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Techniques of Volume Blending for Aiding Seismic Data Interpretation

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Summary

Multi-attribute analysis through volume blending is a powerful tool for enhancing seismic data for interpretation, but it remains under-utilized. It is most effective when a structural attribute, such as seismic discontinuity or shaded relief, is displayed in grayscale and combined with a stratigraphic attribute, such as reflection strength or average frequency, displayed in color. Shaded relief and amplitude gradient attributes are particularly useful in volume blending and complement discontinuity by showing different details in the data.

Introduction

Multi-attribute analysis is employed to aid seismic interpretation by making features of interest more visible, or by identifying anomalies. Four methods are common: volume blending, multi-attribute voxbody detection, attribute cross-plotting, and automatic pattern recognition (see James et al., 2002, for a review). Of these methods volume blending is the most visual approach and therefore the easiest for most seismic interpreters to apply.

While volume blending is widely used, its potential remains underutilized. This is in part due to the emphasis placed on seismic discontinuity for blending and the consequent lack of recognition that other attributes are equally suitable and offer complementary information, particularly azimuth, amplitude gradients, and shaded relief attributes. Using these attributes in conjunction with discontinuity can produce displays that bring out considerably more information and provide the seismic interpreter with new and clearer insights into the geology represented by his data.

Method

Volume blending combines the information of two or more seismic attributes through opacity or other methods. It is most effective one or more attributes are displayed in grayscale and another attribute is displayed in color. Attributes that are most effective displayed in grayscale tend to be structural attributes, and attributes that are most effective displayed in color tend to be stratigraphic attributes (Table 1).

Grayscale Attributes	Color Attributes
Discontinuity, dip, azimuth, shaded relief (dip-azimuth combined), amplitude change (vertical or lateral)	Original seismic, reflection strength, average frequency, response phase, response frequency, acoustic impedance, parallelism, AVO attributes

Table 1: Typical attributes to use in volume blending. Blending is most effective when one attribute is displayed with grayscale and another is displayed in color.

Seismic discontinuity is the most common attribute to display in grayscale for blending. It is particularly effective for this purpose when processed to enhance its resolution and thereby sharpen details. Its success, however, tends to overshadow the potential of other attributes, such as amplitude gradients, azimuth, and shaded relief.

Amplitude gradient attributes remain relatively poorly known. Oliveros and Radovich (1997) described a set of such attributes based on directional derivatives of the reflection strength or trace envelope normalized by the reflection strength. Marfurt and Kirlin (2001) discuss similar attributes. Amplitude gradients bring out details hidden in the reflection strength. The surprise is how much detailed and useful information is in the reflection strength.

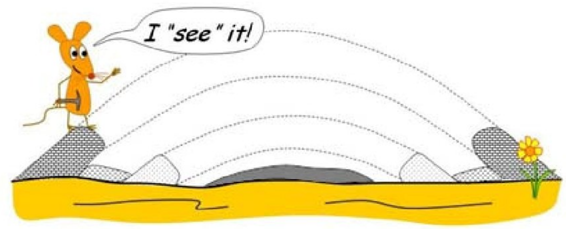

Figure 1: The shaded relief seismic attribute reveals details of geologic structure along a time slice using a simple reconstruction method that conceptually is like how a geologist mentally reconstructs an eroded structure from the dips and strikes of outcrops.

Shaded relief or "lightscape" is employed throughout geophysics to display digital data as illuminated apparent topography. Such displays facilitate geologic understanding because apparent topography often suggests true geology. First developed for elevation data, shaded relief has long been used with gravity and magnetic data, it is a natural product of synthetic aperture radar and side-scan sonar, and it is routinely applied to interpreted seismic horizons.

Shaded relief techniques are readily adapted to 3D seismic data to produce an attribute that resembles illuminated apparent topography when viewed as time slices or along extracted attribute maps (Barnes, 2003). The idea behind shaded relief is similar to that of a geologist who mentally reconstructs eroded structures through inspection of the strike and dip of small outcrops along the surface (Figure 1). The information in a shaded relief attribute is the same as that in standard combined dip-azimuth displays, but it presents this information in a way that is more readily appreciated by geologists. Shaded relief reveals details of geologic structure and indicates the orientation of faults and folds. It is particularly effective when blended with the original seismic data or with discontinuity and amplitude attributes.

The number of stratigraphic attributes greatly exceeds the number of structural attributes, and therefore there is much more freedom in the choice of attribute to display in color for blending. Generally, however, the most effective attributes tend to be reflection strength, average frequency, and acoustic impedance.

Examples

Two examples of the use of the vertical amplitude gradient are shown in Figure 2. In the first of these, the amplitude gradient is blended with the original seismic data. Where the data is coherent and has strong amplitude, the gradient is small, but where the data is noisier and has small amplitude, the gradient acts to show the "roughness" in the data. In the second example of Figure 2, the amplitude gradient is blended with the response frequency. The amplitude gradient has the property that it is strongest at troughs in the trace envelope, which is where reflections interfere. These troughs are exactly where the response frequency changes, as the response frequency is constant between consecutive troughs (Bodine, 1984). Thus the amplitude gradient blends well with response frequency enhance the image. Amplitude gradient attributes that measure lateral changes in amplitude are not commonly available, but they show even greater promise in enhancing details.

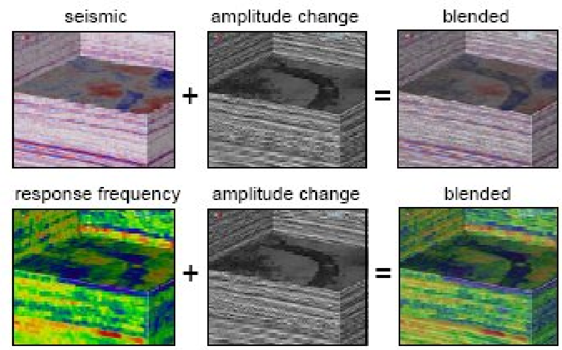

Figure 2: Two examples of blending with vertical amplitude change. In the upper example, amplitude change is blended with the original seismic data, and shows the smoothness or roughness inherent in the data.

An example of combining three attributes through opacity, reflection strength, shaded relief, and high-resolution discontinuity, is shown in Figure 3. This example goes a long way towards making the time slice look like a geologic map, and thereby aids the seismic interpreter's geologic intuition. This particular example highlights the value of volume blending for stratigraphic analysis.

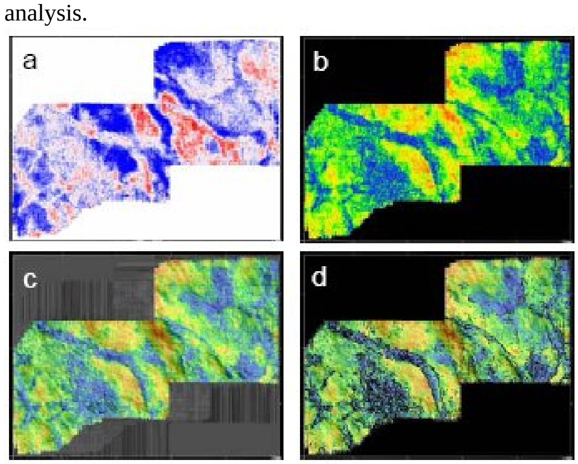

Figure 3: An example along a time slice of blending three attributes. (a) Original seismic data. (b) Reflection strength derived from the seismic data. (c) Reflection strength blended with shaded relief. (d) High-resolution discontinuity blended with reflection strength and shaded relief. This final image makes the features seen in the original data much clearer.

Another example of combining three attributes is shown in Figure 4. Here the attributes are the original seismic data, standard discontinuity, and reflection azimuth, and blending them aids structural interpretation by making the faults stand out. The discontinuity attribute reveals the location of the faults, and the azimuth attribute gives an indication of their throw, which cannot be deduced from the discontinuity alone. The azimuth attribute in this example was filtered through vertical median filtering to produce a cleaner and more interpretable image. While such filtering can remove small scale features, it often produces superior images in blending.

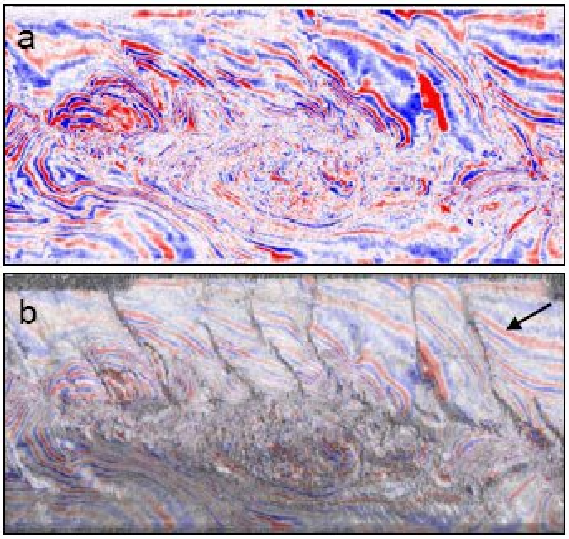

Figure 4: An example of blending to aid structural interpretation. (a) Original seismic data. (b) Original seismic data blended with discontinuity and reflection azimuth to enhance faults and give an indication of their relative displacement. The black arrow shows the effective direction of illumination.

Conclusions

Volume blending is made more effective by using structural attributes that complement seismic discontinuity. The most valuable of these attributes are amplitude gradients, azimuth, and shaded relief or "lightscape." These attributes are often improved for blending through filtering, though at the expense of small scale detail. Blending two or three attributes produces displays that highlight important elements of geologic structure and stratigraphy, thereby aiding seismic interpretation.

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