Houston, Lunar and Planetary Institute, p. 603-604.

Greeley, Ronald, and Batson, R.M., 1990, Planetary mapping: New York, Cambridge University Press, p. 261-276.

Rosiek, M.R., Kirk, Randy, and Howington-Kraus, Elpitha, 1999, Lunar topographic maps derived from Clementine imagery [abs.], in Lunar and Planetary Science Conference XXIX: Houston, Lunar and Planetary Institute, abstract #1937 CD-ROM.

Rosiek, M.R., and Aeschliman, Ralph, 2001, Lunar shaded relief map updated with Clementine data: [abs.], in Lunar and Planetary Science Conference XXXII: Houston, Lunar and Planetary Institute, abstract #1949 (CD-ROM).

Rosiek, M.R., Kirk, Randy, and Howington-Kraus, Elpitha, 2001, Combining lunar photogrammetric topography data with Clementine Lidar data [abs.], in Planetary Mapping 2001, International Society for Photogrammetry and Remote Sensing, Workshop XVIII, Flagstaff, Arizona, web publication http://www.isprs.org/commission4/workshop2001/flagstaff/index.html.

Schimerman, L.A. ed., 1975, Lunar cartographic dossier: U.S. Defense Mapping Agency Aerospace Center, St. Louis, Missouri, n.n., sections 0.0.10 and 0.0.60.

Seidelmann, P.K., and 19 others, 2002, Report of the IAU/IAG Working Group on Cartographic Coordinates and Rotational Elements of the Planets and Satellites--2000: Celestial Mechanics.

Smith, D.E., Zuber, M.T., Neumann, G.A. and Lemoine, F.G., 1997, Topography of the Moon from the Clementine Lidar: Journal of Geophysical Research, v. 102, no. E1, p. 1591-1611.

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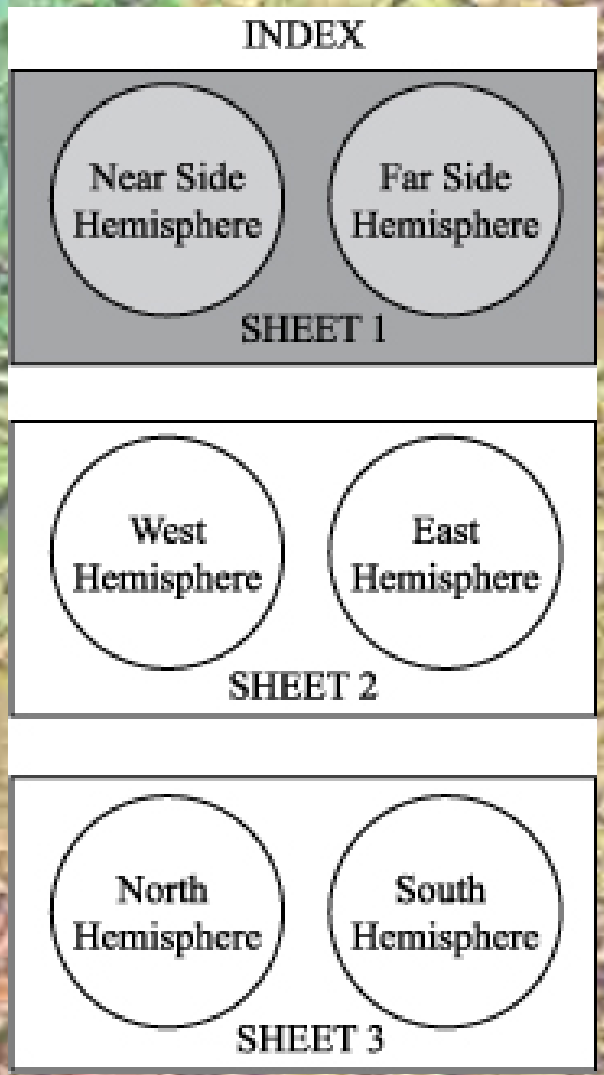
Index Layer



1 Layer

Mark Rosiek

Illustrator

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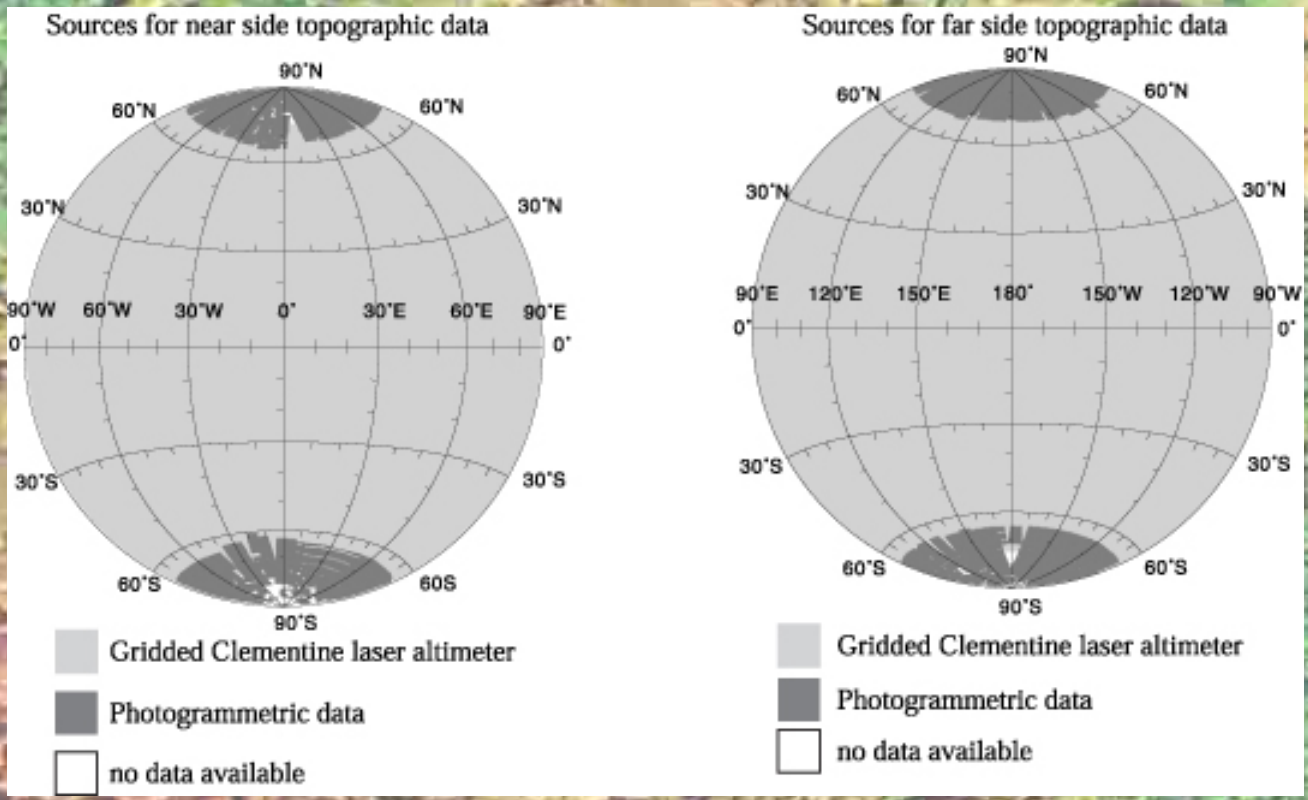
Topographic Data Sources

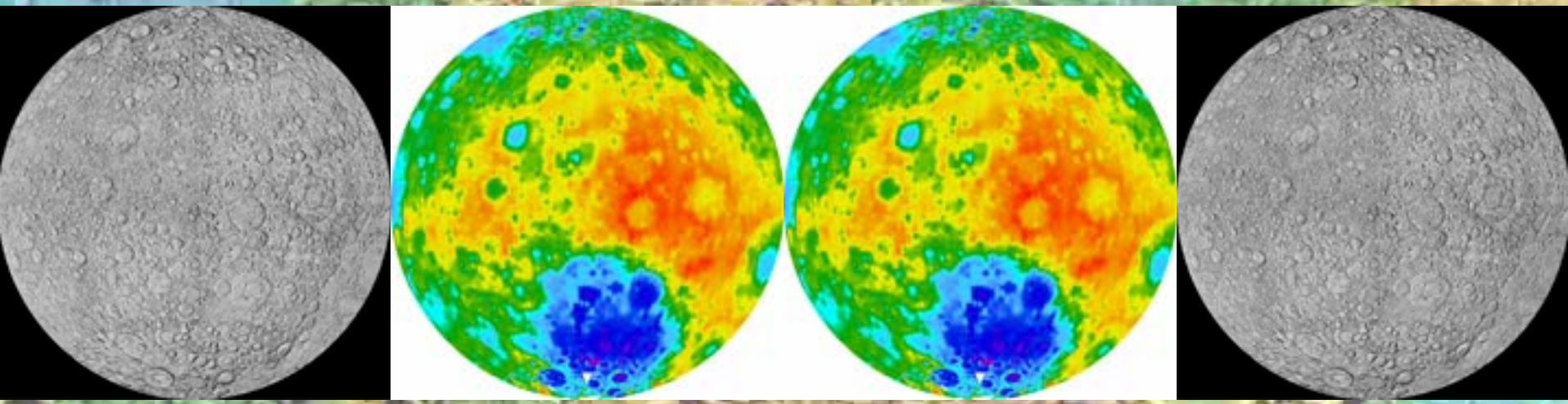
3 layers – text, grid, and coordinates

Mark Rosiek

ArcView, Photoshop, Illustrator



Shaded Relief and Topographic Data



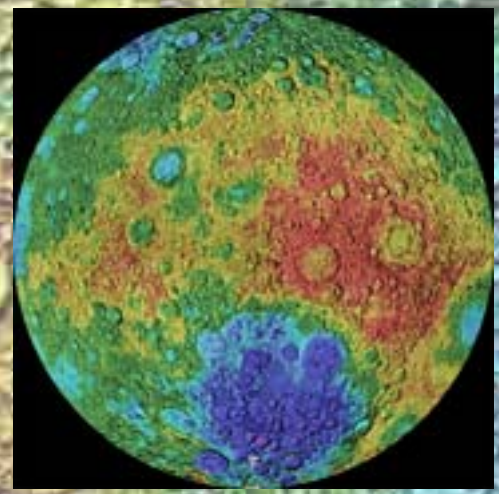
Base

Multiply

Color Burn

Soft Light

1 Layer



Ralph Aeschliman, Ella Lee, Janet Richie, Mark Rosiek, Bonnie Redding, Donna Galuszka, Annie Howington-Kraus, Randy Kirk

Photoshop, Isis, Socet Set, ArcView

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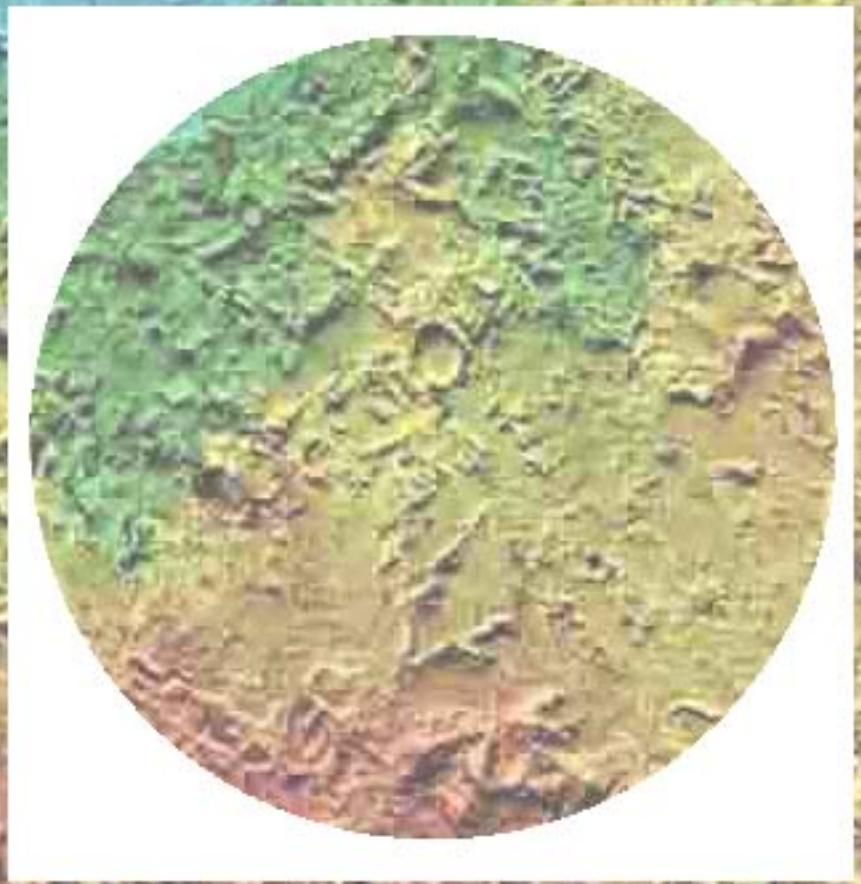
Mask Layer

1 Layer

Jenny Blue

Illustrator



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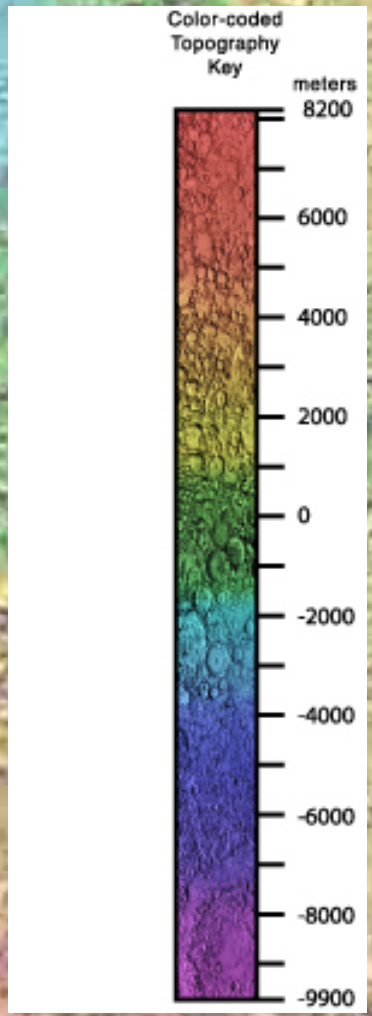

1 layer

Mark Rosiek

Color bar created in ArcView, edited and layered in Photoshop

Text and scale added in Illustrator

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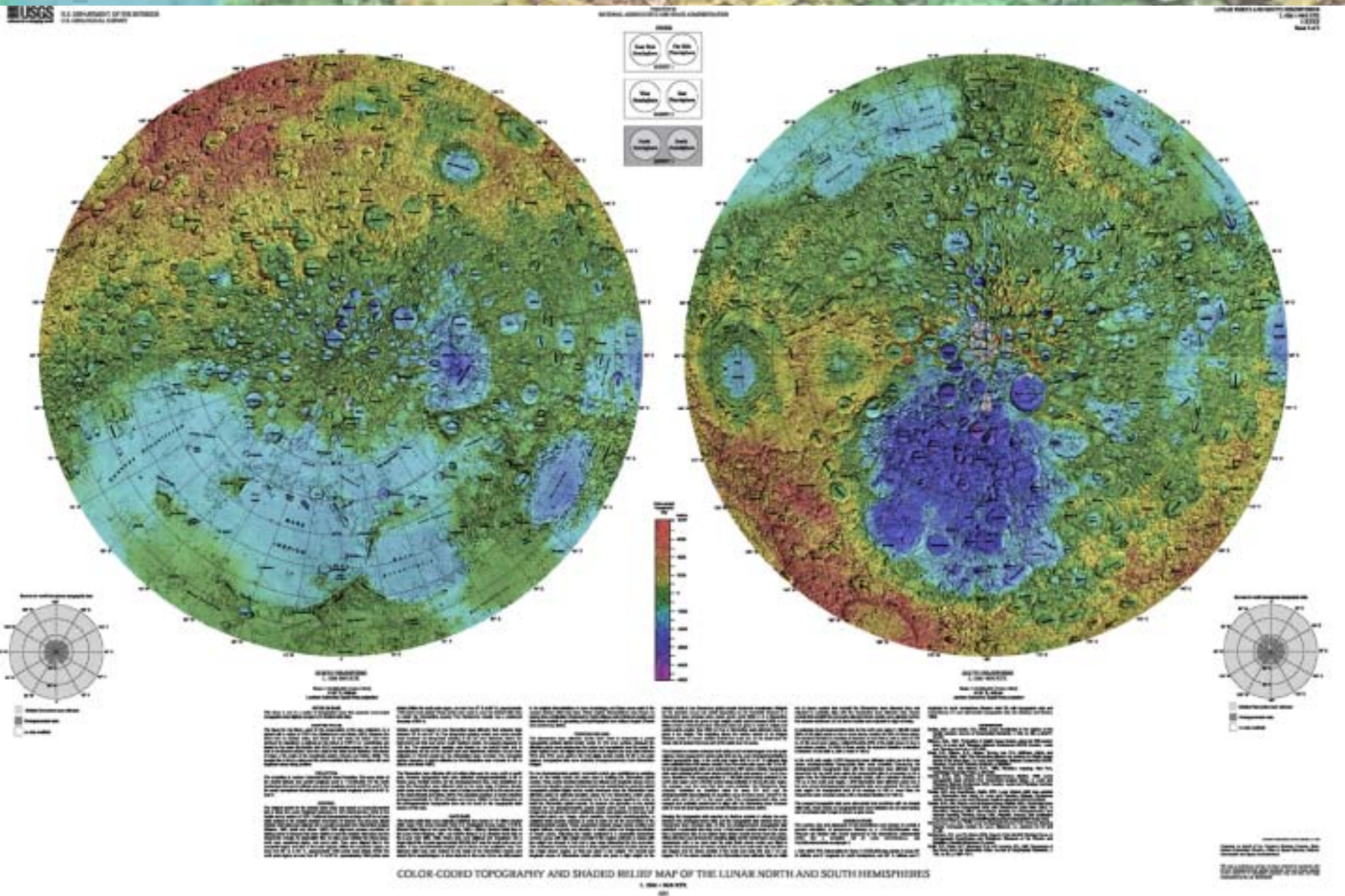
Final Map


COLOR-CODED TOPOGRAPHY AND SHADED RELIEF MAP OF THE LUNAR NORTH AND SOUTH HEMISPHERES

Status

- Out for Review
  - Paul Spudis
  - Lisa Gaddis
- Derrick Hirsch, Technical Editor
- Darlene Ryan, Western Publications Group
- Send Out For Printing