Seismic-structural interpretation of the Barra Fault System (Recôncavo and Camamu basins, NE of Brazil)

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Abstract

This work consists of seismic-structural interpretation of post-stack data of the area abridged by southern Recôncavo and northern Camamu basins, including the mapping of the main fault systems, especially the Barra Fault system (current boundary between the basins), and the top of the basement, thus obtaining the structural framework of the study area. Seismic attributes and well data information supported all the interpretation.

Introduction

The aborted rift system Recôncavo-Tucano-Jatobá, jointly with the passive margin basins of Camamu and Jacuípe are inserted in the tectonic context of the Salvador Triple Junction. Its rifting process involving inversions of half-grabens (e.g., the Recôncavo Basin) has preferential diving from the hanging wall to the southeast, while the Camamu rift section mainly dips northwest. This situation is analogous to what occurs in present-days graben systems in East Africa, as pointed out by study of Rosendahl (1987), especially in the Tanganyika Lake.

The Recôncavo and Camamu basins have proven oil potential associated with their rift sections, but data on the strata continuity between the basins is still scarce in the literature. The present work has as main objective the seismic-structural interpretation of the contact region between the Recôncavo and Camamu basins. An adequate definition of the structural framework of the basins becomes fundamental to the subsequent stratigraphic interpretation, besides allowing the identification of hydrocarbon structural traps.

The contact region of the basins involves complex normal faults associated to the tectonism of the rift phase, which could reach slips up to 1 km. Public seismic data that cross this area, in general, belong to old surveys, with their amplitudes are real negatively affected by the presence of the faults. Therefore, seismic attributes, well data and bibliographic information (specially Bouguer, magnetometry and structural maps) were used to support and consolidate seismic-structural as well as seismic-stratigraphic interpretations.

Study Area / Data Base

The seismic and well data available for the study are part of the database of the GP-03 R & D project financed by the company GEOPARK (Project RECAMU - Comparative geological analysis of the rift phase of the Camamu Basin and Recôncavo Basin). Data from 140 post-stacked seismic lines and 27 wells were used, all of them on the area that composes the southern portion of the Recôncavo Basin and north of the Camamu Basin (Figure 1).

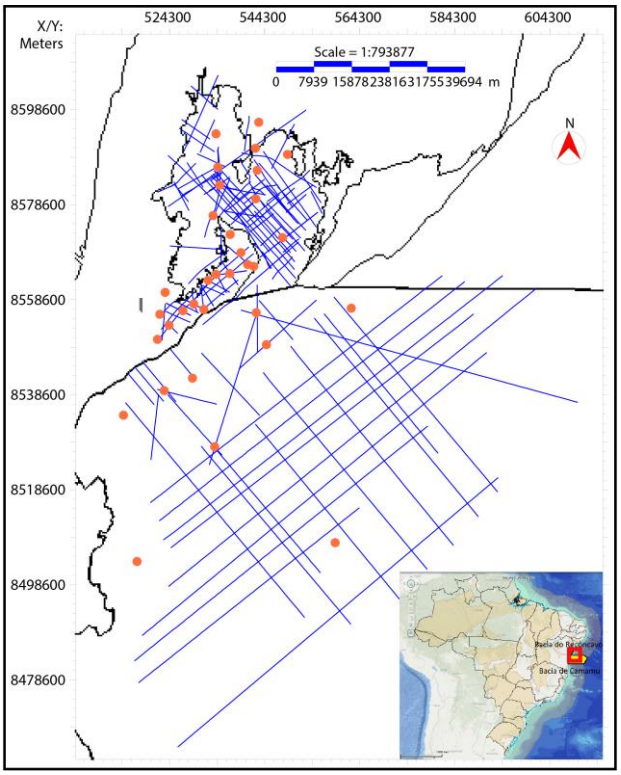

***Figure 1** - Seismic lines (blue) and wells (ired) available for the studied area.*

Method

The seismic interpretation developed conventional steps, mainly using the IHS Kingdom and OpendTect softwares. Seismic attributes of the complex trace assisted all the time structural interpretation, especially the attributes of envelope, instantaneous phase, instantaneous frequency and TecVA (*Técnica Volume de Amplitude*, or pseudorelief). The last one was fundamental for the mapping of the main faults, considering its good

application in discriminate seismic facies and identify discontinuities.

Several maps extracted from the literature were also helpful for seismic interpretation, specially, the gravimetric and magnetic maps from Ferreira *et al.* (2009) and Amaral (2009), and the structural maps from Destro *et al.* (2003). These maps were important for the correlation of the faults between the sections, and in the definition of the restricted grabens and horsts throughout the area.

The stratigraphic correlation, based on the analysis of the geophysical well logs, also supports all the seismic-structural interpretation, especially indicating the depths of the top of the basement and estimates faults slips, given in meters, differently of the seismic sections that did not undergo time-depth conversion, and thus present all seismic analysis only as a function of time on its vertical axis.

Seismic-structural Analysis

The seismic-structural interpretation identified several systems of normal synthetic and antithetic high angle faults, controlling blocks within two large half-graben systems. The main fault systems and the times of the top of the basement interpreted are plotted on the map of Figure 2.

Basically, the basement presents a chaotic seismic facies, with its top generally mapped on a high amplitude positive reflector (resulting of a high acoustic impedance, indicated by an upgrade of seismic velocity with depth), being a base of a seismic facies of stratified reflectors. These, usually presents a group of reflectors with high continuity and amplitudes, approximately plane-parallel, corresponding the pre-rift and sag phase of the basins, i.e., the first sedimentary deposits.

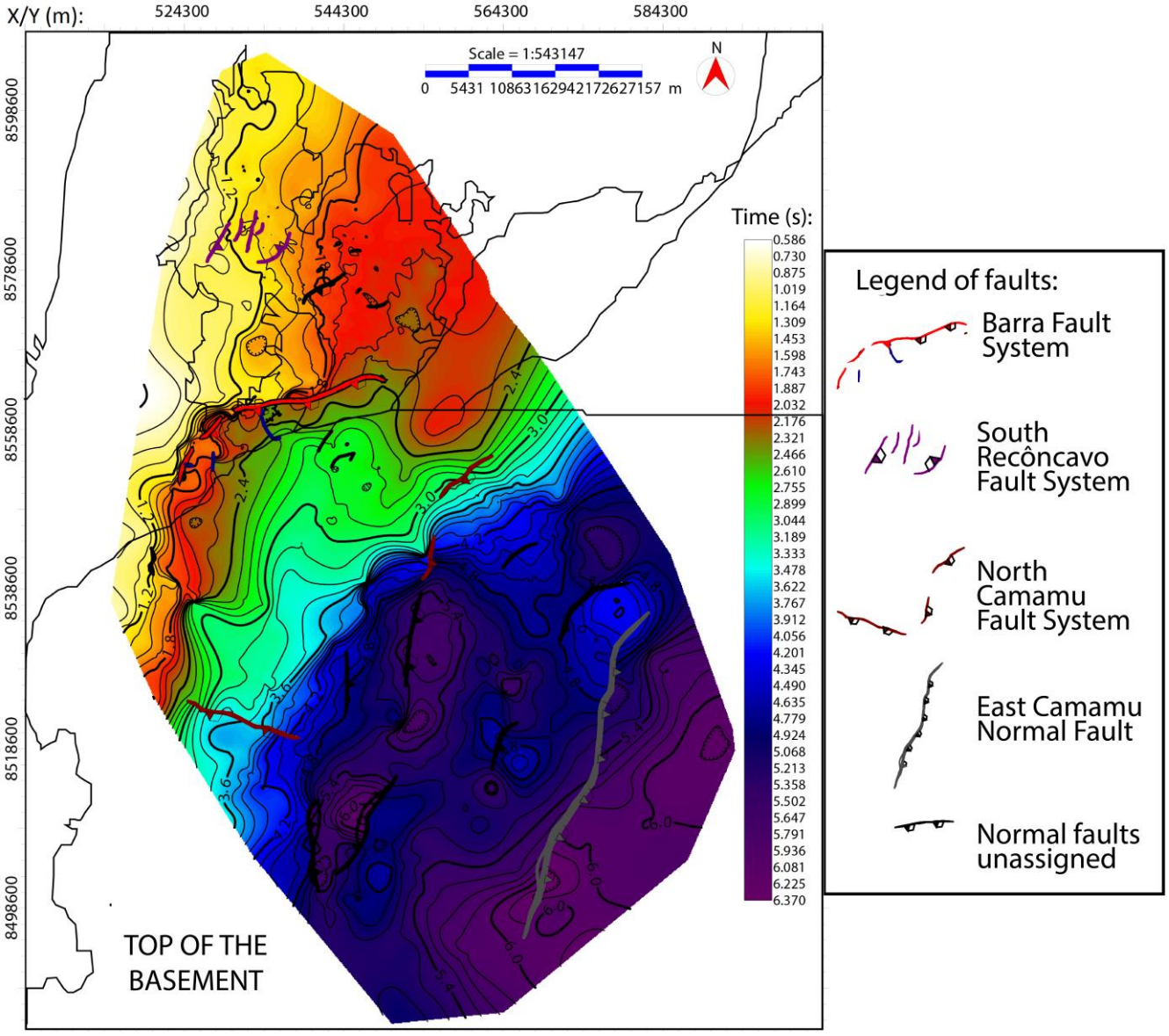

Figure 2 *- Seismic time map of the top of the basement, and the main fault systems interpreted.*

A normal fault system was identified in some seismic sections of the southern region of Recôncavo Basin. It is characterized by a group of five subparallel faults, where three of them dive towards northwest, and two towards southeast, dividing the structural framework in at least three blocks. This structure is mapped in Figure 2 by the purple color system, and is associated with faults already presented by Destro *et al.* (2003). Throughout the Todos os Santos Bay region, other normal faults were also interpreted, with preferential orientation NE-SW and diving towards the Salvador Fault, presenting slips less than 200 ms.

Considered as a boundary between the sedimentary basins under study, the Barra Fault was identified in some seismic sections, and correlated with existing structural guidelines in the available gravimetric maps. Many authors consider it as a single fault, however, in this work it is interpreted in a compartmentalized manner, with three main segments, identified in seismic sections with preferred direction NE-SW, and a series of perpendicular associated faults, thus being considered not a single structure but as the “Barra Fault System”.

The layers shifts in the main section of the Barra Fault System is wide, ranging from 800 ms in the seismic sections that cross the Itaparica Island (as shown in the section of Figure 3B), to slips less than 100 ms recorded in the seismic lines that pass through the South of the current Todos os Santos Bay (illustrated by the composite section of Figure 3A). The lateral differences of slips can also be observed in the map of Figure 2, with a sudden change from yellow to red (region of Itaparica Island) in NW-SE direction and a more gradual change from red to green if taken in an NE-SW (next to the outfall of the Todos os Santos Bay).

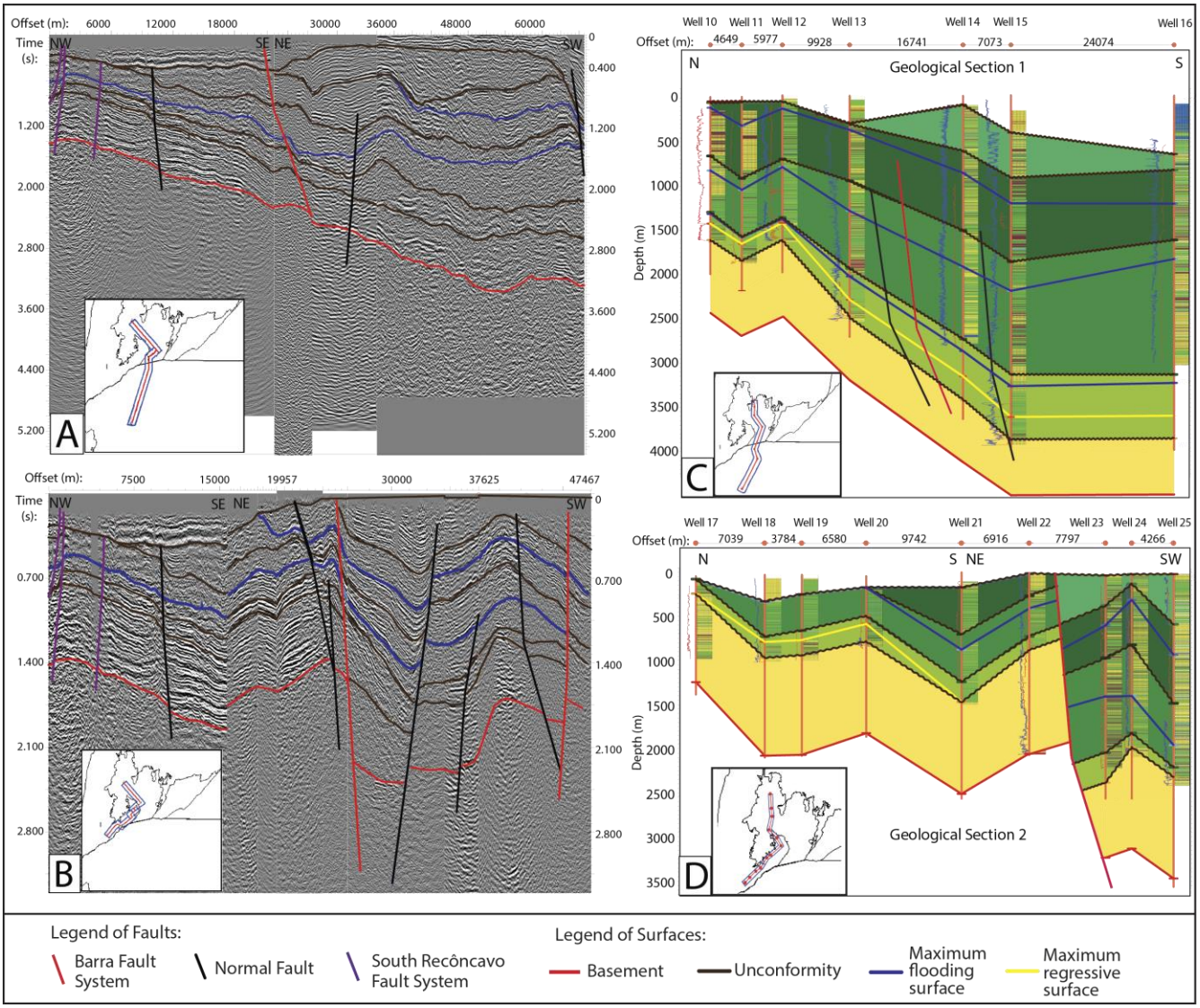

Figure 3 *- Sections that cross Barra Fault System: (A) interpreted composite seismic section, which crosses the outfall of the Todos os Santos Bay; (B) interpreted composite seismic section, which crosses the Itaparica Island; (C) geological section of well correlation, which crosses the outfall of the Todos os Santos Bay; (D) geological section of well correlation, which crosses the Itaparica Island.*

The well correlation sections also show the differences of displacement along of the Barra Fault, as can be seen in the comparison of figures 3C e 3D, which can reach more than one kilometer below the Itaparica Island (Figure 3D).

The performed seismic interpretation consider that the Barra Fault System does not delimited stratigraphically the rift deposits between the analyzed basins. Therefore, in the period of deposition, all the region was connected. The most relevant structural boundary in the stratigraphic distinction between basin deposits lies below the Barra Fault region, called the North Camamu Fault System (shown in a brown color in the Figure 2). The latter is illustrated in the composite seismic section of Figure 4, with a displacement greater than 1.5 s, characterized by a high angle, and to show a chaotic seismic facies next to the fault scarp that might be associated to alluvial fan deposits. This fault system has also be mapped by the abrupt passage of the green to a dark blue area in the map of Figure 2.

In terms of stratigraphy, the North Camamu Fault System is the main structure that distinguishes the rift deposits between the Camamu and Recôncavo basins. While the region north of the fault system (South Recôncavo and Northwest of Camamu) presents a higher chronostratigraphic correlation with the syn-rift sequences of the southern Recôncavo Basin, the central region of Camamu Basin is characterized by syn-rift deposits more similar to those found in the neighboring passive margin basins (Jacuípe and Almada basins).

Results

The seismic-structural interpretation defined the entire structural framework of the study area, thus allowing the following tectono-stratigraphic analysis of the basins, especially in their rift phases. The main results consists in the structural maps (Figure 2) and interpreted seismic sections (as shown in figures 3 and 4).

The set of the Barra Fault System and Salvador Fault are characteristic of a reversal in the direction of the half-graben formed, which result in a system with a flexural margin diving northwestward into the Camamu Basin and southeastward into the Recôncavo Basin. The inversion occurs mainly with the performance of differential distension efforts, capable of generating transcurrences between hemi-grabens. Modern rift systems, found in East Africa, present more detailed studies of the structural phenomena that formed such systems, such as the work of Rosendahl (1987), which presents a series of possibilities for inverting half-grabens (Figure 5).

In addition to the seismic-structural map of Figure 2, a three-dimensional model of the basement surface was generated (Figure 6). This model used as base the performed seismic interpretation and the gravimetric map of the first vertical derivate of Bouguer anomaly, from Amaral (2009), with a detail in the Barra Fault region. The created map analyzes only the crystal structural framework; in other words, as if the sedimentary rocks had been removed, and to construe only the basement by an aerial view.

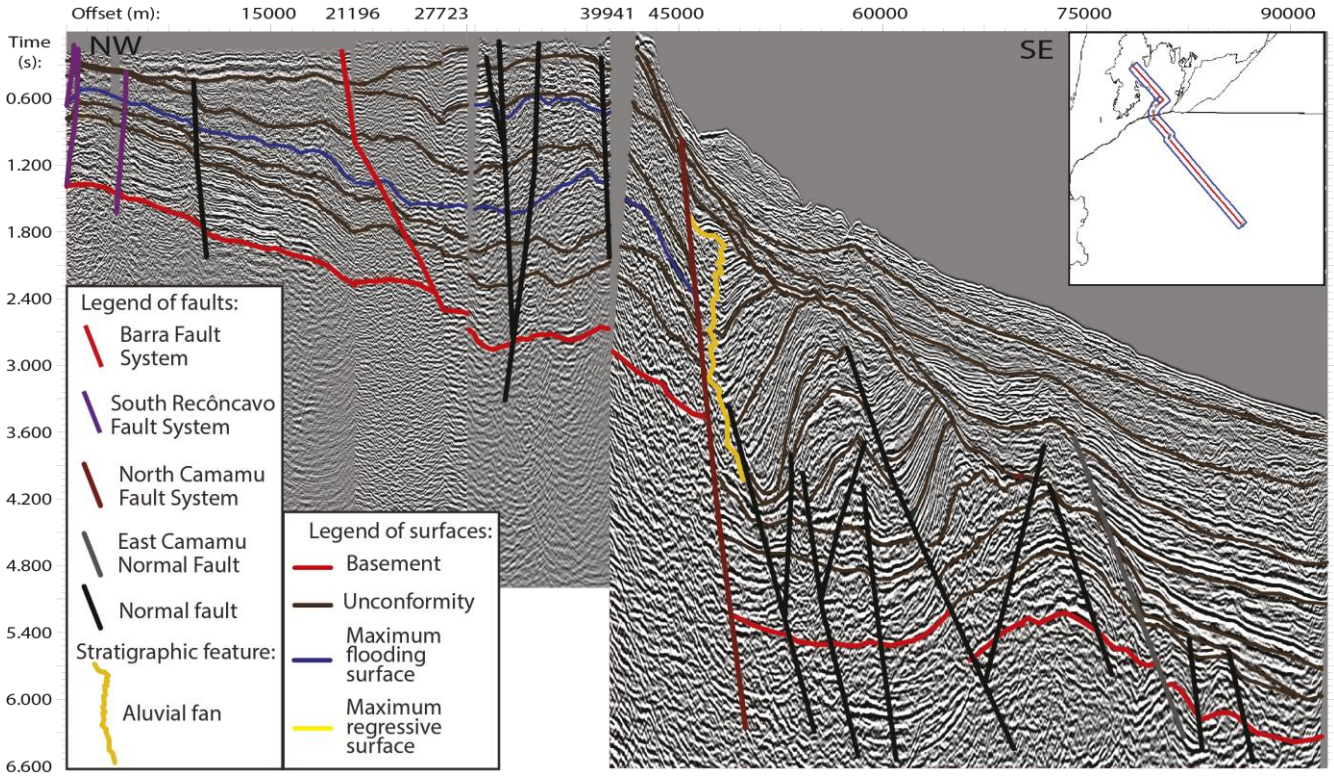

Figure 4 *- Interpreted composite seismic section that cross the South of the Recôncavo Basin and the North of the Camamu Basin. Note the difference of displacement between the Barra Fault System and North Camamu Fault System.*

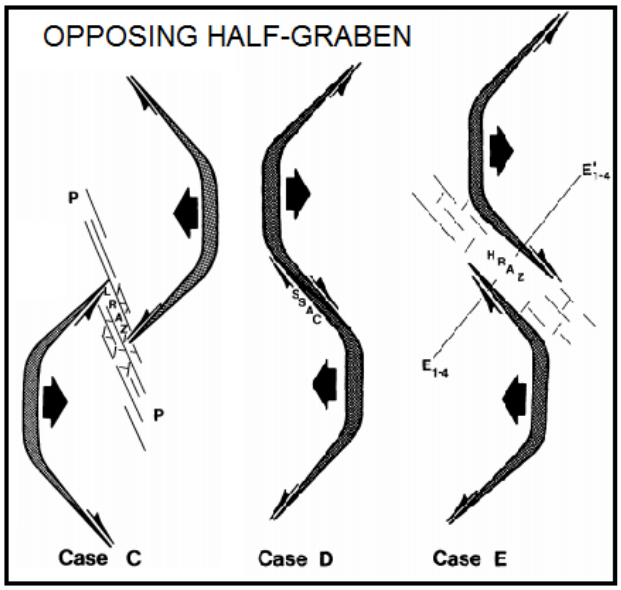

Figure 5 *- Examples of half-graben systems of opposing geometries, where the Case C shows an overlapping of faults, and cases D and E shows a non-overlapping. Opposite geometries create low-relief and high-relief accommodation zone (LRAZ and HRAZ, respectively). In Case D there is a strike-slip accommodation zone (SSAC). Source: Rosendahl (1987).*

The structural interpretation performed in the mapping of the Barra Fault System and the Salvador Fault shows an analogous example to what occurs in Case C of Figure 5, characterized by an overlapping and opposing of half-grabens.

Conclusions

The seismic-structural interpretation identified the main fault systems inserted in the study area. The Barra Fault, accepted by the literature as a structural limit between the basins approached, was considered compartmentalized, forming a fault system composed of three main sections, characterized by normal high-angle faults with a preferential direction NE-SW and diving to the southeast, moreover, there are a series of associated relief faults predominating NW-SE.

The Barra Fault System presents in its seismic mapping a large lateral variation of displacement, ranging from less than 100 ms in the regions closest to the Salvador High (under the outfall of the Todos os Santos Bay), up to just over 800 ms in the region of the Itaparica Island. This fact is also illustrated by the well correlation sections (figures 3C e 3D), that the main fault reaches more than one kilometer of displacement. Layer growth features along the syn-rift phase are also evident in the main system failures, which characterize their syn-sedimentary development.

Although the contact between the Recôncavo and Camamu basins is currently considered as the Barra Fault system, stratigraphically it does not limit its rift phase. Furthermore, the main fault system found in the Camamu Basin area appears in the region south of the last system, then named Northern Camamu Fault System. This was identified by the presence of three normal high-angle faults with displacements that exceed 1.5 s in the seismic sections.

A system of faults to the northwest of the block that composes the current Todos os Santos Bay (southern portion of the Recôncavo Basin) was also identified, in addition to a series of normal synthetic and antithetic faults of a preferential NE-SW direction throughout the entire study area.

The map of Figure 2, besides showing the interpreted main faults, indicate the preferential deepening of the basement surface in the southeast direction, with some local depocenters, as in the central portion of Camamu Basin and next to the Salvador Fault in the Recôncavo Basin.

Acknowledgments

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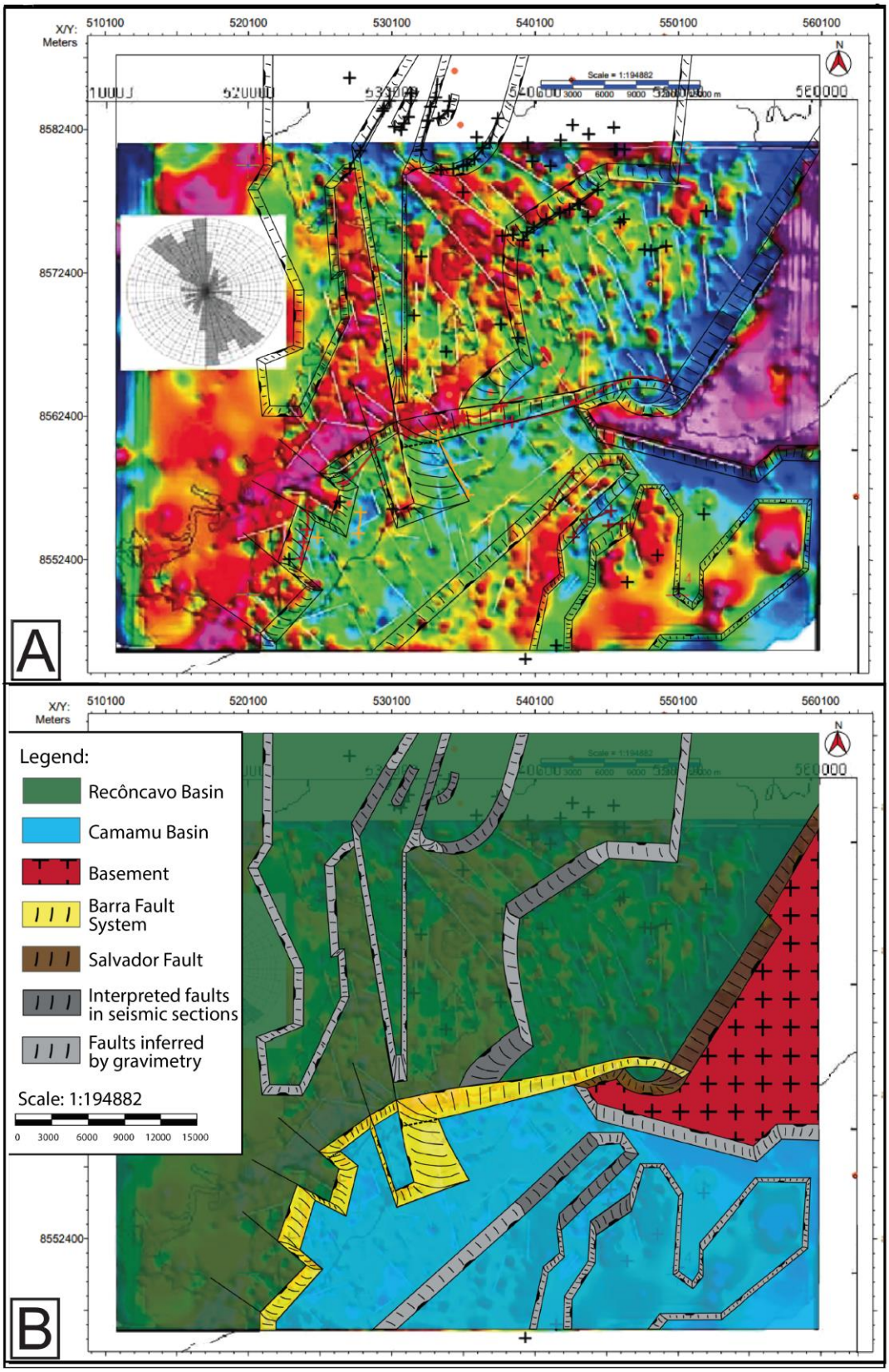

Figure 6 *- Barra Fault System interpreted through seismic data: (A) above the first vertical derivative map of the Bouguer anomaly from Amaral (2009); (B) inserted in the model of the current region of the contact between the Camamu and Recôncavo basins.*