Texture analysis aids interpretation

Studying seismic data volume textures can lead to a more intuitive geological presentation.

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Texture-based evaluation of data is done in different fields, and several commercial applications exist — in paper and saw mills, rock and textile industries, the field of medicine and our own remote sensing — where we analyze multispectral images.

The term "texture" is used to represent the available detail in an image or surface. It is characterized by "tone" (which refers to intensity) and "structure" (which refers to spatial relationships). There are two types of textures — regular and irregular. Regular textures, as seen on a brick wall, can be composed out of a small building-block or "primitive." Irregular textures, as seen on an image of clouds or grass, cannot be constructed by using a primitive and require statistical techniques for their analysis. Second-order statistical techniques have been used for studying textures as they are more sensitive and intuitive than the first-order applications.

The most basic second-order statistical measure is called the gray-level co-occurrence matrix (GLCM). GLCMs have been used to study images of rock surfaces. Gray levels refer to the range of values of pixels in the image. A GLCM is a square matrix which has dimensions equal to the number of gray levels in the image and elements corresponding to the relative frequency of occurrence of pairs of gray levels of pixels (in the image) separated by a certain distance in a given direction. These individual values represent the probabilities of co-occurrence of pairs of pixels in the image. The immediate neighbors of any pixel can lie on four possible directions: 0°, 45°, 90° and 135°. GLCMs are constructed by observing pairs of gray-level values at fixed distances from each other in a given direction. An average GLCM is then computed and normalized (all values in the matrix are divided by the sum of the values). The individual values in the matrix now represent the probabilities of co-occurrence as required by definition.

For application to seismic data, the gray levels refer to the dynamic range of the data. For example, 8-bit data will have 256 gray levels. A GLCM computed for this data would have 256 rows and 256 columns (65,536 elements). Similarly, 16-bit data would have a matrix with 429,496,720 elements. Computation of GLCMs with such high number of elements could be overwhelming even for fast computers. In view of this, the seismic data is re-scaled to 4-bit, 5-bit or 6-bit formats. In practice, it has been found that this does not result in any significant differences in the computed properties.

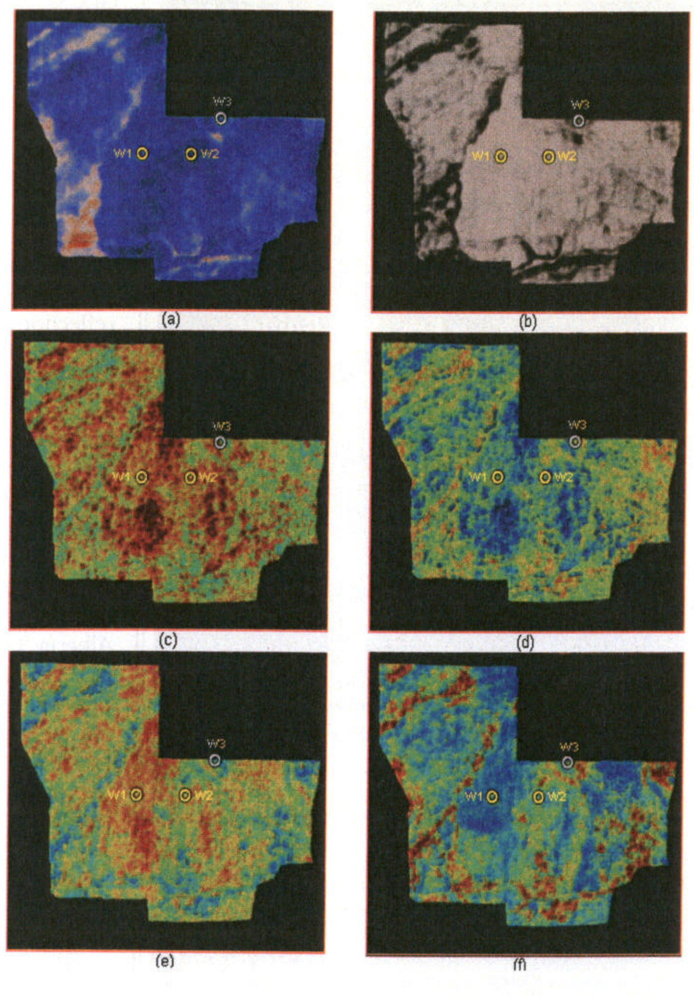

Figure 1. Texture attribute analysis of a migrated stack reveals interesting information about adjacent wells. (Image courtesy of Arcis Corp.)

While GLCMs give us all this information, they are not accurate enough to make quantitative interpretations. They need to be matched by extracting a number of characteristic properties of each matrix. In other words, it is possible to generate texture features by applying statistics to co-occurrence probabilities. These statistics identify some structural aspects of the arrangement of probabilities within a matrix, which in turn reflect some characteristic of the texture. There are various types of statistics that can be used. R.M. Haralick and his colleagues demonstrated in 1973 the derivation of 14 different measures of textural features from GLCMs. Each of these features represents certain image properties as coarseness, contrast or texture complexity. However, due to redundancy in these statistics, the following four measures generate the desired discrimination without any redundancy:

- Energy is a measure of textural uniformity. Energy is low when all elements in the GLCM are equal and is useful for highlighting geometry and continuity.
- Entropy is a measure of disorder or complexity. Entropy is large for surfaces that are texturally not uniform. In such cases, many GLCM elements have low values.
- Contrast is a measure of the contrast or amount of local variation present in an image or surface. Contrast is high for contrasted pixels while its homogeneity will be low.
- Homogeneity is a measure of the overall smoothness of an image. Homogeneity measures similarity of pixels and is high for GLCMs with elements localized near the diagonal. Thus, homogeneity is useful for quantifying reflection continuity.

For 3-D seismic volumes, computing GLCM texture attributes at one location yields estimates of localized features at that point. Repeating the computation of these attributes in a sequential manner throughout the volume transforms the input seismic volume into the above four texture attributes. High-amplitude continuous reflections generally associated with marine shale deposits have relatively low energy, high contrast and low entropy. Low-amplitude discontinuous reflections associated with massive sand or turbidite deposits have high energy, low contrast and high entropy. Low-frequency, high-amplitude anomalies generally indicative of hydrocarbon accumulation generally exhibit high energy, low contrast and low entropy relative to non-hydrocarbon sediments.

Case study

This study focuses on an area in southern Alberta. The target zone is Lower Cretaceous Glauconitic fluvial deposits that have been productive in the area. A 3-D seismic survey was acquired in order to create a stratigraphic model consistent with the available well control and matching the production history. The ultimate goal was to locate the remaining undeveloped potential within the fluvial deposits and to find additional drilling targets within untested fluvial sandstones and within the area in general. The model developed was based on a comprehensive geophysical and geological interpretation where the geological data is closely integrated into the geophysical model. This was required due to the fact that the Lower Cretaceous system in the study area has exhibited a very complex fluvial environment through time that makes single-discipline interpretations very difficult.

As the objective was stratigraphic in nature, the seismic data was processed with the objective of preserving relative amplitudes. Prestack time migration improved our ability to resolve stratigraphic objectives and extract high-quality seismic attributes and so was run on the data. It resulted in an improvement in the stack image in terms of frequency and crisper definition of features as it contributes to energy focusing and improved image positioning prior to stack.

Strat-cube displays are useful for seismic interpreters as they provide them with new insights for studying objects in a 3-D perspective, which in turn sheds light on their origin and their spatial relationships. Strat-cubes are subvolumes of seismic data (or their attributes) bounded by two horizons that may not necessarily be parallel. Figure 1 shows strat-cube displays covering the zone of interest and at the level of the reservoir. Figure 1b shows a strat slice from a coherence volume. While a better definition of some of the subsurface features can be interpreted than in the migrated stack, in this display not much information is forthcoming about the areal extent of the productive sands.

Texture attribute analysis was run on the sub-volume covering the broad zone of interest, and Figures 1c to 1f depict the energy, entropy, homogeneity and contrast attributes. Figure 1c shows high values of energy associated with the fluvial deposits, and the depicted areal distribution is seen as per expectation. However, this inference needs corroboration with the other texture attributes, and we see that in Figures 1d and 1e. High energy in 1c is seen associated with low entropy (1d) and high homogeneity (1e). Another observation seems interesting here. Well W3 (to the northeast of W2) has a different pressure and apparently does not share the same producing formation with W2. The low coherence (Figure 1b) indicates an island-like feature surrounding this well, and the texture attributes (contrast in 1f) confirm this observation.

While it is possible to interpret the productive sands on gamma ray logs for wells W1 and W2 (having values less than 50 API units or so), the texture attribute displays provide a more intuitive presentation of the geology — the areal spread of these productive sands. This has been confirmed by the application of this texture analysis procedure to other case studies involving fluvial deposits and carbonate porosities. E&P