Seismic geomorphology of gravity-driven deposits in the Miranga Low region, Central Recôncavo Basin, Brazil

Vinicius Carneiro, Michael Holz – PPGEOF/UFBA

This paper was prepared for presentation during the 18th International Congress of the Brazilian Geophysical Society held in Rio de Janeiro, Brazil, 16-19 October 2023.

Abstract

Once the quality of seismic data has been improved over time, seismic geomorphology has been applied to map the distribution of depositional systems in many sedimentary basins around the world. In this study, seismic geomorphology was applied to the mapping of gravity-driven deposits in the Recôncavo Basin, a Cretaceous rift basin in Brazil. The study focuses on the Miranga Low area, a depocenter for gravity-driven deposits in the central sector of the basin. The seismic interpretation reveals that mud diapirs control the deposition of gravity-driven deposits, creating a corridor where they are concentrated. In the southeastern part of the study area, a large conglomeratic fan delta complex is identified. The study recognizes two distinct phases of deposition, with variable concentrations of gravity-driven deposits. High-value anomalies correlating with gravity-driven sandstone intervals in wells are highlighted by seismic horizon maps, contributing to the understanding of the depositional architecture and spatial evolution of gravity-driven deposits in the Recôncavo Basin.

Introduction

In the last decades, deepwater depositional systems have been the focus of many seismic geomorphology studies, enabling the mapping of the depositional architecture, morphology, and sometimes sedimentary facies of gravity-driven deposits and contourites (e.g., Posamentier and Kola, 2003; Alfaro and Holz, 2014; Mutti et al., 2015; Chen et al., 2020;). However, most of these works focus on studying turbiditic and debrites systems in marine basins, and few works are developed in lacustrine rift basins.

The Recôncavo Basin is a Cretaceous rift basin located in the northeast region of Brazil, with an area of approximately 11500 km², and a record that extends from the Neo Jurassic to the Early Cretaceous (Magnavita, 2005). Structurally it has a half-graben shape oriented in the NE-SW direction, with an edge fault system (Salvador – Barra Fault System) to the southeast and the flexural margin to the northeast (Figure 1). The Mata-Catu and Itanagra-Araçás transfer faults segment the basin into the southwest, central, and northeast sectors (Destro, 2002).

The Miranga Low is located in the central sector, close to the edge fault system. This structural low was a depocenter during the Neocomian for gravity-driven deposits such as turbidites and sandy debrites, generated by gravitational flows in a lacustrine deep-water setting resulting in the lithostratigraphic units of the Candeias and Maracangalha formations (Magalhaes, 1990; Picarelli & Abreu, 2012).

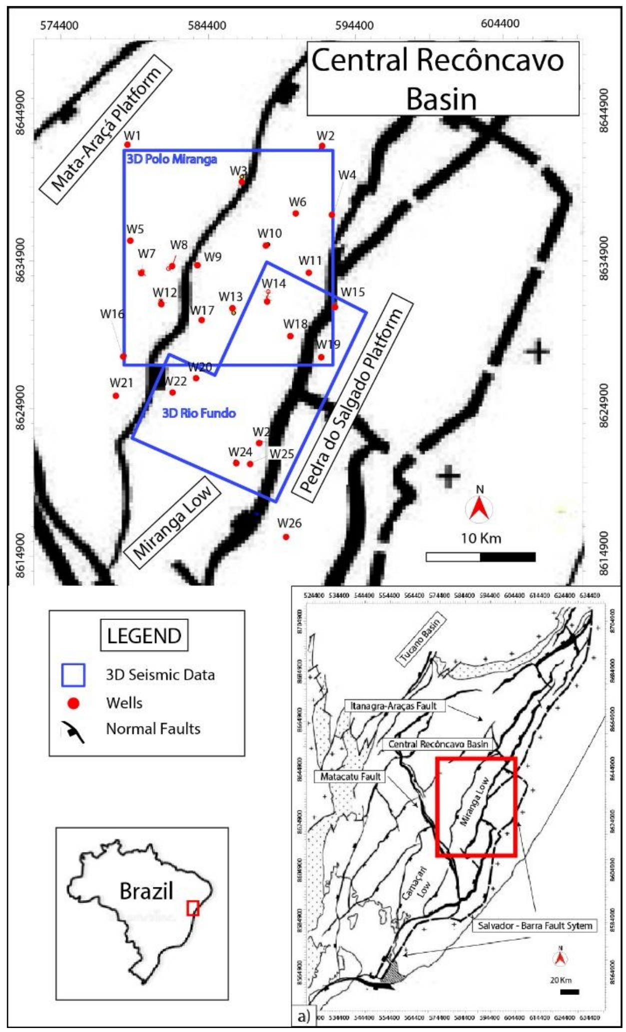

Figure 1 – Study area location map and dataset. The red rectangle in the regional basin map highlights the detailed area above.

Deposits controlled by gravitational flows such as turbidites and sandy debrites constitute important oil and gas reservoirs in several fields in the northeast and southwest sectors of the Recôncavo Basin (Bruhn, 1999; Magnavita et al., 2012; Freire et al., 2020), as well as in the central sector, where occurs the Miranga Field and the new discovery, the Murucututu Field. Considering the intense exploratory activity in the basin, and that many structural traps have already been tested, it is important that these deposits are well delimited as they may constitute reservoirs associated with stratigraphic traps, mainly in the Miranga Low area, a region that constitutes one of the basin's generation kitchens (Destro, 2002).

The present work aims to show the application of seismic geomorphology and seismic attributes to the mapping of the basin's gravity-driven deposits, interpreting new seismic and well data, and also to identify geometric and architectural characteristics, as well as spatial and temporal evolution in the deep lake region in Miranga Low, in the central sector of the Recôncavo Basin

Dataset and Methods

This study uses two 3D seismic data and 26 exploration wells. The seismic data is Post-Stack Time Migrated and comprise a 300 Km² area in the Miranga Low region and includes the Mata-Araças and Pedra do Salgado Platforms (Figure 1). As both seismic volumes have different processing flows, amplitude balancing, time and phase misties were performed, to improve the correlation. All wireline logs from wells were analyzed, and the wells were correlated with the 3D seismic based on the seismic well tie procedure.

The 3D seismic interpretation was based on key horizons mapped in the interval that comprises the Neocomian. Mud diapirs and conglomeratic alluvial fans were interpreted based on seismic lines as well as on time slices with variance seismic attribute. Root Mean Square (RMS) Amplitude seismic attribute were used in the key horizons revealing the distribution of the gravity-driven deposits.

Results

Mud Diapir and Conglomerate Fan Delta distribution

The seismic structural interpretation reveals that in this interval the gravity-driven deposition is controlled mostly by the mud diapirs that spread out in the borders of the Miranga low, creating a “corridor” where the gravity-driven deposits are concentrated. Mud diapirs are very distinctive in the Variance Seismic Attribute (Figure 2) where they are recognized by high variances values. These features have different geometries and distributions but all of them act as delimiting walls for sedimentation in this period.

In the southeast part of the study area, the Pedra do Salgado Platform, a large conglomeratic fan delta complex is mapped. These deposits are well recognized not only by the high variance in the seismic attribute but also by the conglomeratic record in wells located in this region. Most of those wells record conglomerate intercalated with mudstone and sandstone beds, but one particular well displays a thick (~200 m) succession of conglomerates, indicating the very proximity of this area with the basement source area located in the easternmost part of the basin, close to the Salvador-Barra fault system.

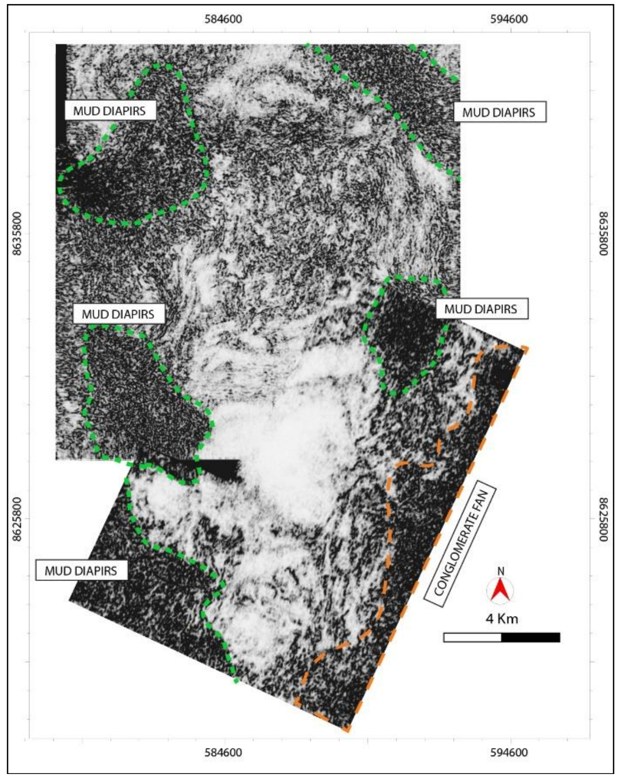

Figure 2 *– Variance time-slice at 1000 milliseconds showing the distribution of mud diapirs around the area and conglomerate fan deltas in the southeast part.*

Structural and Stratigraphic Interpretation

The basement is structured by planar faults oriented NE-SW and tilted to the southeast (Figure 3). It goes deeper from the west on the Mata-Araçá Platform towards the east, in the Miranga Low region, where the basement occurs in one of the deepest areas of the basin, reaching 2.5 seconds TWT (~ 4.5 Km estimated depth).

The early rift sequences are very influenced by the basement faults, but the late ones are strongly influenced by shale tectonics, which is very noticeable in the Miranga Low.

The isopach map (Figure 4) shows that the depocenter is elongated in the north-south direction, with the mud diapirs controlling the deposition. In addition, the fault that limited the Miranga Low from the Pedra do Salgado Platform acts as a barrier as well. It is notable that the thickness of the deposits changes laterally from the center of the Baixada de Miranga (where the thickness is ~1700 m) to the edges (where it is ~1000 m), suggesting that mud diapirs control sedimentation, decreasing the thickness of the sequence. The deepest well in the study area reaches 4.2 Km depth and shows a succession of stacked gravity-driven deposits, interfingered with mudstones recording the deep lake background sedimentation. Those deposits are concentrated between the mud diapirs, and it is possible to recognize them in the seismic section, due to the strong correlation with seismic anomalies in the Amplitude sections as well as with the attribute of RMS Amplitude as shown in figure 3.

Two distinct phases with major or minor influence from the mud diapirs were interpreted; they are limited by the key horizons H1 to H3 shown in Figure 3. Stage 1 has a higher concentration of gravity-driven deposits than stage 2. This is corroborated by wells that have a higher concentration of sand in interval 1, as well as a low sand concentration in interval 2, but showing thick mudstone intervals (~300 m). Another important characteristic is the seismic facies in interval 1, which are high amplitude, semi-continuous to continuous reflections; whereas in interval 2 they have low to moderate amplitude, and some intervals are nearly reflection-free.

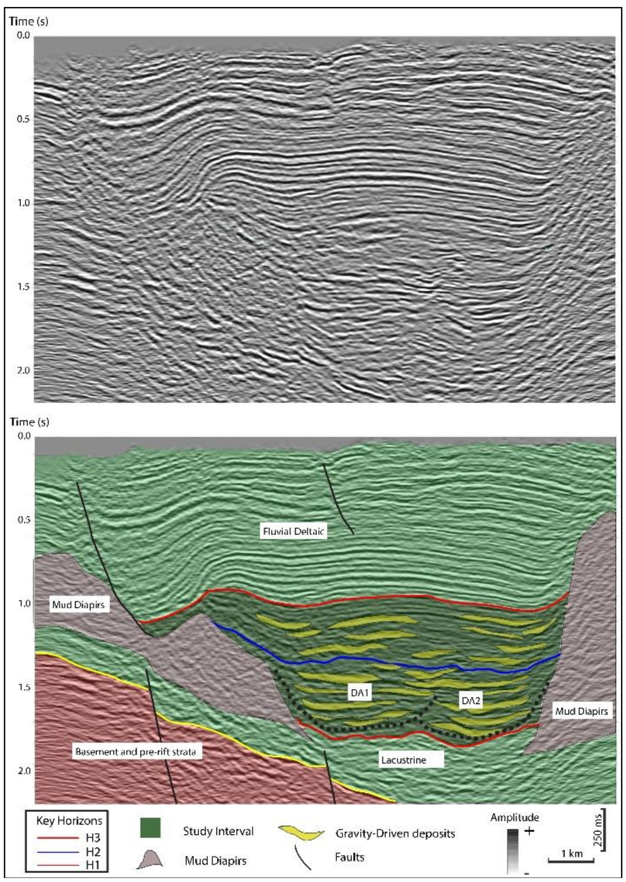

Figure 3 *– Regional W-E strike-oriented seismic section crossing the 3D seismic data, showing mud diapirs at the borders that control the sedimentation of gravity-driven deposits in the Miranga Low. The study interval is limited by red horizons. Note key horizons H1 to H3 delimiting two intervals with different concentrations of gravity-driven deposits. Black dashed lines indicate the location of depositional axis 1 (DA1) and 2 (DA2).*

In stage 1 two different depositional axes were recognized. These depositional axes extend about 12 km from north to south until reaching the main depositional area.

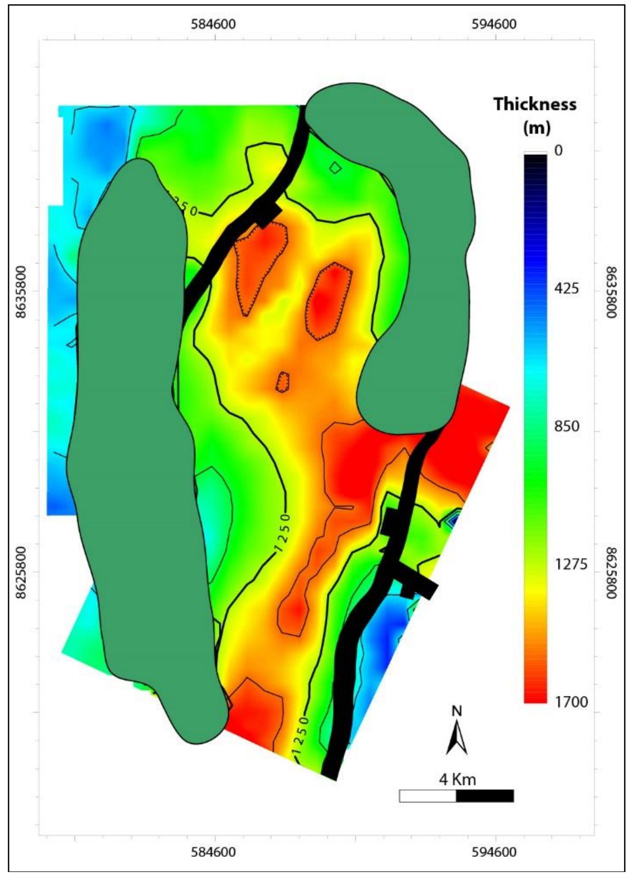

Figure 4 *– Isopach depth converted map from the study interval (i.e., total thickness from H1 to H3) showing the north-south oriented sedimentation.*

Gravity-driven deposits distribution

The seismic horizons map in RMS Amplitude (Figure 5) shows a series of high values anomalies that have a strong correlation with the gravity-driven sandstone intervals in the wells. The aforementioned depositional Axis 1 (DA1) in the western part and Axis 2 (DA2) in the eastern part of the study area (Figure 3) can be clearly recognized in the slice (Figure 5) as well. The low-values RMS anomalies have a strong correlation with mud-prone facies in the wells, and due to this interpreted as the background deep lake sedimentation.

The interpreted gravity-driven deposits in the DA1 and DA2 are elongated parallel to bounding shale diapirs and oriented in a north-south axis, where the sediment entry point is in the north, while the bulk of the sediments forms a distal lobe complex in the southern area. As well as the mud diapirs confine the sediments due to their being positioned in the east and west borders of the study area, the Pedra do Salgado Platform probably acts as a limit to the sediments that come from the north.

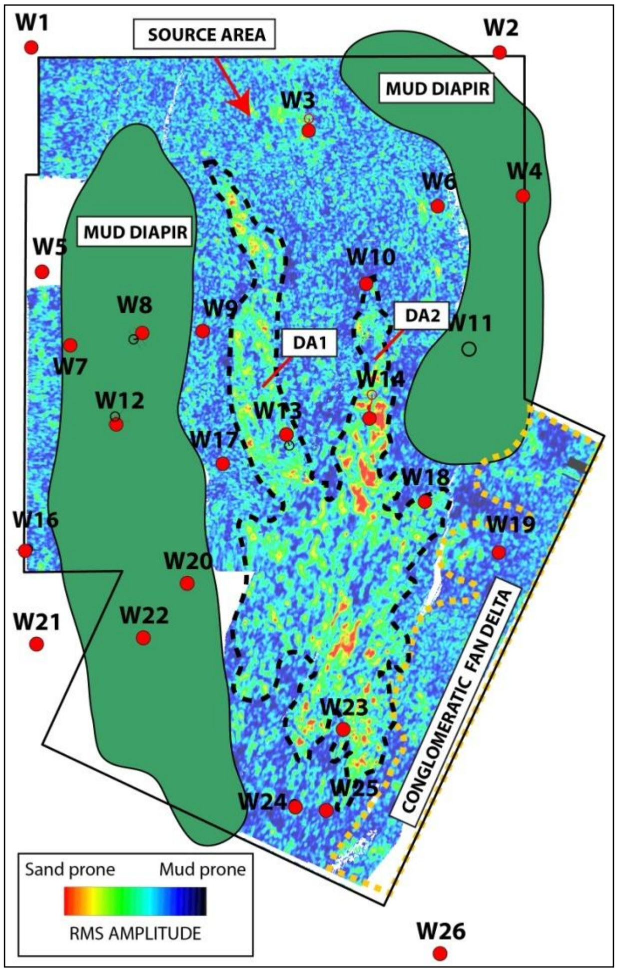

Figure 5 – Seismic stratal slice with the RMS Amplitude seismic attribute and corresponding geological interpretation. The depositional axis 1 (DA1) and depositional axis 2 (DA2) are shown in figure 3.

Conclusions

The seismic geomorphologic analysis applied herein resulted in maps displaying the distribution of gravity-driven deposits in the Recôncavo Basin. Mud diapirs were found to have a strong influence on the distribution of these deposits since they created a north-south elongated "corridor" that concentrated the gravity-driven flows. This orientation suggests that a source from the North, probably a delta, acted as a feeder system to this deep-water lacustrine fan system.

Acknowledgments

The authors would like to thank Geopark E&P Brazil for financing the GOMO Project, of which this work was part, as well as the IHS for providing an academic licensing of the Kingdom Suite. V.C acknowledges the Fundação de Apoio a Pesquisa do Estado da Bahia (FAPESB) for the PhD scholarship, M.H. thanks CNPq for PQ study grant.

References

ALFARO, E., & HOLZ, M. (2014). Seismic geomorphological analysis of deepwater gravity-driven deposits on a slope system of the southern Colombian Caribbean margin. Marine and Petroleum Geology, 57, 294-311.

BRUHN, C. H., 1999. Reservoir architecture of deep-lacustrine sandstones from the Early Cretaceous Recôncavo rift basin, Brazil. AAPG bulletin, 83(9), 1502-1525.

CHEN, H., ZHU, X., SHI, R., & ZHANG, Z., 2020. Seismic geomorphology of shoal-water deltaic and mixed carbonate-siliciclastic beach-bar systems in hanging wall of rift basins: Paleogene of the Raoyang Sag, Bohai Bay Basin, China. Interpretation, 8(2), SF1-SF19.

DESTRO, N., 2002 Falhas de alívio e de transferência: o significado tectônico e econômico do rifte do Recôncavo-Tucano-Jatobá, NE Brasil. Tese de Doutorado, Universidade Federal de Ouro Preto, Ouro Preto

FREIRE, A. F. M., DOS SANTOS, G. F. R., DA SILVA, C. F., & LUPINACCI, W. M., 2020. Recognition of turbidite stages in the Massapê oil field, Recôncavo Basin-Brazil, using well logs. Journal of Petroleum Science and Engineering, 192, 107279.

MAGALHAES, A. J. C., 1990, Modelo deposicional e características de reservatório dos arenitos das Camadas Caruaçu (Cretáceo inferior) no Campo de Miranga Profundo, Bacia do Recôncavo, Brasil: Dissertação de Mestrado, Universidade Federal de Ouro Preto, 208 p.

MAGNAVITA, L. P., SILVA, R. D., & SANCHES, C. P., 2005. Roteiros Geológicos. Guia de Campo da Bacia do Recôncavo, NE do Brasil. Petrobras, Rio de Janeiro, 13(2), 301-334.

MAGNAVITA, L.P., SZATMARI, P., CUPERTINO, J.A., DESTRO, N., ROBERTS, D., 2012. The Reconcavo Basin. In: Phanerozoic Rift Systems and Sedimentary Basins, pp. 383–419. Martins-Neto, M.A., Catuneanu, O., 2010. Rift sequence stratigraphy. Mar. Pet. Geol. 27 (1), 247–253.

PICARELLI, A., & ABREU, V., 2012. Sequence Stratigraphy Applied to Continental Rift Basins: Example from Reconcavo Basin, Brazil.

POSAMENTIER, H. W., & KOLLA, V., 2003. Seismic geomorphology and stratigraphy of depositional elements in deep-water settings. Journal of sedimentary research, 73(3), 367-388.