The importance of recognizing multiples in legacy data: A case study from the Brazilian equatorial margin

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Summary

The Ceará Basin is a deepwater exploration frontier basin that comprises part of the Brazilian equatorial margin. This basin has been receiving renewed attention from the petroleum industry since the discovery of important deepwater oil fields in its African counterpart. However, detailed seismic stratigraphic, depositional, and structural frameworks for the Ceará Basin are still lacking in the literature. We have analyzed a series of 2D seismic data sets and stumbled into the pitfalls of migration artifacts (i.e., multiples) ultimately realizing that reprocessing was the best option to avoid the mistake of interpreting these artifacts as geologic features. Multiples can be difficult to identify in seismic data in which they mimic the true geology of the region, and they often present a pitfall for less experienced interpreters. Indeed, the identification and removal of multiples is crucial because they do not reflect the true geology in the subsurface and may otherwise lead to incorrect business decisions.

Geological feature: Stratigraphy of the Ceará Basin, offshore Brazil

Seismic appearance: Strong seismic horizons mimicking geological layering

Alternative interpretations: Multiples arising from poor seismic migration processing

Features with similar appearance: Strong seismic horizons reflecting basement and carbonates

Formation: Rift sequence of the Ceará Basin

Age: Cretaceous

Location: Ceará Basin, offshore Brazil

Seismic data: Obtained by the Brazilian National Petroleum Agency and reprocessed by the authors

Analysis tool: Reprocessing

Miscorrelating

An example of a seismic profile processed without a careful analysis of the velocity model is shown in Figures 1a and 2a, and it shows the occurrence of several multiples and noise (the red arrows) that mimic geologic events. These events are further exacerbated using seismic attributes such as the amplitude volume technique (AVT) (Bulhões and Amorim, 2005) (Figure 2a). Seismic interpreters can correlate and interpret these multiples as false horizons because they are well-marked and change their shape because it increases the order multiple (see the blue lines in Figure 1b).

Processing data

A conventional processing sequence was applied to marine seismic data. The main steps of the processing flow applied were (1) geometry definition, (2) deghosting, (3) deconvolution, (4) surface-related multiple elimination (SRME) multiple prediction, (5) spectral balance, (6) velocity analysis and normal moveout correction, (7) Kirchoff time migration, and (8) AVT attribute. To improve the recognition and removal of multiples, we calculated their depth location by modeling and subsequently extracted them (Figure 1a, the red arrows; Figure 1b, the blue and green lines).

We used the SRME (Verschuur et al., 1992) method that consists of attenuating multiples generated by the free surface. This method uses only the recorded data to predict all orders of free-surface multiples. Due to timing and amplitude errors that arise in practice, the predicted multiples are typically subtracted from the data using adaptive filtering.

The velocity model was improved using commercial seismic processing software that uses the constant velocity stack theory. In this method, the complete seis-

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mic section is stacked several times, each with a constant velocity, with a defined velocity increment. Using multiple panels, velocity analysis can be performed at any point of the seismic section with the aid of supergathers (gathers generated by collecting traces from adjacent common midpoints) and the semblance function (Figure 3). In this way, the analysis is completed anywhere in the seismic section and more sampling in the regions where the geology is more complex.

A frequency-enhancing algorithm was used to aid interpretation at both low and high frequencies, the AVT attribute introduced by Bulhões and Amorim (2005) (Figure 2a and 2b).

Remarks

The seismic section in Figure 2a does not have clarity and definition in several parts of the seismic line. The combined presence of noise and multiples combined usually confuses the interpreter with false horizons or mask true horizons. Also, high-frequency noise causes reflector discontinuity, which makes it difficult to evaluate the lateral continuity. The multiples cause uncertainty in the seismic interpretation of the basal portions of the basin and the presence or absence of basement. Figure 2b shows that the reprocessing allows a more accurate interpretation of subsurface geology in the area, which can increase the chances of finding geologic structures favorable to hydrocarbon accumulation. Noteworthy, the Pecém well was drilled on this line and was the first deepwater oil discovery in the Ceará basin; thus, improved images may reveal other opportunities.

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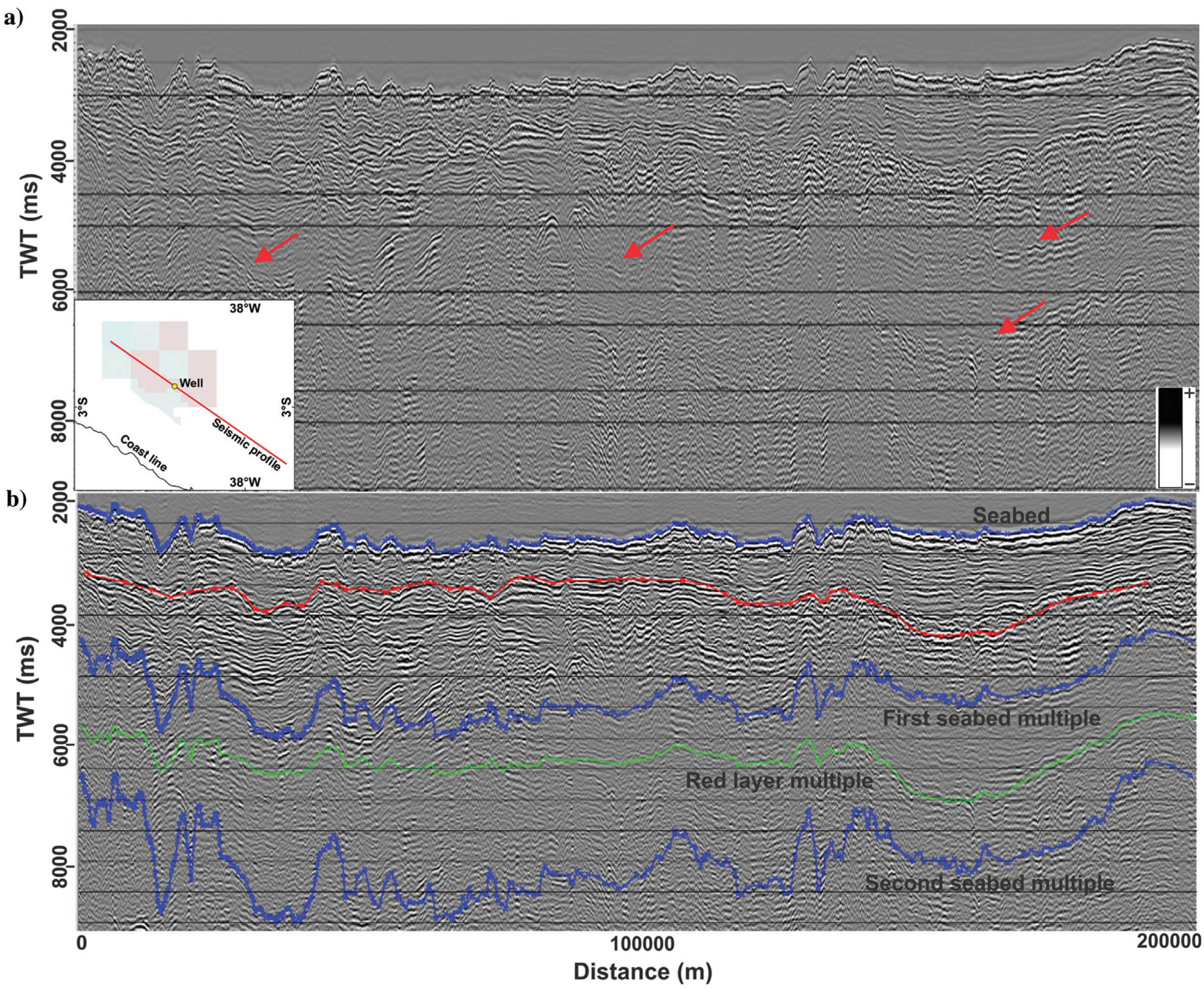

Figure 1. (a) Seismic reflection section with the presence of the first multiple of the seabed and the red layer multiple (the red arrows) mixing with the signal and noise — A location map view is shown with the seismic profile, the Pecém well, and the exploration blocks in Ceará basin, Brazilian equatorial margin, and (b) two multiples related to the seabed and another derived from a slightly deeper horizon. The blue lines refer to the seabed reflector, and the green line refers to the red line layer.

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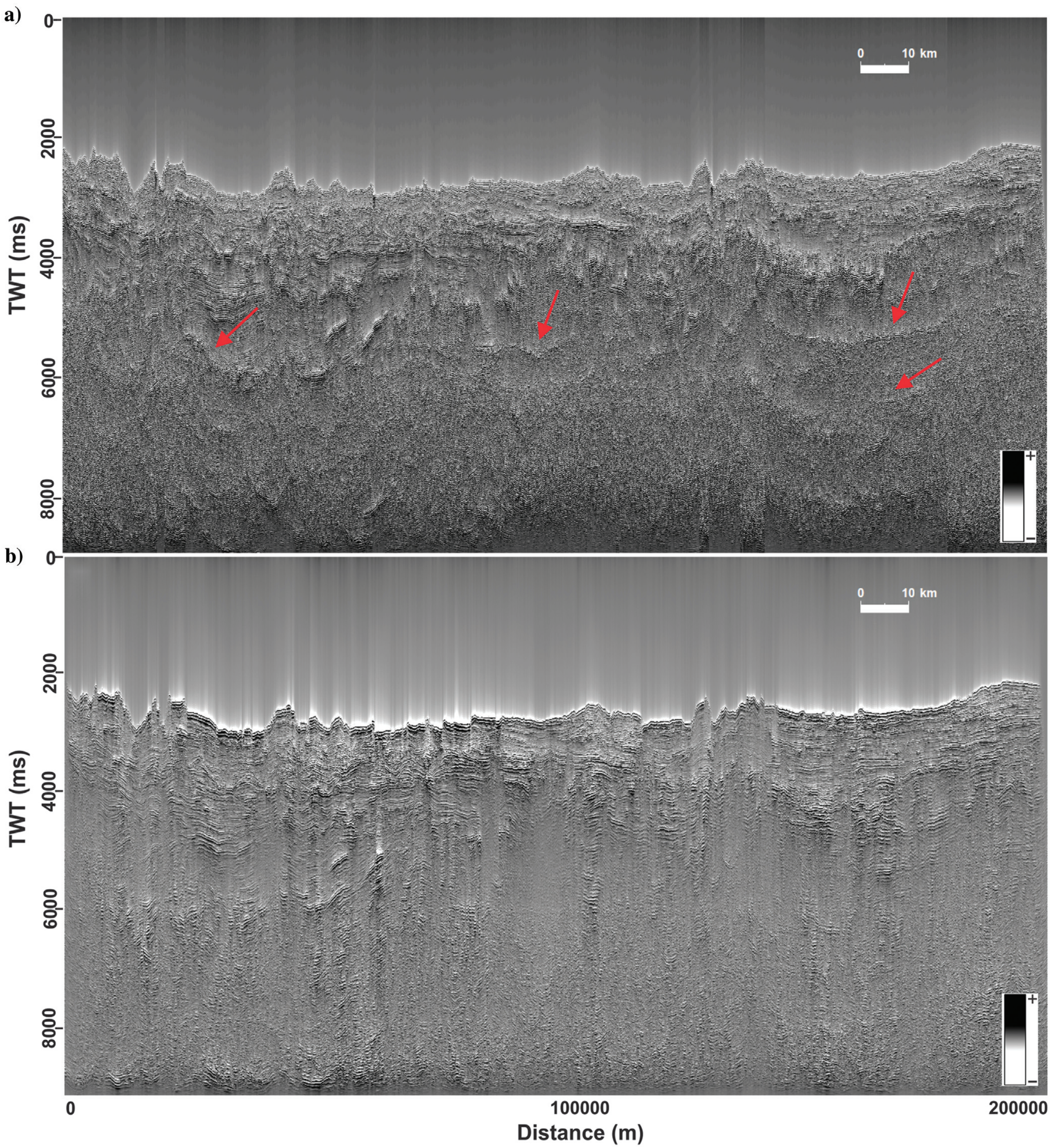

Figure 2. (a) Seismic line obtained by the Brazilian National Petroleum Agency with the presence of multiples (the red arrows), and (b) the reprocessed seismic line and true horizons can be mapped without bias. Note that the multiples and noise were extracted and the seismic signal is much better defined. Both lines are displayed with the AVT attribute as described by Bulhões and Amorim (2005).

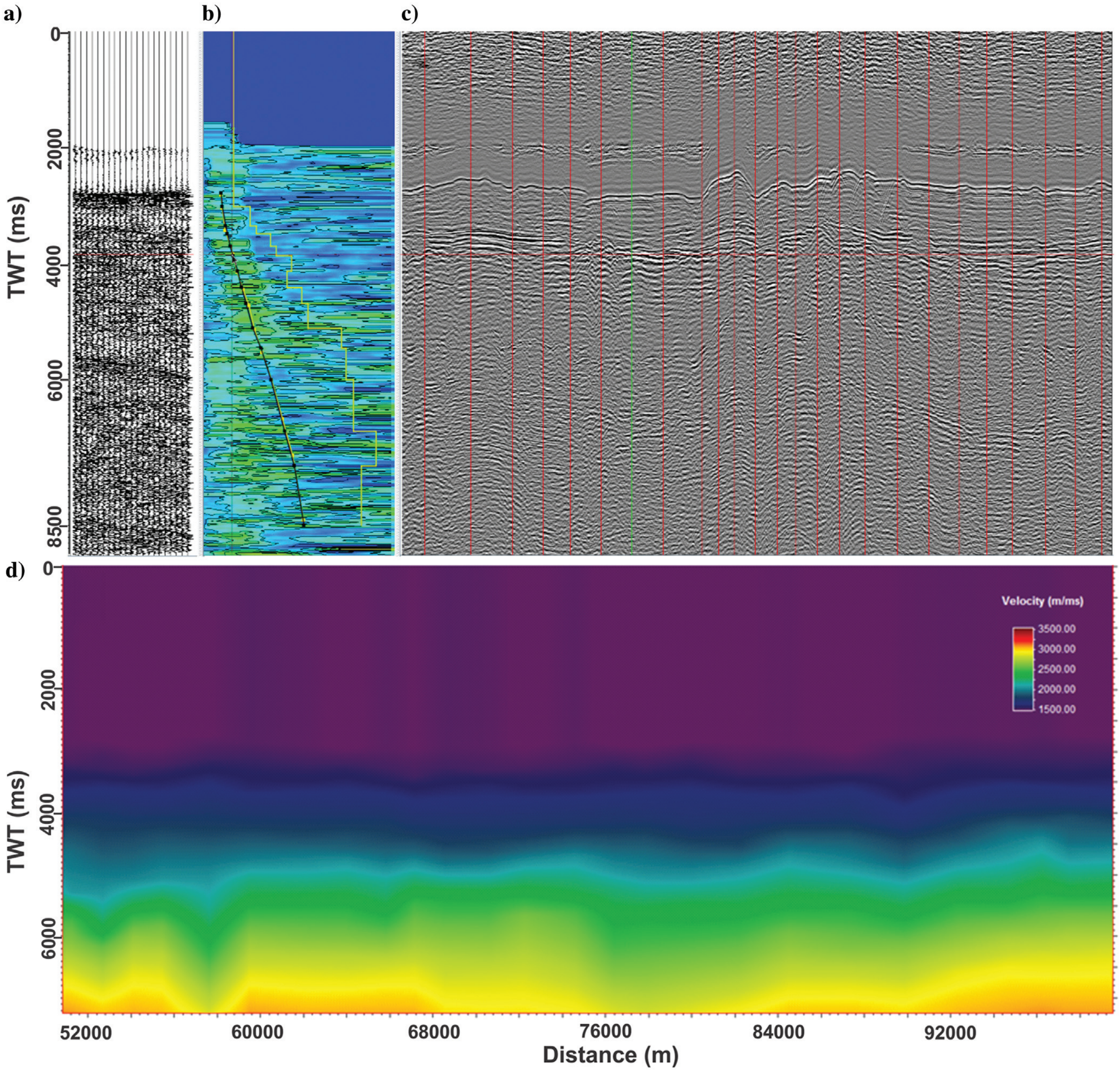

Figure 3. The three panels of velocity analysis of this seismic line. (a) The supergather panel is shown on the left as a function of time and offset, (b) the semblance panel, (c) the stacked section with each vertical red line representing a location where the velocity analysis was performed and the green line representing the current location in analysis, and (d) the result of this process is shown in a 2D velocity model.

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Data and materials availability

Data associated with this research are confidential and cannot be released.

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