Seismic facies of turbiditic and deltaic systems of Maracangalha and Marfim formations on the Massapê Field, Recôncavo Basin

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Abstract

This work has the purpose to recognize seismic facies of turbidite reservoirs of the Caruaçu Member, Maracangalha Formation, using a 3D seismic volume. We complement previous works about the study area, correlating sandstones distribution and system thickness identified in oil wells drilled in the Massapê oil field, southern part of the Recôncavo Basin by Petrobras. We identified several “cutting-filling” features related to a channel-lobe-levee turbidite complex, sometimes superposed, intercalated and difficult to separate. An unconformity was identified on the upper part of the Maracangalha Formation, that is a probable sequence upper boundary with the Marfim Formation, Aratu age. This sequence boundary is an important feature observed, once it was never identified before, according to published papers.

Introduction

Informally known as a School Basin, the Recôncavo Basin has an enormous economic and strategic significance for Brazil, since it represents the first steps towards the petroleum exploration in that country. With 65 oil fields, 16 gas fields and 6.725 wells, the production in that basin has summed more than 1.6 bbl of oil and 73.2 billion m³ of gas (Bastos, 2017). The production, however, was not always constant. By the late 1990’s, production and exploration have decreased. With the creation of ANP, in 1997, new round of exploration started, leading to the discovery of new proven hydrocarbon accumulations (Prates & Fernandes, 2015).

This work takes place in the context of the great production increase the Massapê Field (Figure 1) passed after 2004 with the Caruaçu Member production zone. Several works have been made to characterize this production zone in the Massapê Field. Freire *et al.* (2020) identified 23 turbiditic stages within the Caruaçu Member using well logs. Those 23 stages were divided in three systems: CR-1, with 12 stages and sandstone/shale ratio of ca. 50%; CR-2, with 6 stages and the largest sandstone/shale ratio; and CR-3 composed of 5 stages and an intermediary sandstone/shale ratio.

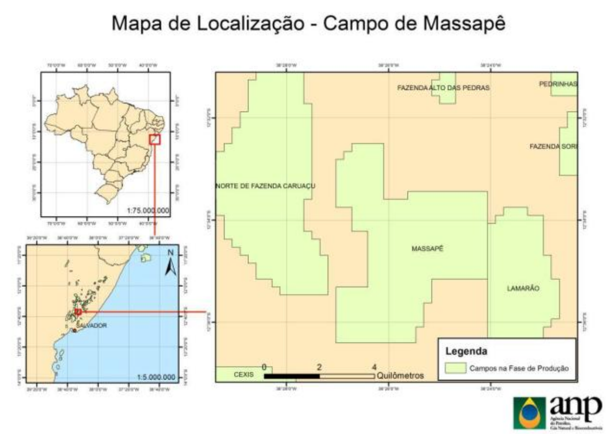

Figura 1: Location map of the Massapê Field (Prates & Fernandes, 2015).

The division of the 3 stages was made based on 2 stratigraphic markers identified on well logs. These markers were named Acarajé Marker and Abará Marker by Freire *et al.* (2020) and might be related to tectonic quiescence periods and/or aridity, resulting on lower sedimentary supply to the paleolakes. Leone (2020) observed that the sandstones of the CR-2 and CR-3 systems have impedance values higher than shales, though near the cross-over point. On the other hand, the sandstones of the CR-1 have impedance values almost equal to those of shales. Leone (2020) also mapped an important known regional marker, the “15” Marker, composed of calcarenites (ostracods) that represents the change from Marfim Formation to Pojuca Formation, according to Mato *et al.* (1991). Ferreira da Silva (2020) generated isopach maps of each one of the three turbidite systems. The CR-3 system is thicker on the central-southern region of the field, and thinner on the northern region; the CR-2 system is thicker at the central region and thinner northwards; the CR-1 system has more distributed thickness, with thicker regions on the southern, east-central, and northern areas, and the thinner areas mostly restricted to the western areas.

Candido da Silva (2021) created sandstone distribution models for each stage, that are in accordance with the thicker regions of each system, with lower shale volume of the CR-3 system around the central and northeast region of the Massapê Field, while on the CR-2 system sandstones are concentrated on the lower central region and the higher sandstone distribution on the CR-1 system are located at the central region.

This work is intended to complete the interpretations of turbidites distribution within the Massapê Field by correlating the previous works with seismic interpretation.

Method

The seismic data used in this work were loaded to the OpendTect software, developed by dGB Earthsciences. Wells with sonic and density logs were used to tie with seismic using the stretch & squeeze technique, to calibrate the horizons interpretation. The cutting-filling features on the CR-2 and CR-3 zones were mapped as positive reflectors, based on Leone (2020). On the other hand, negative reflectors were interpreted as sandstones within the CR-1 system.

The Acarajé Marker was barely visible due to seismic resolution, and it was mapped, with a step of 3 in-lines and 3 crosslines as a tendency of continuity of negative reflections that matched the well markers. The Abará Marker couldn't be mapped, since it is too thin for this data resolution.

Channel and lobe features, as well as the mud diapir, were mapped on a step of 3 in-lines and 3 crosslines. A sequence boundary was identified and mapped with a step of 2 in-lines and 2 crosslines.

Z-slices were also used to identify some turbiditic features on a spatial perspective.

Results

Figure 2 shows the interpreted Acarajé Marker, the "15" Marker and the diapir boundaries in section. The Acarajé Marker dips to E-SE (Figure 3), which is expected due to the mud diapir development and the overall dip tendency of the basin.

The sequence boundary was mapped based on the identification of reflections terminating on onlap or apparent onlap and is represented on Figure 4 which also shows the markers 15 and Acarajé and some lobes interpreted as pro-deltas features.

It was possible to grid and filtrate the white reflections above the sequence boundary due to their good continuity. Figure 5 shows some of these reflections interpreted as pro-deltas after being spatially mapped, gridded, and filtered. It is important to emphasize that many well logs show higher gamma ray values above both the Acarajé Marker and the sequence boundary, as shown in Figure 6, which suggests higher shale volume, possibly related to pro-deltas.

Most of the turbiditic features, such as channels, lobes and levees were mostly restricted to the CR-2 and CR-3 systems. These features did not show good spatial continuity, so their interpretation was restricted to 2D visualization, with a few exceptions. Figure 7a shows an example of small and rarer large scale channel features, while Figure 7b shows a smaller scale channel with possible levee feature, overlain by a larger scale channel, and Figure 7c shows some flat lobe features. It is important to highlight that the channel and lobe features, expected to be filled by sands, match the thicker regions, shown by Ferreira da Silva (2020), with higher sand content, shown by Candido da Silva (2021).

Some turbiditic features were observed on time-slices. Figure X shows one possible feature of channel and lobe, probably in the CR-2 system, due to the lack of Abará Marker on this case.

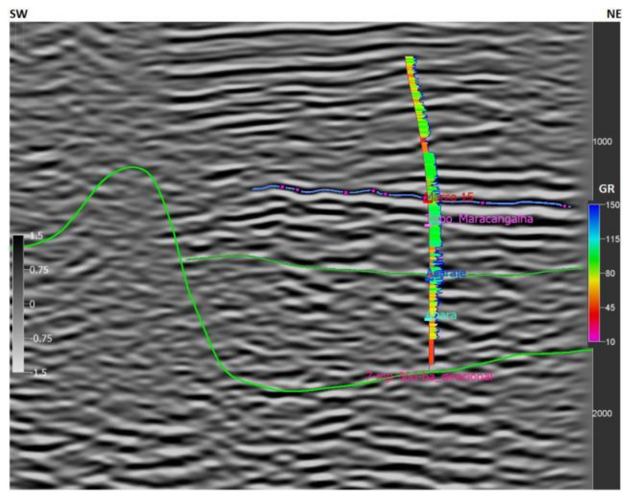

Figure 2: crossline 378 with the interpreted mud diapir (light green), the Acarajé Marker (dark green) and the "15" Marker (blue) with the well 7-MP-36-BA tied.

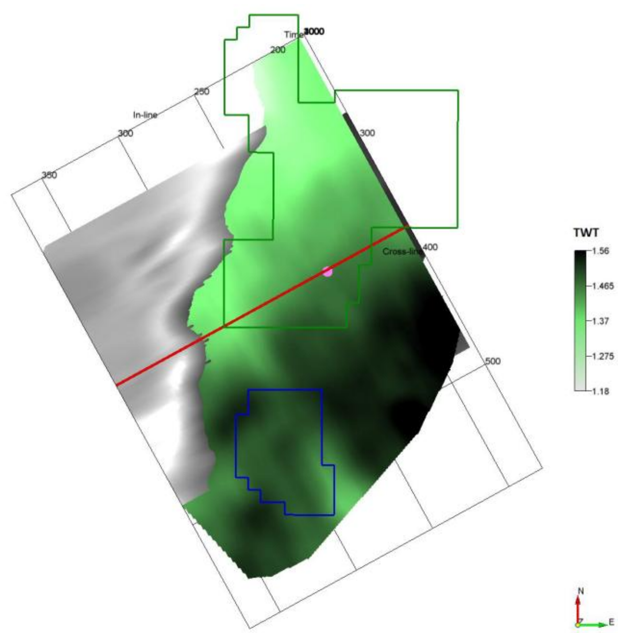

Figure 3: Acarajé Marker (green scales) in map view over the mud diapir (grey scales) and the cross-line 378 in red and the well 7-MP-36-BA tied.

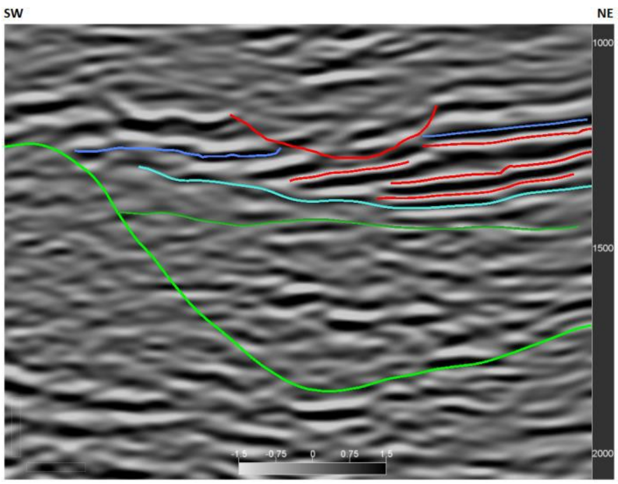

Figure 4: crossline 333 showing the sequence boundary (light blue), some pro-delta features (red) onlapping the boundary, and the markers previously shown.

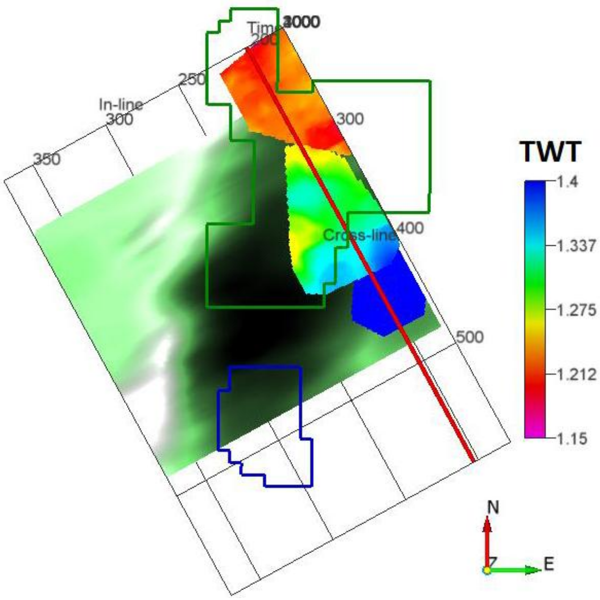

Figure 5: mapped pro-delta features above the sequence boundary.

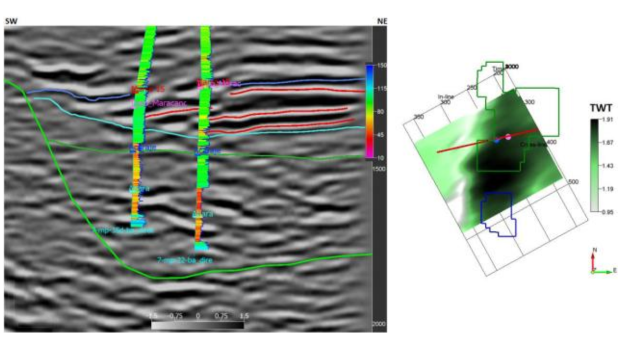

Figure 6: random line SSW-NNE with two wells showing higher gamma ray values above the sequence boundary.

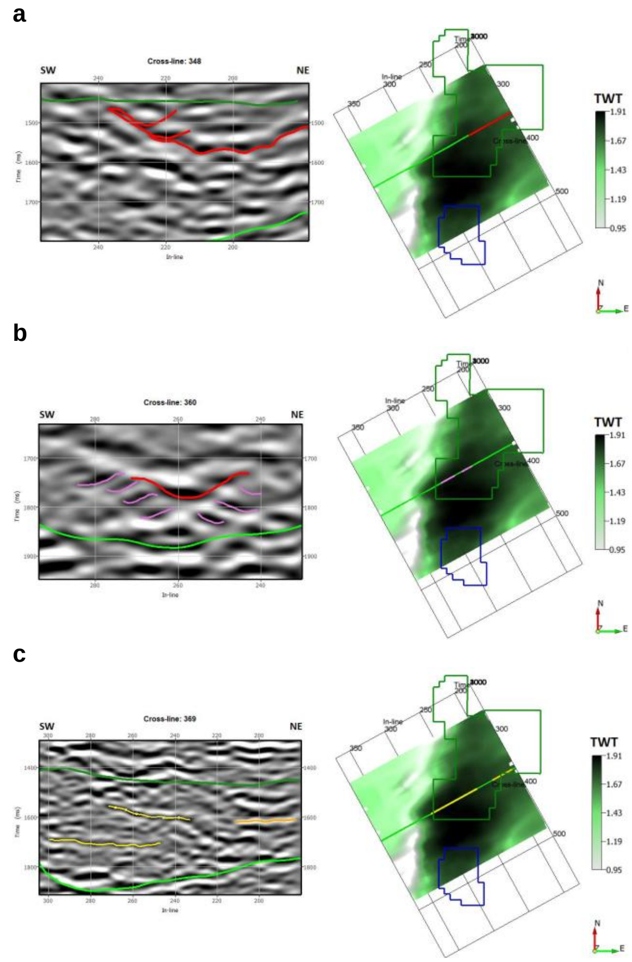

Figure 7: a) small-scale channels filling a large-scale channel feature; b) small scale channel with levees overlain by large-scale channel feature; c) lobe features.

Conclusions

The identification of a sequence boundary brings new perspectives about the earlier interpretations about the Caruaçu Member in this area. A so clear sequence boundary suggests an important change on the sedimentary dynamics on the basin and it matches the descriptions of the Marfim Formation, composed of prograding deltaic sediments deposited as onlaps on platform areas earlier subjected to bypass or erosion, based on stratigraphic description of the basin in other works. So, the interval between the sequence boundary here shown and the “15” Marker should be replaced on the Stratigraphic Chart of the Massapê Field as part of the Marfim Formation.

Based on the quality of the seismic data used on this work, it is also possible to conclude that, in this case, it is impossible to map small scale turbiditic features continuously in three dimensions, particularly with so much noise, common on onshore seismic. So, mapping these features should be limited to 2D sections.

At last, this work is in accordance with previous works about the same area in terms of distribution of sandstones which are related to turbiditic channels and lobes.

Acknowledgments

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