

Color-coded Topography and Shaded Relief of the Lunar Hemispheres

A new 3 sheet map

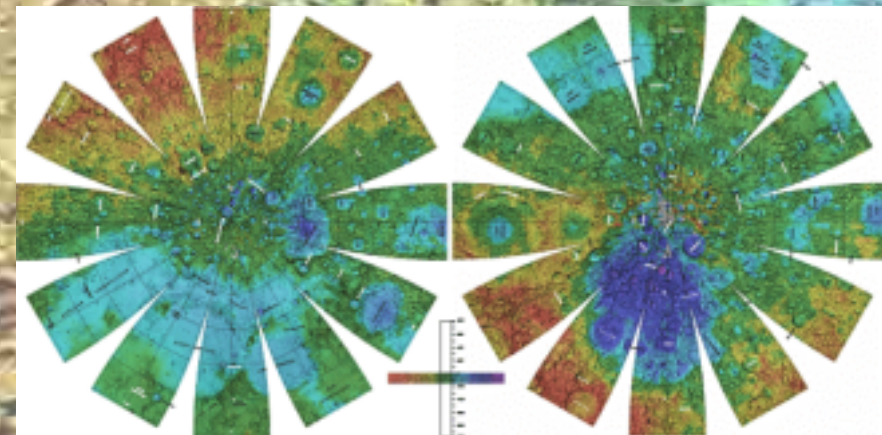
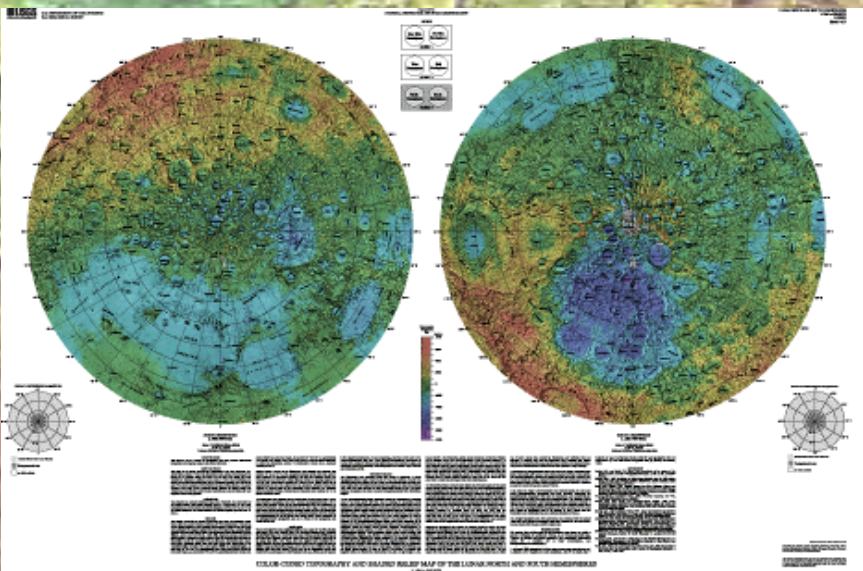
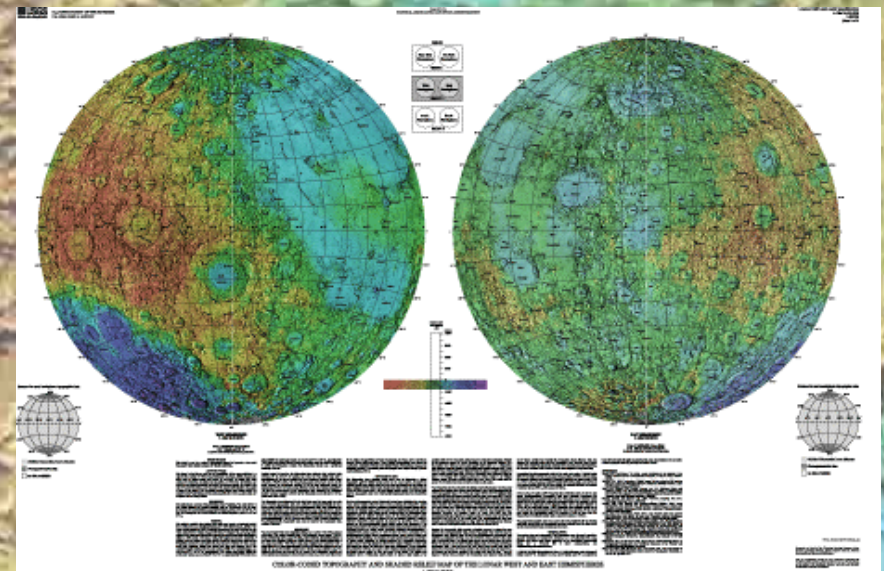
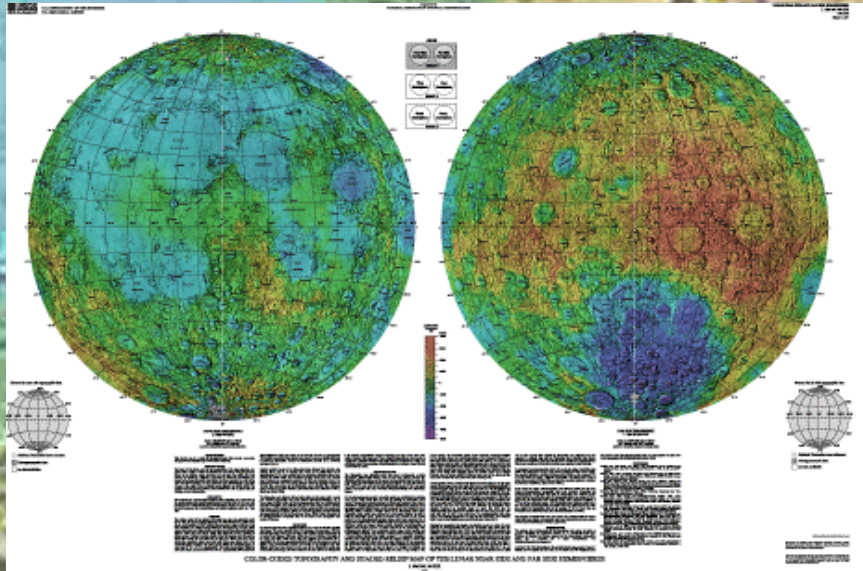
February 2002

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

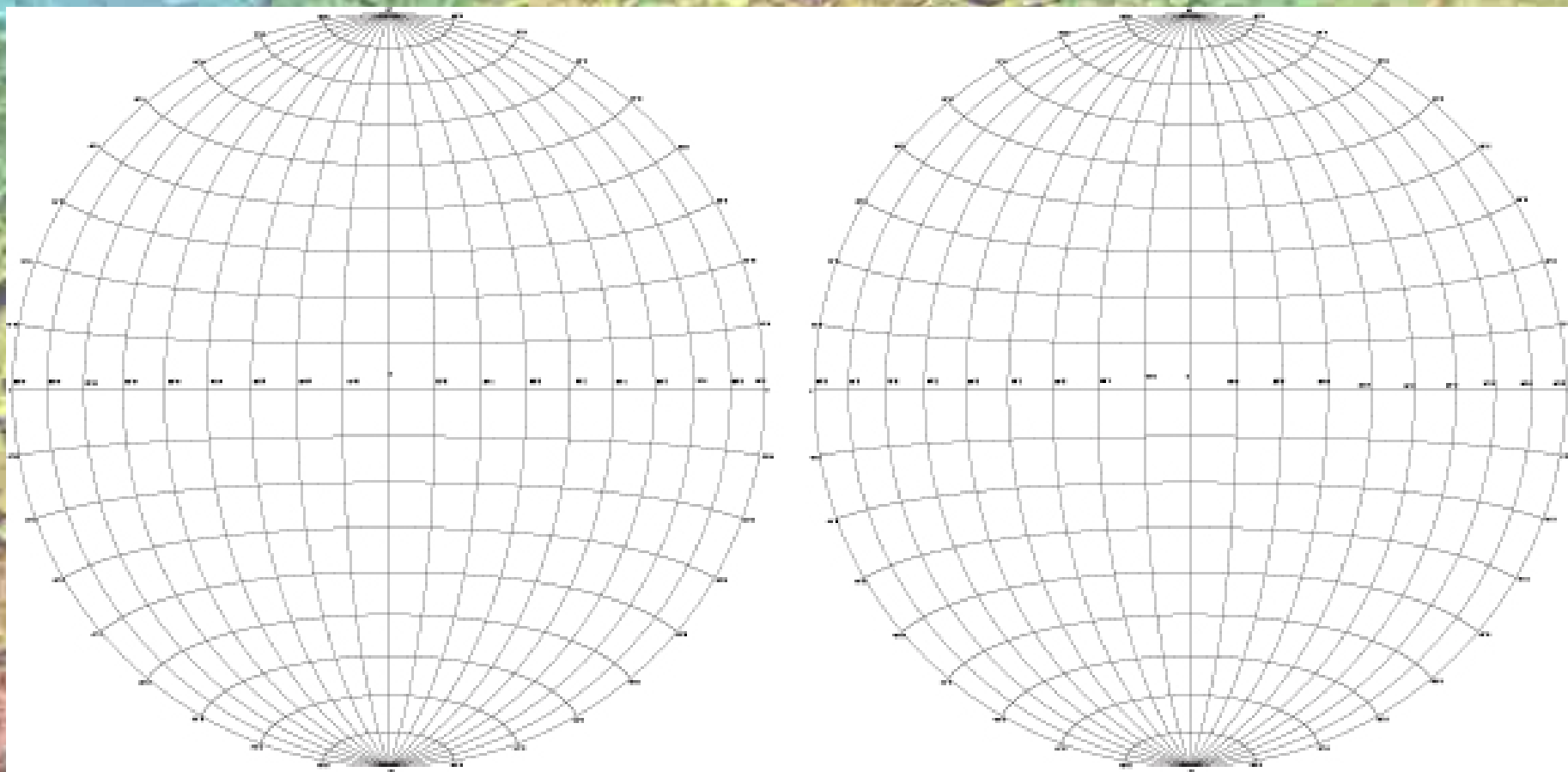


Grid and Coordinates Layers

1 Layer

Bonnie Redding, Mark Rosiek

PICS, Illustrator

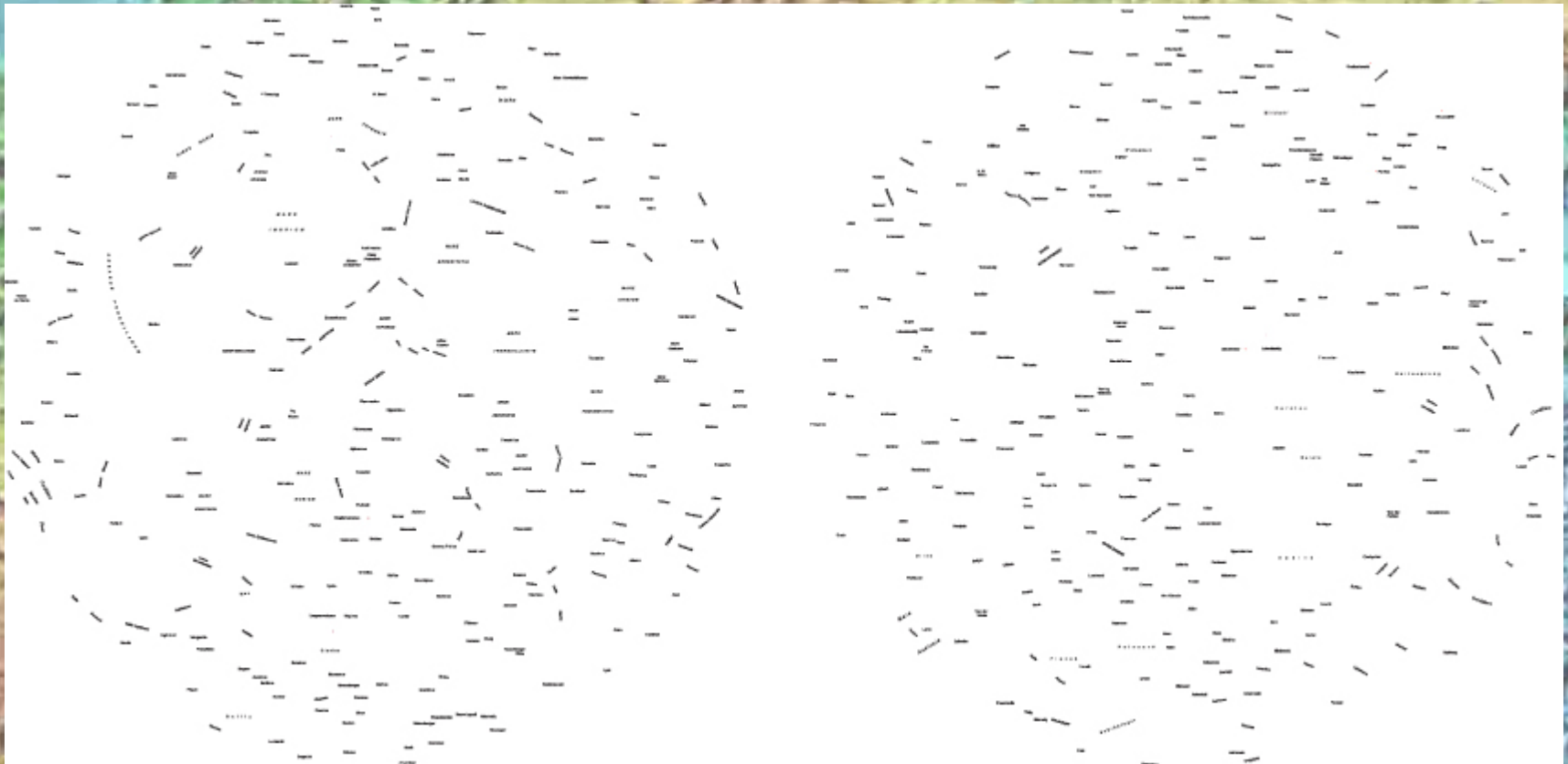


Nomenclature

2 layers – one for each hemisphere

Jennifer Blue

Illustrator Program



Standard Text

1 Layer

Bonnie Redding

Illustrator



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

1-XXXXX

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

INTERNATIONAL SURVEY POSTAL SA-001

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 released 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.

Titles

1 layer

Mark Rosiek

Illustrator

**NEAR SIDE HEMISPHERE
L 10M 0/0 RTK**

Scale 1:10,000,000 (1mm=10km)
At 0° latitude and 0° longitude
Lambert Azimuthal Equal-Area projection

**FAR SIDE HEMISPHERE
L 10M 0/180 RTK**

Scale 1:10,000,000 (1mm=10km)
At 0° latitude and 180° longitude
Lambert Azimuthal Equal-Area projection

Notes on base

1 layer

Mark Rosiek

Microsoft Word

NOTES ON BASE
This sheet is one in a series of topographic maps that illustrate order-order topographic data digitally merged with shaded relief data.

ADOPTED FIGURES
The figure for the Moon, used for the comparison of the map projection, is a sphere with a radius of 1737.4 km (Baldwin and others, 2001). Because the Moon has no surface water, and hence no sea level, the datum (the zero contour) for elevation is defined as the radius of 1737.4 km. Coordinates are based on the mean Earth-surface datum (M.E.S.D.) coordinate system, the datum is the axis of the Moon's rotation, and the zero is the mean Earth direction. The center of mass is the origin of the coordinate system (Eliades and Cohen, 2000). The equator lies in the *x-z* plane and the prime meridian lies in the *x-y* plane with east longitude values being positive.

PROJECTIONS
The projection is Lambert Azimuthal Equal Area Projection. The scale factor at the central latitude and central longitude point is 1.000000. For the near side hemisphere the central latitude and central longitude point is at 0° and 0°. For the far side hemisphere the central latitude and central longitude point is at 0° and 180°.

CONTROL
The original control for the shaded relief map was based on horizontal control tied to either the Lunar Positional Reference at 1974 (Schrammer, 1970) or the Apollo control system of 1971. Horizontal discrepancies as large as 50 m or more existed in the original shaded relief base. To improve the accuracy, digital shaded relief data were aligned with a mosaic produced from Clementine images (Rosiek, 1987; Rosiek and others, 1992). The alignment process consisted of picking points at locations 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 five in the equatorial region and then in the pole regions. Within the equatorial region, an area from 80° S to 80° N, approximately 1500 points were aligned within the north-pole region, an area from 0° to 80° N, approximately 1000 points were

aligned within the south-pole region, an area from 0° to 80° S, approximately 1100 points were aligned. These points were used to warp the shaded-relief map to match the Clementine mosaic. The Clementine mosaic has a positional accuracy of 50 m.

Vertical control is based on the Clementine laser altimeter that collected data between 87° S and 87° N. Spacing was based on the orbital track and is approximately 90 km in the equator and less elsewhere. Unfilled areas were collected at 75,248 points. The along-track spacing across most areas amount more sufficient an along-track spacing of 50 km was achieved, where the instrument lost track over some rough highland terrain, the spacing degraded to 100 km. The across-track for the Clementine laser altimeter. The estimated vertical accuracy of points collected by the Clementine laser altimeter is 1.6 m. (Smith and others 1997).

The Clementine laser altimeter did not collect data over the lunar north or south poles. Clementine topographic data were collected programmatically in 10 m by 10 m areas. Vertical control, for the photogrammetric data, was established by using the Clementine laser altimeter data at the outer edge of these circular polar areas, and the imagery area used to bridge across and fill in the central part of the disk (Smith and others, 2001). The expected precision of points collected programmatically is 100 m. (Rosiek and others, 1998). Further discussion of the photogrammetric topographic data can be found in the topographic data section of the notes.

RANGE BASE
The shaded relief data were originally published as a series of 15 million shaded relief maps. This series included from U.S. Geological Survey maps 1-124-3, Shaded Relief Map of the Lunar Far Side, 1960; 1-130-4, Shaded Relief Map of the Lunar Near Side, 1961 and 1070, Sheet 2 of 2, Shaded Relief Map of the Lunar Near Side, 1962. These data were digitized and resampled into a single digital file. An area approximately 65,000 km² near the south pole was not visible in any pre-Clementine images and is based on the published map. The digitized relief base was warped on the basis of the Clementine mosaic and most Earth-based imagery to show features in the area. Errors are still present

in the original topography of lunar morphology, and false areas exist in the original shaded relief map base. These original inaccuracies were based on early data, uncertainties introduced by highly oblique solar incidence angles, and distortions created by generating topography from oblique images (Peters and Kleinman, 2007).

TOPOGRAFIC DATA
The Clementine laser altimeter (LALT) data were used to integrate a global topographic gridded digital terrain model for the lunar surface. Because the altimeter points were sparse near the poles and non-existent over the poles, the polar regions from this digital terrain model were dropped and only data between 90° S and 90° N were used in the final digital terrain model. To fill in the polar regions, topographic data were collected programmatically from Clementine images.

For the photogrammetric project, horizontal control was established by tabulating some of the mean points that were used in building the Clementine relief 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 the two images together in order to build the Clementine global mosaic. To improve the geometry of the control points for the photogrammetric project, match points were tabulated at all images that contained the point. Additional points were selected to have low distributed points per image, where possible. Analytical stereorestitution, a weighted least squares process, is used to solve for all the parameters of the photogrammetric project. These parameters include image sensor position and angles, latitude, longitude, and elevation of match points, and image coordinates of match points. Adjusting the weight assigned to a parameter determines whether values with high weight are held in the original solution or values with less 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, as they are given a low weight. The latitude and longitude values of Clementine match points are given a high weight so the

solution holds to the Clementine global mosaic horizontal coordinates. Weight for the elevation values are varied depending on the horizontal distance to a Clementine laser altimeter point within 2000 m of a Clementine laser altimeter point are given a high weight, match points between 2000 m and 5000 m have a Clementine laser altimeter point are given a medium weight and match points greater than 5000 m from a Clementine laser altimeter point are given a low weight. This weighting allows the vertical control to be adjusted linearly areas of more reliable control—the outer part of the circle—and the areas with of control—the inner part of the circle over the poles.

The Clementine mosaic 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 (80° S to 60° S), altitudinal data were collected from full stereo-mosaic. Over the south-pole region (80° S to 60° S), altitudinal topographic data were collected from RT stereo-mosaic. Topographic data were collected within each stereo-mosaic with a pixel spacing of 1 km in the *x-y* direction. This spacing resulted in 1,637,500 points being collected in the north-pole region and 1,024,000 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 for every 3574 km² in the photogrammetric data collected an elevation value for every every 12 km² in the north-pole and 1.2 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, 2007).

Merging the topographic data required an iterative process to resolve 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 east-west error in that error exists longer to the poles than an error exists to be higher than error exists further from the poles. When this bias was removed the resulting digital terrain model had a low elevation appearance with a low spot near the pole. Each stereo mosaic was fitted to remove the bias/offset for stereo-mosaic to the north-pole area the was 100 m, in the image sensor angles, as they are given a low weight. The latitude and longitude values of Clementine match points are given a high weight so the

error of stereo mosaic that overlaid the Clementine laser altimeter data was adjusted to vertically align with the Clementine laser altimeter data. Stereo-mosaic that overlaid the previously adjusted stereo mosaic were adjusted further, the process continued until all stereo mosaic were adjusted to align vertically.

REFERENCES
It is analyzing the photogrammetric data for the south-pole region 1,180,000 points (80% of the data) occur on two or more stereo-mosaic. For 90% of these points, the standard deviation of elevation is between 3m and 400 m, with a mean of 180 m. In the south-pole region, 1,090,248 points (70% of the data) occur on two or more stereo-mosaic. For 90% of these points, the standard deviation in elevation is between 10 and 300 m, with a mean of 160 m.

In the north-pole region 1,206 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 730 m. In the south-pole region, 1,070 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 163 m lower than the Clementine laser altimeter points, with a standard deviation of 1200 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 areas.

NOMENCLATURE
The number, size and placement of set coordinates were chosen to provide a general orientation of composite 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://www.astronomy.com>.

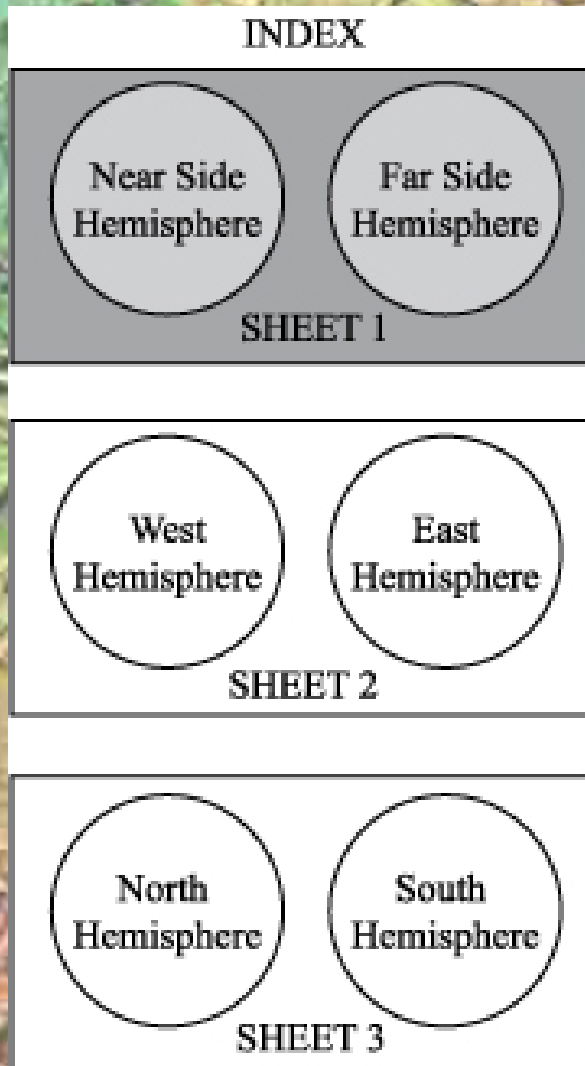
1-1001-00 180 FITC Abbreviation for Sheet: 1:10,000,000 map, center of disk 0° latitude and 0° longitude for near side, and 0° latitude and 180° longitude for the

far side. Shaded relief (R) with topographic data and nomenclature (T) and color-coded topographic data (C) (Rosiek and others, 1992).

Davis, M.L., and Cook, T.R., 2000. Lunar coordinates in the regions of the Apollo Landing Journal of Geophysical Research, v. 105, no. 16, p. 20,277-20,280.
Eliades, S.M., 1987. Production of Digital Image Mosaic using the ISIS system. Paper in Lunar and Planetary Science Conference 20XIV, Houston, Lunar and Planetary Institute, p. 211-230.
Harris, C.E., Edmon, B.M., Harlow, Nancy, Lab, E.A., Mathews, Alfred, and Schoenewald, David, 1997. The Clementine Mission—An archive of a digital image mosaic. Lunar and Planetary Science Conference 20XIV, Houston, Lunar and Planetary Institute, p. 652-654.
Ginsburg, Harold, and Blanton, P.M., 1993. Planetary mapping. New York, Columbia University Press, p. 59-178.
Rosiek, Mark, Kulk, Randy, and Houghlin-Kissel, Lynda, 1988. Lunar topographic maps derived from Clementine images (SMI) in Lunar and Planetary Science Conference 2002, Houston, Lunar and Planetary Institute, p. 200-201.
Rosiek, Mark, Kulk, Randy, and Houghlin-Kissel, Lynda, 1991. Lunar topographic maps derived from Clementine images (SMI) in Lunar and Planetary Science Conference 2002, Houston, Lunar and Planetary Institute, p. 200-201.
Rosiek, Mark, Kulk, Randy, and Houghlin-Kissel, Lynda, 1992. Constructing Lunar topographic topographic data with Clementine Laser data (SMI) in Planetary Meeting 2001, International Society for Photogrammetry and Remote Sensing, Washington D.C., August. Abstracts were published: <http://www.isprs.org/pubs/proceedings/2001/abstracts/004/index.html>
Schrammer, L.A., ed., 1970. Lunar topographic database. U.S. Geological Survey Agency, Astrobletic Center, St. Louis, Missouri, U.S. Section 5:1-2 and 5:2-2.

Schrammer, P.K. and 10 others, 2002. Report of the MAPPING Working Group on Clementine Coordinates and Positional Standards of the Planets and Satellites—Canadian Member's Contribution.
Smith, D.E., Doser, M.T., Neumann, G.A. and Linderoth, F.B., 1997. Topography of the Moon from the Clementine Laser Journal of Geophysical Research, v. 102, no. 15, p. 1591-1591.

Index Layer



1 Layer

Mark Rosiek

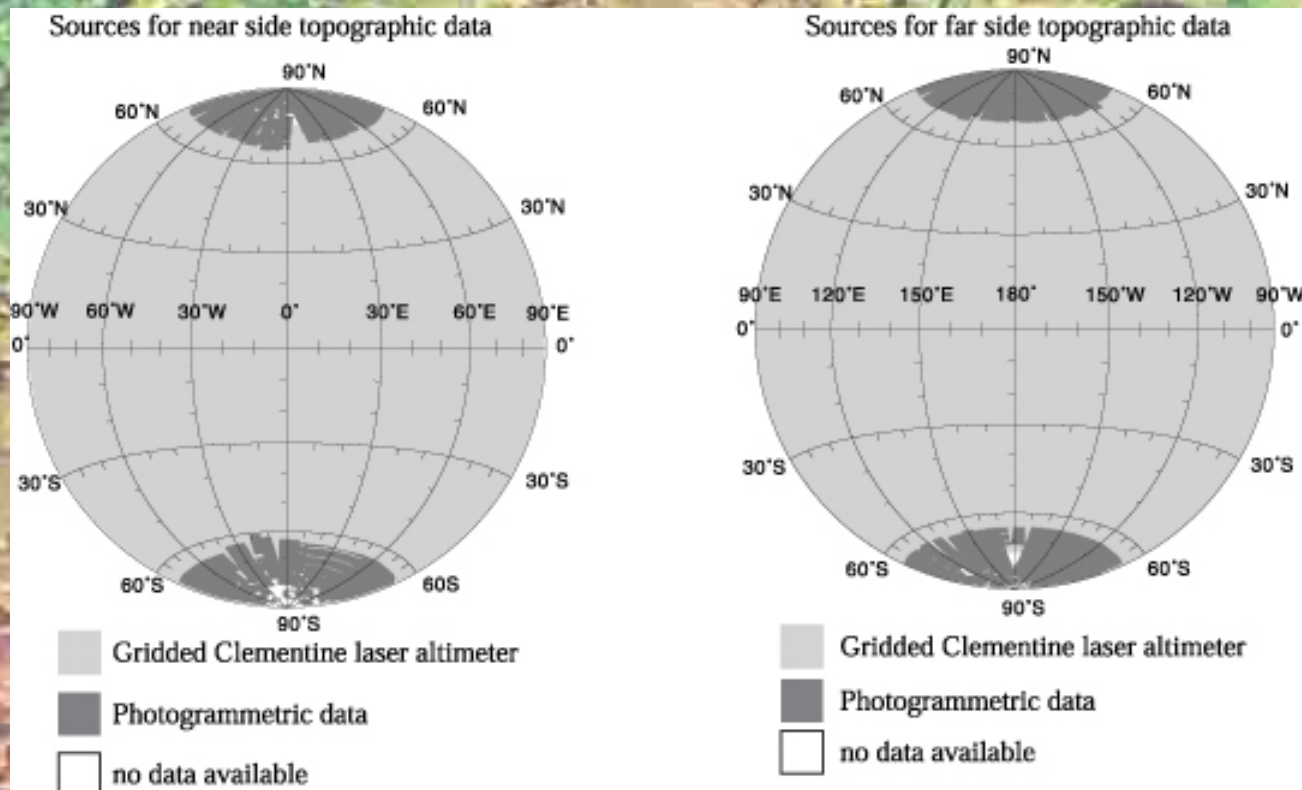
Illustrator

Topographic Data Sources

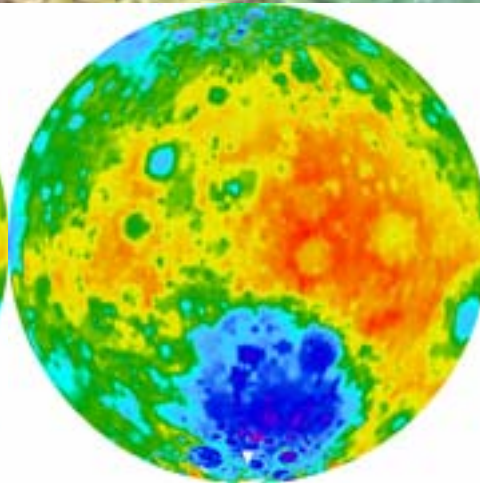
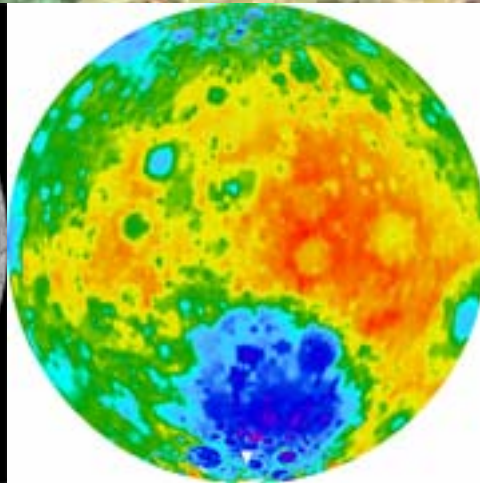
3 layers – text, grid, and coordinates

Mark Rosiek

ArcView, Photoshop, Illustrator



Shaded Relief and Topographic Data



Base

Multiply

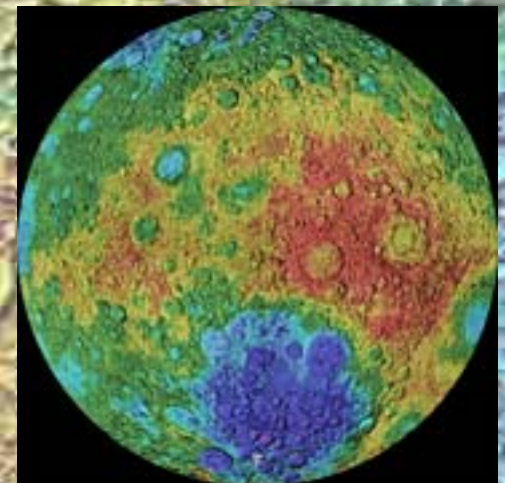
Color Burn

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



Mask Layer

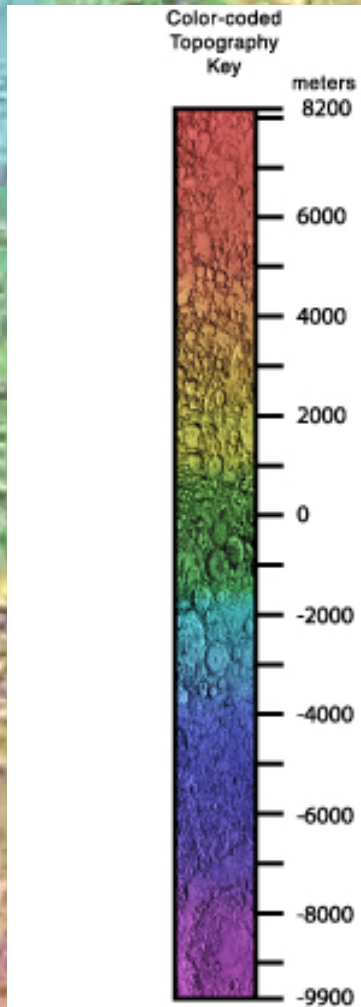
1 Layer

Jenny Blue

Illustrator



Scale Bar



1 layer

Mark Rosiek

**Color bar created in
ArcView, edited and layered
in Photoshop**

**Text and scale added in
Illustrator**

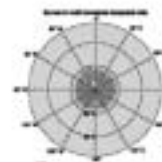
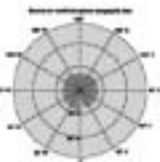
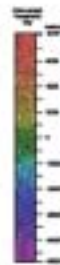
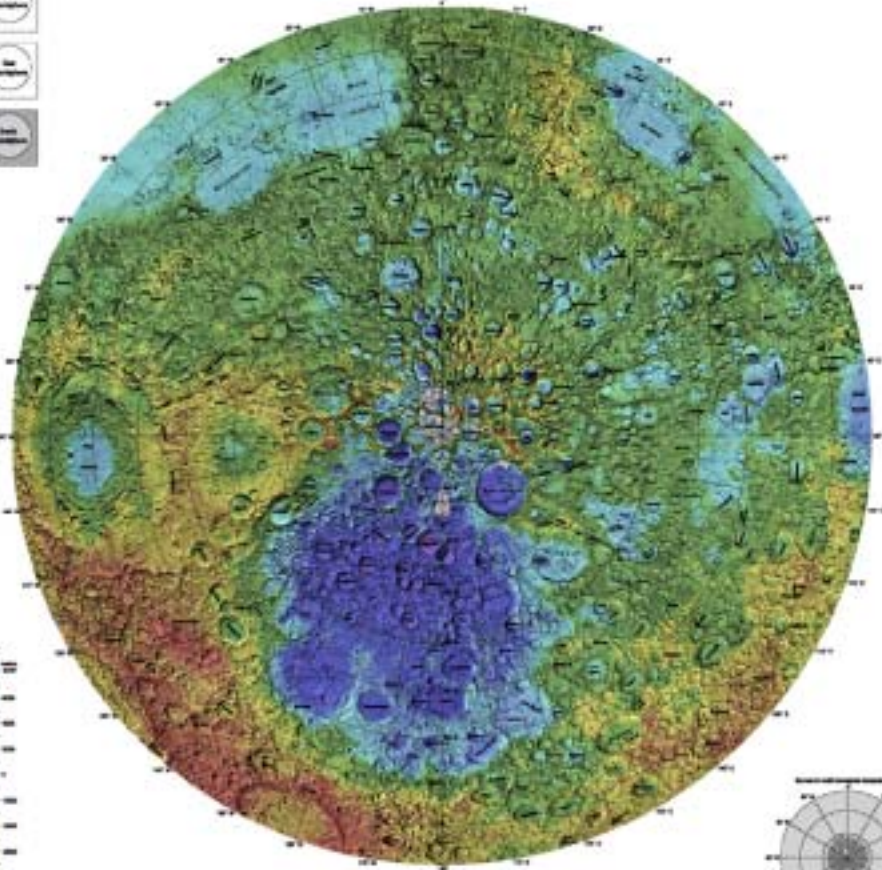
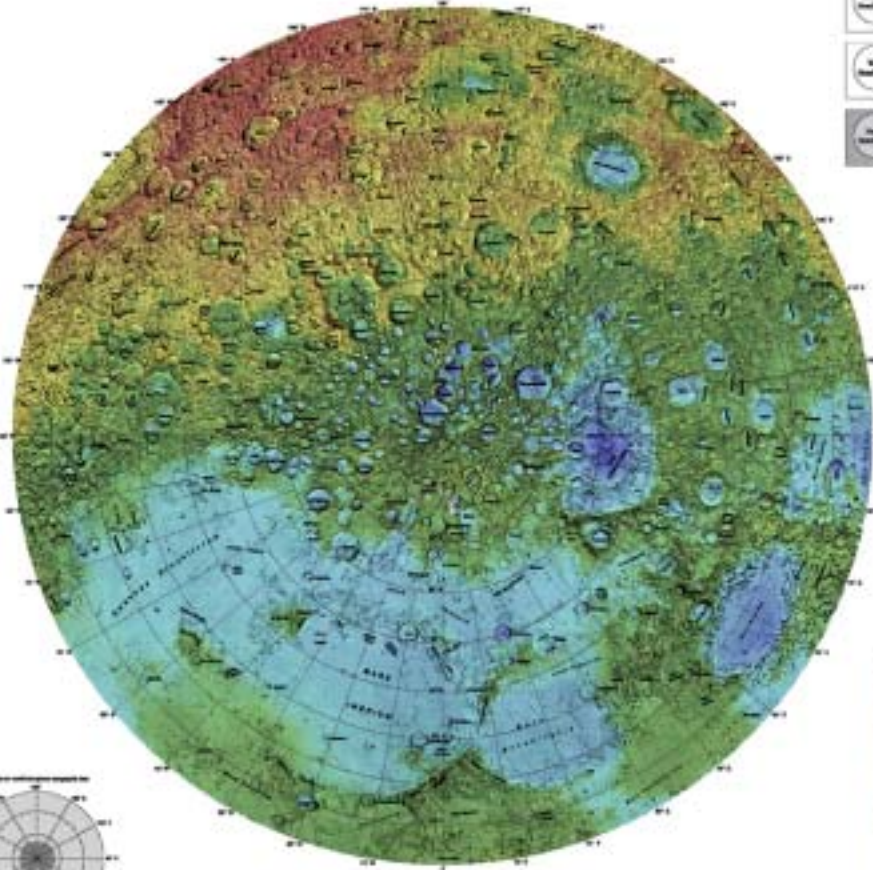
Final Map



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

MAP OF THE LUNAR NORTH AND SOUTH HEMISPHERES

U.S. GEOLOGICAL SURVEY
Lunar Map 100
Map 100



MAP OF THE LUNAR NORTH HEMISPHERE
This map shows the topography of the lunar north hemisphere. The color scale indicates elevation in meters, with blue representing the lowest elevations and red representing the highest. The shaded relief highlights the rugged terrain of the highlands and the smoother plains of the maria.

MAP OF THE LUNAR SOUTH HEMISPHERE
This map shows the topography of the lunar south hemisphere. The color scale indicates elevation in meters, with blue representing the lowest elevations and red representing the highest. The shaded relief highlights the rugged terrain of the highlands and the smoother plains of the maria.

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

1:500,000,000

U.S. GEOLOGICAL SURVEY
DEPARTMENT OF THE INTERIOR

Status

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