Enhancing Fault Visibility Using Bump Mapped Seismic Attributes

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Summary

Bump mapping is the process of modulating the RGB colors of an image with the light intensity values of a shaded relief image. The resultant display is still a two-dimensional image but it has the appearance of being a three-dimensional surface. The goal of this paper is to use bump mapping to enhance an interpreter's ability to identify faults and other discontinuities on time slices.

A bump mapped image has two components, a shaded relief image and a color image. Usually these two components come from the same data source. In this paper, however, we use two different components. We use coherency for the shaded relief and the seismic amplitude for the color.

The discontinuities evident on the shaded relief coherency display appear as clearly defined ridges on the final bump mapped image. The seismic event amplitudes evident on the original variable density display are on the whole unaffected by the bump mapping process. This is because the coherency shading is only noticeable where the seismic events are discontinuous. Where the events are continuous the shading is almost flat and produces very little effect.

The final bump mapped image retains all of the seismic amplitude information from the original time slice but superimposes, as ridges, the coherency discontinuities. It appears as an almost pre-interpreted time slice.

Introduction

The identification of both major and minor faulting in a seismic section is one of the most important and difficult tasks that an interpreter faces. The advent of semblance based coherence techniques (Marfut et al 1998, Bahorich et al 1996) has made this task somewhat easier and coherence has consequently become an important tool for the seismic interpreter.

Seismic coherency is a measure of the consistency of a seismic section. Where events are continuous, coherency is high. But where events are terminated either by faulting or stratigraphy, there is a loss of continuity, which is clearly evident as dark lines on coherency displays. Coherence is calculated directly from the seismic data and thus provides an unbiased view of the faulting in a section.

Consider Figures 1 and 2, which show the time slice and coherency slice for a region around a series of prominent faults (data courtesy unnamed source). The faults are evident on the vertical section but on the time slice of Figure 1 they are difficult to follow spatially. If all we had to go on were the time slices, interpreting even the major faulting would be a time consuming task.

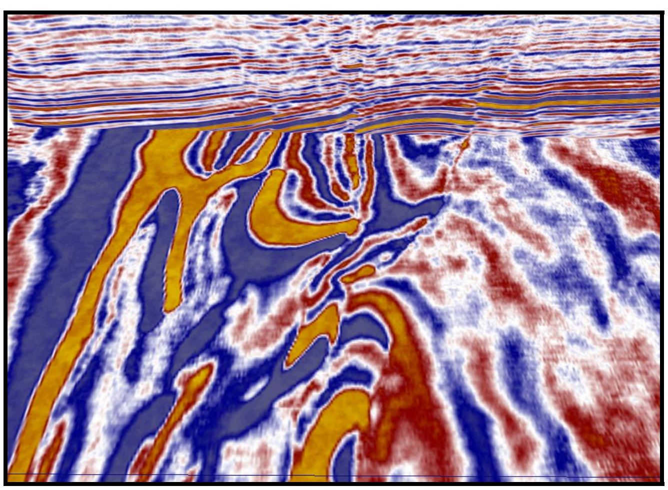

Fig 1. Variable density time slice of a faulted seismic section. Data courtesy unnamed source. Notice how difficult it is to follow the faults from the vertical section onto the time slice.

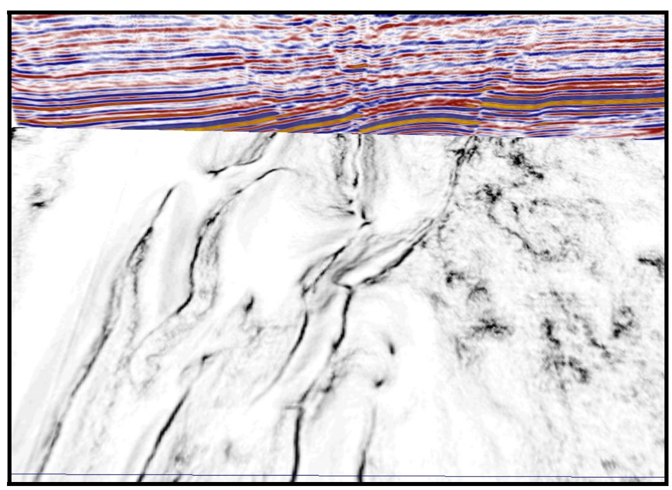

Fig 2. Coherency slice of the same data shown in Figure 1. Notice how much clearer and more distinct the faulting is. But how does what we see here relate to the amplitudes of Figure 1?

The faults show up very clearly, however, on the corresponding coherency slice shown in Figure 2. On this display the discontinuities (faults) show up as dark lineations making their spatial interpretation a simpler task. Coherency has become one of the staples of fault interpretation and there are many papers in the literature detailing its uses and benefits. For example, Neves et al used C2 coherence to detect small fractures in a Saudi Arabian 3-D; Carter and Lines used coherence to image faults in the Hibernia 3-D data set. Al-Dossary et al have extended coherency into the pre-stack domain.

As useful as coherence displays are, they are not perfect. They show discontinuities but without the seismic amplitude data it is difficult to assign relevance to what we are seeing. For example, the time slice of Figure 1 shows the seismic amplitudes but it is difficult to determine where the amplitude changes represent faulting. The coherency slice of Figure 2 shows us the discontinuities but we don't see how they relate to the seismic amplitudes. To interpret a coherency slice correctly we need to make continual reference back to the amplitude data which is a time consuming and less than optimum task.

What is needed is a method for combining these two displays so that the discontinuities on the coherency display show up clearly on the amplitude time slice. In the remainder of this paper we show how this can be accomplished by using a well-established computer graphics technique called Bump Mapping.

Bump Mapping

Batson et al, 1975, introduced the concept of the "Shaded Relief" image to display digital elevation data. Shaded relief tricks the visual cortex into believing that a two-dimensional texture is actually a three-dimensional surface. Rather than displaying the amplitude of an attribute (originally digital elevation data), shaded relief displays show how the attribute would reflect a given light source. The patterns of light and shade in the resultant image look "real" to the visual cortex and that is how it interprets them. Shaded relief images are now used extensively in gaming and in many industries to simulate 3-D surfaces using 2-D textures. In a recent short note in Geophysics, Barnes used shaded relief to help visualize time slices.

Bump Mapping, first introduced by Blinn in 1978, extends this shaded relief concept. A bump mapped image is formed from a combination of a colored image and a shaded relief image. The RGB values of the colored image are modulated by the intensity values of the shaded relief, essentially stamping the patterns of light and shade onto the image. Since the visual cortex is highly proficient at interpreting patterns of light and shade, it is tricked it into thinking that the colored image is a three-dimensional object. And that is how we see it.

In the paper "Composite Density Displays", CREWES Research Report 2003, Lynch extended the bump mapping concept to vertical seismic data. In that paper Lynch used a shaded relief image produced from the seismic amplitudes to modulate the colors of a variable density display. The resultant 2-D images are called a "Composite Density" displays and they have a pronounced 3-D effect.

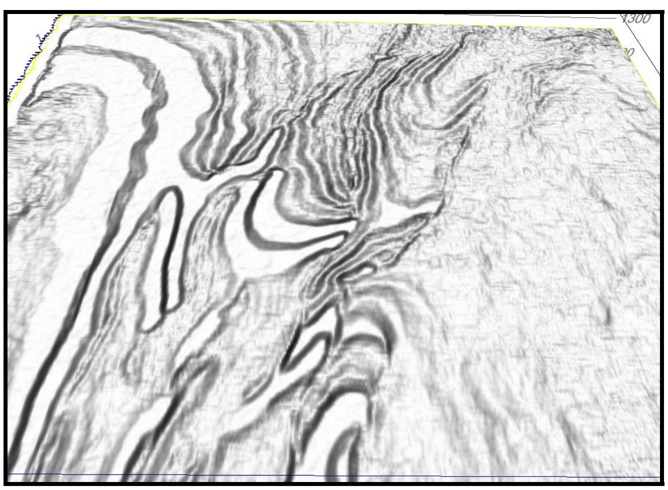

Fig 3. Shaded relief of the seismic amplitude time slice shown in Figure 1. The vertical section has been removed for clarity. Notice the pronounced 3-D effect produced by the shading.

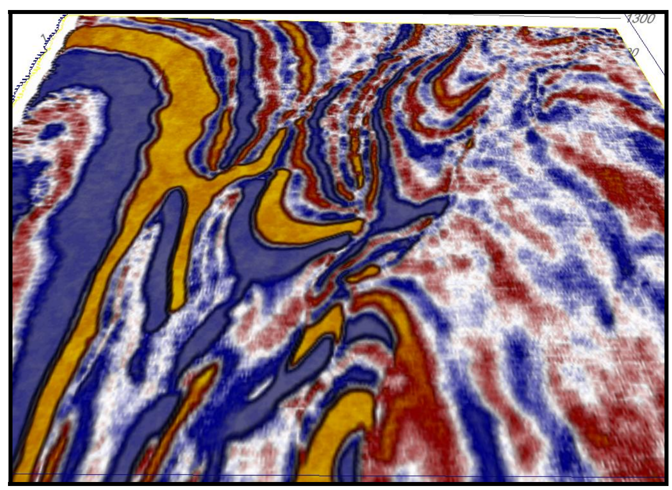

Fig 4. Composite density (bump mapped) display using the variable density of Figure 1 and the shaded relief of Figure 3. Notice that the 3-D effect visible on Figure 3 persists.

For example, Figure 3 is a shaded relief image of the time slice shown in Figure 1 with the vertical seismic removed for simplicity. The variable density display of Figure 1 shows the gross features of the time slice but it lacks any direct mechanism for identifying the actual structure. We cannot tell intuitively what is high and what is low. We can make continual reference back to the color palette, which in this case shows, red-yellow as high amplitude and blue-gray as low but we have no inbuilt mechanism for automatically equating these colors to structure. If we didn't know the color palette we would have no idea what the time slice represented.

The shaded relief display (Figure 3) shows how the amplitude structure of the time slice would reflect light. It is a map of reflectivity and the highs and lows are now obvious. This is because the visual cortex is proficient at interpreting these patterns of light and dark. We don't need any other information here to see the structure – it is intuitively obvious.

From an interpretation perspective, however, Figure 3 is incomplete. It shows us the structure of the data but without the variable density coloring it is still hard to interpret. Compare this now with Figure 4, which is the bump mapped counterpart to Figures 1 and 3. On Figure 4, the intensity values of Figure 3 are used to modulate the RGB colors of the variable density display (Figure 1). Notice that the time slice now appears to be three-dimensional and that the improvement in perception noted on Figure 3 has persisted.

Bump Mapping Coherency

Having seen the improvements in perceptibility brought about by bump mapping we can ask the question, "What would happen if we used a different attribute for the shaded relief". Figure 4 uses a shaded relief of the seismic amplitudes to modulate the colors of the variable density display (again of the seismic amplitudes). We are not restricted, however, to using the same attribute for the light source that we use for the variable density component. In this section we use the shaded relief of a coherency slice to modulate the variable density seismic amplitudes.

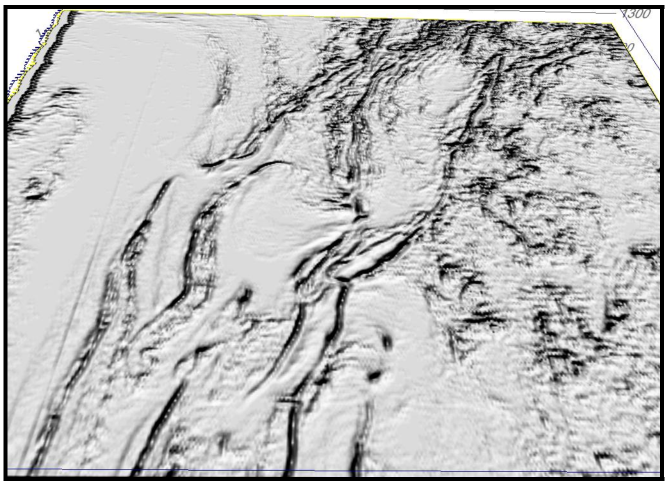

Fig 5. Shaded relief of the coherency slice shown in Figure 2. Note how much clearer and sharper the discontinuities are than on Figure 2.

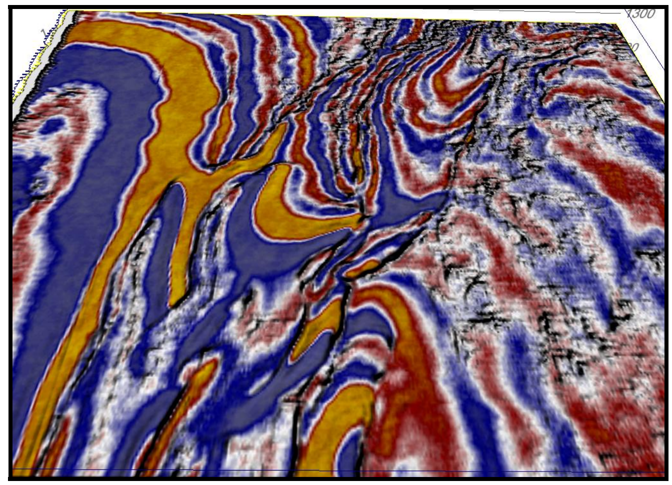

Fig 6. Composite density display using the variable density display of Figure 1 and the shaded relief of Figure 5. The discontinuities now appear as pronounced ridges whereas the bulk of the seismic amplitudes remain unaffected.

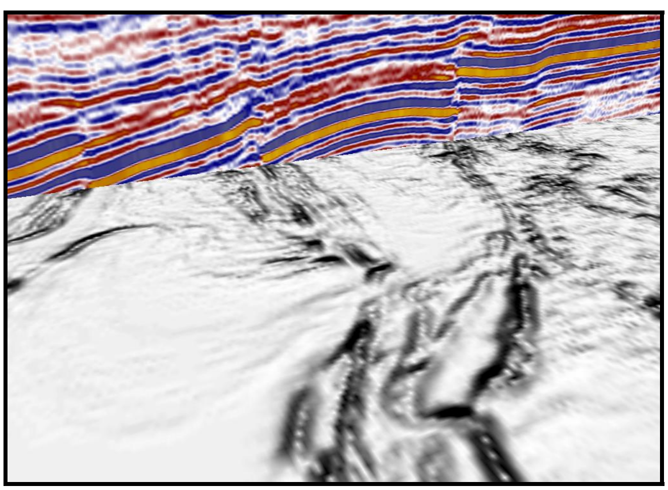

Fig 7. Close-up of the faulted region using shaded relief coherency.

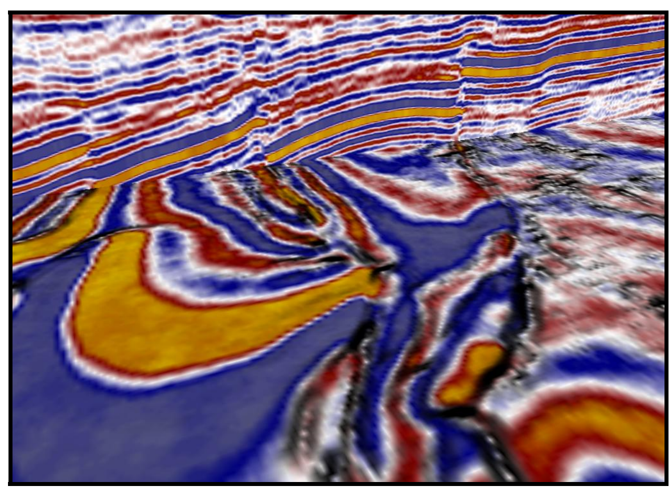

Fig 8. Same close-up as Figure 7 but using the bump mapped image of Figure 6. Notice again how distinct the discontinuities appear.

Consider Figure 5, the shaded relief image of the coherency slice shown in Figure 2. Here we see that viewing the coherency slice as shaded relief has, by itself, an immediate benefit. The discontinuities, which could be called "wispy" on Figure 2, are now more clearly defined and easier to follow. Even though the discontinuities are clearer, however, Figure 5 is still incomplete and hard to interpret. Without the seismic amplitudes as a guide, it is difficult to know what to make of what we are seeing.

Consider now Figures 6 and 8 where we used the shaded relief of Figure 5 to bump map the seismic amplitude time slice of Figure 1. The shaded relief coherency now appears as ridges on the amplitude time slice and clearly relates the discontinuities back to the amplitude data. When we decided to test this combination we were concerned that since the lighting and the coloring came from two different attributes that the resultant display would be visually confusing and meaningless.

Clearly, however, this is not the case. The discontinuities evident on the shaded relief coherency displays (Figure 5 and 7) appear as clearly defined ridges on the final bump mapped images (Figures 6 and 8). The seismic event amplitudes evident on the original variable density display (Figure 1) are on the whole unaffected by the bump mapping process. This is because the coherency shading is only noticeable where the seismic events are discontinuous. Where the events are continuous the shading is almost flat and produces very little effect.

Considering that coherency provides an unbiased view of discontinuities, Figures 6 and 8 could be thought of almost as automatically interpreted time slices.

Conclusions

In this paper we introduced the technique of using two separate attributes for the shaded relief and coloring of a bump mapped time slice. We used the shaded relief of the coherency data to modulate the colors of a variable density seismic amplitude time slice. This was done in an effort to render the time slice more interpretable by clearly identifying where the seismic data was discontinuous (i.e. faulted).

We reached the following conclusions:

- Bump mapping of single attribute time slices renders them more realistic and interpretable.
- Shaded relief, by itself, makes coherency displays more interpretable by making the discontinuities sharper and more clearly defined.
- Bump mapping an amplitude time slice with the shaded relief coherency clearly identifies discontinuities on the time slice without introducing visual confusion and produces an almost pre-interpreted time slice.

References

Al-Dossary, Saleh, Simon, Y. and Marfut, K., 2004, "Inter Azimuth Coherence Attribute for Fracture Detection", Expanded Abstracts, SEG international Expostion and 74th Annual Meeting.

Bahorich, M. S., and Farmer, S. L., 1995, "3-D Seismic coherency for faults and stratigraphic features", The Leading Edge, 1053–1058.

Blinn, James, "Simulation of wrinkled surfaces", Computer Graphics (SIG-GRAPH '78 Proceedings), pp 286-292, August 1978

Barnes, Arthur E., "Shaded relief seismic attribute", Short Note, Geophysics 68, 1281-1285.

Batson, R. M., Edwards K. and Eliason, E.M., 1975, Computer generated shaded relief images: J. Research, U.S. Geol. Surv., 3, No 4, 401-408.

Carter, Nicholle and Lines, L., 2001, "Fault imaging using edge detection and coherency measures on Hibernia 3-D seismic data", The Leading Edge, 64-69

Lynch, Steven, "Composite Density Displays", CREWES Research Report-Volume 15 (2003)

Marfut, Kurt J., Kirlin, R. L., Farmer, S. L. and Bahorich, M. S., "3-D seismic attributes using a semblance-based coherency algorithm", Geophysics 63, NO.4, 1150-1165.

Neves, Fernando A., Zahrani, M.S.and Bremkamp, S.W., 2004, "Detection of potential fractures and small faults using seismic attributes", The Leading Edge, 903-906