GCQuantifying Confidence in Horizon-Picking*

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General Statement

Risk analysis is a crucial task in making drilling decisions and involves many factors, such as well logs, modeling results, production maps and interpretation quality. In his book on 3-D seismic interpretation, AAPG award-winning member Alistair Brown presents a workflow for the quantification of interpretation confidence. In this workflow, picks at 0, 1, and 2s indicated low, medium and high reflector quality. The interpreter then generates a confidence map from a coarse grid of picked lines.

In practice, such interpretation confidence maps are commonly excluded from risk analysis, simply because such quantification is not easy. In this article we demonstrate the quantification of horizon-picking confidence, using two seismic attributes that are sensitive to chaotic features – namely the Sobel-filter and disorder attributes.

Method

Our study area is located within the Halten Terrace, Norwegian North Sea. The area involves rift-related geologic structure, particularly a system of listric faults with a weak, soft layer of salt between basement and the upper sedimentary rocks.

Figure 1a shows the time structure map of an interpreted horizon in the study area.

Figure 2 shows representative vertical slices through the seismic amplitude data.

While the horizon is relatively easy to pick in many areas, there are other areas where it is contaminated by steeply dipping migration alias artifacts. Autopickers work poorly on this horizon. In order to quantify the confidence of the horizon picking task, we calculate attributes that are sensitive to chaotic features, such as salt, karst and seismic noise. The general idea is that the noisier the data, the less confidence the interpreter will have in picking a horizon.

The Sobel-filter implementation of coherence (the same Sobel filter as in your digital camera software) independently computes first derivatives of the seismic amplitudes between neighboring traces along the X and Y directions and combines them to form a coherence-like image. Disorder, on the other hand, cascades second derivatives in the X, Y and time directions.

Coherence algorithms are designed to emphasize continuous reflectors disrupted by incoherent structural and stratigraphic edges. In contrast, the disorder algorithm is designed to emphasize noise and considers edges to be signal. Both noise estimates are computed along local reflector dip and are normalized by the energy of the data within the analysis window.

Example

Figure 1b and Figure 1c show the results of the Sobel filter and disorder attributes extracted and smoothed along the same horizon in Figure 1a. Most of the horizon corresponds to relatively low coherence and high disorder, suggesting that seismic data quality is generally low. Such data quality impacts the continuity of time-structure maps.

In line AA' shown in Figure 2a, the right part of the image corresponds to a smooth time-structure map and high values of coherence and low values of disorder (appearing as green in Figure 1b and Figure 1c) corresponding to a smoother part of the map in Figure 1a. In contrast, line CC' in Figure 1c exhibits poor data quality at the target horizon that gives rise to lower coherence and higher disorder displayed as yellow and red in Figure 1b and Figure 1c, and also results in a less smooth time-structure map in Figure 1a.

Interestingly, the horizon on the west side of line CC' (Figure 1c), shows high coherence (in green) but medium disorder (in yellow). Note that while the horizon is picked as a (white) peak, it is overlain by a higher coherence event that appears as a (black) trough. The coherence algorithm appears to measure the continuity of this higher amplitude neighboring reflector. In this example, the disorder attribute represents data quality more accurately.

Conclusion

In summary, seismic attributes that are sensitive to chaotic features and noisy data, such as coherence and disorder, can be used to quantify horizon-picking confidence. Of the two attributes, disorder is relatively insensitive to faults and provides the more accurate result.

While both attributes are a measure of data quality along a picked reflector, they are not a measure of erroneously picking a more coherent neighboring reflector. Such interpreter error may be the biggest risk of all in the final map.

Acknowledgment

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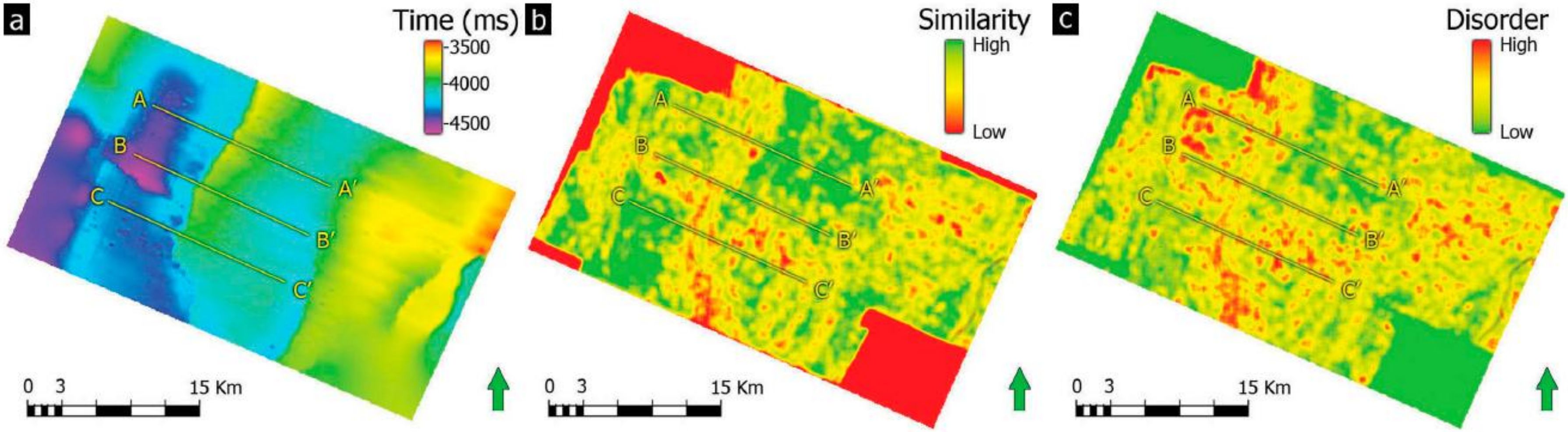

Figure 1. (a) Time-structure map of yellow horizon shown in Figure 2 (below), and corresponding horizon slices through the (b) coherence, and (c) Disorder volumes. Coherence is sensitive to structural and stratigraphic edges as well as noise. By design, disorder is insensitive to edges and only sensitive to chaotic noise.

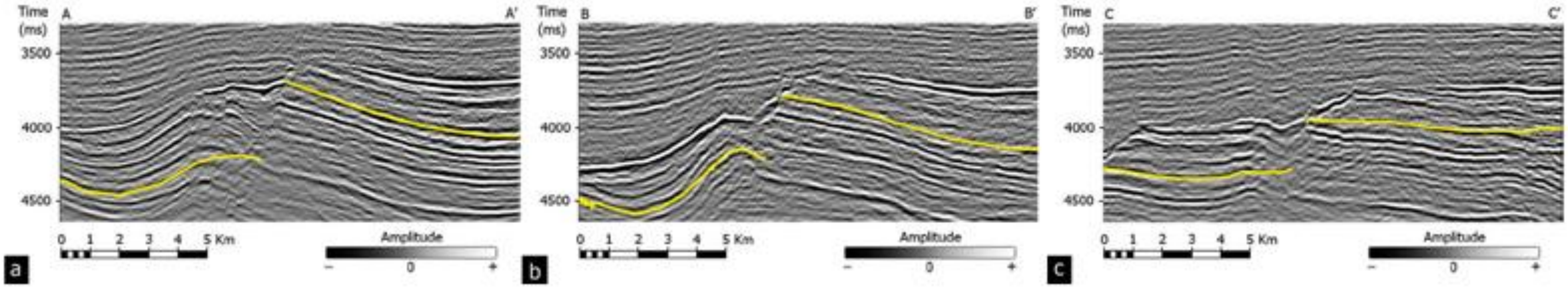

Figure 2. Three vertical slices through the seismic amplitude volume showing the yellow picks used to make the map in Figure 1a. (a) In line AA' the horizon on the east (right) side is relatively continuous and easy to pick. (b) In line BB' the data quality is poor along the entire picked line. (c) In line CC' the left side of yellow horizon is also noisy, but corresponds to a high coherence (green) area in Figure 1b. In this example, the coherence map is sensitive to the overlying, higher amplitude continuous (black) trough.