Computing volumetric estimates of the signal-to-noise ratio - Program disorder

Contents

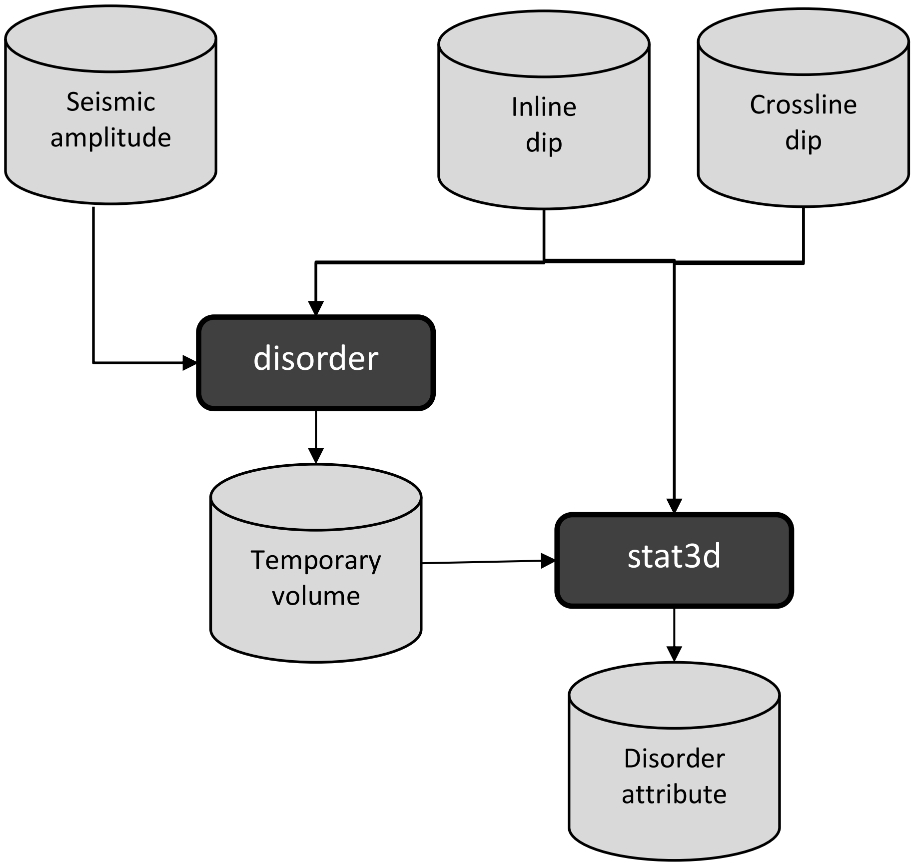
Overview

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. Program **disorder** provides a good measure of the difficulty in mapping a horizon.

Computation flow chart

To compute disorder attributes, the inline and crossline dip components of the seismic amplitude data need to be computed first, via dip3d program. Next, disorder program will perform disorder attribute calculation on the seismic amplitude data to generate a temporary disorder attribute volume. Finally, the temporary volume and the dip components are used by stat3d program to calculate the standard deviation of the temporary volume, which is the final result.



Output file naming convention

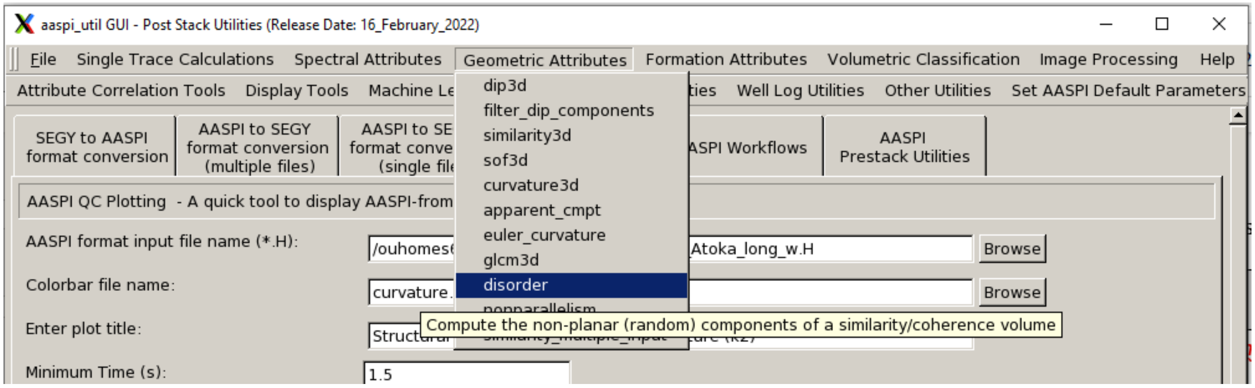
Program **disorder** always generates the two output files:

Output file description	File name syntax
Program log information	disorder_*unique_project_name_suffix*.log
Program error/completion information	disorder_*unique_project_name_suffix*.err
Disorder in the analysis window	disorder_*unique_project_name_suffix*.H

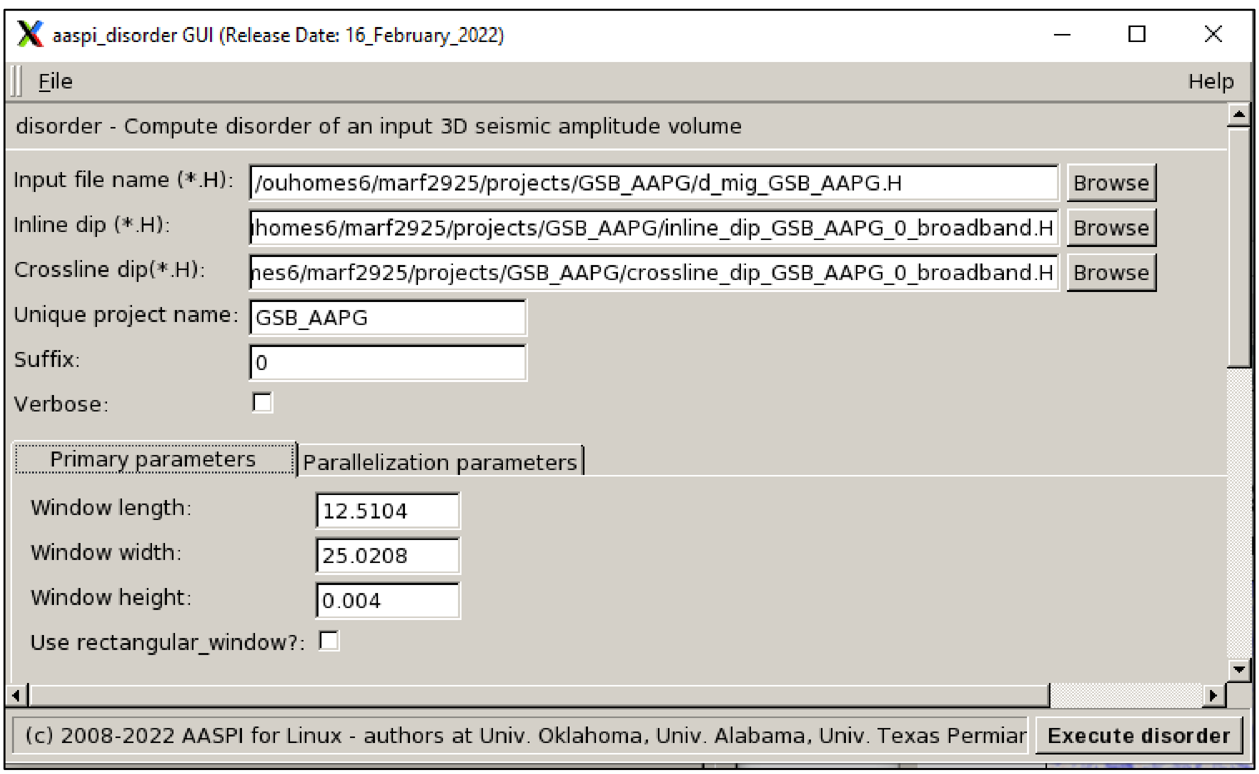
where the values in red are defined by the program GUI. The errors we anticipated will be written to the *.err file and be displayed in a pop-up window upon program termination. These errors, much of the input information, a description of intermediate variables, and any software trace-back errors will be contained in the *.log file. The program outputs a single output volume called *disorder_unique_project_name_suffix.H* .

AASPI Implementation

Program **disorder** is launched from the *Geometric Attributes* tab in the **aaspi_util** GUI:



Clicking on *disorder*, the following GUI appears:



There are only a few parameters: the input seismic amplitude file name, and the file names of the inline and crossline dip components computed previously using program **dip3d**. The other parameters define the dimension of analysis window in which the computation takes place. Here, the default (small) window contains five traces by three samples for a total of 15 voxels. If I had chosen Use rectangular windows the analysis window would be rectangular and contain 9 traces and 5 samples for a total of 27 voxels.

Theory of the disorder attribute

Disorder is a recent attribute developed by Al-Dossary (2013). His original algorithm cascades second derivatives in the x, y, and time directions on a window of the energy (or the power) of the data. This is equivalent to squaring the data and then filtering it with a 3x3x3 operator:

$$L = \left\{ \begin{bmatrix} 1 & -2 & 1 \\ -2 & 4 & -2 \\ 1 & -2 & 1 \end{bmatrix}, \begin{bmatrix} -2 & 4 & -2 \\ 4 & -8 & 4 \\ -2 & 4 & -2 \end{bmatrix}, \begin{bmatrix} 1 & -2 & 1 \\ -2 & 4 & -2 \\ 1 & -2 & 1 \end{bmatrix} \right\} \qquad (1)$$

The original algorithm suffers from two main drawbacks: (1) it is sensitive to the local average amplitude, and (2) it gives rise to diagonal artifacts. To compensate for the local average amplitude sensitivity, we modified the algorithm by normalizing the attribute by the RMS magnitude of the windowed data:

$$Disorder = \frac{\mathbf{L} \cdot \mathbf{e}}{\|\mathbf{L}\| \|\mathbf{e}\| + \varepsilon}, \qquad (2)$$

where **L** is given by equation 1, **e** is a volume of amplitude energy, the dot indicates a triple inner product, ||L|| and ||e|| indicate the L_2 norm, or magnitude, of the operator and data, and ε is a small number to prevent division by zero. To minimize diagonal artifacts, we compute this attribute

Example 1: Finding areas that are hard and easy to pick

Figure 1 shows an interpreted time-structure map of a horizon in a survey acquired by PGS in the US Gulf of Mexico. The missing picks in the southern part are due to two salt domes. Figures 2-4 show the coherence, GLCM entropy, and disorder attributes extracted along the horizon. Figures 5-8 show vertical slices through the amplitude, coherence, GLCM entropy, and disorder volumes along line AA'. Note that coherence highlights faults and other discontinuities but fails to delineate the very-hard-to-pick region between two salt domes. In contrast, GLCM entropy is so sensitive to textural difference that it finds even the easy-to-pick areas to have high entropy. In contrast, the disorder attribute more accurately represents the horizon-picking confidence. By construction, it is also insensitive to faults.

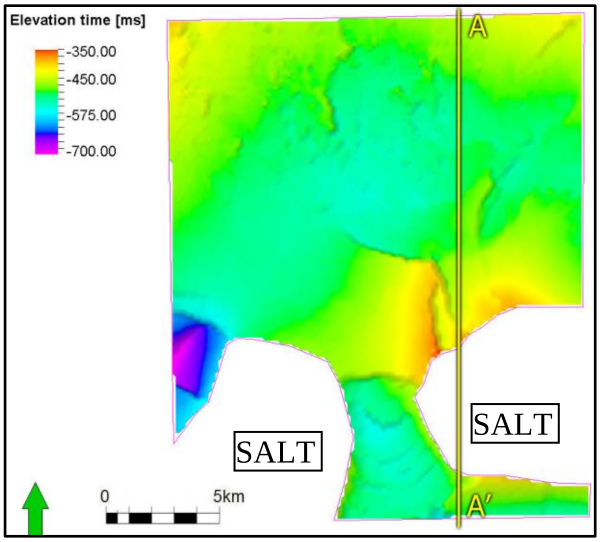


Figure 1. Time-structure map.

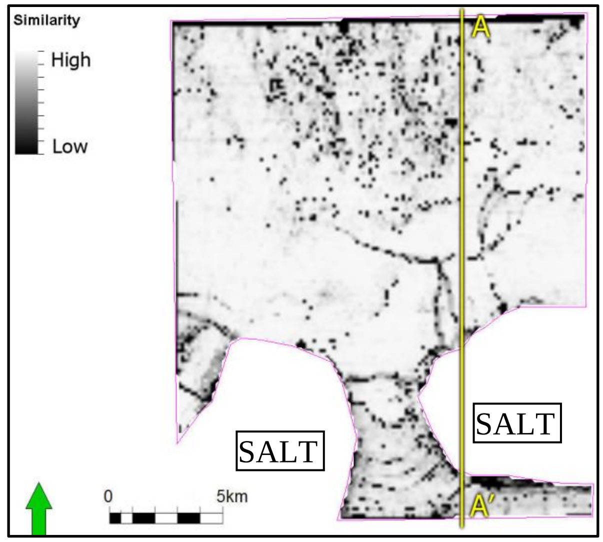


Figure 2. Horizon slice through coherence, delineating the faults as well as noise in the northern part of the survey.

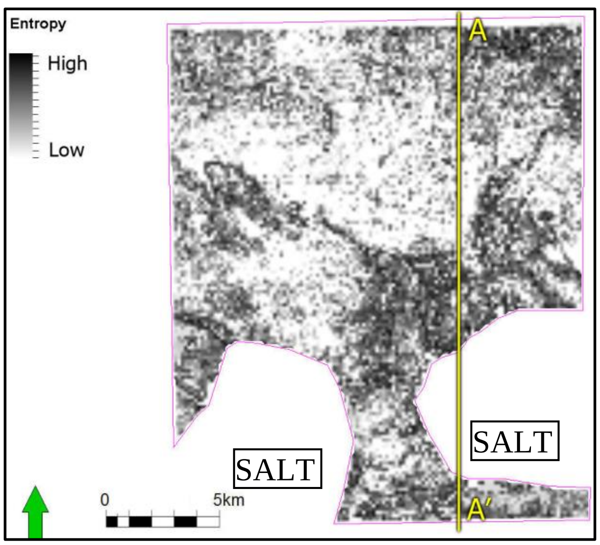


Figure 3. Horizon slice through the GLCM entropy volume showing easy-to-pick areas as having low entropy.

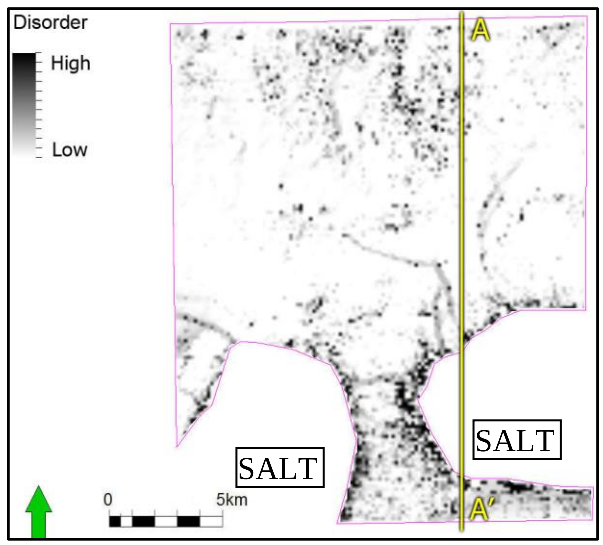


Figure 4. Horizon slice through the disorder volume. The fault responses are suppressed, but the more random incoherent in the northern part of the volume and near the salt domes are highlighted.

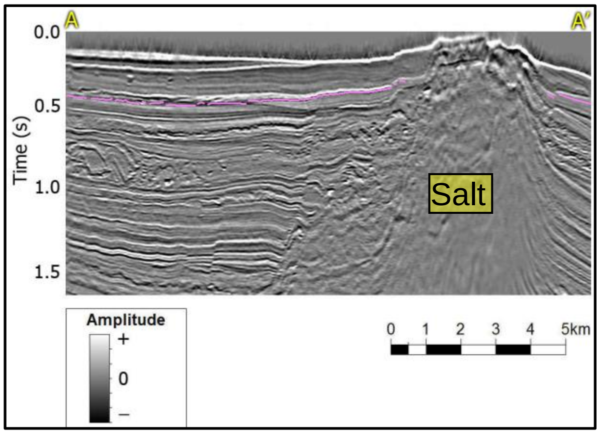


Figure 5. Vertical slice AA’ through the amplitude volume.

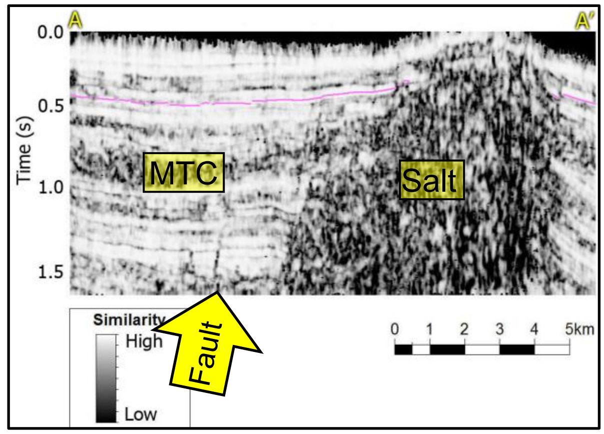


Figure 6. Vertical slice AA’ through the coherence volume. Note both the salt and a mass transport complex (MTC) appear with low coherence. Several faults are also highlighted.

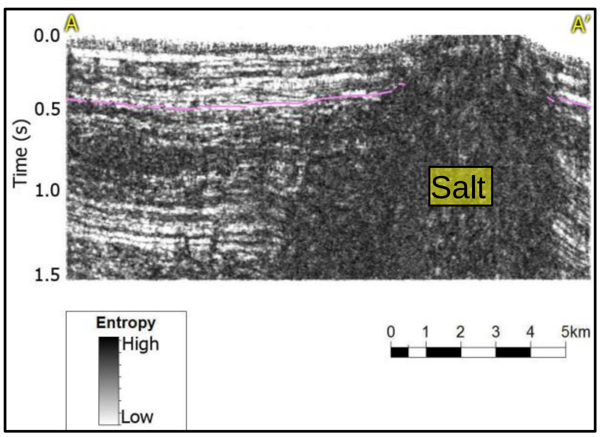


Figure 7. Vertical slice AA’ through the GLCM entropy volume.

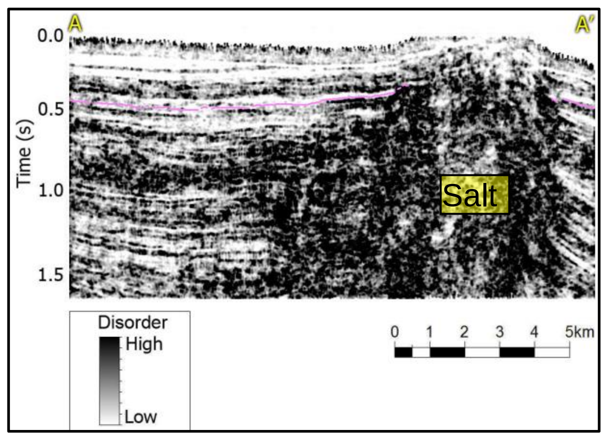


Figure 8. Vertical slice AA’ through the disorder volume. Note that the two faults are no longer highlighted.

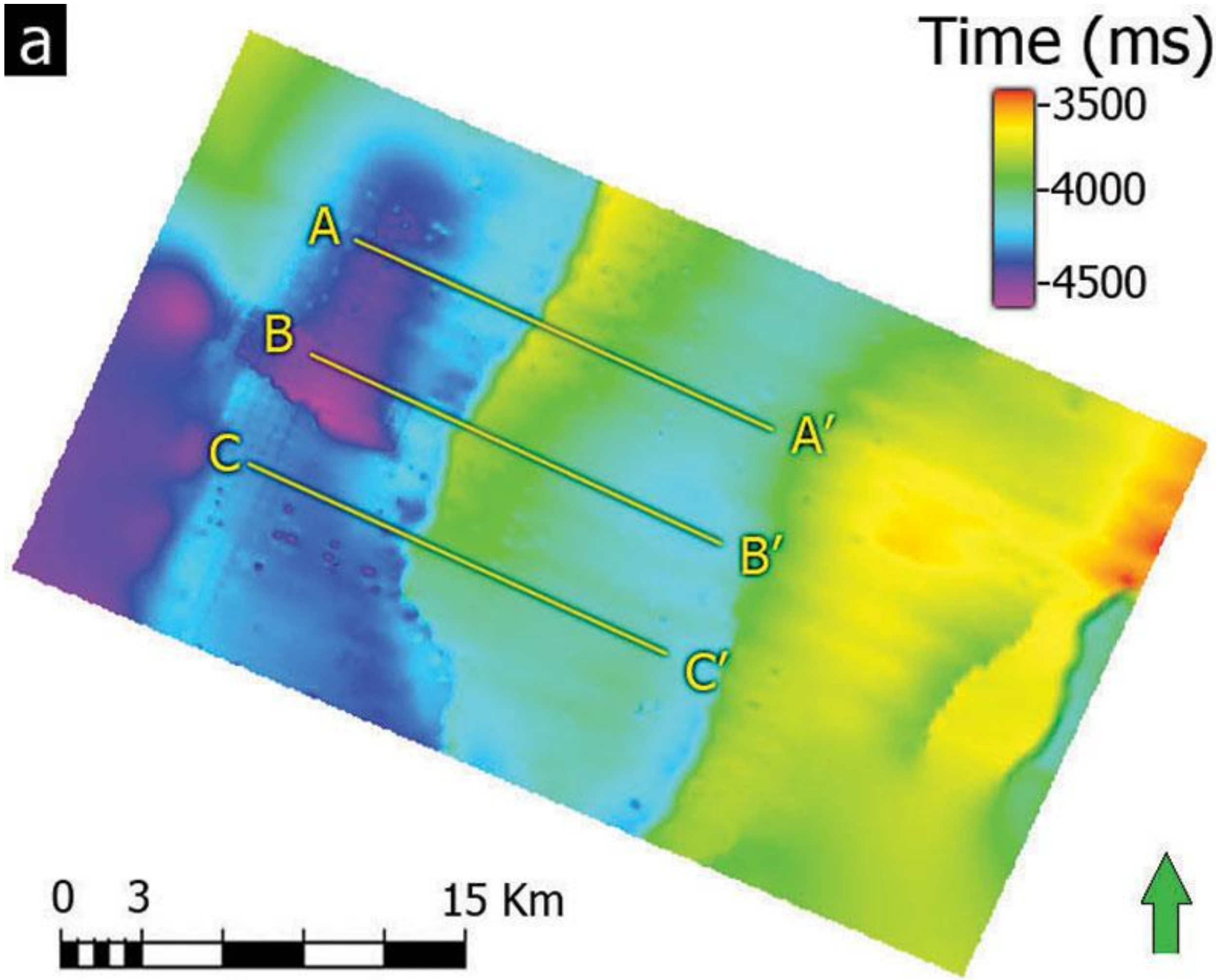
Example 2: Quantifying the confidence of a horizon pick

The next example was published in the AAPG Explorer by Ha and Marfurt (2014). The 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 9a shows the time structure map of an interpreted horizon in the study area whereas Figure 10 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. Coherence (similarity) algorithms are designed to emphasize continuous reflectors disrupted by incoherent structural and stratigraphic edges. In contrast, the disorder algorithm is design to emphasize noise and considers edges to be signal. Both coherence and disorder estimates are computed along local reflector dip and are normalized by the energy of the data within the analysis window.

Figures 9b and 9c show the results of the Sobel filter similarity and disorder attributes extracted and smoothed along the horizon shown in Figure 9a. 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 10a, 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 contrast the left side of the horizon along line CC’ exhibits high coherence (appearing again as green) but high disorder (yellow and red). In this example, the coherence estimate is contaminated by a nearby, higher amplitude reflector, suggesting higher confidence than we have in our picks.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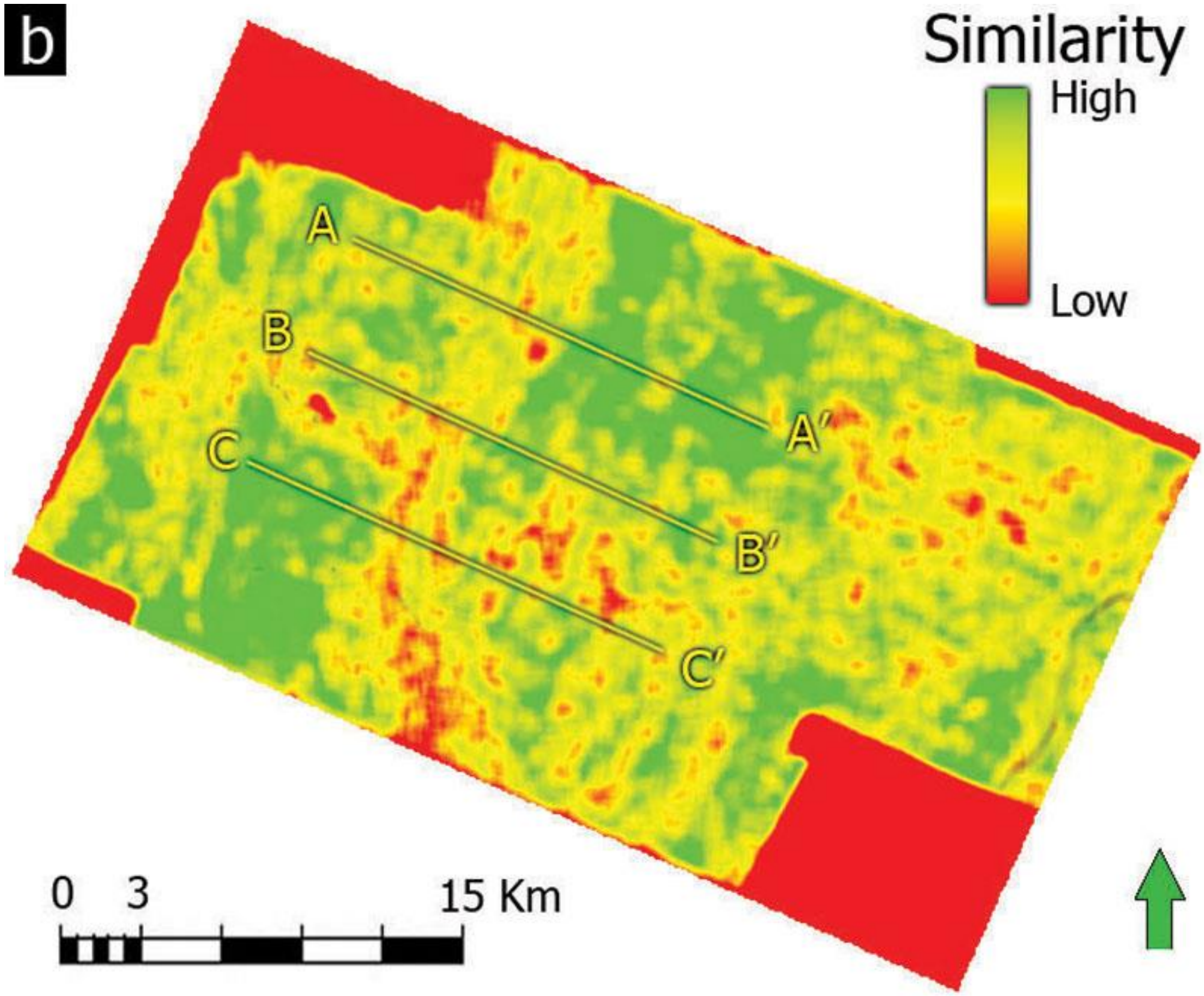
b
Similarity
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Low
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B
B′
C
C′
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3
15 Km

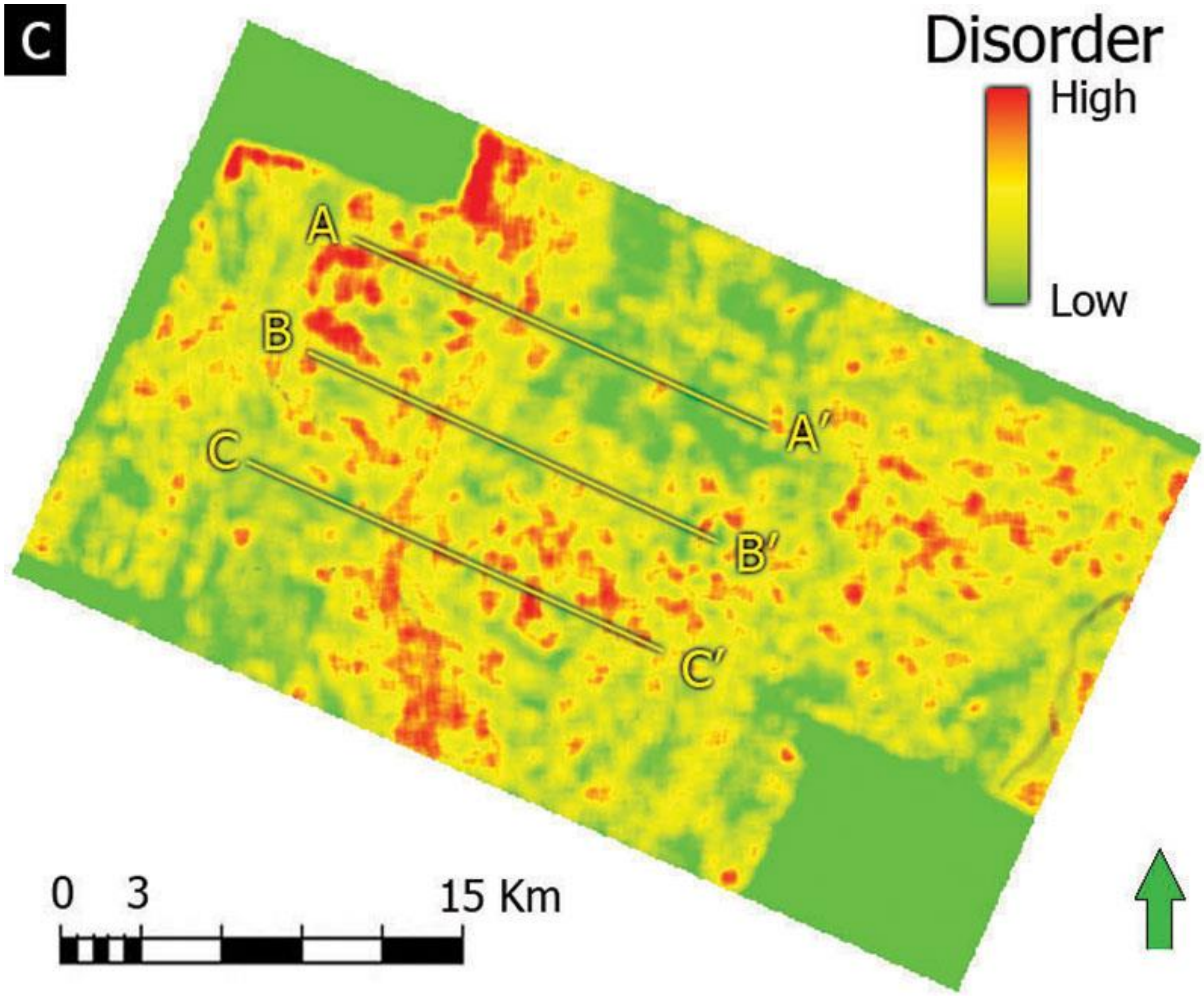
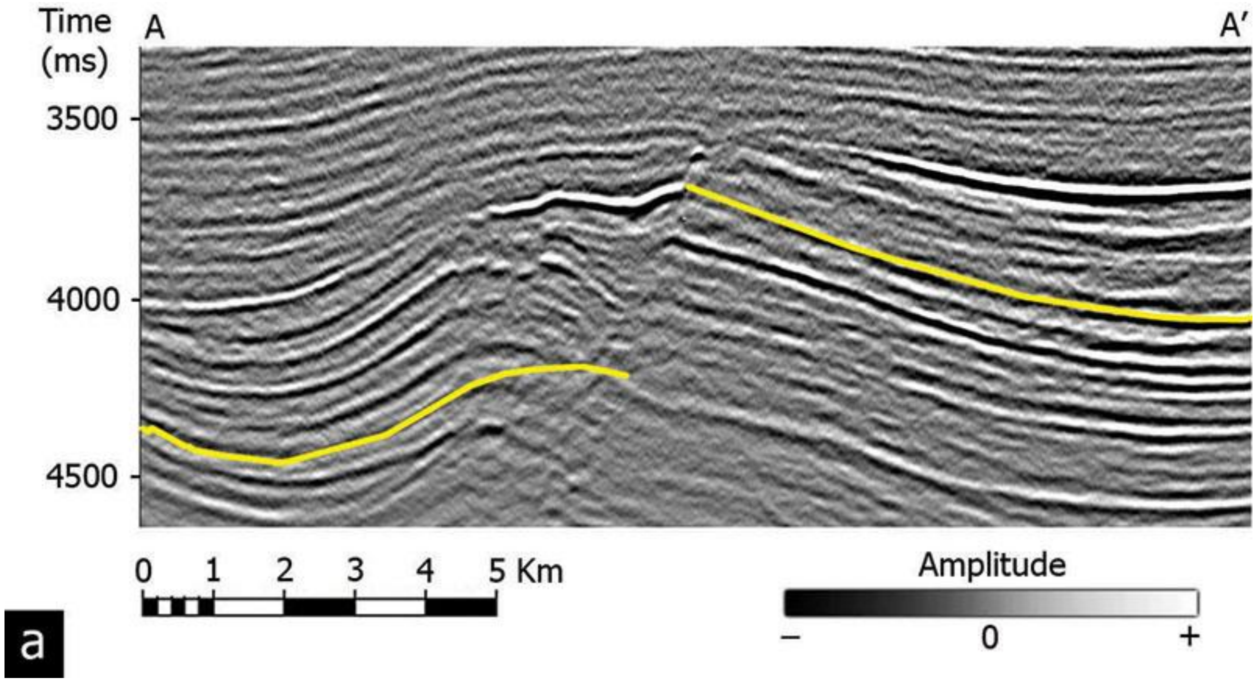


Figure 9. (a) The time-structure map corresponding to the yellow pick show in Figure 10.. Our objective is to determine which parts of these horizons are accurate, and which parts may be relatively inaccurate. (b) The corresponding horizon slice through the Sobel filter similarity volume. Similarity is sensitive not only to noise, but also to structural and stratigraphic edges of interest. Because our horizons may be quite accurate against such edges, similarity will turn out to be a less than ideal measure of our picking confidence. (c) A horizon slice through the disorder volume. Disorder is relatively insensitive to edges but quite sensitive to the chaotic noise. In this image, areas that appear as green are easy to pick whereas areas that appear as red and yellow are harder to pick, thereby providing a measure of relative confidence the accuracy of our map in (a).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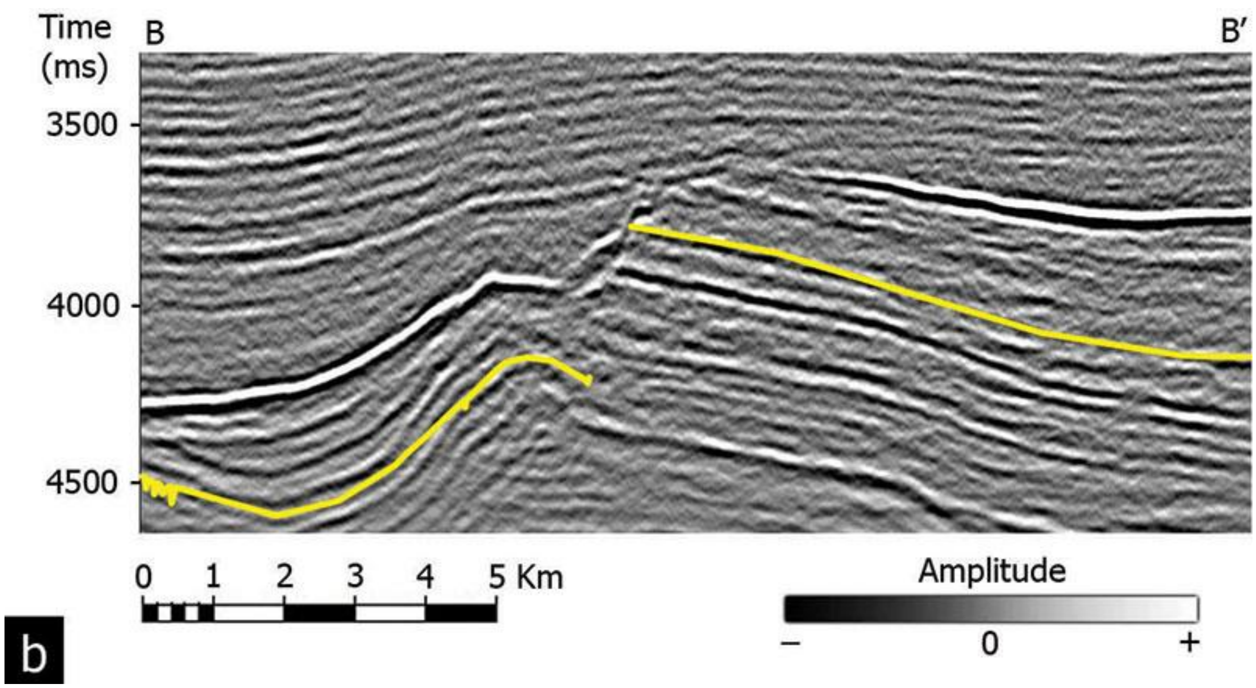
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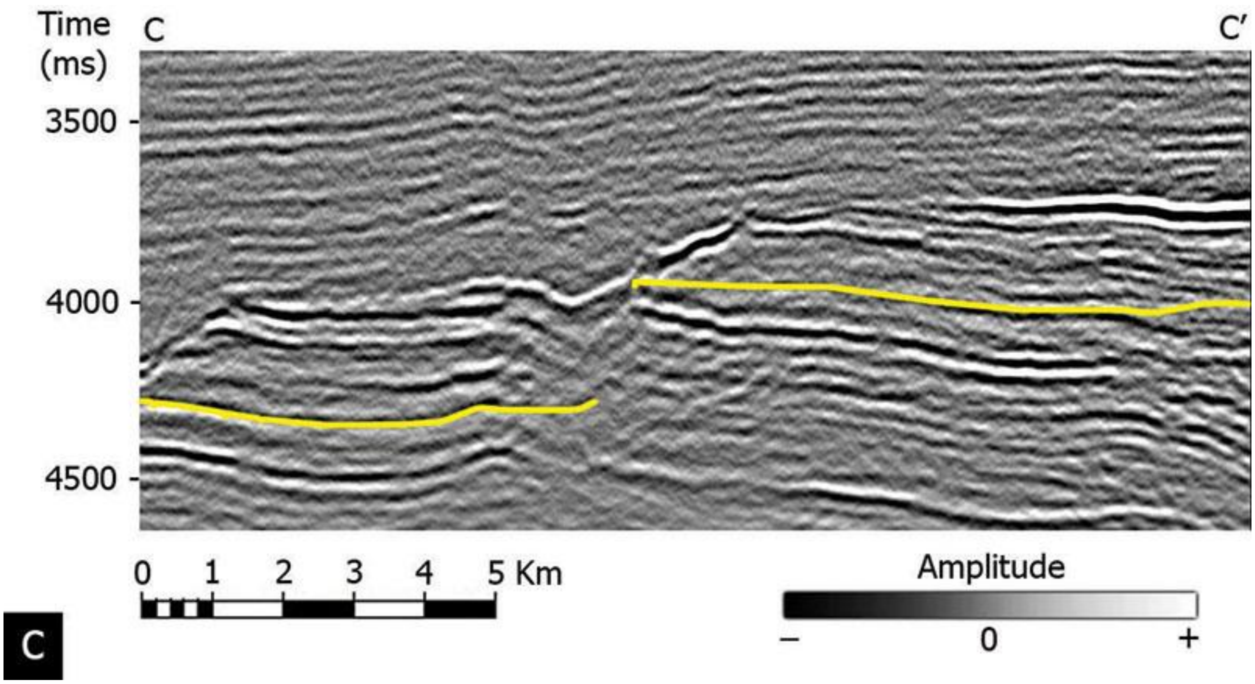

Figure 10. The three vertical slices AA', BB', and CC', where the yellow picks correspond to the horizon displayed in Figure 9. (a) Although the pick is good on the right-hand side of the image, it has been "pushed through" on the left-hand side. (b) The data quality is poor along the entire pick. (c) The pick on the left side is noisy but corresponds to a high similarity value (green) in Figure 9b. Here, the coherence is sensitive to the overlying higher amplitude black trough.

References

Al-Dossary, S., W. Yuchun, and M. McFarlane, 2014, A new algorithm for the seismic disorder attribute: Interpretation, 2, SA93-SA97.

Ha, T., and K. J. Marfurt, 2014, Quantifying confidence in horizon picking: AAPG Explorer Geophysical Corner, July. https://explorer.aapg.org/story/articleid/10751