A SHADED RELIEF MAP OF MEXICO

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ABSTRACT:

Digital shaded relief images offer the possibility to depict the landforms in a detailed and accurate form. In this work, a Digital Elevation Model (DEM) , three digital images and four paper maps were made. A single DEM, covering all the continental territory of Mexico was derived from 255 individual one by one degree DEMs. From this model a shaded relief image was produced, and combining this image again with the DEM, two other images were obtained, one for stereoscopic viewing with anaglyphs, and other with shaded hypsographic colors. With these images three maps, one for each image were prepared in scale 1:4,000,000, and one (stereoscopic) also in scale 1:14,000,000. The use of shaded relief images in physiographic and geological studies, and also in other fields like ecology and education as well as a component in the preparation of other maps is discussed. Prospects for other derived products from the DEM, and shaded relief images preparation with more resolution are mentioned.

BACKGROUND

Digital Elevation Models in Mexico.

Derived from the topographic map series in scale 1:250,000, there are 255 DEMs that cover Mexico. Each model covers an area of one degree of latitude by one degree of longitude, with elevation values every 3 seconds of arc. The Dirección General de Geografía, Instituto Nacional de Estadística, Geografía e Informática (DGG-INEGI: General Bureau of Geography, National Institute of Statistics, Geography and Informatics), is in charge of the distribution of these DEMs to the general public. They have been used for different purposes, (communication facilities and highway construction planning, ecological and environmental studies, etc.). Now, with the digitization of the 1:50,000 topographic map series, more detailed DEMs are being produced and its distribution has just started.

Physiography and relief maps.

The complex physiographic characteristics of the Country are described in several works, among them: Raisz 1964, Cuanalo de la Cerda et. al, 1989. E . Raisz, based on aerial photography and extensive field trips produced a hand drawn map "Landforms of Mexico", portraying the relief of the country with an unequaled detail. The map includes a text in which Raisz proposed a physiographic division in 11 provinces and 38 regions, with a description of each.

Cuanalo de la Cerda et al., 1989, made a revision of the physiographic division of Mexico, and proposed a hierarchical scheme based on terrestrial provinces, regions and subregions. For their work they used band 7 of Landsat-MSS satellite images in paper prints at scales from 1:5,000,000 to 1:1,000,000, and applied a modified version of the method of Brink. The purpose of their work was to offer a base for land use planning, especially for rainfed agriculture. Their description of each unit includes information about geology, geomorphology, climate, soils and vegetation. In the other hand, the mapping agency, DGG-INEGI, made another physiographical division for its own Physiographical map series in scale 1:1,000,000. In this case the maps were based on interpretation of topographic and geological maps in scales 1:50,000 and 1:250,000.

However, from these maps, only the one drawn by Raisz shows an image of the topography. In their map of terrestrial provinces, regions and subregions, (Ortiz Solorio et al., 1984), the limits between the provinces and regions are represented with lines over the 1:1,000,000 DGG-INEGI topographic maps. The DGG-INEGI physiographic maps represent the physiographic divisions with lines, colors and codes, but they do not include any portrait of the landforms.

Maps intend to offer an image of some aspect of some region of the world. In most of the cases they show the distribution of some specific feature or variable in a two dimensional space. The shape of the Earth's surface, the relief is represented normally in the topographic maps through the contour lines; the elevation can be read from them, and from the density patterns of the same contours, some idea of the landforms can be obtained.

The relief however, can be better appreciated if it is represented in a form that, at least, gives the impression of a three dimensional space. Shading has been used as one of the tools to give the perception of distance, shape and volume, and in the case of maps, the shape of the terrain. So far, in most of the cases the shading has been done manually, resulting many times in beautiful, and sometimes relatively realistic maps. But the complexity of the relief makes almost impossible to portrait all the topographic features and its details (Thelin

G.P. and R.J. Pike, 1991, Pike R.J. and G.P. Thelin, 1992). Digital shading using DEMs, gives the possibility of creating realistic, detailed and accurate images of the relief (Burrough 1986, Thelin G.P. and R.J. Pike, 1991). The brightness of each point or pixel in the shaded relief image, depends on its elevation relative to the elevation of its neighbors, its slope and aspect, and the simulated position of the source of light; direction (azimuth) and elevation (angle above the horizon).

Shades are a primary clue to depth perception. But true 3D peception involves the existence of two images of the same place or feature seen from different angles (Toutin, P. And B. Rivard, 1995). A virtual 3D image of the shaded relief can be generated by applying the DEM to the original shaded relief image to obtain a second image with parallax. For viewing, one stereoscopic image is made assigning the original image with the blue and green colors, and the image with parallax is assigned the red color. When seen through anaglyphs a 3D image "jumps". Other techniques include the use of polarized glasses, stereoscopes, etc.

In a new technique, Toutin,T. and B. Rivard, 1995, use a single color image taking advantage of the effect of chromostereoscopy. In this case, depth is coded in color, so that blue hues are seen farther, and red objects look closer. A hypsographic map, when seen through special lenses, the areas in hues of blue and green will seem to be at lower elevations, and those with red will appear higher.

DATA AND METHODS.

Digital elevation models and vectorial data.

The 255 DEMs that cover continental Mexico and most of its islands were used. Taking as a base the 1:250,000 scale topographic map series from INEGI, these models were generated by the United States Defense Mapping Agency (US-DMA), and currently are available to the general public. Vectors for international borders and coastlines were obtained from the 1:4,000,000 scale topographic map from DGG-INEGI.

Digital elevation model processing.

The individual one by one degree models were combined first to form larger models (6 degrees of longitude by 4 degrees of latitude), keeping the resolution (3 seconds) and geographic projection. A single elevation model was designed to cover all the Country, with elevation values every 500 meters and in a Lambert Conical Conformal projection. Using the EASI/PACE* program REGPRO running in VAX workstations, all the mosaics were registered to this single model. The registration process involved a resampling of the elevation data and a projection change. No estimation of the accuracy of the resulting model was made.

Shaded relief image.

The shaded relief image was obtained from the DEM using the program REL, with 315° (NW) of azimuth and an elevation of 30°. A mask was created for all the zero elevations, corresponding to the sea, and to portions of the model with no data (other countries). The image under this mask was set to a gray value of zero to separate them from flat areas above sea level. The shaded image was transformed through a piece-wise transformation to enhance the relief perception in relatively smooth areas.

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Stereo shaded relief image.

Taking the first image and combining it with the DEM, a second image with parallax was generated using the program STER. The factor for parallax was 100. This means that the displacement in number of pixels for a given point between the original image and the second is the elevation value from the DEM divided by 100.

Shaded hypsographic image.

The elevations were divided in 11 ranges, most of them in 500m intervals. For each range, a mask was created from the DEM. Next, one base color was selected for each interval, going from light blue in the sea (elevation zero), and blue-green in the lowest parts to dark brown and gray in the highest points. The colors were first selected in a Red Green Blue (RGB) color space, and then were mapped to the masks corresponding to each elevation range. The three band RGB image was transformed to an Intensity Hue Saturation (IHS) image. A lookup table for transforming the shaded relief gray image, was prepared for each elevation range. In the lookup tables the value 128 (mean value in the gray image) was substituted by the intensity value of the color of the corresponding interval. Besides, the lookup tables included a piece-wise stretching to enhance relief perception. The lookup tables were then applied to the shaded relief image to derive a new image, which was then used as the intensity channel. The IHS image was transformed back to RGB. This resulted in an image in which each elevation range has a single base color (same hue and saturation) but different shades (intensity) of the same color; lighter of darker, according to the shaded relief. A series of tests with different colors was conducted until a satisfactory color combination was achieved. In the last trials the colors were chosen directly in the IHS color space; keeping constant the saturation level, and varying the intensity and hue. This was also a better way to make sure that a gradient from colors with a major blue component to those with red as the main component was produced.

Map production.

The previous paragraphs describe the DEM and image processing. For the final map production, the images were exported to the Laser - Scan (LAMPS) environment, for adding a frame, international borders, names, graticule of meridians, parallels, and legend. The final steps were made with Barco Graphics software, and included the transformation of the RGB images to CMYK (for the 3D and hypsographic maps) the integration of images, with the cartographic frame, preparation of hard copy tests and print positives, with color separates in the case of the 3D and the hypsographic maps.

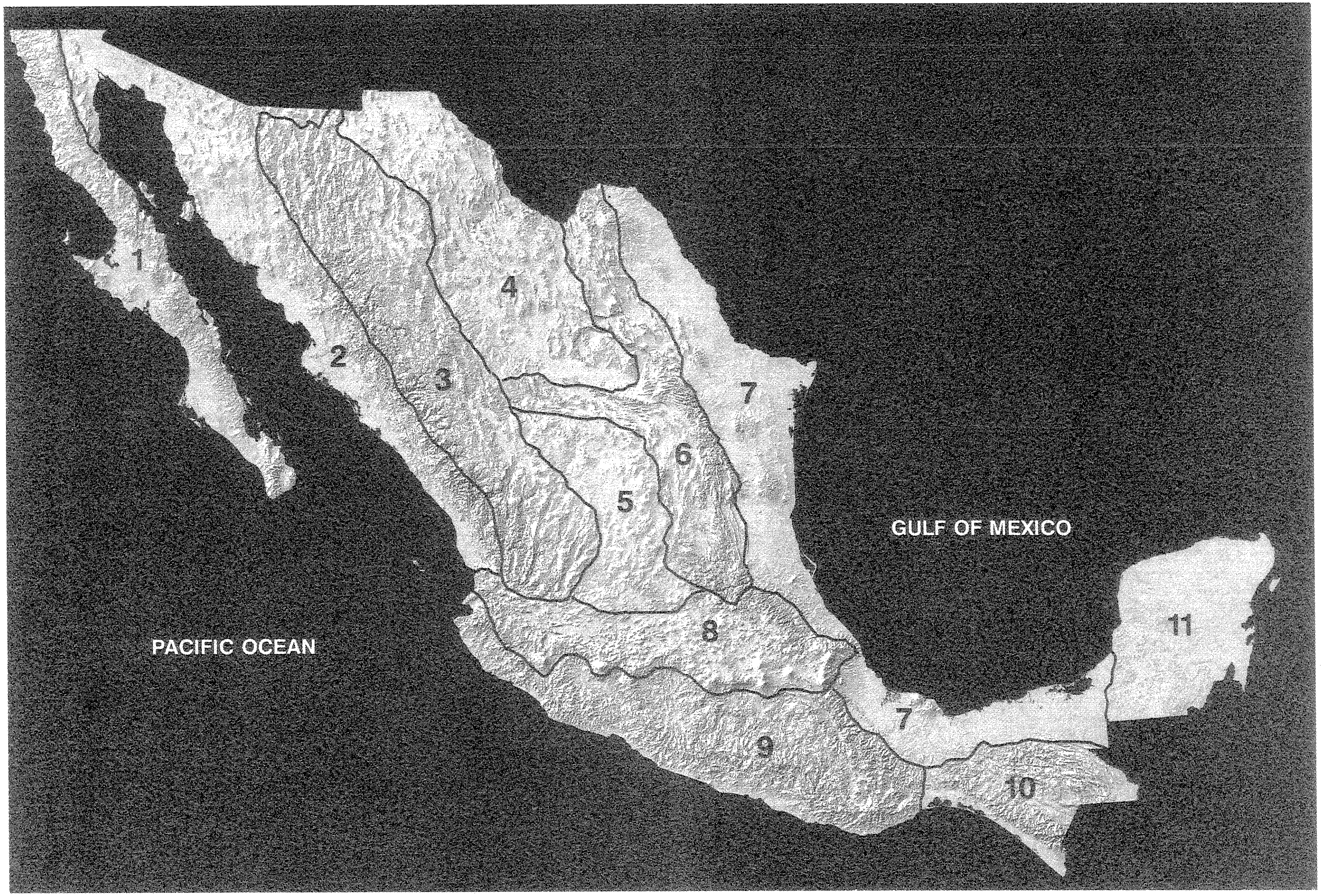

Figure 1. Shaded relief image of Mexico. The limits of the physiographic provinces of Raisz (1964) are sketched. 1. Baja California, 2. The Buried Ranges, 3. Western Sierra Madre, 4. Basin and Ranges, 5. Central Mesa, 6. Eastern Sierra Madre, 7. Gulf Coast Lowlands, 8. Neovolcanic Plateau, 9. Southern Sierra Madre, 10.Chiapas - Guatemala Uplands, 11. Yucatan. Approximate scale, 1:14,000,000.

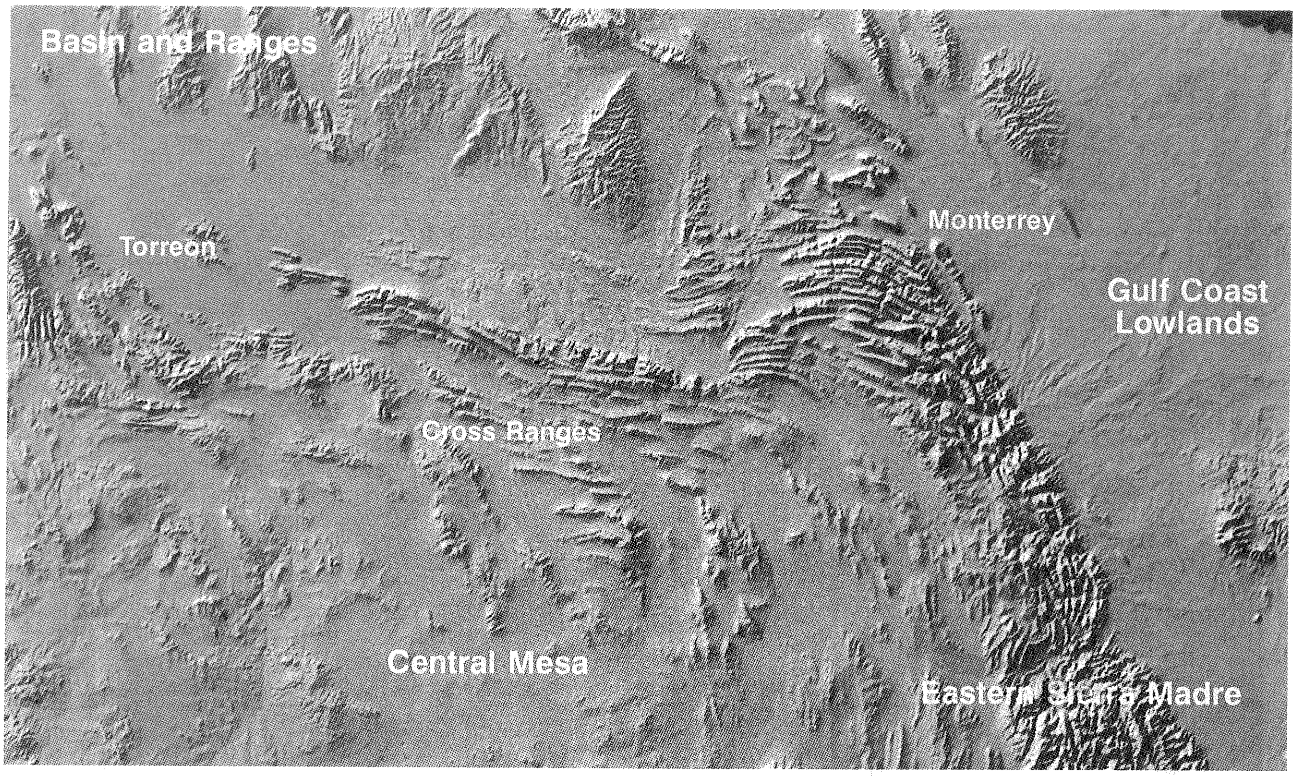

Figure 2. Part of Northeast Mexico. Just south of the city of Monterrey, the ridges of the Eastern Sierra Madre turn abruptly to the west. Also visible are parts of the Gulf Coast Lowlands, Central Mesa and Basin and Ranges provinces. The left half is part of the Chihuahuan Desert. Approximate scale, 1:3,000,000.

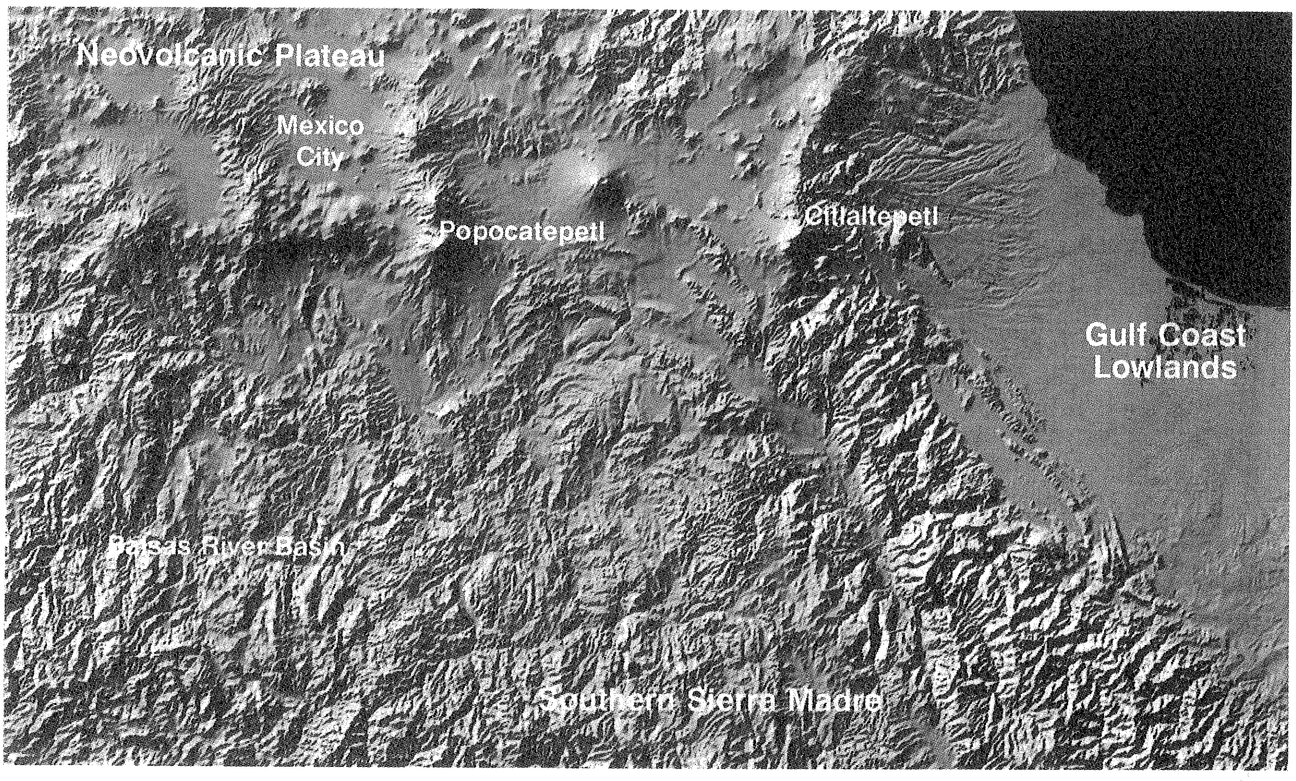

Figure 3. Central Mexico. In the top, the Neovolcanic Plateau province slopes reach the coast of the Gulf of Mexico (to the right). The three highest mountains are visible: Citlaltépetl, Popocatépetl and Iztaccíhuatl (just above Popocatépetl). The lower half shows part of the Southern Sierra Madre, the most complex region. Here, the Balsas River Basin, an inmense deppresion. To the east, the Gulf Coast Lowlands have a marked contrast with the other two provinces visible in the image. A curved linear feature south from a line between the Citlaltépetl and Popocatépetl resembles the shape of the west turn of the Eastern Sierra Madre seen in figure 2.. Approximate scale, 1:3,000,000

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detailed portrait of the topography that the relief maps offer.

Mexico is one of the most heterogenous countries. For example in biological diversity, it is thought that around 30,000 species of vascular plants exist in Mexico (Rzedowski, J. 1991). There are more species of pines in Mexico than in any other country (Perry, J.P., 1991). The climate varies from humid tropical to dry tropical and to temperate and arid. And so varies the vegetation. From tropical rain forests to various types of temperate forests, grasslands, scrublands and deserts. The reasons for this diversity are several. Two great biogeographic regions meet in Mexico: the Neartic and the Neotropical: so species and/or group of plants from both regions exist here. There is also an important component of native plants; (Rzedowski, J. 1991). Climatic heterogeneity is also one of the most important factors for the diversity. Topography acts in fact as the major single factor controlling the spatial climatic variations in Mexico through elevation and effects like rain shadow.

Early in the primary (elementary) schools, children learn that Mexico is a country with a great variation in landforms: mountain ranges, plateaus, plains, valleys. However, the usual school maps show the relief in a schematic, generally poor way, and most of the information is only textual, sometimes including photographs of important features. Now students could have access to this relief map series of the whole country. The maps could be distributed in a massive way in schools through the educational system.

As the shaded image can be combined virtually with any other image, shaded maps of any theme can be prepared; topographic, climatic, geological, soils, vegetation, etc. The combination of thematic information and the shaded relief can help not only to make better looking maps, but also to learn about relations between the different features and phenomena with the relief.

The shaded image and the DEM can also be registered and mixed with Satellite images for enhancement. For example with low resolution images like those from the AVHRR (Advanced Very High Resolution Radiometer) sensor, relief shading can help to improve them for visual appreciation (transforming the RGB image to IHS, then taking the shaded image as intensity an transforming it back to RGB). Elevation information can be included by color coding it in the images, (Toutin. T, and B. Rivard, 1995).

Prospects.

Some other derived maps from the DEM can be obtained, like slope and aspect maps. Quantitative studies of landforms, and improvement of climatic maps are possible by modeling the influence of elevation and relief on temperature and precipitation.

New, improved versions of the relief-series maps wiil be developed, as well as maps at greater scales. A map series in scale 1:2,000,000 is attainable using the images produced in this work. Considering the 500m resolution, the pixel size in the printed map at this scale would be 0.25mm. For a scale of 1:1,000,000 a resampling of the original DEMs to a resolution of 125 or 250 meters would be needed. The DEMs derived from the topographic map series scale 1:50,000 make possible to obtain relief maps with much greater detail and accuracy, at scales like 1:250,000 or larger.

Finally, besides the technical issues that have been discussed, the shaded relief maps offer also a different way to appreciate and enjoy the beauty of the Earth.

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