GC Waveform Classification Proves Itself a Valuable Tool*

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General Statement

The shape and character of the seismic waveform is often used to characterize reservoir quality. This is because the seismic waveform carries information about the phase, frequency and amplitude – and any variation in these parameters is considered reflective of the lateral variations in lithology, porosity and fluid content.

If the shape and character of seismic waveforms in a given target zone can be studied using some pattern recognition type of a process, and then displayed in a map view, the display would indicate seismic facies variation at the target level.

One approach to pattern recognition is with the use of neural networks to compare seismic waveforms and group them into different classes. Under this approach two types of methods could be distinguished, namely *unsupervised* and *supervised* classifications. In the unsupervised method – apart from defining an analysis interval – no other *a priori* information is used for the classification of seismic traces into groups or classes. The supervised method uses the known information available at specific well locations for the classification process. In this article, we discuss the unsupervised approach.

Method

There are two steps to the process in the unsupervised classification:

1) As the first step, all the traces within the interval of interest are analyzed using a neural network, and a series of synthetic traces (according to the user-defined number of groups) are generated that best represent the different shapes in the interval. These

synthetic traces are arranged in a progression (assigning numbers to these traces), which is examined to get a feel for the shapes of the waveforms.

2) As the second step, each trace in the interval is compared with the different synthetic traces and those traces that have maximum correlation with a given synthetic trace are classified into a group.

The resulting map is essentially a facies map, which itself is essentially a similarity map of the actual traces to the different synthetic traces. The seismic facies so generated also can be overlaid on a vertical seismic section to study their lateral variation. Evidently, this method does not require any input in the form of any well log or any guidance about where the character divisions should occur.

Once a seismic facies map is generated using unsupervised waveform classification, it is possible to apply the process again to individual classes. In that sense, the process is *hierarchical* and subdivides each class into smaller subsets. Iteratively applying it enhances the resolution of each class. We discuss these two processes in the following application.

Example

Western Canada's Middle Triassic Doig Formation is composed of argillaceous siltstone and calcareous shale. It is uncomformably overlain by the Halfway Formation and itself overlays the Montney Formation. It is seen to occur in northwestern Alberta, northeastern British Columbia and southern Yukon provinces of Canada.

While the maximum thickness of the Doig Formation reaches over 180 meters in the foothills of the Rocky Mountains, it thins out to the north and the east. Within the Doig Formation, thick sandstone bodies occur within the shale, and many of them are found to be economic hydrocarbon reservoirs – hence the attraction for their exploration and development.

Examination of the available core from the Doig sandstone reservoirs suggests an association between sedimentary facies such as shoreface, offshore transition and offshore/shelf. Phosphates and other accessory minerals in the Doig sandstone bodies can drive the gamma ray tool response and mask the sands, so correct identification of the bodies on logs requires multiple curves. The facies change quickly in both the vertical and the horizontal directions. Recognition of these facies changes and characterization of the Doig sandstones serves as a useful input for exploration and development purposes.

In Figure 1 we show a segment of a seismic section from a 3-D volume from northeast British Columbia. After correlation with the available log control, the Doig sandstone signature was located on the seismic data and is indicated with yellow arrows. These high amplitude events seem isolated, but appear to have a deposition pattern on the horizon slice shown in Figure 2a. Their deposition outline has been traced in black, as indicated.

Next, to study the facies variation exhibited by the sandstone, the upper horizon (in green) was tracked as the zero crossing event. For selecting the interval covering the seismic signature, the lower horizon was not picked as it was not a continuous and smooth marker. Therefore, the upper horizon was used to generate the lower horizon by adding a constant 24 ms to it. This gives a consistent slab of waveform data bounded by the green and the cyan horizons, around the signature of the Doig sandstone and comprising a peak in between two troughs.

For performing waveform classification, the *a priori* specification of the number of desired classes was chosen as 12. The different classes with their color codes are shown in the inset next to Figure 2b, and the shapes of the individual waveforms in the inset above. Notice, the facies map in Figure 2b shows a variation in terms of the colors, but the overall facies pattern seems to follow the sand boundary overlaid on it.

Realizing that the number of classes chosen may not have yielded an optimum facies variation, we next decided to adopt the *hierarchical waveform classification*. We begin with four classes and the facies variation is shown in Figure 3a.

On this display we notice that cyan and yellow colors do not represent the Doig sands of interest – but the blue and red colors do. So, next, we sub-divide these two colors and the results are shown in Figure 3b. Notice, this display shows an even distribution to all the colors within the sand boundary, and so a reasonable facies variation.

Conclusions

Seismic waveform classification thus represents a useful tool for studying the facies variation within an amplitude map representing a particular lithology or different lithologies, which happens to be the Doig sandstone in this case. This classification represents a qualitative way of extracting useful facies variation. More work needs to be done in such cases to ascertain the authenticity of such facies variations and their correlation with the available well log control. Such works will form the basis for similar articles in future issues of the Geophysical Corner.

Acknowledgments

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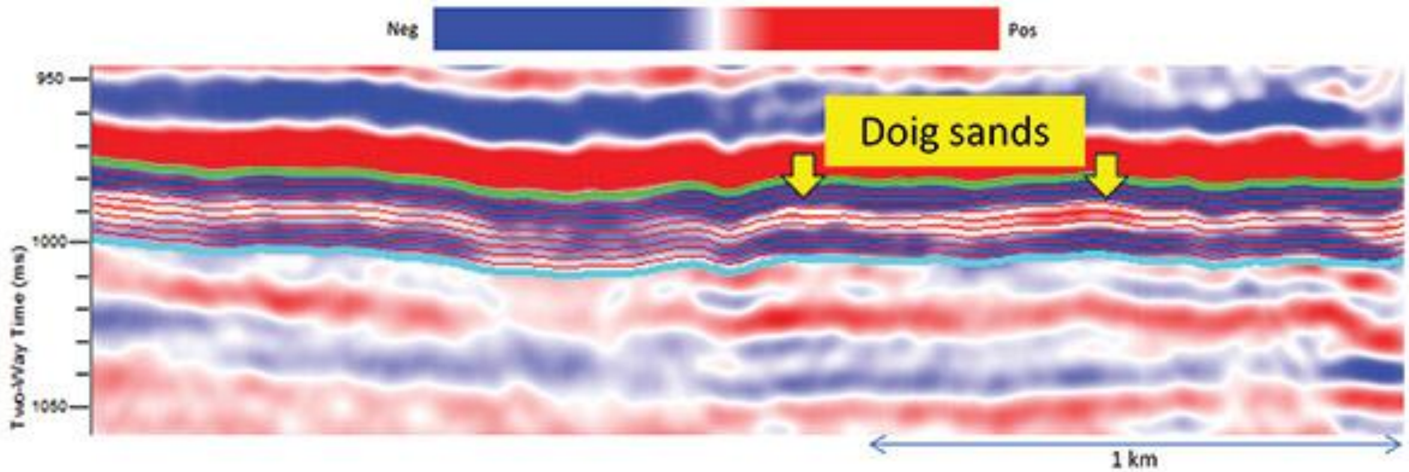

Figure 1. A segment of a seismic section shows the signature of the Doig sandstone as high positive amplitudes. To isolate the sand zone the upper horizon is picked, which looks quite smooth. The lower horizon, peak, trough or zero crossing if picked, however, looks quite haphazard and does not yield a consistent slab of waveform data that could be used to run waveform classification. The upper horizon is used to generate the lower horizon by adding 24 ms to it. The interval between the two horizons is divided into 10 parallel horizons.

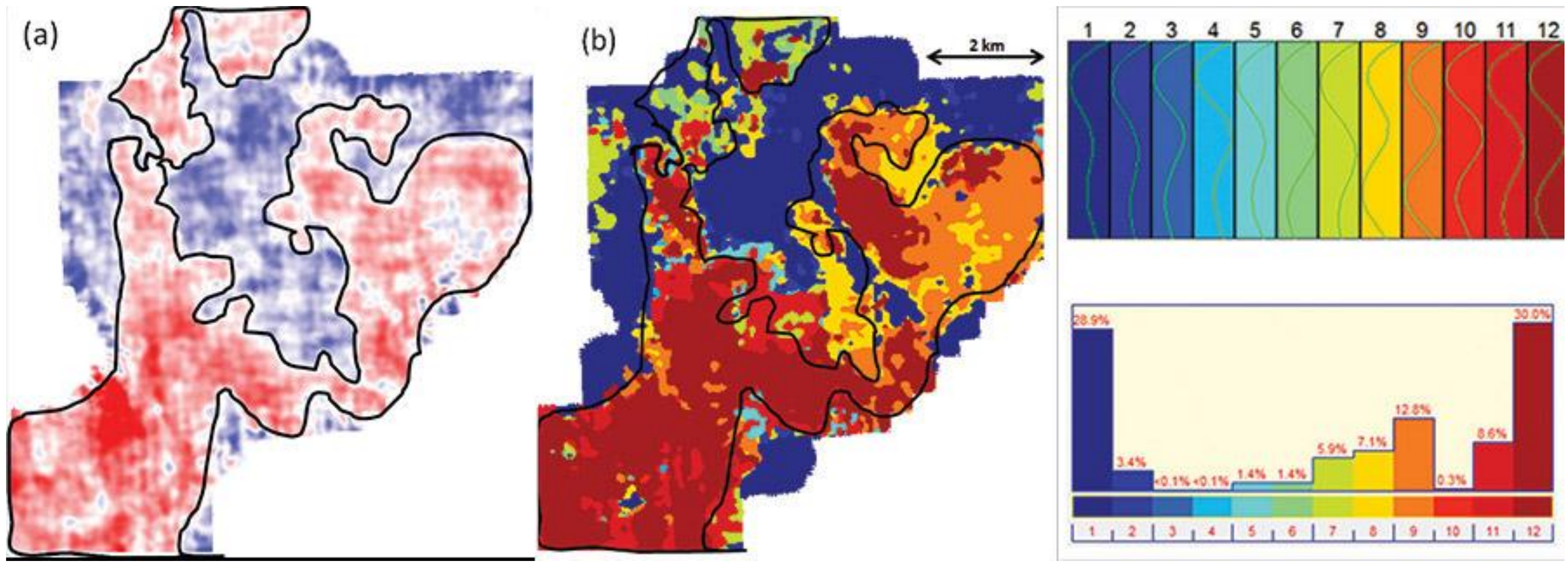

Figure 2. (a) Horizon slice through the seismic volume and along parallel horizon five, passing through the Doig sandstone. (b) Waveform classification performed by choosing 12 classes. The individual waveform in each of the 12 classes is shown in the inset and the relative contribution of the individual classes is shown below.

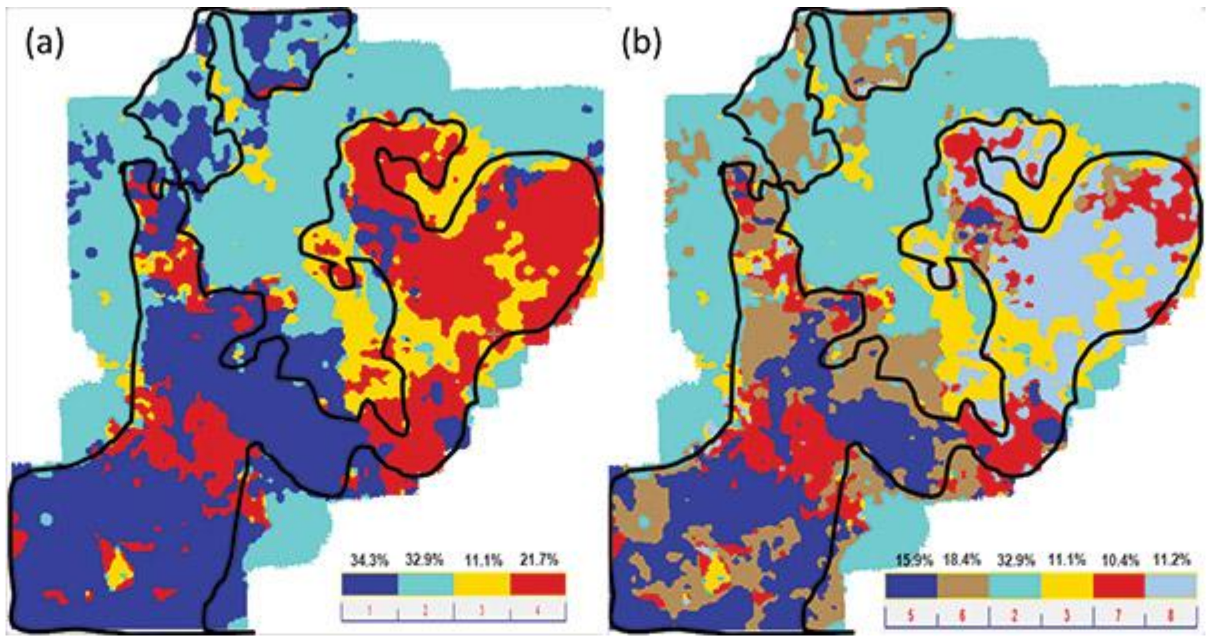

Figure 3. Waveform classification map generated by (a) using 4 classes; (b) subdividing classes 1 and 4 in (a). Notice the higher level of detail that is seen in (b) as compared with (a), within the sandstone boundary drawn in black.