

RELIEF ASPECTS

PRODUCING MANUAL SMALL-SCALE SHADED RELIEF

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ABSTRACT

This paper introduces two hand-drawn shaded relief images, one of the World and the other the contiguous United States, which are available on the Natural Earth Data website. The motivation for this project: at small map scales, manual methods yield relief shadings with a generalized appearance not possible via automated methods. Discussion focuses on manual drawing procedures using Adobe Photoshop and a Wacom tablet. Production considerations also receive attention, including projections, lighting, generalization, drawing style, and map scale.

Keywords: shaded relief, small-scale, generalization, manual, Photoshop, Natural Earth

1 INTRODUCTION

Out of necessity, to fill a mapping void not adequately met by existing data and software, I produced two small-scale shaded relief pieces by hand. The first relief, created in 2015, depicts the entire world. It is available for free on NaturalEarthData.com (Kelso and Patterson 2009) as a grayscale GeoTIFF (10,800 x 5,400 pixels) in the Geographic projection. The shaded relief art registers with 1:50-million scale Natural Earth vector data (Figure 1).

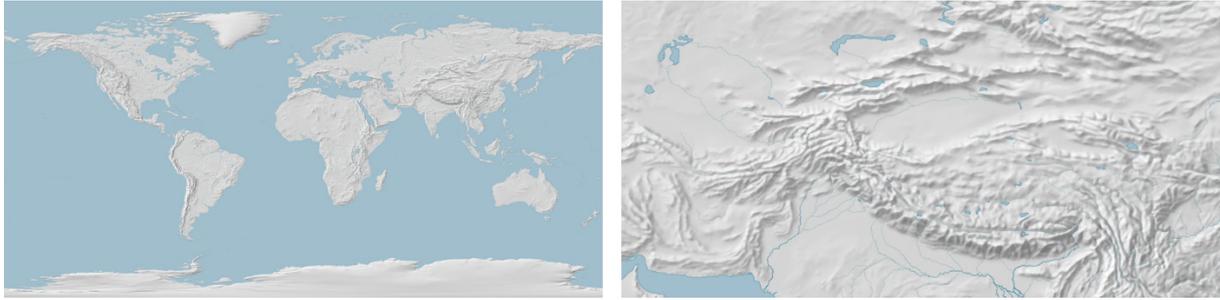


Figure 1: Manual shaded relief of the world. (left) Full coverage with blue water bodies added for reference. (right) Detailed excerpt of Central Asia, Tibet, and the Himalayas.

In 2016, I drew a second and more detailed shaded relief of the contiguous United States, which includes adjacent areas in southern Canada, Latin America, and the Caribbean. Also available on the Natural Earth website, it is offered as a grayscale GeoTIFF (12,578 x 9,494 pixels) in the Web Mercator projection. The contiguous United States relief registers with 1:10-million scale Natural Earth vector data (Figure 2).



Figure 2: Manual shaded relief of the contiguous US. (left) Full coverage with blue water bodies added for reference. (right) Detailed excerpt of the Colorado Plateau and southern Rocky Mountains.

The following sections examine how small-scale shaded relief differs from large-scale shaded relief and my rationale for undertaking this project. I discuss how to draw manual shaded relief for use by mapmakers in a wide range of projects. The paper finishes with a review of the planning and production considerations for drawing shaded relief.

2 RATIONALE FOR MANUAL SHADED RELIEF

Digital relief production is now at a mature stage after several decades of development. At large and medium scales, automated techniques routinely yield shaded relief depictions that rival and sometimes surpass the visual quality of the very best hand-drawn artwork of the past (Figure 3). Digital shaded relief renders are certainly more accurate than their manual counterparts - no potentially fallible human interpretation of terrain is involved. In addition, digital reliefs take just a few minutes to produce compared to tens of hours required to produce a manual reliefs. Given these advantages, why then did I turn to anachronistic manual production methods?

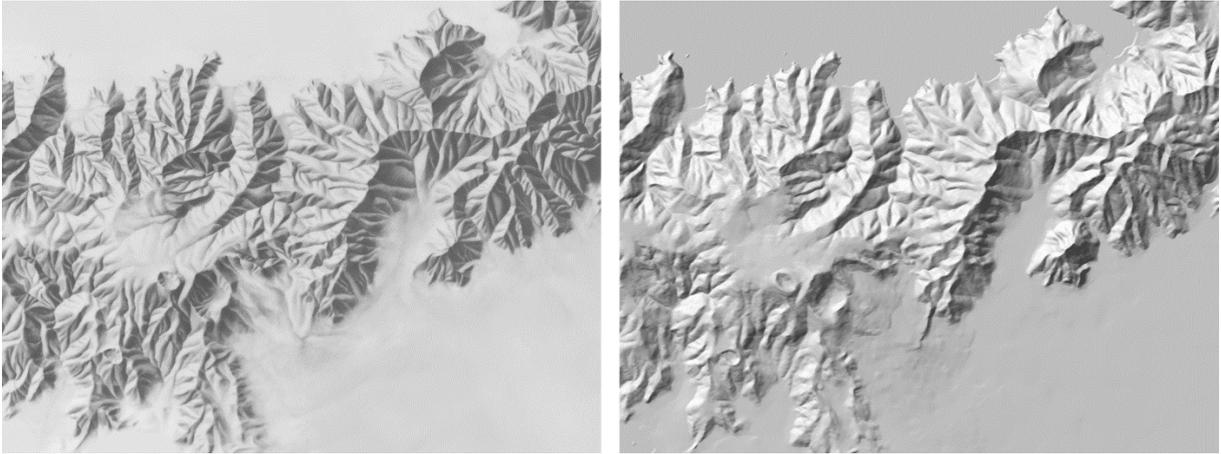


Figure 3: Tutuila, American Samoa, at 1:24,000-scale. (left) A 1980 manual relief by Michael Wood. (right) A 2016 digital relief created with default settings in Natural Scene Designer Pro 7.0.

The answer has everything to do with appearance. At very small map scales automated relief shading methods fall short due to poor generalization. High-resolution elevation data when rendered with standard cartography and GIS software yield shaded relief with excessive detail - mountain ranges often look like gritty "sandpaper" textures (Figure 4A). In extreme cases, the tightly packed mountain shadows coalesce as a uniform dark tone when rendered.

The problem lies with the heterogeneous nature of small-scale elevation data. The height values on these data have great variability over short distances, such as when a tall peak and deep canyon are close to one another. When rendered digitally, these data produce shaded relief with similarly heterogeneous pixels - the brightest and darkest pixels are immediately adjacent, creating a noisy pattern across the shaded relief. Ideally, in order for your eye to discern illuminated and shadowed slopes on either side of a ridge, these slopes must have at least several pixels of width, and preferably even more.

Downsampling elevation data (Figure 4B) and then smoothing it (Figure 4C) is the common method of reducing noisy terrain detail at small scales, which when rendered produces blurry, indistinct shaded relief resembling melted plastic. The resolution bumping technique (Patterson 2001), which involves merging detailed and smoothed elevation data prior to rendering a shaded relief, yields similar results (Figure 4D). And Terrain Sculptor software (Leonowicz et. al. 2010), which produces nicely generalized shaded relief artwork at large and medium-scales, is ineffective at very small scales (Figure 4E).

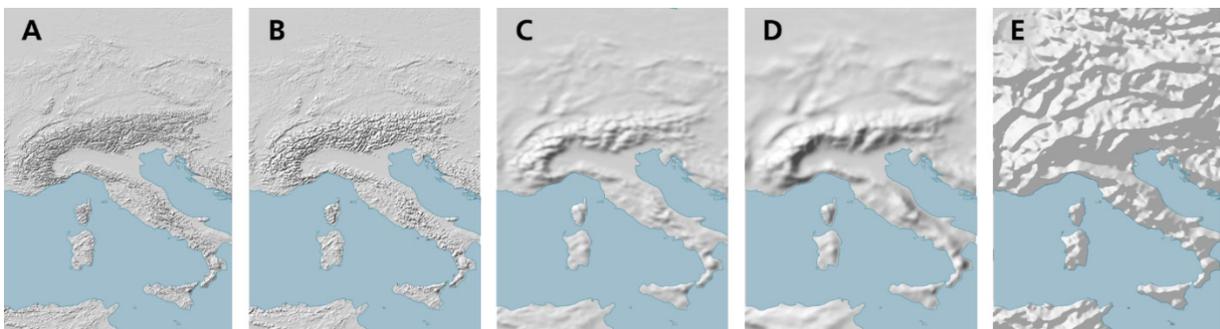


Figure 4: Small-scale shaded relief created digitally. The choice is between highly detailed relief (A and B) and too much generalization (C, D, and E).

To develop appropriately generalized small-scale shaded relief, I turned to the manual relief shading techniques that I learned in the 1980s. (For manual relief examples, visit ShadedReliefArchive.com). This approach allowed me to represent complex mountain ranges as gray and white tones that captured their key characteristics, including orientation, ruggedness, relative elevation, and large secondary features. Given the small scale and limited space in which to draw, the resulting shaded relief is similar to a caricature. But instead of exaggerating a person's facial features - noses, chins, eyes, etc., I emphasized mountains, plateaus, canyons, and escarpments at the expense of lower and flatter terrain, while simultaneously being mindful of map accuracy. I also wanted the shaded relief to have a soft, clean style that could combine unobtrusively with other information on reference and thematic maps. Going back to my manual roots was the only way to create what I needed. The project, however, had a modern dimension (Tóth 2010): I drew the reliefs using digital production tools (Figure 5).



Figure 5: Drawing shaded relief in Adobe Photoshop with a Wacom tablet and stylus.

3 DRAWING TECHNIQUE

To draw shaded relief images that exhibited both manual style and digital accuracy involved multiple layers in Adobe Photoshop. The base layer was a digital shaded relief created with the resolution bumping technique described previously. I generated the base relief in Natural Scene Designer Pro with 1,800 percent vertical exaggeration (Figure 6A). This generic gray base provided a way to gauge the relative height and generalized structure of terrain features. The next Photoshop layer above this was an empty layer that received my drawing strokes made with the Wacom tablet, which would eventually become the final shaded relief when

merged with the base relief below (Figure 6B). As a reference while drawing, I would temporarily turn on a layer containing Natural Earth vector coastlines, drainages, and spot elevations (Figure 6C). Having this information as a guide allowed me to fit the final relief precisely to the rivers. The topmost layer was another reference layer containing highly detailed shaded relief generated from SRTM elevation data. I would briefly turn this layer on while drawing to see subtle terrain features (Figure 6D).

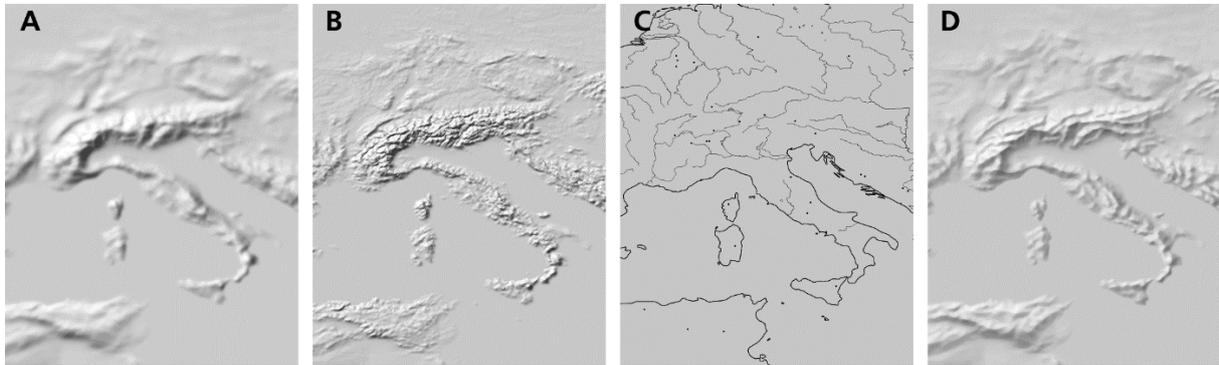


Figure 6: Photoshop layers. (A) Digital shaded relief base. (B) Drawing layer. (C) Natural Earth vectors used for reference. (D) Detailed reference shaded relief.

The manual reliefs that I drew were not entirely manual. For example, the world shaded relief in the Geographic projection had extreme east-west polar stretching, which presented drawing challenges. For example, a small mountain range in a polar region could stretch out to nearly the entire width of the map, creating an inadequate base for manual relief drawing. Consequently, Antarctica and high arctic islands contain mostly digital shaded relief supplemented with minimal manual touchups. Some large, flat areas elsewhere, such as the Amazon basin, Canadian Shield, and West Siberian Plain, also received only minor manual work. The digital shaded relief that appears very lightly in these areas looked acceptable as is.

The focus of my drawing correlated with terrain prominence - bigger, higher features received the most attention. I drew with a soft brush in Photoshop that I could quickly change in size using keyboard commands (the Wacom tablet also has programmable buttons for accomplishing this). Drawing in grayscale, I alternated between light and dark tones by toggling the foreground/background colors using another keyboard command. I applied tones lightly using multiple brush strokes with the brush opacity ranging from 10 to 50 percent. Using the pressure sensitive Wacom tablet and stylus allowed for the application of very subtle tones.

Some areas were harder to draw than others, such as mountain ranges that trend parallel to the assumed northwest light source, such as the Caucasus. In these local situations, I shifted the illumination direction slightly to the north or west to draw the range more clearly. Even trickier to depict were arcing mountain ranges that required switching the shadowed slopes from one side to the other, usually at natural breaks in the terrain. The mountains along the Pacific coast of North America from Alaska through British Columbia and on to Washington exemplify this problem. I also took into account light and shadows on adjacent terrain when locally varying the light source to maintain consistency. Another difficulty was depicting complex but relatively low terrain, such as the mountains of southeast China, in an understandable manner. I had to carefully study this area to identify topographic trends and patterns.

Drawing shaded relief efficiently requires a relaxed, but attentive state of mind. Taking frequent breaks helps. Over thinking how to depict the terrain would slow down progress and result in poor renderings. Fortunately, working in Photoshop gave me a second or even a third chance to get it right. I redrew the Canadian Rockies three times.

Besides the mechanics of drawing, the final shaded relief is a reflection of my geographic and aesthetic preferences. Some prominent landforms that were hard to discern on small-scale digital relief, such as the southern Andes, received greater emphasis. I broadened and darkened the short but steep slopes that characterize these mountains. I deemphasized other areas. For example, to diminish visual noise, not all of the many mountain ranges found in the Great Basin of the US appear on the relief map. Relatively low features with straight, regular sides rising above flat lowlands, such as the Ural Mountains of Russia and several mesas on the prairies of northwestern Canada, appear with too much contrast on digital relief. They received slight flattening adjustments.

As a final tweak to the relief art, I lightly applied Photoshop's Dry Brush and Median filters to the entire map - a grayscale DEM inserted into Photoshop layer mask limited this filtering to mountain summits and other high elevation areas. This yielded crisp ridgelines that accentuated the three dimensional appearance of landforms.

4 PRODUCTION CONSIDERATIONS

Creating a manual shaded relief involves careful planning. I considered the following variables before and while engaged in drawing.

4.1 MAP PROJECTION

Choosing the right map projection for a shaded relief released online, downloaded by unknown persons, and used for making a variety of different maps is a challenge. The main problem: whichever projection you select will probably differ from what the user will want to use - there are dozens of common small-scale map projections to choose from. Transforming the shaded relief from one projection to another at the very least degrades image quality and often introduces undesirable distortion, such as stretching or compression, especially on the map periphery. Lighting is another concern. For example, northwest illumination on shaded relief in a cylindrical projection becomes multidirectional when transformed to a polar projection (Figure 7). To minimize these potential problems, one must select a map projection that will accommodate the most likely projection choices by end users.

I selected the Geographic (Plate Carrée) projection for the shaded relief of the world (Figure 7, left). This generic cylindrical projection is the default choice for delivering world raster data by online providers. Although few final maps employ the Geographic projection, it is nevertheless a malleable choice that transforms with acceptable levels of distortion to more preferred world map projections, such as the Eckert IV, Robinson, and Winkel Tripel (Šavrič et. al. 2015). However, transforming the relief to the now popular Web Mercator projection is not advisable because of the extreme stretching at high latitudes. In fact, no available relief product, digital or manual, works adequately with the Web Mercator projection near the poles.

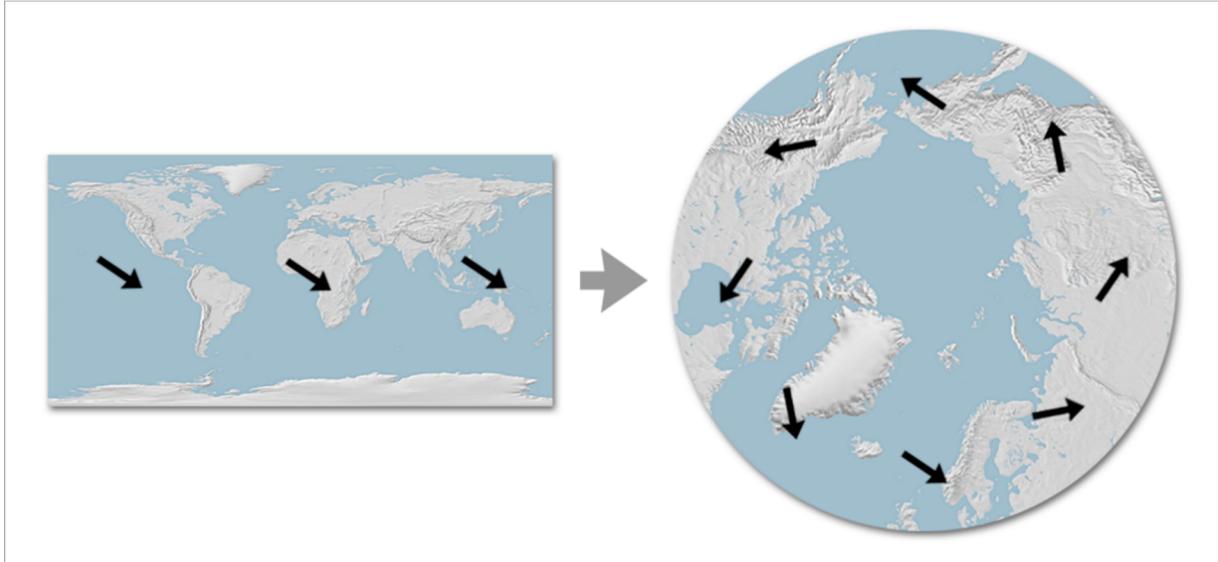


Figure 7: (left) World shaded relief with black arrows indicating standard northwest illumination.
 (right) Transforming the world relief from the Geographic projection to a polar projection results in inconsistent illumination.

I selected an entirely different projection for the shaded relief of the contiguous US. Because the map coverage focuses on mid and low latitudes, I drew the relief in the Web Mercator projection. This choice is obviously ideal for Web mapping and it also works well when transforming the relief to more traditional equal-area projections, such as the Albers Conic and Lambert Azimuthal. To compensate for some image compression that occurs in northern areas during reprojection, I drew these areas with slightly less relief detail (Figure 8, right).



Figure 8: Transforming shaded relief of the contiguous US from the Web Mercator projection (left) to the Lambert Azimuthal Equal-Area projection (right).

4.2 LIGHT DIRECTION

As was discussed previously, illumination originating from the northwest (315 degrees azimuth) is standard for shaded relief depiction, but it does not work well when ridges and valleys trend in the same direction as the light. The lack of shadows causes even high mountains to become inconspicuous when they blend in with the flat gray background tones. Locally adjusting the light direction slightly (up to 30 degrees in either direction from northwest) counters this problem (Imhof 1982).

I varied the light direction using two methods. Generating the base relief in a beta version Natural Scene Designer Pro 7.0 allowed the use of auxiliary light sources (with the light coming from different directions) for local areas, in addition to standard northwest lighting elsewhere on the relief (Figure 9). The program interpolates the light direction in intervening areas between the auxiliary lights that the user sets. These adjustments allowed me to better define major mountain ranges on the base relief. Additionally, when drawing the final relief in Photoshop, I applied light direction adjustments to subordinate terrain features. My goal was to depict all terrain features, from the smallest ridge to the largest range, as clearly as possible. Many of these adjustments occurred with little conscious thought; I relied on decades of experience to instinctively make on-the-fly light adjustments as I drew.

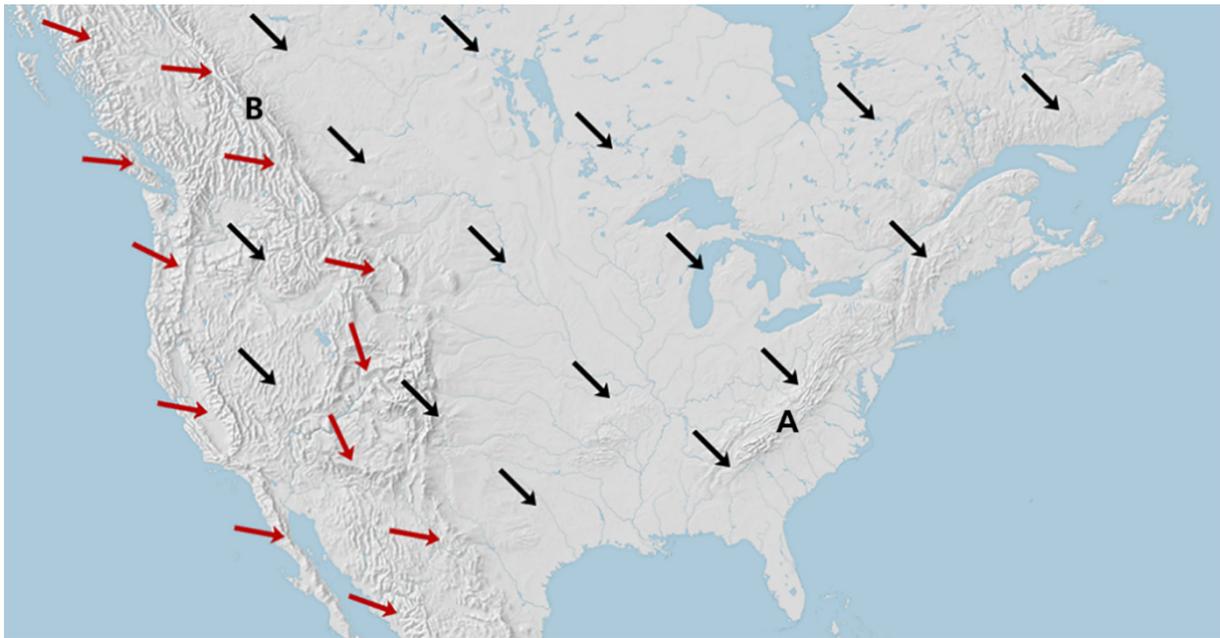


Figure 9: Black arrows indicate shaded relief depicted with standard northwest illumination, such as the perpendicularly aligned Appalachian Mountains (A). Red arrows show changes to the illumination direction to better depict uncooperative terrain, such as the northwest trending spine of the Canadian Rockies (B).

4.3 GENERALIZATION

The amount of detail found on a small-scale shaded relief in large part depends on the production method. Digital shaded relief tends toward greater detail because the data from which it derives are already detailed, and applying generalization involves additional work often using inadequate methods that yield poor results (Figure 4). Manual shaded relief, on the other hand, is often highly generalized because drawing proceeds very slowly and including more detail beyond the bare minimum requires an even greater investment of time.

The manual reliefs that I drew attempt to fill the middle ground between these generalization extremes. Drawing on top of a base relief derived from digital data helped make the work go quicker - and produced more accurate results. When drawing, I tried not to vary the magnification level in order to keep the amount of terrain detail consistent from one region to the next. I would look at the detailed digital terrain (on the reference layer in Photoshop) with a slightly unfocused gaze to allow the primary and secondary terrain features to emerge (Figure 10, left). My final relief drawing depicted what I saw minus the tertiary terrain features (Figure 10, right).

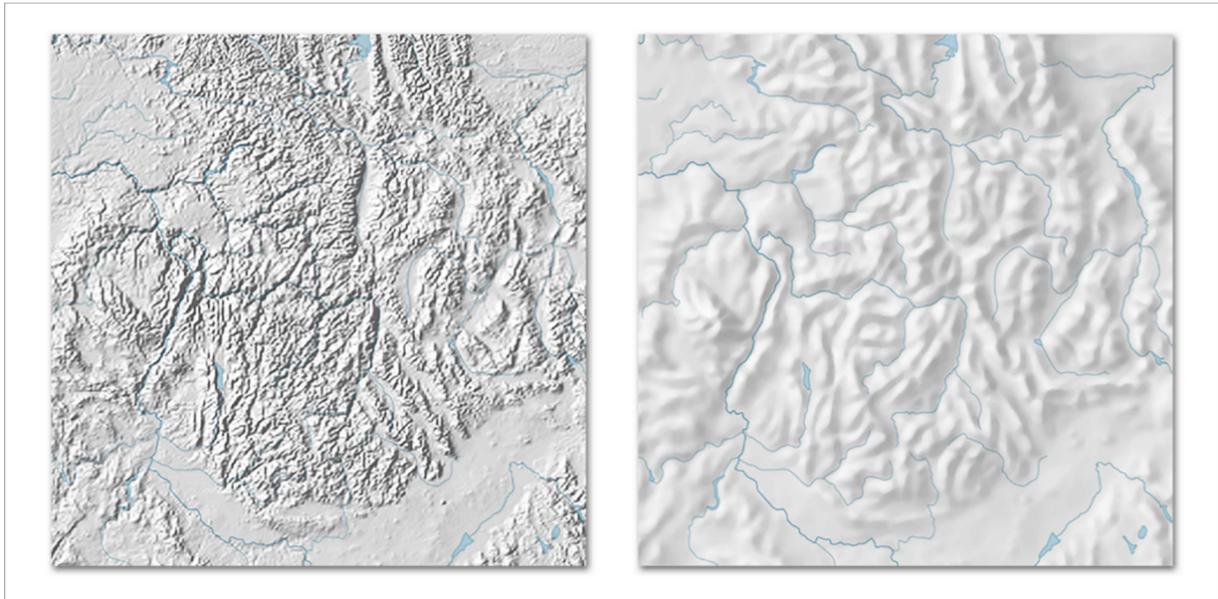


Figure 10: (left) Digital shaded relief derived from SRTM data used for reference when drawing. (right) The final generalized manual shaded relief.

I also adjusted relative terrain height while drawing. The base relief had 1,800 percent vertical exaggeration. After my initial drawing was complete, I compared the prominence of mountains, plateaus, etc. and made necessary adjustments based on their surveyed elevations. Adding slightly more contrast to a mountain crest made it appear higher; removing tone and contrast would lower it.

4.4 DRAWING STYLE

A distinguishing characteristic of manual shaded relief is the great variety in drawing styles between artists (Figure 11). My stylistic preference is for soft, clean relief that can serve as a neutral backdrop on thematic maps. To keep the overall relief light, I paint the illuminated northwest slopes with white. This technique gives landforms a three-dimensional appearance without having to paint excessively dark shadows on the southeast slopes. In addition, flat lowland areas contain only a modest amount of gray in the interest of overall lightness. How I draw small-scale shaded relief artwork takes a stylistic cue from the appearance of digital relief rendered at large scales (Figure 3, right).

4.5 MAP SCALE

Shaded relief and map scale have an elastic relationship. To determine which map scales most benefit from manual shaded relief depiction, I inspected digital shaded relief prepared for a National Park Service web-mapping project (Patterson 2013). Focusing on the rugged western United States, I judged that at scales less than Zoom Level 6 (about 1:10 million) the digital shaded relief was too detailed and would benefit from manual generalization (Figure 12). At scales greater than Zoom Level 9 (about 1:1 million) the digital relief generally looked acceptable as is. And between Zoom Levels 6 and 9 lies a gray area where manual enhancements could help depending on the nature of the terrain - higher, more rugged terrain being the most in need of manual touchups. It is important to note that these recommendations are highly subjective, based on my personal preferences and the terrain characteristics of the United States. Landscapes elsewhere in the world may differ.

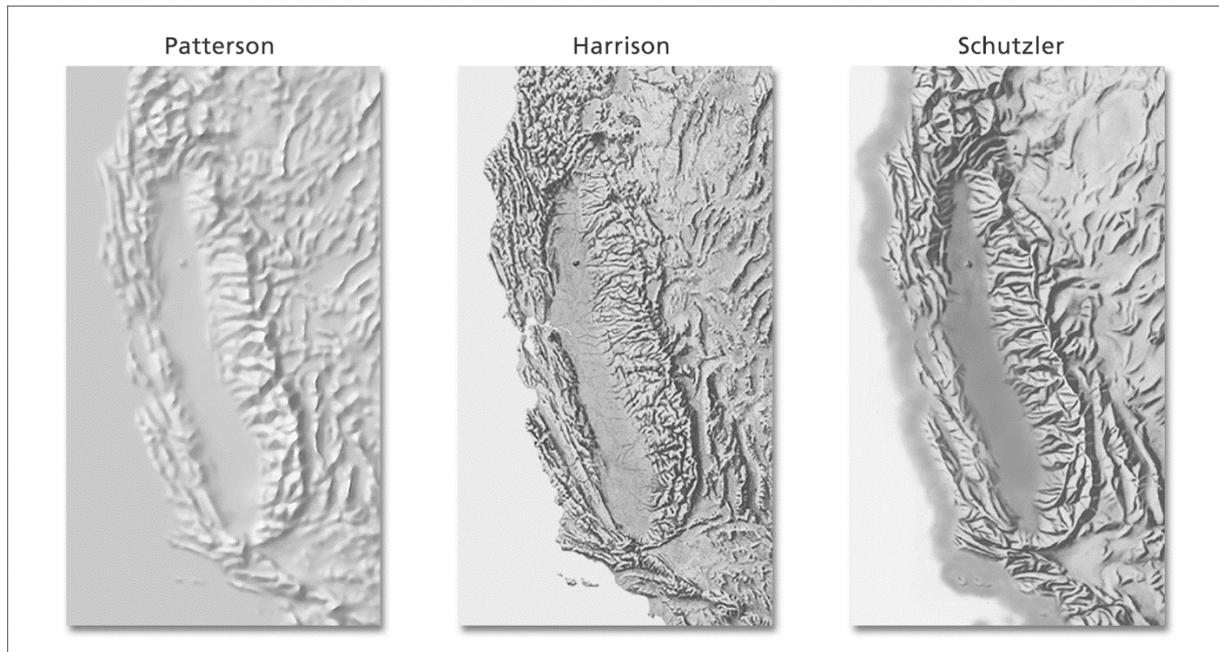


Figure 11: Manual relief artists have different drawing styles. The author (Patterson), influenced by digital relief production, favors brighter illumination and lighter shadows compared to Harrison (1969) and Schutzler (1965).

The two shaded relief pieces that I drew are useable on maps at a range of scales. For instance, although the world shaded relief fits 1:50 million-scale Natural Earth vectors, map scales between 1:40 and 1:100 million looked acceptable in test printings. Just how large the scale is depends on your tolerance for generalized relief and the purpose of your map. The final relief art contains more pixels than needed relative to the terrain detail, so image resolution is not an issue at modestly larger scales. Large wall maps viewed from a distance are amenable to the most relief enlargement. At smaller scales approaching 1:200 million, the relief starts to look like a busy texture rather than a terrain depiction. The relief of the contiguous US, prepared for use with 1:10 million-scale Natural Earth, is also usable at a range of map scales.

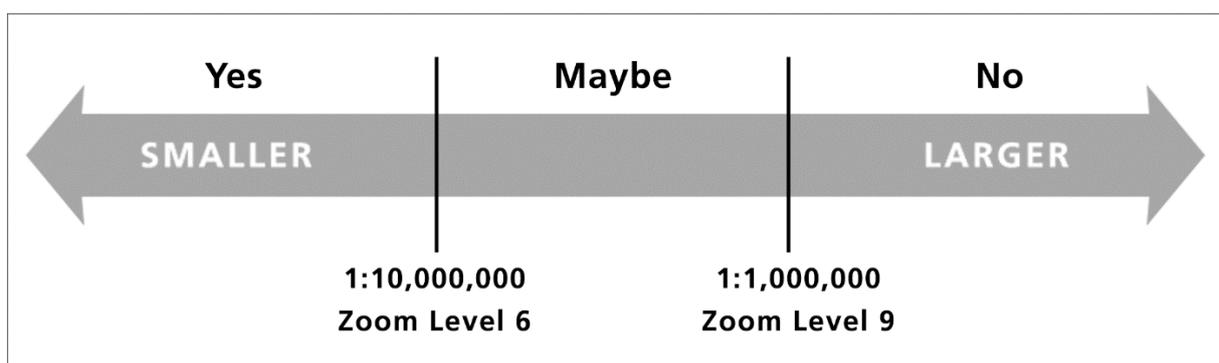


Figure 12: Manual shaded relief enhancements work best at map scales of 1:10 million and smaller.

5 CONCLUSION

Because relief shading by hand takes considerable time and requires skills that a dwindling number of people today have, my work could be among the last of its kind. I do not plan to draw more small-scale shaded relief artwork.

On the other hand, the manual shaded relief pieces discussed here have proven popular online. Users have downloaded the manual shaded relief of the world over 5,600 times since its release two years ago. The manual shaded relief of the US has had nearly 3,000 downloads in one year. Considering that the reliefs are reusable on multiple maps once someone has obtained them, the raw downloaded numbers may underestimate actual use.

Considering the supply versus demand impasse, a need exists for producing automated small-scale shaded relief with appropriate generalization and a pleasing style. With the many triumphs that automation has brought to relief presentation in the last 25 years, small-scale relief presentation remains one of the last major problems in need of solving. I pose this challenge to those of you with a technological bent.

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