Shaded Relief in Display of Seismic Data*

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Introduction

In the shaded relief image of Figure 1 you see a rugged mountain with craters on its flanks. Lunar topography? A stretch of remote desert on Earth? Hardly – it is a time slice through a seismic volume. Compare this image with Figure 2, a conventional display of the same data, and you will agree that shaded relief wonderfully complements standard displays by revealing details and presenting them in a form that geologists readily appreciate. Yet, already knew that, for shaded relief has been employed for over a century in displays of topography, and today it is ubiquitous in the display of any geological or geophysical data that is presented as a map, including digital elevations, gravity and magnetic data, interpreted seismic horizons and geologic models. Whatever the application, the motivation for shaded relief displays is always the same – to transform data into realistic-looking apparent topography and thereby aid interpretation by revealing or suggesting true geology.

Figure 1. A picture of the moon? No, a time slice through a seismic volume displayed as shaded relief. Note the left-to-right fault cutting across the dome.

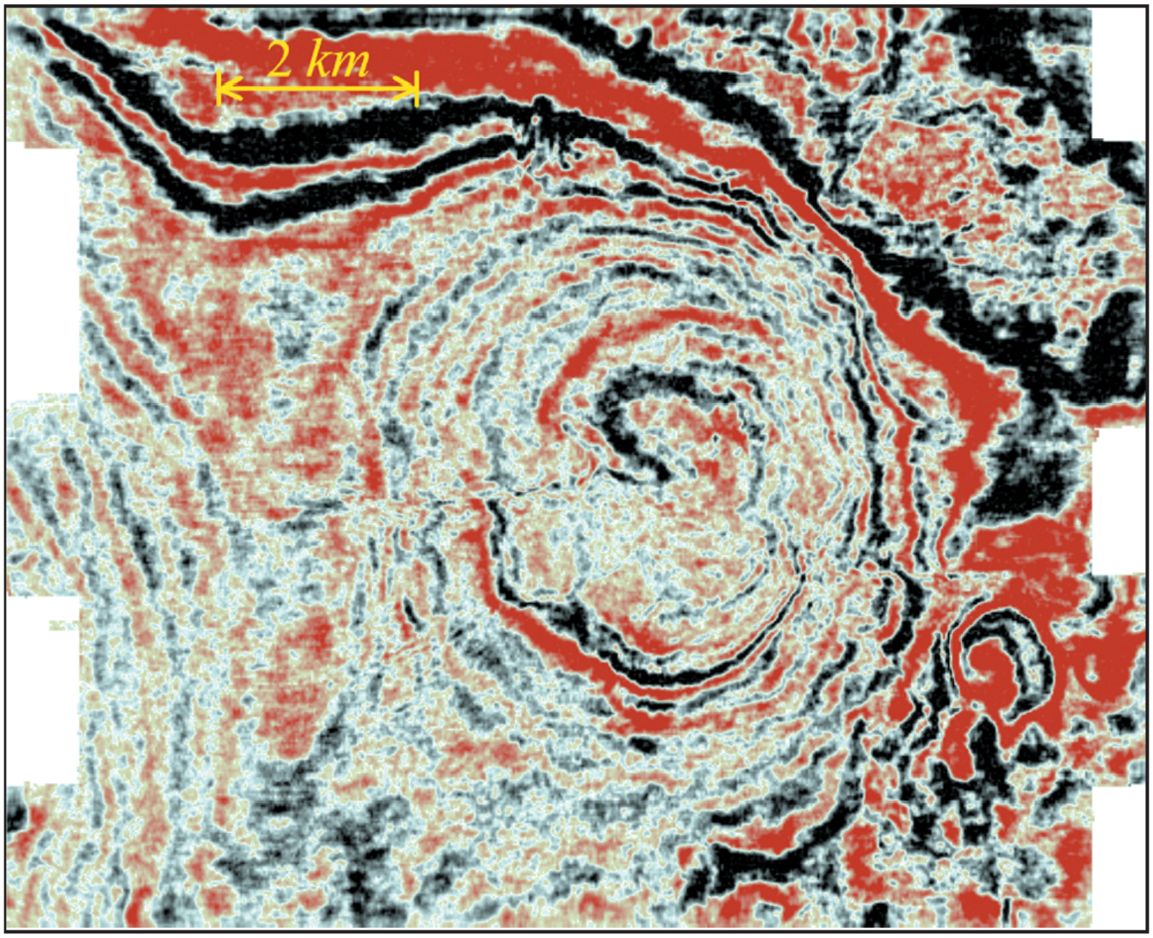

Figure 2. The conventional display of the same time slice shown in Figure 1.

Shaded Relief and Seismic Data

Why was shaded relief not applied to the display of seismic data long ago? After all, seismic reflections may fairly be taken as representing buried topography, and so they seem natural for shaded relief.

Two reasons stand out:

- Shaded relief requires 3-D seismic data, which has only become widely available in the last decade.
- There is a conceptual hurdle to jump over. Unlike most geophysical data, which define a solitary surface to illuminate, 3-D seismic data must be thought of as a collection of surfaces to illuminate simultaneously. This concept is the key to seismic shaded relief.

To apply shaded relief to a 3-D seismic data volume, then:

- Consider the entire volume as a collection of reflection surfaces, and consider every data point in the volume as lying on some particular reflection surface (Figure 3).
- Illuminate these surfaces simultaneously with a single distant light source, the "sun." Because the sun is distant, illumination is uniform in direction and intensity throughout the seismic data volume.
- Compute the shaded relief of a surface as its relative illumination, which is some function of the angle between the incident light and the reflection surface. The orientations of the reflection surfaces are found through available reflection dip and azimuth attributes, which measure the strike and dip of the buried rock layers.
- Decide whether the surfaces appear dull or shiny, exaggerate the slopes in your data to enhance the relief, and you are done.

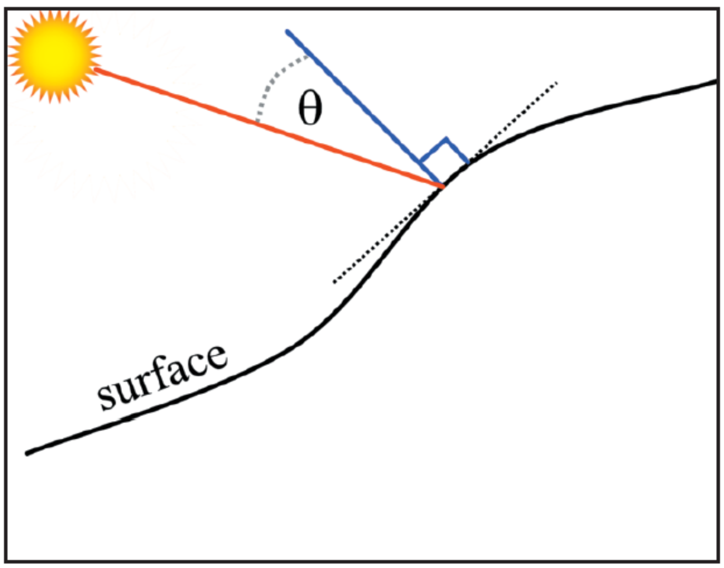

Figure 3. The relative illumination at a point on a surface is a function of the angle between the incident light and the surface normal.

Shaded relief actually contains the same information as the common dip-azimuth attribute (Figure 4). This common information is the reflection dip and azimuth. Shaded relief combines them into apparent topography, whereas dip-azimuth shows them together with dip determining the shading of the display and azimuth determining its color. The difference is only in how it presents this information. Of course, as any marketer can attest, presentation is significant – and in this case, geoscientists are likely to find that dip-azimuth confuses as much as shaded relief enlightens.

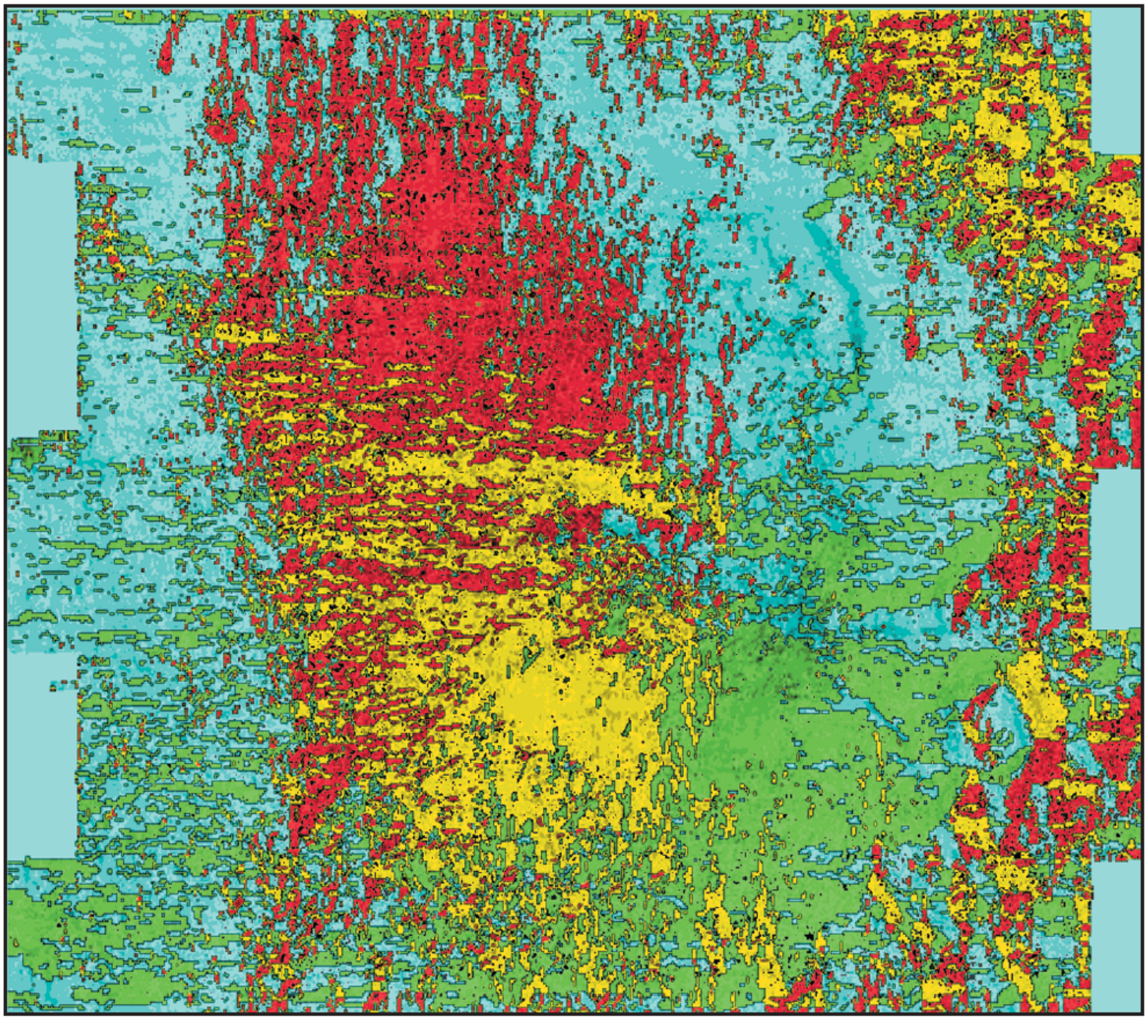

Figure 4. Dip-azimuth corresponding to Figure 2. The color represents the azimuth, which refers to the down-dip direction and is therefore perpendicular to geologic strike. Blue is north, green is east, yellow is south, and red is west. The shading of the color represents the dip, with more shading signifying steeper dips. Dip-azimuth presents the same information as shaded relief, but is less intuitive.

While shaded relief replaces dip-azimuth, it complements other attributes, such as continuity (Figure 5). Both shaded relief and continuity reveal details hidden in the data, but continuity highlights faults and other discontinuities, whereas shaded relief shows changes in reflector orientation.

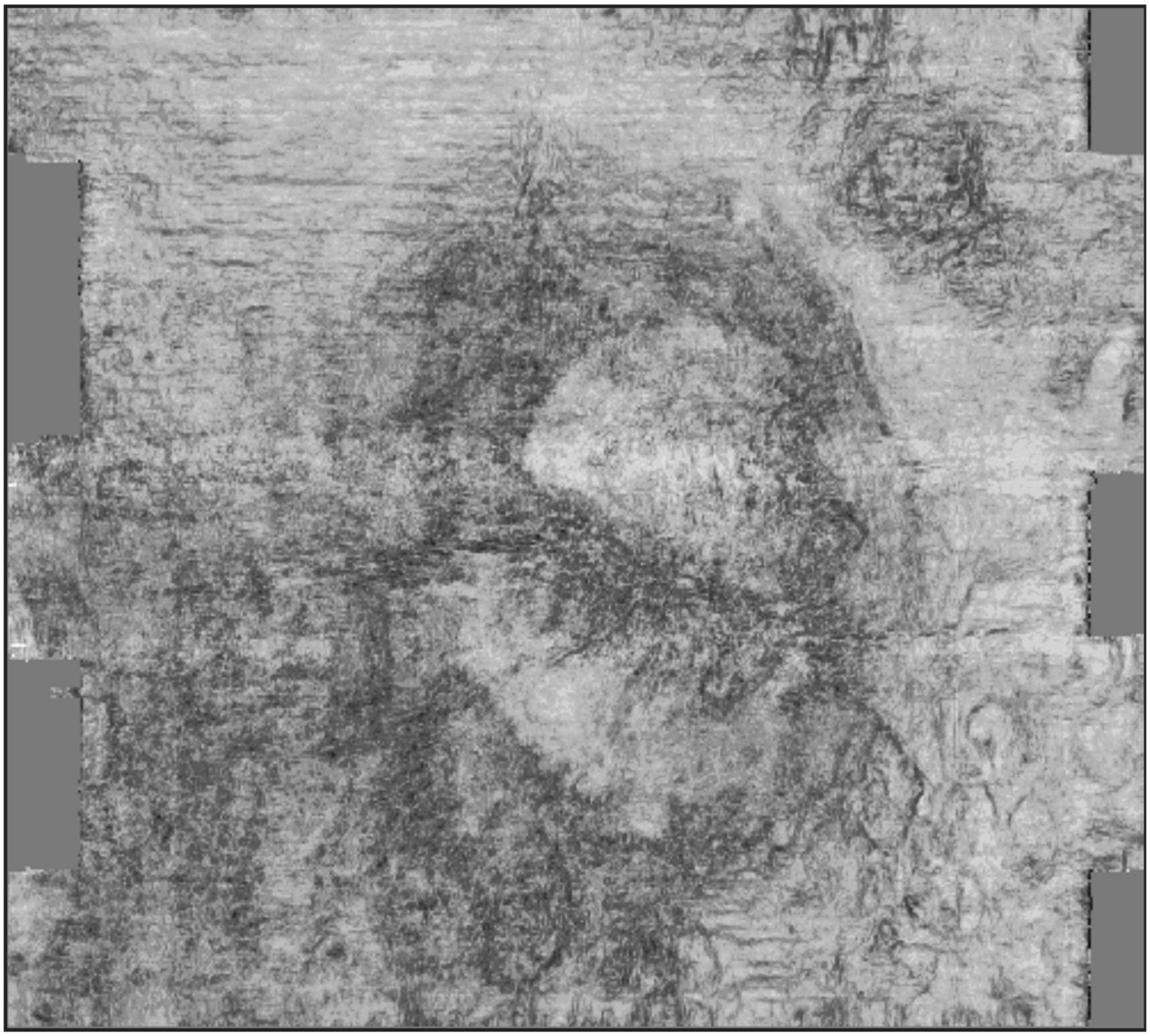

Figure 5. Reflection continuity corresponding to Figure 2. Shaded relief complements continuity.

There is also a difference of directionality, for most attributes reveal structures in all directions, whereas shaded relief is directional, enhancing features perpendicular to the illumination direction while suppressing those that are parallel. As a result, shaded relief displays should be created in pairs with orthogonal illumination directions so as to capture all features. This directionality is useful, as it makes a powerful directional filter of shaded relief, enabling a user to selectively highlight certain trends while hiding others.

Summary

Seismic shaded relief represents seismic reflections as apparent topography. This facilitates geologic understanding by revealing structural and stratigraphic details hidden in seismic data and presenting them in a familiar and intuitive display. Shaded relief is effective, cheap, and fun. What a relief!