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The geometry, sedimentary filling and depth estimate of the Mirandiba Basin, Pernambuco, Brazil: new insights about the depositional regional gap of rift phases in the interior basins

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Abstract

The Mirandiba Basin has a well-defined stratigraphic sequence and its sedimentation may be directly correlated with the Jatobá Basin and some other interior basins. The sedimentation began in intracratonic conditions with a Paleozoic sequence (Tacaratu/Inajá Formations), which acted as a substrate without any genetic relationship with the basin. The fluvial Tacaratu Formation emerges beyond the limits of this basin, where a remnant core named here as Poço do Icó was found wrapped around the basement to the west of the basin. Subsequently, there was a deposition in a shallow marine environment of the Inajá Formation (Devonian) formed by the intercalation of clay/siltstones and sandstones with ichnofossils. Pre-rift sedimentation occurs over the Paleozoic sequence, characterized in the basin by the lacustrine sediments of the Aliança Formation, represented by the intercalation of shales and calcarenites with desiccation cracks and fossil fragments. In spite of depositional gap described between the local Aratu and Alagoas Stages, the presence of Salvador Formation close to the north border fault may represent a rare rift phase record in the interior basins. The post-rift sequence is represented by the Marizal Formation, deposited during the Aptian. This formation is distinguished by the intercalation of fine sandstone, siltstone and conglomerate deposited in an alluvial fan environment. The pre-rift, rift and post-rift sedimentation are embedded in the depocenter of the basin, where the main NE-SW graben stands out. A gravity survey was carried out, which obtained a negative, asymmetric Bouguer anomaly, with gradients added to the northwest, suggesting the existence of a half-graben. The result of the gravity 3D model indicates the existence of a main depocenter in the NE-SW direction with depths of up to 400 meters. These geophysical results support the tubular well location drilled 410 m in depth that was used in this work to better characterize the basin. The joint interpretation of gravity, aeromagnetic and structural data suggest that the half-graben framework of the basin developed by the evolution of a pull-apart extension system. The structural system that gave rise to the Mirandiba Basin has the maximum compression tensioner oriented to NE-SW and the distention to NW-SE. It has a depth of around 400 meters and the depressions formed by tectonic events were filled by Post-Tacaratu sedimentation.

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1. Introduction

The central-western portion of the Borborema Province concentrates the majority of the Cretaceous intracontinental basins at the northern end of the Recôncavo-Tucano-Jatobá rift (Milani and Davison, 1988) formed in the Brazilian territory (e.g. Araripe, Cedro, Mirandiba, Betânia, Fátima basins, among others).

The deformation that controlled the development of these basins has a clear connection with previous structures of the crystalline basement that constitute discontinuous areas of weakness that act as concentrators of the associated deformation. Some discontinuities such as Patos and Pernambuco lineaments were partially derived from the Transbrasiliano Lineament and may have played an important role in the lateral escape of masses (Ganade et al. 2013) and were effectively reactivated in the Cretaceous times (Destro et al. 1994; Lopes et al. 2019; Vasconcelos 2018). The tectonic rearrangement resulting from these reactivations and which favored the installation of the interior basins suggests a set of distensional systems dominated by strike-slip deformation (Heine et al. 2013).

In this context, the Mirandiba Basin has dimensions of approximately 120 km^2. Located in the homonymous

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municipality in Pernambuco, it is preferentially elongated in the ENE-WSW direction and its occupation in a central position between major Jatobá and Araripe basins may provide some clues about stratigraphical levels preserved that might be useful in the framework reconstructions. Despite the growing number of studies on these interior basins, the available literature on the Mirandiba Basin only includes works of regional character such as correlation of its depositional system observed with the Jatobá Basin.

This paper presents the integrated results of a terrestrial gravity survey, the interpretation of 405m of geophysical logs of gamma-ray (GR), spontaneous potential (SP), resistivity (SN) and sonic log (DT) parameters obtained from the Sítio Ervanso borehole and the systematic geological mapping (scale 1:100.000), using fieldwork, petrographic, structural and paleontological aspects including stratigraphical sections surveyed along the basin units.

2. Geological setting

The interior basins of Northeastern Brazil evolved from a rift system developed from the reactivation of lineaments and discontinuities from the Precambrian basement rocks. These basins were generated through Cretaceous geological and tectonic processes, linked to the opening of the Atlantic Ocean, which led to a transition regime, without which the traction efforts led to the development of normal faults with the opening of grabens and half-grabens (Carvalho and Melo 2012). These basins were considered as fragments of a single basin, although stratigraphically they have their particularities indicating different geological histories (Cordani et al. 1984). The origin mechanism of the interior basins of the northeast was through the Cariri-Potiguar Rift System, with the main direction of extension at NW-SE (Matos 1992). Within this context, the Mirandiba Basin is embedded on the Precambrian rocks of the central-western portion of the Transversal Zone, Borborema Province, and was formed by a semi-graben, limited by normal faults (Carvalho 2014).

Sedimentation in the Mirandiba Basin started with the pre-existing sedimentary sections of the Paleozoic sequence that acted as a basis for the other units, not keeping a genetic relationship with the basin that contains it, being called Paleozoic substrate (Milani et al. 2007). The basin was filled with Cretaceous sediments whose units are correlated to the lithostratigraphic units of the Recôncavo-Tucano-Jatobá rift, such as the Aliança and Marizal Formations (Braun 1966).

The sedimentary filling recorded in Mirandiba basin is subdivided into a Paleozoic Supersequence and a Mesozoic Sequence, of which the latter is subdivided into pre-rift (Neo-Jurassic), rift (Eo-Barremian), and post-rift (Neo-Aptian) (Matos 1999; Costa et al. 2007). These sequences are based on the model proposed by Lambiase (1990). Over the Paleozoic sequence (Tacaratu-Inajá), the pre-rift sedimentation is characterized by the Aliança Formation composed of the Boipeba and Capianga members (Braun 1966). There are no records of the rift sequence in the literature and lastly, the post-rift sequence was deposited in the context of a thermal subsidence as a sag basin where the Marizal Formation was deposited.

Pereira et al. (2012) described in the Mirandiba Basin four lithostratigraphic units (Tacaratu, Inajá, Aliança e Sergi Formations), with deposition only up to the Pre-rift stage, and the Marizal Formation was suppressed.

3. Methods

3.1. Survey and processing of gravity data

The gravimetric survey of the Mirandiba sedimentary basin aimed to define the three-dimensional framework for determining sediment thickness and fault location to support hydrogeological studies and provide strategic locations for deep wells.

A total of 230 gravimetric stations were surveyed, distributed along roads with an average spacing of 0.5 km in the interior of the basin and 1.0 km in the outcrop areas of the crystalline basement. The gravity survey was carried out with a CG-5 Autograv. The gravity value calculation was referenced to the International Gravity Standardization Net - 1971 (IGSN-71), through the occupation of gravity bases of the Brazilian Fundamental Gravity Network with previously known absolute gravity value (g = 977997.367 mGal). The altimetric survey was carried out with a pair of geodesic GPS, maintaining a fixed GPS in a base with precise and previously known ellipsoidal altitude and a traveling GPS occupying the stations to be determined. The orthometric altitudes were calculated by incorporating the geoid undulation by means of IBGE's MAPGEO 2010 software.

Gravity data were processed using Geosoft's Oasis Montaj software, gravity module. Instrumental drift, tidal corrections, normal gravity (1967 formula), gravity value, terrain correction and free-air and Bouguer anomalies referenced to the geoid surface were calculated for a topography density equal to 2. 67 g/cm^3.

3.1.1 2.5D gravity modeling

The 2.5D modeling method was adopted, by calculating and comparing the signals of 2.5D geometry bodies using the algorithm of Talwani et al. (1959) adapted for the GravSys software. The steps followed during the modeling process were as follows: i) to build two-dimensional models of the basin considering the residue of the Bouguer anomaly using the isogalic -58 mGal as a reference; ii) calculate the effects; iii) compare the calculated effects with the observed data; iv) adjust the calculated gravity profile to the observed data profile. In this procedure, geological information and available tubular wells were always considered.

3.2. Sítio Ervanso tubular borehole

The well was drilled by roto-percussion equipment and the penetration times were marked by meter, with a detailed lithological description of the entire borehole and profiling performed geophysics. The geophysical profiling of the well was conducted by the company HYDROLOG LTDA., which included geophysical well-logs of gamma-ray (GR), spontaneous potential (SP), resistivity (SN) and sonic log (DT).

3.3. Facies descriptions and mapping

The regional mapping of the sedimentary sequences used in this work obeyed a minimum scale at E: 1:100.000 and the section surveyed stands intervals between 0.5 and 1.0m. The facies descriptions were classified following the proposal elaborated according to Miall (1996).

Radiometric measurements of the outcrops were made by using a hand gamma spectrometer model RS-230. The readings of radiation levels were made in the ferruginous sandstones, the concentrations of the radioisotopes are measured in percentage (%) for Potassium (K), part per million (ppm) for equivalent Uranium (eU) and equivalent Thorium (eTh).

4. Geology of Mirandiba Basin

4.1. Lithological and Facies Analysis

This Mirandiba Basin study recognized five sedimentary formations in addition to the recent covers (Figure 1). The stratigraphic chart of the Mirandiba Basin was elaborated based on the existing maps of the Jatobá Basin (Figure 2) and is composed of three sedimentary sequences.

4.1.1. Tacaratu Formation

The Tacaratu Formation is the basal unit of the basin. This formation occupies the largest extension and its deposition goes beyond the limits of the basin, such as the deposition of the testimony hill (Poço do Icó), discovered in this study, which is located approximately 10 km west of the Mirandiba Basin (Figure 1). This formation exhibits essentially sandstones. Through the survey of sections, it was possible to identify five facies (Sp, St, Sh, Sl and Gp) (Figure 3).

The most representative rocks are medium to coarse-grained sandstones (Sp, St) with a general sense of paleocurrent predominantly towards NW (Figure 3). These sandstones are also marked by the presence of fractures and faults, forming bands of deformation and silicification in the fault planes. Sometimes between sets of sandstones, there are conglomerates with centimeter layers that make up Gp facies. The descriptions and interpretations of the lithofacies of the Tacaratu Formation are summarized in Table 1.

The petrographic characteristics of the Sp and St facies are similar and the sandstones are classified essentially as quartz-sandstones (up to 98% of quartz) and eventually sublitarenites (5% of rock fragments) and sub-arkose (maximum 10% of feldspars). Sandstone cement, when present, is composed of iron oxide and is more rarely siliceous. Associated with the Sp and St facies occurs the Sh facies that have characteristics similar to these, however, the primary structure is plane-parallel lamination type.

Fine to very fine-grained (Sl) sandstones do not occur very often and usually emerge as slabs. In Sl facies, the sandstones are friable with whitish color, quartz, sometimes micaceous with low angle stratification. Under the microscope, it has a good granulometric selection and is apparently cemented by interstitial silicate material. Sandstones are classified as quartz-sandstone according to the classification of Folk (1968).

Some sandstones of the Tacaratu Formation are reddish with ferrous concretions and characteristics Gamma-ray spectrometric patterns are observed in them regarding the

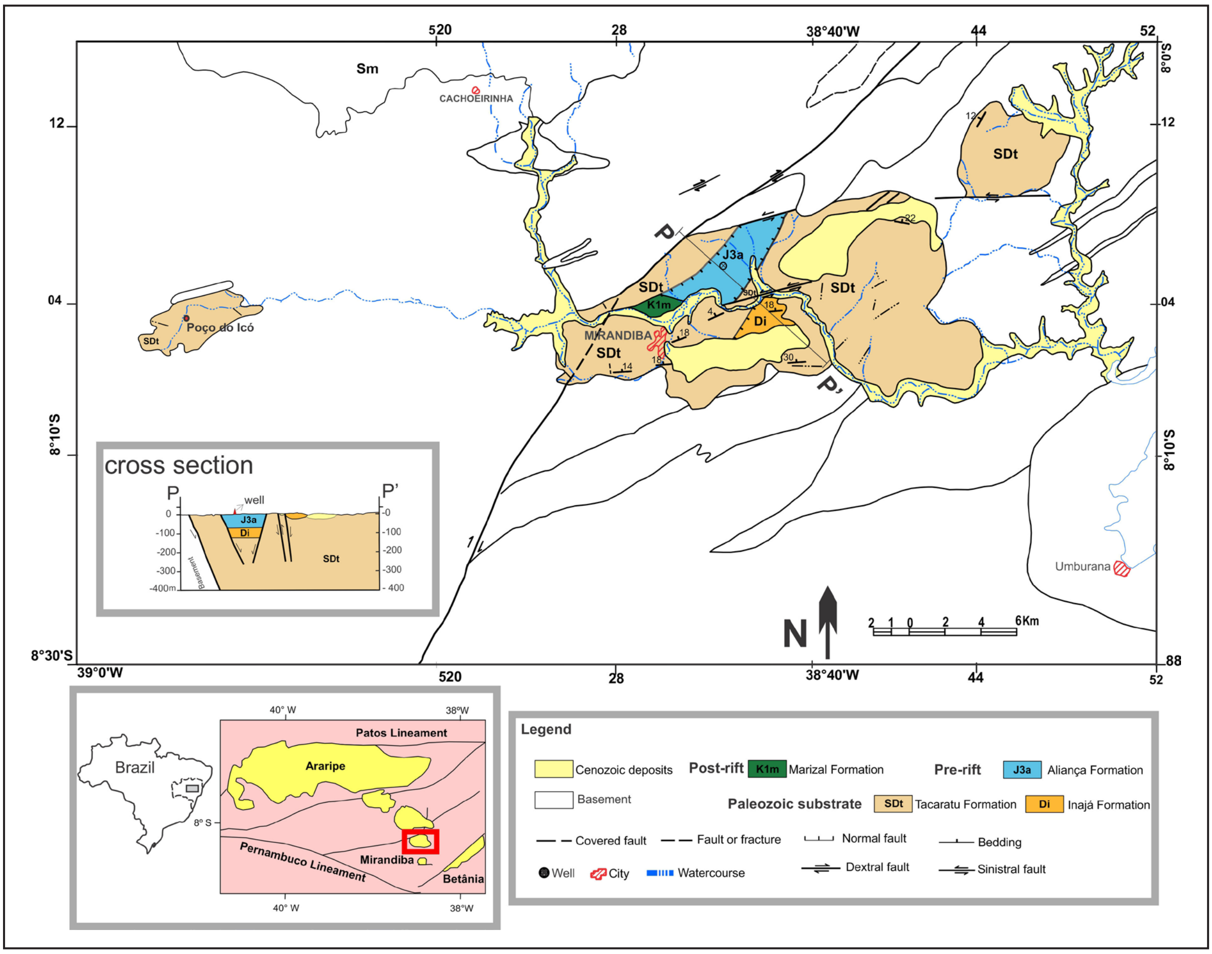


FIGURE 1. Simplified tectonic framework and Geological map of the Mirandiba Basin. Modified after Brasilino et al. (2014). Cross section P-P' indicated on the map.

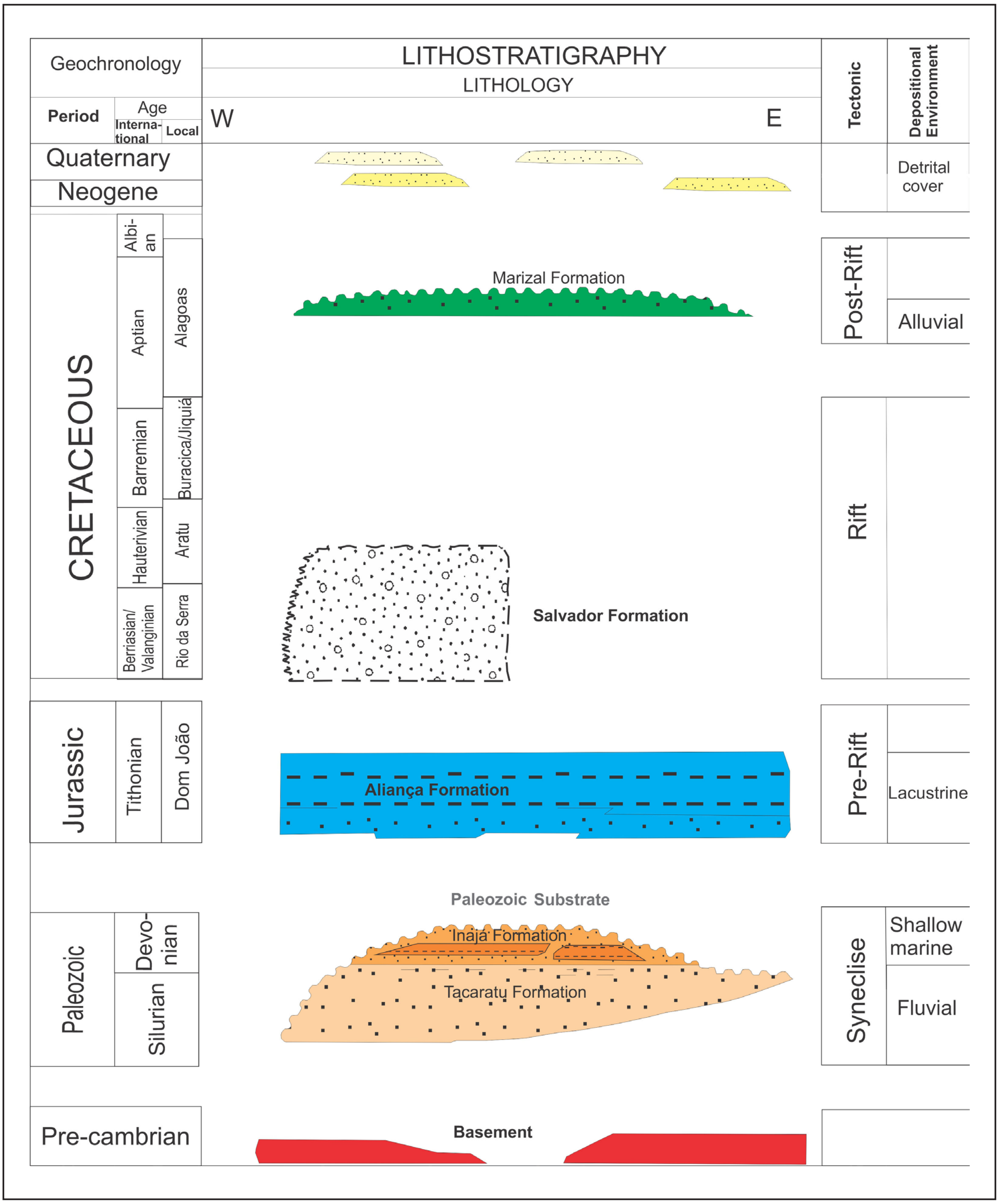


FIGURE 2. Chronostratigraphic chart of the Mirandiba Basin in Northeast Brazil, after Costa et al. (2007).

other sandstones of the Tacaratu Formation. The other has low K (<0,6%), average eTh (~ 17.2 ppm) and eU (~ 4.2 ppm). In the latter case, light eU and eTh enrichment is possibly related to an oxid-reduction process that led to the deposition of hematitic iron and cryptic U oxides in the sandstone interstices.

The facies Sp, St, Sh and Sl compose an association of facies that form the middle or braided bars that can migrate in favor of the flow forming the Downstream Accretion, or are dunes that can migrate and ride generating the deposits of Sand Bed Forms, probably these are the two architectural elements formed in the association of these four facies, in addition to the Gravel Bar that is essentially formed by the Gp facies.

4.1.2. Inajá Formation

The Inajá Formation was identified within Mirandiba Basin during the mapping fieldwork (Geological map reported in Brasilino et al. 2014). Despite the way it is exposed in devastated areas and in the form of flagstones, it was possible to identify 5 facies that are described in table 2 and figure 4.

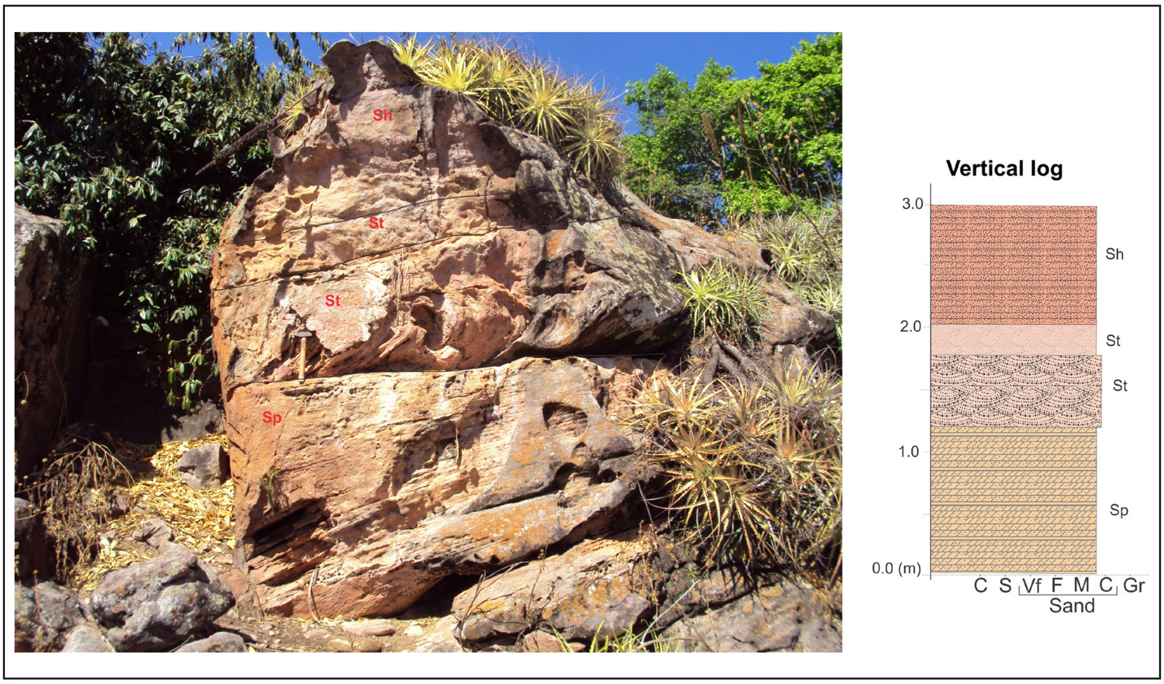


FIGURE 3. Interposition of the Sp, St and Sh facies in the sandstones of the Tacaratu Formation and their respective schematic section.

TABLE 1. Facies description and interpretation in the Tacaratu Formation.

Facies	Description	Interpretation
Sp	Medium to coarse-grained sandstones; planar cross-stratification. Usually associated with Gp facies.	2D subaqueous sandy dunes, by a lower flow regime (Collinson et al. 2006).
St	Medium to coarse-grained sandstones with conglomeratic levels of quartz; well-sorted, with trough cross stratification.	St facies were generated by unidirectional flow, formed of 3D sand dune deposits, lower flow regime (Miall 1977; Collinson et al. 2006).
Sh	Fine to coarse-grained sandstones; poorly to well-sorted, with dispersed pelitic intraclasts; horizontal lamination.	Planar-bedded deposits originated by upper flow regime (Miall 1977).
Sl	Little representative in the area, it is characterized by very fine to fine, micaceous sandstones; White color and friable;w low-angle cross-stratification.	Washed-out dunes and humpack dunes (transition between subcritical and supercritical flows) (Harms et al. 1982; Bridge and Best 1988).
Gp	Conglomeratic sandstone composed essentially of centimetric quartz grains to clast supported conglomerates of polymeric composition with feldspars and clasts of granite rocks up to 5cm thick; planar crossed stratifications that are sometimes incipient.	Transverse bedforms, growths from older bar remnants (Miall 1977).

The Inajá Formation has a gamma-ray spectrometric pattern with depletion of K (<1.5%), eTh (<7.5 ppm) and eU (<1.5 ppm). This unit is distinguished by the intercalation of siltstones, claystones and sandstones. The siltstone (Fsm) has a brownish and whitish gray color with some portions changing to kaolin. Claystones (Fl) are brownish and sometimes have fissures.

The base and the top of the outcrops are formed by sandstones (Sm and Sr); at the base they are finer with granulation ranging from fine to very fine, sometimes ferruginous and massive. At the top, the sandstones are fine- to medium-grained with incipient ripples and are quite bioturbated. Bioturbations are represented by ichnofossils, classified as invertebrate brands, identified as *Arenicolites* isp. and *Skolithos* isp.

There is a sandstone facies (Sh) that emerges only in the form of flagstone and is composed of a very reddish sandstone of medium granulation, with parallel flat stratification and is very fractured. These sandstones are very bioturbated with records of ichnofossils of the *Skolithos* isp. type (Figure 4D).

The ichnofossils found have the same set of characteristics; with thick wall, passive filling and absence of branching, they occur as isolated vertical, inclined, or horizontal forms, the latter being generally curved. These shapes can be interpreted together as U-shaped excavations with the curved horizontal structures composing the base and the vertical ones representing the chimneys. There are no indications of accumulation structures (spreite) between the chimneys. This set of characteristics allows the determination of ichnofossils such as *Arenicolites* isp., which corresponds to housing structures (Domichnia) of small invertebrates. Some of the structures correspond to *Skolithos* isp., rounded vertical excavations with a rounded bottom (Figure 4C and D).

The bioturbation index is high, reaching level 4 according to the classification of Droser and Bottjer (1986; 1987), which aims to estimate the density of the ichnofabric in a semi-quantitative way.

The observed fossil occurrences typically present low diversity and high density of simple vertical or U-shaped excavations. The predominance of housing structures is characteristic of opportunistic communities formed by a few species of strategist organisms, that is, little specialized. Producing animals are often suspensivorous or passive predators. This type of community usually forms when

TABLE 2. Facies description and interpretation in the Inajá Formation.

Facies	Description	Interpretation
Sm	Very fine to fine sandstone; massive; sometimes ferruginous.	Rapid deposition of hyperconcentrated flows (Miall 1978, 1996).
Sr	Fine to medium-grained sandstones with conglomeratic levels, sometimes ferruginous, climbing ripples; later modification by bioturbation dominated by *Arenicolites* isp. e *Skolithos* isp	Subaqueous current ripple migration under unidirectional, lower flow regime (Miall 1996). Fast deposition storm-generated above fair-weather wave base(Sedorko 2018; Plint 2010).
Sh	Medium-grained red sandstones, with horizontal lamination and bioturbation (*Skolithos* isp)	High energetic unidirectional flows above fair-weather wave-base (Miall 1977; Sedorko 2018).
Fsm	Off white gray siltstone and in some portions it is possible to find a change to kaolin	Decantation episodically disrupted by storm flows (Miall 1977).
Fl	Brownish mudstones, that is sometimes laminated.	Deposition from suspension in low energy conditions (Miall 1977).

the substrate is re-colonized after reworking or erosion of previously deposited layers or in inhospitable conditions to most forms of life, such as dysaerobic or anaerobic environments with varying salinity or with non-uniform sedimentation rates (Bromley 1996).

4.1.3. Aliança Formation

This unit emerges in the region of the main graben of the NE-SW direction inside the basin and three facies have been described in it (Table 3). The Aliança Formation is characterized by a large amount of clay and with some calcarenites outcroping in devastated areas.

In a single outcrop, a sandstone with low angle cross-stratification was found in contact with the Aliança Formation. However, due to the high degree of weathering it was not possible to determine more details and thus distinguish the stratigraphic unit, but it may be from the Sergi Formation.

Lithologically, the Aliança Formation is characterized by a large amount of reddish-brown clay, interspersed with levels of calcarenites and greenish shales (Figure 5). The calcarenites are light brown to whitish in color with desiccation cracks, lamination and incipient wave marks. These limestones also contain rare fossil fragments of vertebrates, aragonite and maganese oxide.

The limestone, petrographically, is essentially bioclastic, composed of bivalves with micrometric sizes up to a few millimeters (1 to 2 mm), with the majority of ostracodes being filled with calcite (Figure 5C). The granulation is calcarenite, where the limestones are made up of particles equivalent in size to sand (between 0.062 and 2 mm in size), supported by the grain and without matrix that according to Dunham's classification (1962) are grainstone. There are also more siliciclastic facies containing up to 40% of fine to very fine-grained quartz grains, the other components being ostracodes and the micritic matrix and were classified as packstone according to the classification of Dunham (1962). The carbonate is composed of mollusk and ostracod debris, together with carbonate sand and bio-induced mud (Renaut and Gierlowski-Kordesch 2006).

The ostracods of the Aliança Formation were classified by Braun (1966) as two non-marine species: *Metacypris sp.*

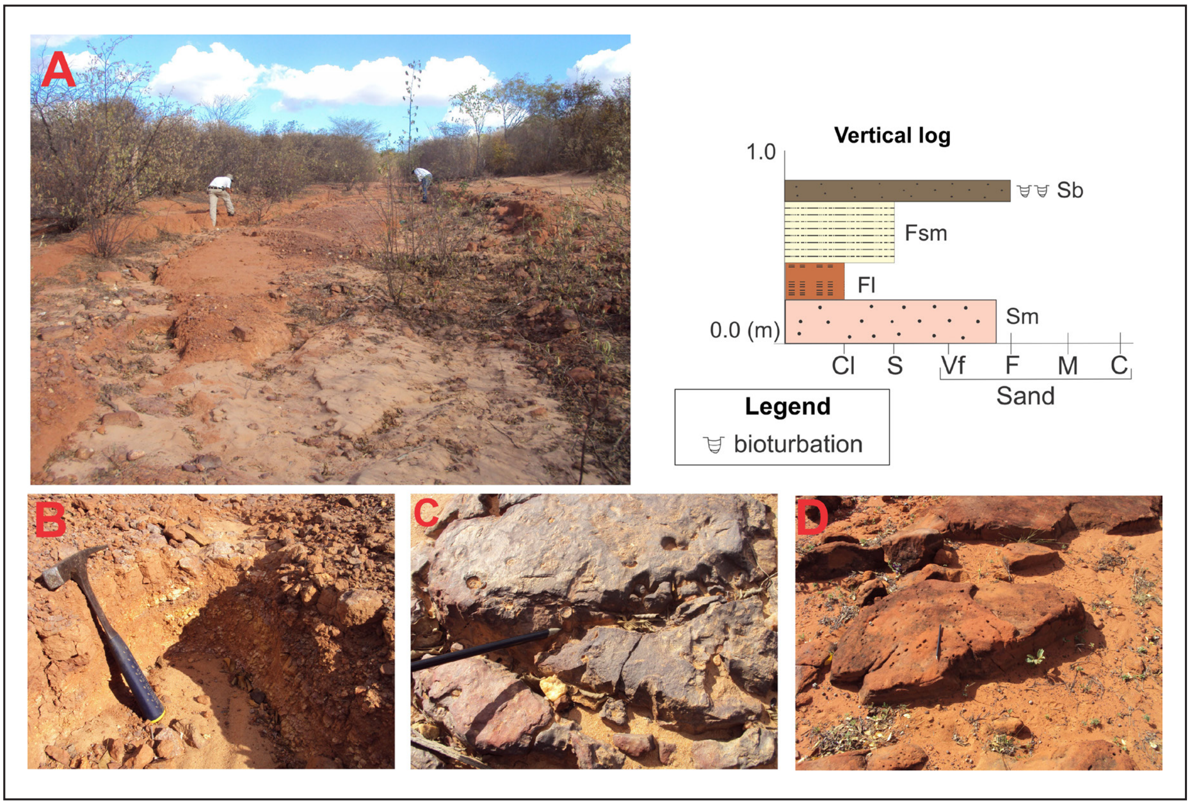


FIGURE 4. A) Overview of the outcrop with its schematic section. B) Detail of the facies siltstone Fsm. C) Detail of the sandstone (Sh) at the top with ichnofossils. D) Detail of reddish arenite (Sh) with *Skolithos* isp.

and *Darwinula oblonga*, both related to the Jurassic, Dom João local stage.

This facies association composed of facies Fl, reddish Fm and sometimes interlayered with Co, in metric scale is characterized by a lake environment. The red coloration of the mudstone indicates oxidizing conditions for mud deposition. According to Renaut and Gierlowski-Kordesch (2006), coquina grainstones/packstones are common in shallow lake settings. The presence of exposure features, such as mud cracks, indicates subaerial deposition of these rocks.

TABLE 3. Facies description and interpretation in the Aliança Formation.

Facies	Description	Interpretation
Fm	Reddish brown mudstones; massive.	Suspension settling on overbank areas; post-depositional reddening under oxidizing conditions (Miall 1977, 1990; Foix et al. 2013).
Fl	Greenish shales	Suspesion settling (Rogers and Astin 1991; Mángano et al.1994).
Co	Ostracods calcarenite; light brown to off-white. Occurrence of ostracode shells and fossil fragments of vertebrates. With desiccation cracks, lamination and incipient wave marks.	Chemical deposition on small shoreline benches of impure limestone on lake shallow portions (Platt and Wright 1991, 1992; Renaut and Gierlowski--Kordesch 2006).

In the Mirandiba Basin, only the Capianga Member emerges while there is no record of the fluvial sedimentation of the Boipeba Member. This fact is probably due to a great extension of Capianga Lake flooding areas over the sedimentation dominated by the Boipeba Member or simply there was not fluvial sedimentation in the basin during the Jurassic.

4.1.4. Salvador Formation

We interpreted a single outcrop characterized as Salvador Formation characterized by the large volume of polymictic conglomerates with the following facies shown in Table 4.

The base is composed of massive sandstone with light brown to whitish coloration that can grade to medium to coarse granulation (Sm). The thinnest lithologies (Fl) are characterized by 15 centimeters thick greenish-gray shales which are interspersed with both sandstone and conglomerate.

The coarser granulation facies (Gcm) are represented by a polymictic clast supported conglomerate, composed of fragments of granitic rocks, gabbros, sandstones and quartz pebbles. The clasts are rounded and sized up to 30 centimeters in diameter (Figure 6).

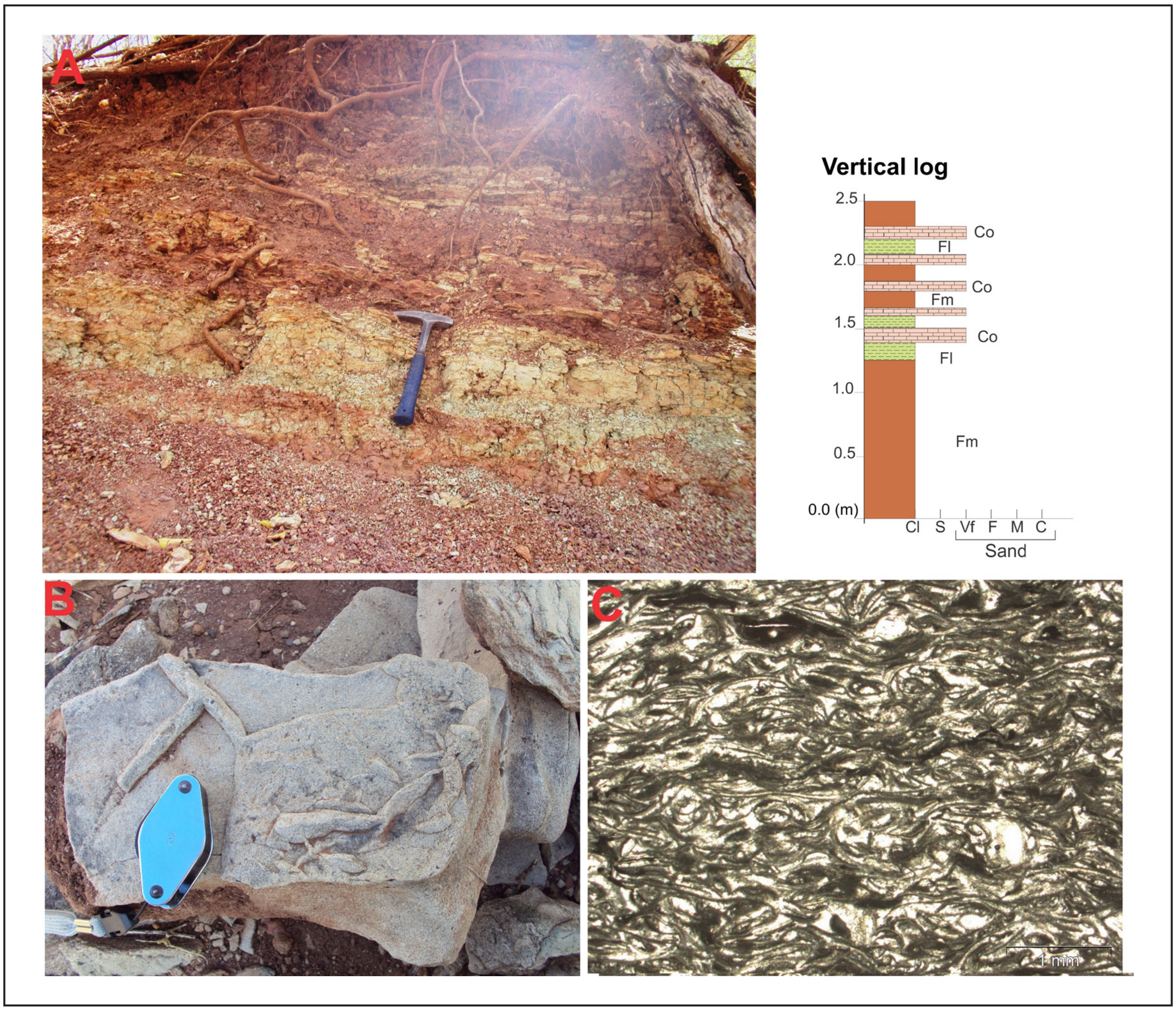


FIGURE 5. A) Outcrop of the Aliança Formation in the Mirandiba Basin with a schematic section showing the facies. B) Calcarenite facies with cracks of the Aliança Formation (Co). C) Microscopic photo of the grainstone showing the ostracodes with calcitic nuclei.

The Salvador facies can be further divided into two distinct interbedded processes: (1) non-cohesive debris flow and (2) stream flow (Figure 6). According to Todd (1996), clast-supported conglomerates may be the result of rapid suspension from sediment charged hyper-concentrated flows or turbulent non-cohesive mass or debris flow.

Thus, facies Gcm is interpreted here as being formed by debris flow. The association of facies Sm, and Fl is characterized by deposits of stream flow. The finer sediments (Fl) may be correlated with channel overflow, with silts and clays being carried in suspension. A low percentage of silt and clay (<10%) are common features in non-cohesive debris flow (Nemec and Steel 1984; Todd 1989).

4.1.5. Marizal Formation

In this work, it was possible to identify 2 facies associations of the Marizal Formation, composed of conglomerates, sandstones and pelites (Table 5). This formation emerges in the deepest region of the basin in the main graben (NE-SW), the base being composed of massive micaceous sandstone (Sm), with light brown to whitish coloration that can gradate to medium to coarse granulation (Figure 7).

The coarser granulation facies of the Marizal Formation (Gm) are represented by a tightly packed gravel. They are a polymictic clast supported conglomerate, composed of few lithic fragments, much sandstones and quartz pebbles. The clasts are rounded to sizes up to 15 centimeters in diameter, sometimes wrapped in a sandy-clay matrix and erosive base (Figure 7A).

TABLE 4. Facies description and interpretation in the Salvador Formation.

Facies	Description	Interpretation
Gcm	Clast-supported conglomerate; polymictic ranging from granules to cobbles,with sub-rounded, massive.	Deposition by non-cohesive debris flow (Todd 1996; Collinson and Thompson 1989).
Sm	Medium to coarse-grained sandstones; micaceous sandstones and massive	Rapid deposition of hyperconcentrated flows and high viscosity (Miall 1978, 1996).
Fl	Greenish shales; parallel lamination.	Suspension settling dominantly from standing water (Rogers and Astin 1991; Mangano et al. 1994).

Sedimentary structures are more present in fine sandstones with tabular (Sp) and plane-parallel (Sh) cross-stratification. Under the microscope, this rock is classified as a sub-slate and different from the sandstones of the Tacaratu Formation, it contains 0.5% matrix which is made up of clay and silt (Figure 7B).

The thinnest lithologies of the Marizal Formation were included in the Fl facies. The brownish siltstone, sometimes laminated and with scattered clay nodules. They are interspersed with both sandstone and sometimes there is no lateral continuity (Figures 7A and B).

In the Marizal Formation the sandy fraction predominates, it has two facies association; stream and sheet flows. The one with coarser granulation with facies (Gm), was probably deposited in the distributional channels where the conglomerates are associated with gravel bars correlated to the action of stream flow. The arenites (Sm) are possibly associated with migration of the fan-delta sandbars correlated to the action of stream flow.

The thinnest granulometry associated with well-selected sandstones (Sp, St) is correlated to sheet flow. The thinner sediments (Fl) may be correlated with channel overflow, with silts and clays being carried in suspension (Nemec and Steel 1984).

4.2. Sítio Ervanso well

The Geological Survey of Brazil – CPRM drilled a tubular well in the Mirandiba Basin in the locality of Sítio Ervanso (LAT -8.0903 / LONG -38.702). The location of the drill was supported by gravity interpretations and the whole-well reached 410 m in depth. The well has a description of the gutter samples and geophysical profiling, with which it is possible to make an interpretation and analogy with the data already known and which are directly correlated with those collected in the field (Figure 8).

The Tacaratu Formation composes the base of the well where it was drilled to the crystalline basement. This unit is represented by sandstones with the peaks of the Gamma-

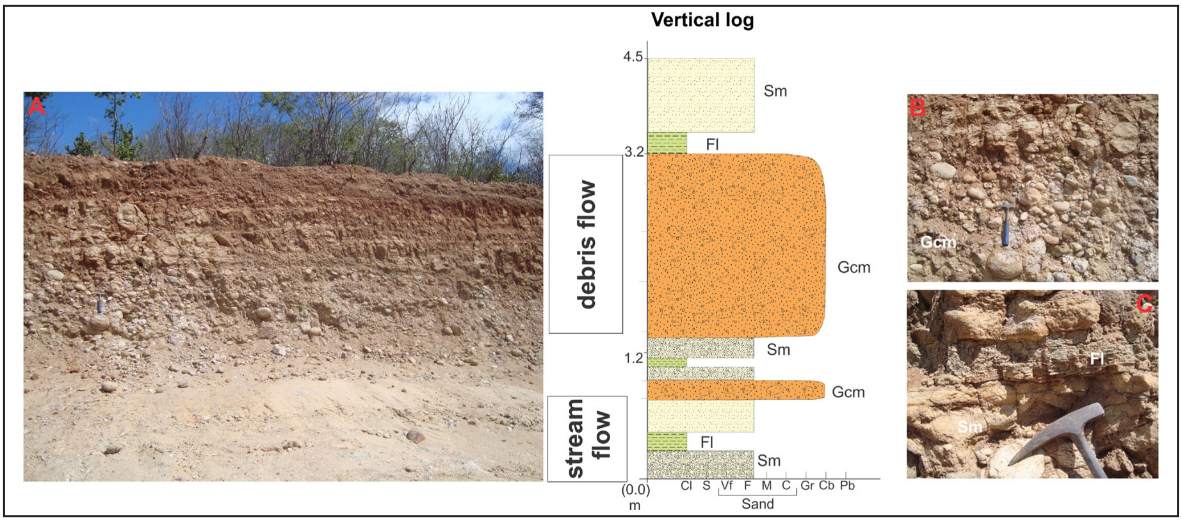


FIGURE 6. A) Overview of the outcrop (S-N) of the typical section of the Salvador Formation in the Mirandiba Basin. B) Detail of the supported clast polymictic conglomerate. C) Detail of the greenish shale level.

TABLE 5. Facies description and interpretation in the Marizal Formation.

Facies	Description	Interpretation
Gm	Clast-supported conglomerate; polymictic with rounded, massive.	Gravel bar of the distributional channels; Inertial bedload, turbulent flow (Miall 1978).
Sm	Fine to coarse-grained sandstones; micaceous sandstones and massive.	Rapid deposition of hyperconcentrated flows and high viscosity (Miall 1978, 1996).
Sp	Fine sandstones, well-sorted; planar cross-stratification.	2D subaqueous sandy dunes (lower flow regime) (Collinson et al. 2006).
Sh	Fine sandstones, well-sorted; horizontal lamination.	Planar-bedded deposits originated via upper flow regime (Miall 1977).
Fl	Brownish siltstones; parallel lamination. Sometimes occur clay intraclasts.	Suspension settling dominantly from standing water (Rogers and Astin 1991; Mangano et al. 1994).

ray and Sp profiles being represented by the ferruginous red sandstones. At the top of the formation appears a layer of siltstone that marks the base of the Inajá Formation, characterized by the intercalation of sandstone with siltstone. The entrance to the greenish shale, with Gamma-ray peaks and DT profile, marks the Aliança Formation.

5. Kinematic analysis of brittle structures

The main structures in the Mirandiba Basin are faults and joints that have different orientations (Figure 9A). These structures are observed more frequently in the sandstones of the Tacaratu Formation, which sometimes, due to tectonic activity, are identified with silicification levels and with the slopes slightly inclined towards North / Northwest.

The normal faults are essentially oblique and have a preferential orientation for NE-SW. Some of these faults delimit the main graben of the basin, which has the same orientation (NE-SW). The occurring sinistral faults have a NE-SW to NNE-SSW direction, with some subordinate features oriented in the W-E direction. Transcurrent distal faults have NW-SE direction and only a single inverse fault with NE-SW direction was found as a result of a local rearrangement of blocks.

In some outcrops, the faults occur in the form of conjugated pairs with geometry in X, with an angular relationship close to 60°. The analysis of the stretching features in conjunction with the deposition shoulders direction is compatible with vertical directional flaws of both right and left kinematics. The geometric and kinematic characteristics of the conjugated pairs allow estimating the position of the maximum compression direction (σ1) at SW-NE (Figure 9B and 9C).

In the absence of conclusive kinematic indicators, the other brittle structures identified in the basin were classified as joints, although some of them can be characterized as extension joints, associated with the major faults in the basin. The joints have preferential W-E direction, with some at NW-SE and NE-SW. In many cases, the faults and/or joints occur as deformation bands, which prevail in the NE-SW direction,

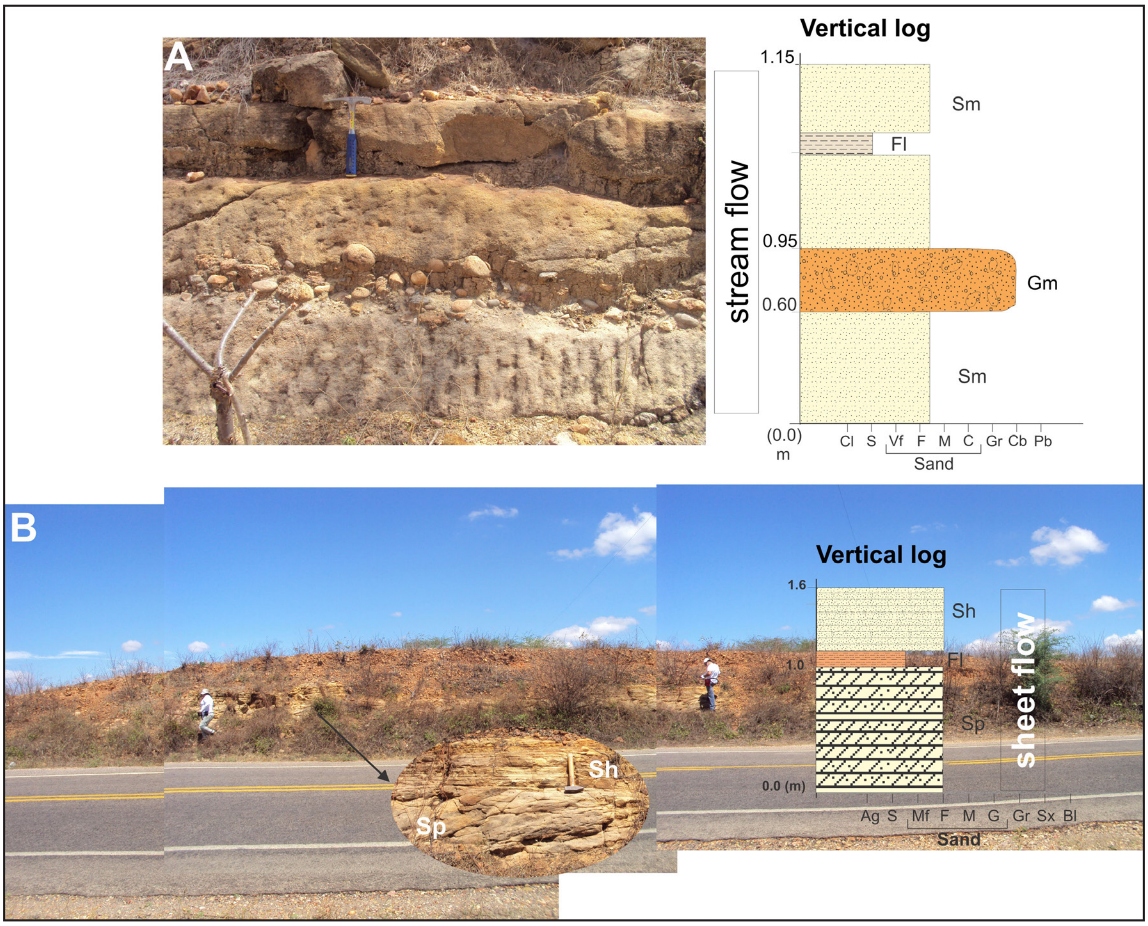
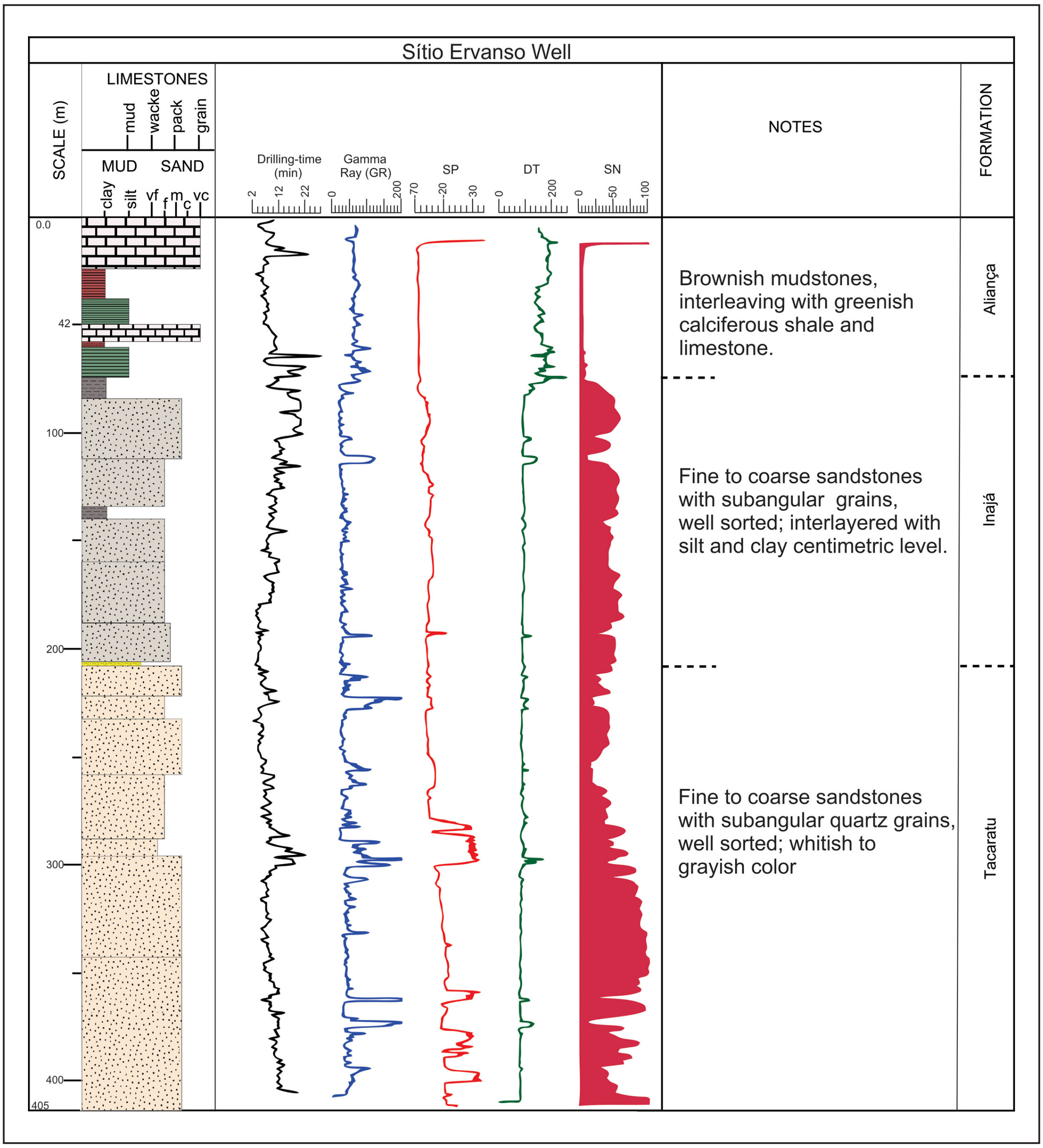


FIGURE 7. A) Facies association of Marizal Formation in a stream flow deposit. B) Outcrop with facies of thinnest lithologies of Marizal Formation in a sheet flow deposit, detail for Sp and Sh facies and their measured section.



Brownish mudstones, interleaving with greenish calciferous shale and limestone.

Fine to coarse sandstones with subangular grains, well sorted; interlayered with silt and clay centimetric level.

Fine to coarse sandstones with subangular quartz grains, well sorted; whitish to grayish color

FIGURE 8. Lithological description of drill cuttings and well logging (LAT -8,0903 / LONG -38,702) extracted and modified from (Diniz and Silva 2014).

in agreement with the sinistral sense occurring or normal oblique faults. Probably, some deformation bands with no apparent movement are associated with the damage zones of the basin faults.

Of all the structures analyzed, sinistral and normal oblique kinematic faults are prevalent. The geometric pattern of the structures combined with their respective kinematic characteristics are consistent with a tectonic model of the pull-apart type. In this case, the WNW and ESE edges of the basin should preferably be limited by normal faults. Although the visualization on a map of the limits of the basin refers to a slightly rhombohedral configuration, some important structures that would facilitate the confirmation of this model do not appear at the surface or are simply covered by late deposits in the basin.

6. Geophysics: data and interpretations

The Bouguer anomaly values show a maximum variation of 15.0 mGal (between -64.0 and -49.0 mGal) (Figure 10). The positive values are concentrated in the outcrop area of crystalline rocks, outside the limits of the basin. The negative values are concentrated within the limits of the basin where the sediments of the Tacaratu Formation dominate is shown in the 0.5 x 0.5 km grid of the Bouguer anomaly interpolated by the minimum curvature method (Figure 10).

The basin depocenter is formed by a negative Bouguer anomaly axis, elongated in the NE-SW direction, with a maximum amplitude of 6.0 mGal (between -58.0 and -64.0 mGal). It is observed that the negative Bouguer anomaly is asymmetrical, with larger gradients located in the northwest

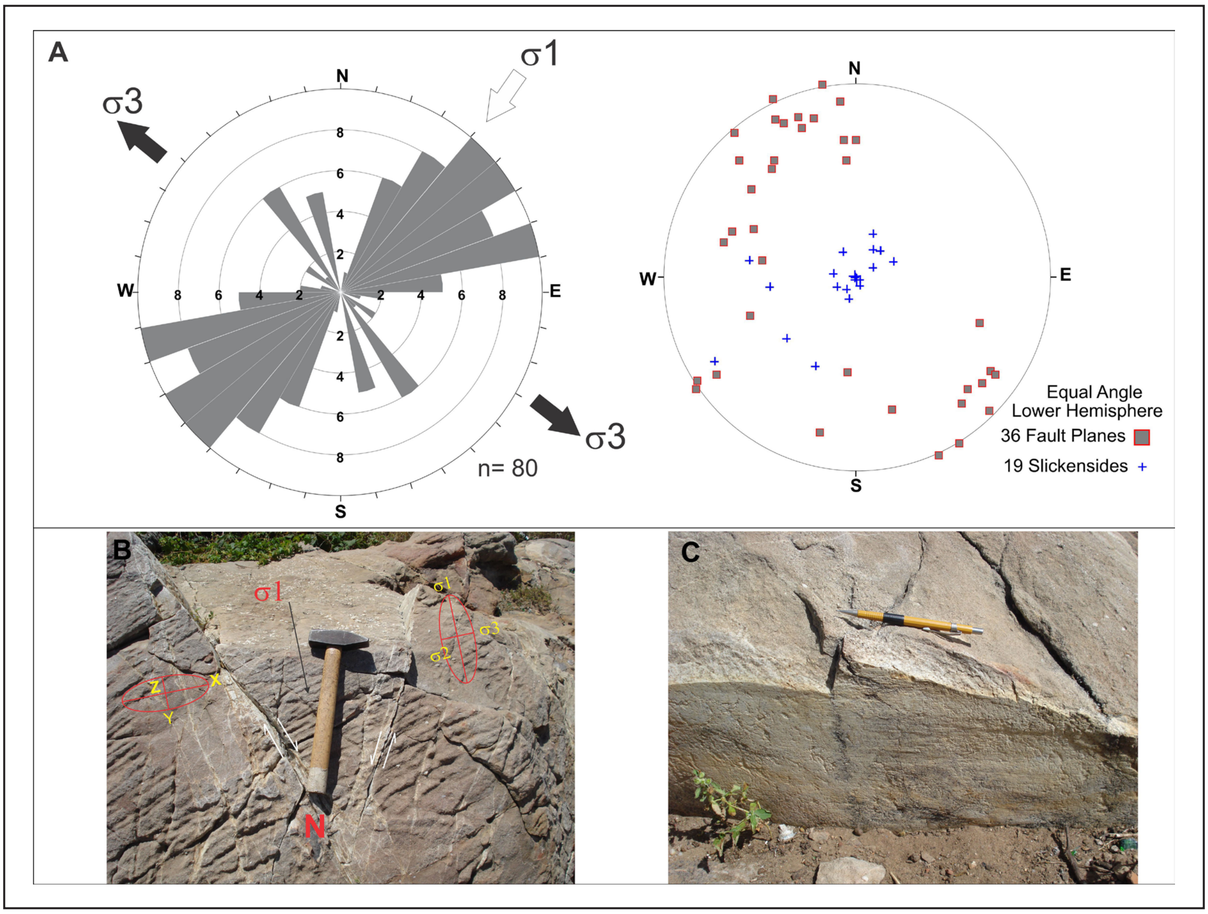


FIGURE 9. A) Rosette diagram for the joint set, normal and transcurrent faults and planes/lineations of faults collected in the Mirandiba Basin. The estimated position of the paleotensor suggests the σ1 paleotensor is attributed to the set of shear fractures, showing oblique stress combined with the development of basin grabens compatible with a sinistral directional transtraction. B) Conjugated pair system in the sandstones of the Tacaratu Formation (Mirandiba Basin) with an estimate of the positioning of the stress and strain ellipsoids (the North indicated by the hammer handle). C) Sinistral fault plane with friction slickensides (04º / 326).

(Figure 10). This type of anomalous conformation in sedimentary basins suggests that the sediments are deposited in a tectonic structure of the half-graben type, with the main fault located on the northwestern edge of the basin.

The Bouguer anomaly map is produced by shallow sources that reflect variations in densities in small areas and prospective geological interest, and deep sources related to anomalies caused by variations in densities in regional areas. In gravity studies of sedimentary basins, it is usual to remove the component referring to regional sources, to leave as a residue the anomaly produced only by the sediments. In this case, traditional methods of regional-residual separation based on spectral analysis, polynomial separation and removal of trend surfaces have not produced good results for the Mirandiba basin. In all of them, the resulting residual anomaly contained information that went beyond the limits of the basin, generating exaggerated amplitudes that could harm depth estimates. Thus, the solution adopted was to choose the -58.0 mGal isogalic as the limit for Bouguer residue (Figure 11), because of its good correlation with the sediment limits whose thickness is capable of producing detectable gravity contrasts. For this, data from wells drilled in the basin were analyzed, especially those that reached the crystalline basement. The residue obtained from this procedure was used in the quantitative modeling of sedimentary thickness.

6.1. 2.5 D Gravity Modeling

An important step in the interpretation of gravity data is the transformation of geophysical information into quantitative models that assist in the geological interpretation of the study region. For this, a 2.5D modeling was carried out in 24 profiles transversal to the longest length of the negative Bouguer anomaly (Figure 11B). This modeling provides only a two-dimensional view of various sections of the basin (Figure 17B).

To define the density of sedimentary rocks, the density measurement of 39 samples of sandstones from the Tacaratu Formation were performed. Despite the knowledge that these sandstones are not the only geological units that filled the basin, it was not possible to sample other formations exposed on the surface, such as the Aliança Formation, because of the low degree of consolidation of these rocks in the outcrops. The measurement result showed an average density of 2.35 g/cm^3 with a standard deviation of 0.29 g/cm^3.

The density of the basement rocks was fixed at 2.80 g/cm^3. Rocks were not sampled to measure basement density because of their very large lithological variation, with outcrops

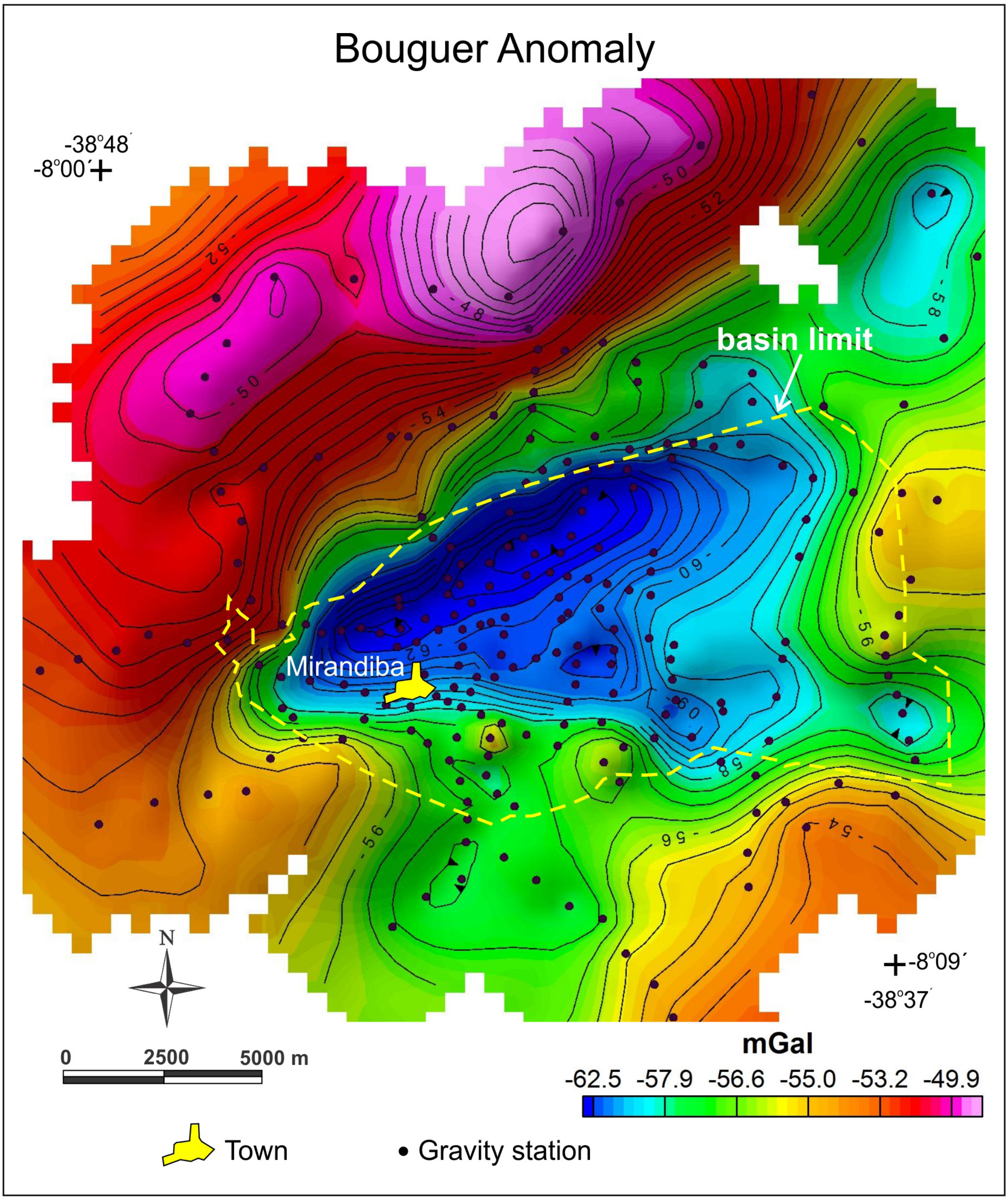


FIGURE 10. Bouguer anomaly of the Mirandiba Basin and its basement with the location of gravity stations. The dashed line represents the limit of outcrops of sediments in the basin. The data were interpolated by the minimum curvature method in a 0.5 x 0.5 km grid.

of granites, orthogneisses, paragneisses, shales, iron formations and basic rocks (Brasilino et al. 2014). Thus, it was considered that the chosen density represents an adequate average for the different types of rocks that occur around the basin. From the results of the measurements in the sediments and the premise regarding the density of the basement rocks, a contrast equal to -0.45 g/cm^3 was considered between sedimentary and crystalline rocks.

To obtain a three-dimensional view, the 24 model sections, parallel to each other and transversal to the longest length of the negative anomaly, were grouped in a single database and the depth values interpolated by the tinning method in a 0.5 km x 0.5 km grid (Figure 11C).

7. Discussions

7.1. Ages and depositional environment

The age of the Tacaratu Formation is attributed through stratigraphic correlations as Silurian-Devonian. The possibility of extending this formation to the Devonian is based on the palynological data obtained by Regali (1964) in the Jatobá

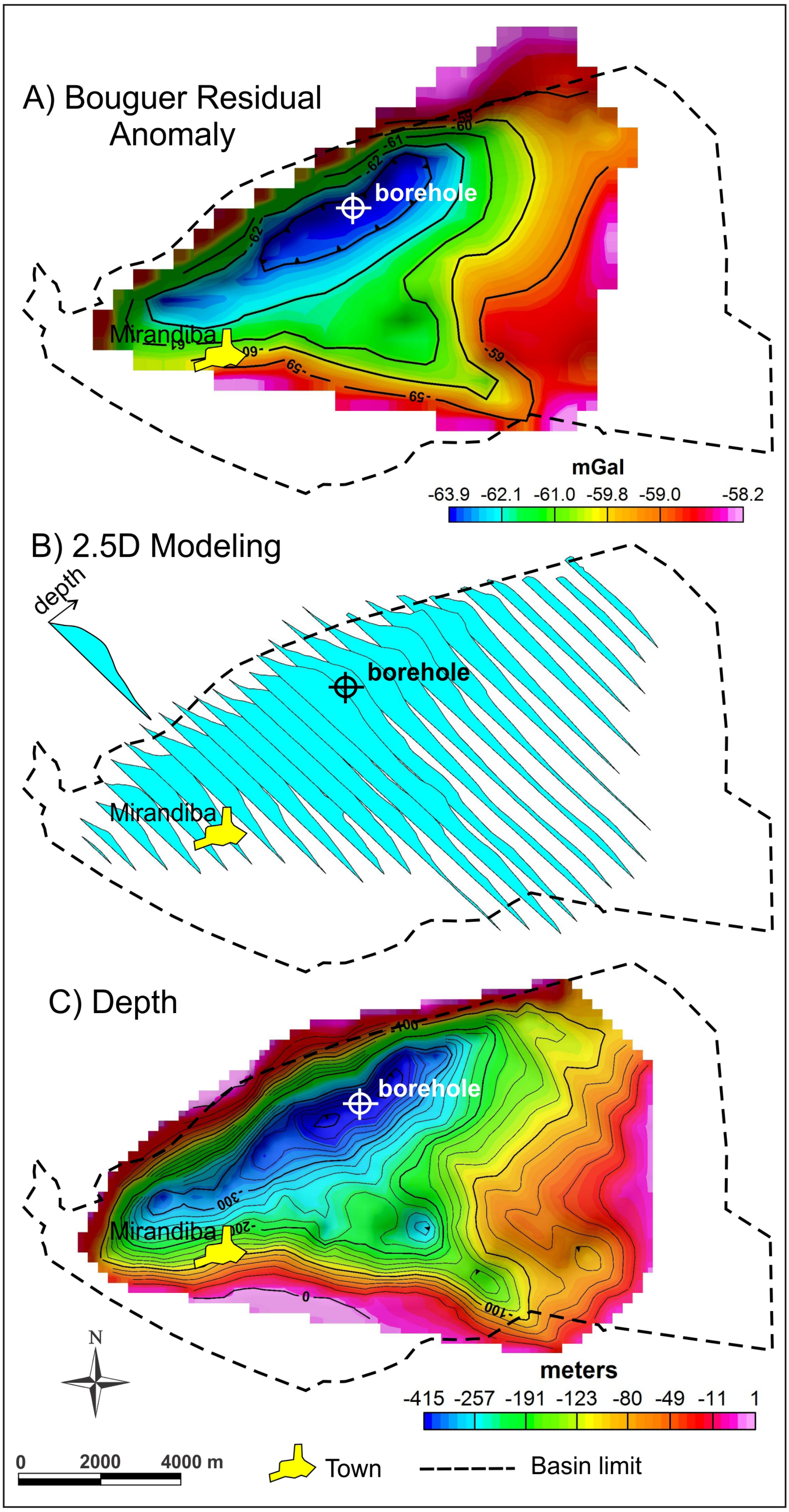


FIGURE 11. A) Bouguer residual anomaly defined by -58.0 mGal isogalic. B) Results of modeling by direct method through calculation and comparing the signals of 2.5D geometry bodies with density contrast of -0.45 g/cm3. C) Framework for the basement of the Mirandiba Basin obtained by joining in a single database the results of modeling the Bouguer anomaly of 24 profiles. The results indicate a maximum depth of approximately 400 meters.

Basin. The sediments of this formation were deposited by an interwoven river system with the architectural elements formed within the main river channel. The river was probably not very deep due to the absence of a floodplain based on the interpretation of Miall (1996).

The Inajá Formation was dated as Devonian based on the macrofossils content studied in the Jatobá Basin by Barreto (1968) and Muniz (1976). In this work, we reported only ichnofossils.

In the Mirandiba Basin, the icnogenus *Arenicolites*, despite being typically marine, has already been recorded in continental environments. Stratigraphically, it is distributed from Cambrian to Holocene, not being a good stratigraphic indicator. There are no occurrences for the Inajá Formation, but it has already been recorded in Devonian rocks in the Paraná and Parnaíba basins and also occurs in Silurian, Permian, Triassic and Cretaceous rocks in several Brazilian basins. The icnogenus *Skolithos* occurs in marine and continental environments with a wide stratigraphic distribution, with most of the sedimentary geological formations being common. According to MacEachern et al. (2010), *Skolithos* ichnofacies is typical of high energy environments in shallow marine environments dominated by waves.

The depositional environment of the Inajá Formation according to Barreto (1968) was a shallow-marine platform and in this work this proposal is ratified. Through the analysis of the physiological descriptions it is possible to state that it was dominated by the actions of the waves. Based on the schematic model of the parallel depositional systems of Smith and Jacobi (2001) the Sh sandstone facies that occur separately represent the foreshore and the association of the facies (Sm, Sr, Fsm and Fl) can be interpreted as from an environment of upper shoreface (Figure 12).

The ostracods found in the Aliança Formation in Mirandiba Basin are similar to those classified by Braun (1966) as two non-marine species: *Metacypris sp.* and *Darwinula* oblonga, both related to the Jurassic, Dom João local stage.

The Marizal Formation characterizes an environment of gravity flow dominated by fans with stream and sheet flow facies. Probably the deposition of these stream flow developed in the distributional channels where the conglomerates are associated with gravel bars and the sandstones are related to sand fan migrations. When there is an increase in the volume of water it causes overflow and generates to a sheet flow giving rise to well-selected sheets of sand. The pelites may be correlated to the channel overflow with silts and clays being carried in suspension.

The age of the Marizal Formation was attributed as Neocomian-Aptian based on data from the phyllicine flora found in the siltstones. The fossils were identified leaves and leaflets of Sewardia sp (?), *Baiera* sp., *Pterophyllum* sp. and *Podozamites* sp (?). (Braun 1966).

7.2. Tectono-sedimentary evolution

During the event generator of the interior basins of the Northeast of Brazil, the Borborema Province was subjected to conditions of crustal stretching of WNW-ESE direction that allowed the generation of normal NE-SW and NW-SE trending and, secondarily, E-W faults, all of which are related to the reactivation of the Brasiliano structures (Matos 1999).

Within this context, the Mirandiba Basin is located between the Patos and Pernambuco Lineaments in the Transversal Zone of the Borborema Province. The Transversal Zone acted as a resistance domain, delaying the rifting process of the opening of the Atlantic Ocean, where the Patos and Pernambuco lineaments of E-W direction acted as large transfer zones (Matos 1992).

Mesozoic sedimentation in the interior basins of the Northeast has its first record in the upper Jurassic and Paleozoic sedimentation and behaves as a substrate basis in the face of Cretaceous reactivation. The lithological descriptions presented here corroborate to correlate the sedimentation of the Mirandiba Basin with to those ones of the Jatobá and Araripe basins (Figure 13).

The Pre-Rift sequence is characterized in the Northeast region of Brazil by the Afro-Brazilian Depression (Ponte 1971), an extensive and shallow interior basin that stretched from

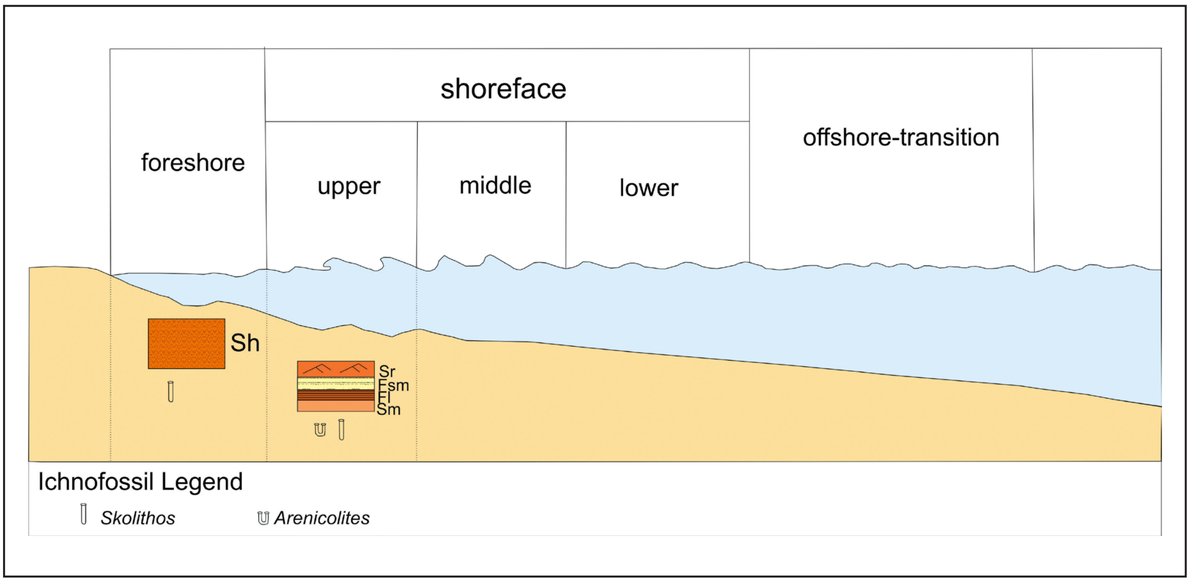


FIGURE 12. Schematic profile of the shallow marine system of the Inajá Formation with the facies distributed in the sub-environments, with ichnofacies identified in Mirandiba Basin.

Almada (south of Bahia) to the region of Cariri (south of Ceará). It is represented by the deposition of continental sediments under arid climate during the Dom João Stage (Neojurassic) and, in the Mirandiba Basin this sequence is represented by the Aliança Formation.

The Mirandiba Basin had no record of rift sedimentation up to date because in the basins located north of the Pernambuco Lineament there is a large regional gap represented between the local Aratu and Alagoas Stages (Ponte et al. 1990). This gap is due to prevention of the spread of the rift along the Cariri-Potiguar trend by this lineament (Matos 1992). That's precisely why the possibility of the Salvador Formation occurring in the Mirandiba Basin is an important component to help to understand this regional hiatus.

The regional records for the interior basins are also confirmed here with the presence of the Dom João Local Stage (Aliança Formation) south of the Patos Lineament (Arai 2006) already for the regional gap of the rift phase, existing in the basins at the north of the Pernambuco Lineament described by Ponte et al. (1990), the Salvador Formation possibly has ages correlated with the Abaiara Formation of the Araripe Basin (Figure 13).

We interpreted a unique outcrop by its characteristic as Salvador Formation and correlate it to the Jatobá Basin (Horn and Morais 2016).

Pereira et al. (2012) described the outcrops here interpreted as Salvador Formation as belonging to the Sergi Formation. However, the Sergi formation in the Jatobá Basin is interpreted by Costa et al. (2007) as a fluvio-eolian system and associated with the Aliança Formation. For Scherer et al. (2007) the Sergi Formation is subdivided into three sequences composed predominantly of fluvial eolian deposits and pelites, correlated to a lake environment. The conglomerates of the Sergi Formation are intraformational and associated with lags and filling of small depressions (Scherer et al. 2007), unlike those of the Salvador Formation, which are typical of deposition by debris flows and are associated with the major fault of the catchment basin. These deposits in Mirandiba Basin have close association with a major fault related to the basin depocenter and according to facies associations were interpreted as debris flows.

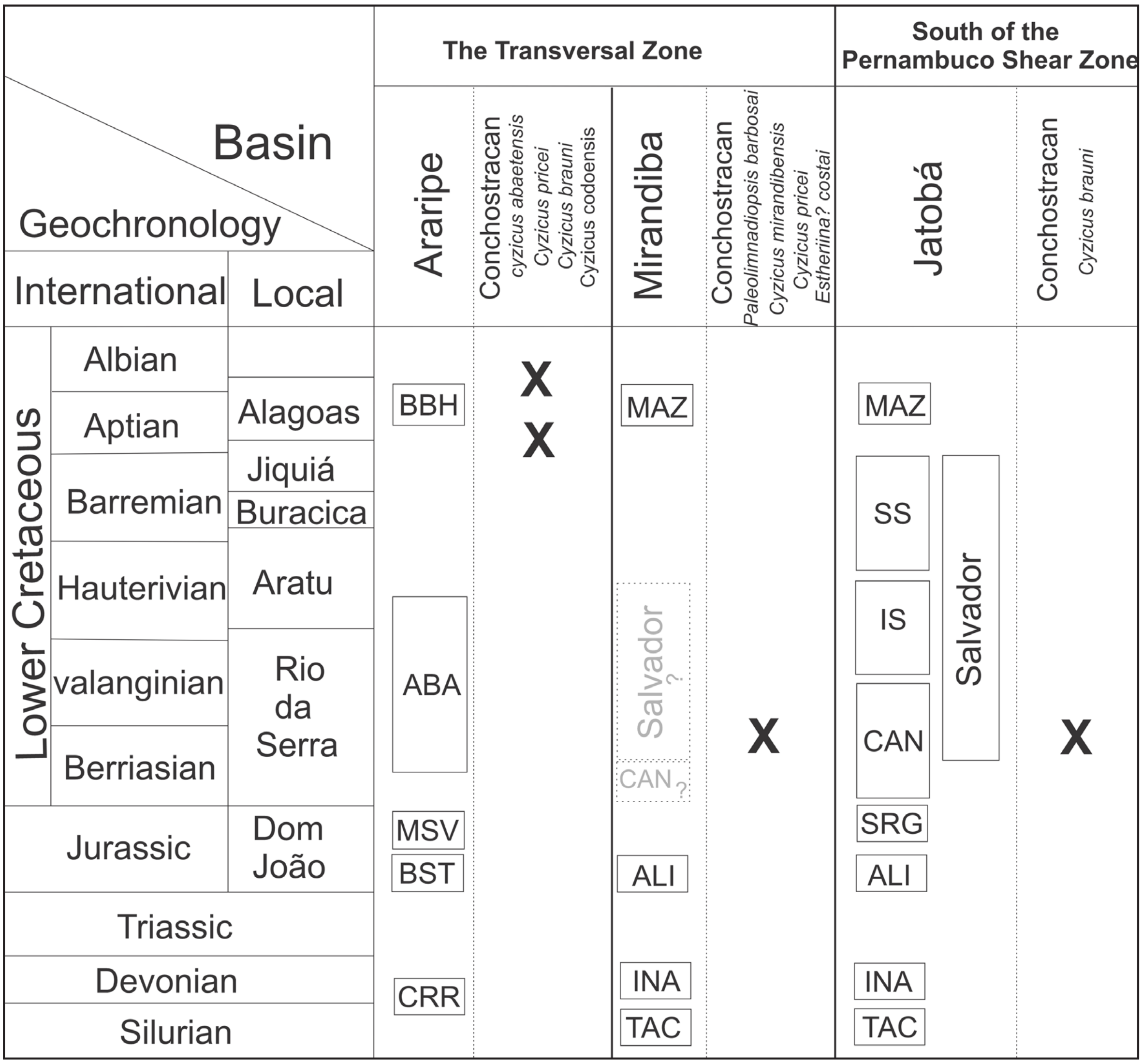


FIGURE 13. Explanatory diagram of the lithostratigraphic columns of the Araripe, Mirandiba and Jatobá basins with the distribution of conchostracans. ABA: Abaiara Formation ALI: Aliança Formation BST: Brejo Santo Formation IS: Ilhas Group. LDM: MAS: Marizal Formation MSL: Missão Velha Formation SRG: Sergi Formation TAC: Tacaratu Formation INA: Inajá Formation BBH: Barbalha Formation CAN: Candeias Formation [adapted from Arai (2006) and Carvalho (2014)].

According to Nichols (2009), alluvial fans develop at the margins of sedimentary basins and these can be sites of tectonic activity, with faults along the basin margin creating uplift of the catchment area and subsidence in the basin. In this sense, the outcrop we interpreted as Salvador Formation has proximity with the north border fault of the basin enclosed by a large volume of polymictic conglomerates presenting several extra-clasts (basement source) such as granitic and gabbros blocks and boulders.

Carvalho (2014) made an overview of the conchostracofauna present in the interior basins discovered by several authors. In the Mirandiba Basin, the presence of the species *Palaeolimnadiopsis barbosai, Cyzicus mirandibensis* and *Cyzicus pricei* dated from the Lower Cretaceous (Rio da Serra - Aratu Stage) were described. This same author did not report the presence of Neocomian conchostraceans in the Araripe Basin, just in the Jatobá Basin (*Cyzicus brauni*), so we can correlate these sediments with the Candeias Formation, and these deposits were not identified in this work (Figure 13).

After this depositional hiatus that occurs in the Mirandiba Basin between the local Rio da Serra and Jiquiá Stages, the Post-rift tectono-sequence occurs, deposited during the Aptian period, which is represented in the basin only by the Marizal Formation (Figure 13).

The basal unit of the post-rift phase of the Aptian-Albian sequence in the Araripe Basin is registered by the Barbalha Formation, which is correlated litho, chronologically and genetically with the Marizal Formation of the Recôncavo-Tucano Basin, both showing similar paleo-flow toward S-SE. This indicates that the tectonic events of the rift phase did not significantly alter the continental paleo-drainage, which to the south of the Pernambuco Lineament continued to flow towards the Recôncavo-Tucano basins (Assine 1994). This paleo-flow was also registered in the basins of the Transversal Zone of the Borborema Province as the Mirandiba Basin.

The NW portion of the Mirandiba Basin possibly constitutes the deepest part, since the bedding has a sense of gentle dipping for NNW. The data obtained by the gravity modeling corroborate this hypothesis, since in this area it was possible to determine the depocenter of the basin, located in the main orientation graben (NE-SW) with an estimated depth of 400 meters. This estimate was confirmed by the final depth of 409 m from the Sítio Ervanso well.

As for the shape and origin of the Mirandiba Basin, the joint interpretation of the geophysical and structural data suggests that the basin is of the semi-graben type and that it was developed by this pull-apart system, formed by sinistral transtraction. The set of main normal faults generated the depressions that were filled by Mesozoic sediments from the basin. This event would also explain the tilting of the layers, as well as the deformation and recrystallization of some portions of sandstone of the Tacaratu Formation along the fault planes. The genesis of the Mirandiba Basin is similar to that of other interior basins in the Northeast, as a result of the extension to the interior of the extension efforts related to the rupture process of Gondwana during the Mesozoic. The crustal heterogeneity and the presence of zones of weakness culminates in the formation of small interior basins and deposition of sedimentary sequences.

The model now proposed for the basin implies a maximum compression tensionoriented in the NE-SW direction with an NW-SE extension direction, which is also characterized by the occurrence of normal oblique NE-SW faults (Figure 14).

7.3. 3D Model and Interpretations

The result of this procedure can be seen in Figure 15 (on a map) and in Figure 17 from two different angles of a three-dimensional perspective. Estimates of depth supported a drilling campaign whose borehole reached 410 m in depth (Figure 15) and provided 150 m3/h of flow rate.

The result of the gravity modeling shows that the Mirandiba Basin has the shape of a half-graben with the main fault located on the northwestern edge, with maximum depths inferred around 400 meters confirmed by the borehole. This tectonic framework explains the strong northwest slope observed in the strata of the Tacaratu Formation in the central-eastern region of the basin. In this region, the depth decreases slightly to the east. The general conformation of the basement of the basin suggests two main directions of NE-SW and E-W trends (Figure 9A). These two directions coincide with the largest gravimetric gradients and, therefore, with the deepening of the basin.

The strong gravity gradient with NE-SW direction correlates with ductile shear zones. However, it is also possible to observe the existence of gradients aligned in the E-W directions in the vicinity of the town of Mirandiba. In the latter case, the field data indicate a correlation between brittle or ductile-brittle structures.

The interpretation of the aligned gravity gradients suggests the hypothesis that the tectonic framework of the Mirandiba Basin may have been developed by the evolution of a pull-apart extension system. This interpretation suggests that movements of faults in the E-W direction, synchronized with the transtrational reactivation of the old shear zones with NE-SW direction, could have provided space for the capture of the sedimentary package of the Tacaratu Formation (Siluro-Devonian). This event would be subsequent to the deposition of this formation and would explain the strong slope of the sedimentary strata and the deformation-recrystallization of the sandstones, both in the NE-SW direction and in the E-W direction. However, it is expected that this event may have provided sufficient space for the deposition of new sediments. A natural candidate would be the Cretaceous sediments from the Marizal Formation that outcrop near the Bouguer negative axis and, therefore, close to the edge fault and the region of greater depth. In addition, the sediment strata of the Marizal Formation do not present the slope observed in the Tacaratu Formation (in a lower stratigraphic position), implying that they were deposited on the Tacaratu sandstones that supported the bottom of the graben, and in time synchronicity with the tectonic extensional event.

7.4. Regional correlation

We correlate three wells carried out in the same drilling campaign performed by the Geological Survey, the Sítio Ervanso well (Figure 8) in the Mirandiba Basin and those ones drilled in the Betânia and Jatobá basins (Figure 16). In profiling analysis, it was possible to notice that these basins have similar geophysical profiles, for comparison and illustration the GR, SP, SN e DT profiles of the three basins were compared where the gamma ray (GR) profile showed the best correlation among them.

The Tacaratu Formation has the same pattern in all of them and the GR peaks and can represent ferruginous sandstones

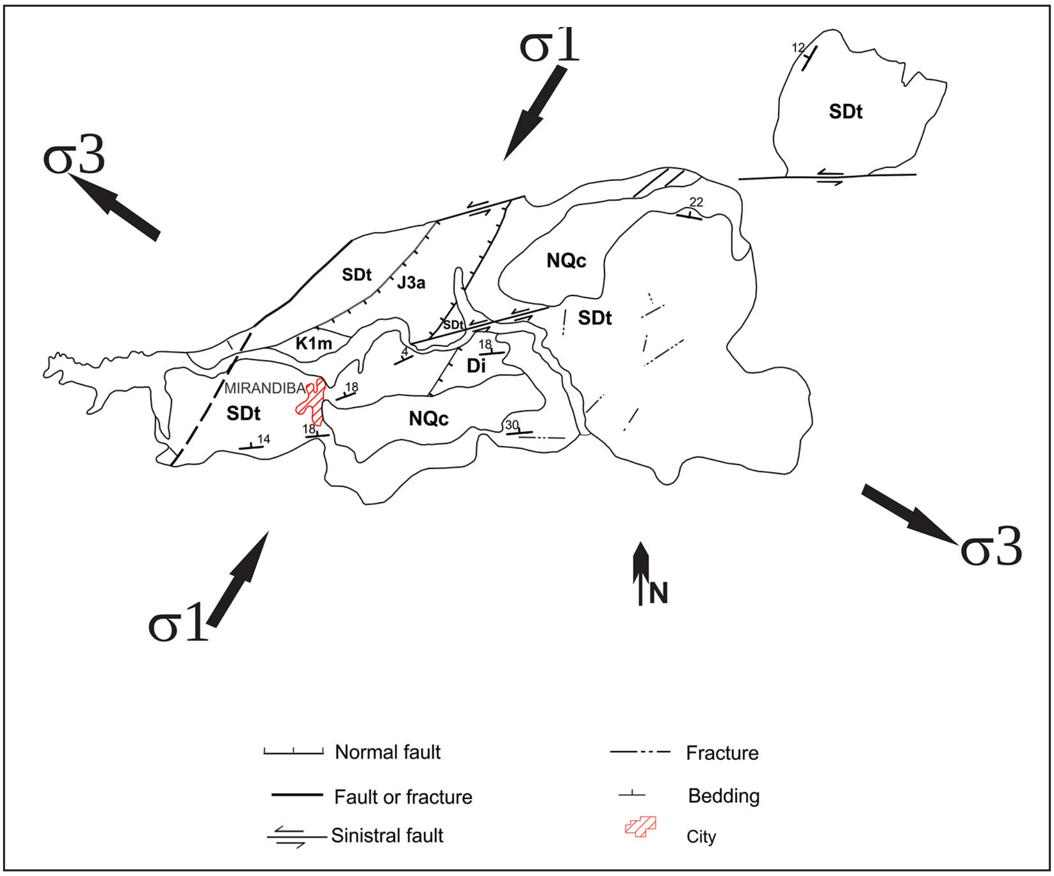


FIGURE 14. The Mirandiba Basin system featuring maximum compression tensioners oriented in the NE-SW direction and the distensive efforts in the NW-SE direction.

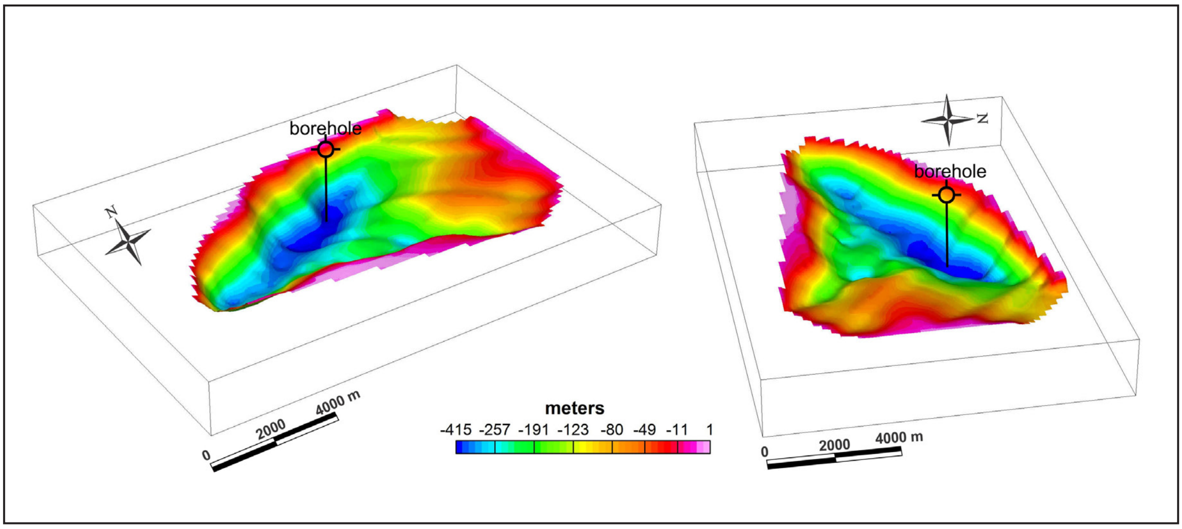


FIGURE 15. Three-dimensional framework for the basement of the Mirandiba Basin. The modeling result indicates that the basin is a half-graben, with a main fault at the northwest edge with throw of approximately 400 meters.

rich in U and Th. These sandstones were found on the surface in the Jatobá Basin by Accioly and Morais (2018) and interpreted as roll front deposits with up to 32 ppm eU.

These sandstones are well marked in GR on top of the Tacaratu Formation (~400m depth) (Figure 16). We interpret as paleofluid circulations relative to the basin inversion or the extension that precedes or mark the cretaceous interior basins establishment. If it is confirmed that these GR peaks are the High-U levels in the ferruginous sandstones in the subsurface of the Tacaratu Formation, it may indicate rollfront deposits driven by shallow meteoric waters (Skirrow et al. 2009; Busigny and Dauphas 2007). The GR peaks are very similar in the Mirandiba and Betânia basins, whereas the Jatobá Basin is only evident in the Tacaratu/Inajá formations, as there was a loss of information during profiling in the upper units. The data obtained and interpreted here are clear that the Jatobá Basin is deeper than the basins located north of the Pernambuco Lineament because of the reactivation of the Lineamento Pernambuco during the Paleozoic provided greater thickness in the Jatobá Basin (Figure 16).

Cordani et al. (2009) affirm that the interior basins are not basins in the specific sense of the word, but remnants of basins or even an eroded single basin based on the fact that they do not have their own stratigraphic sequence or their own delimitation (with some exceptions). However, the Mirandiba Basin has boundaries, has good depth, and has distinct lithostratigraphic sequences including now a possible deposit associated with border faults, which are similar to the Jatobá

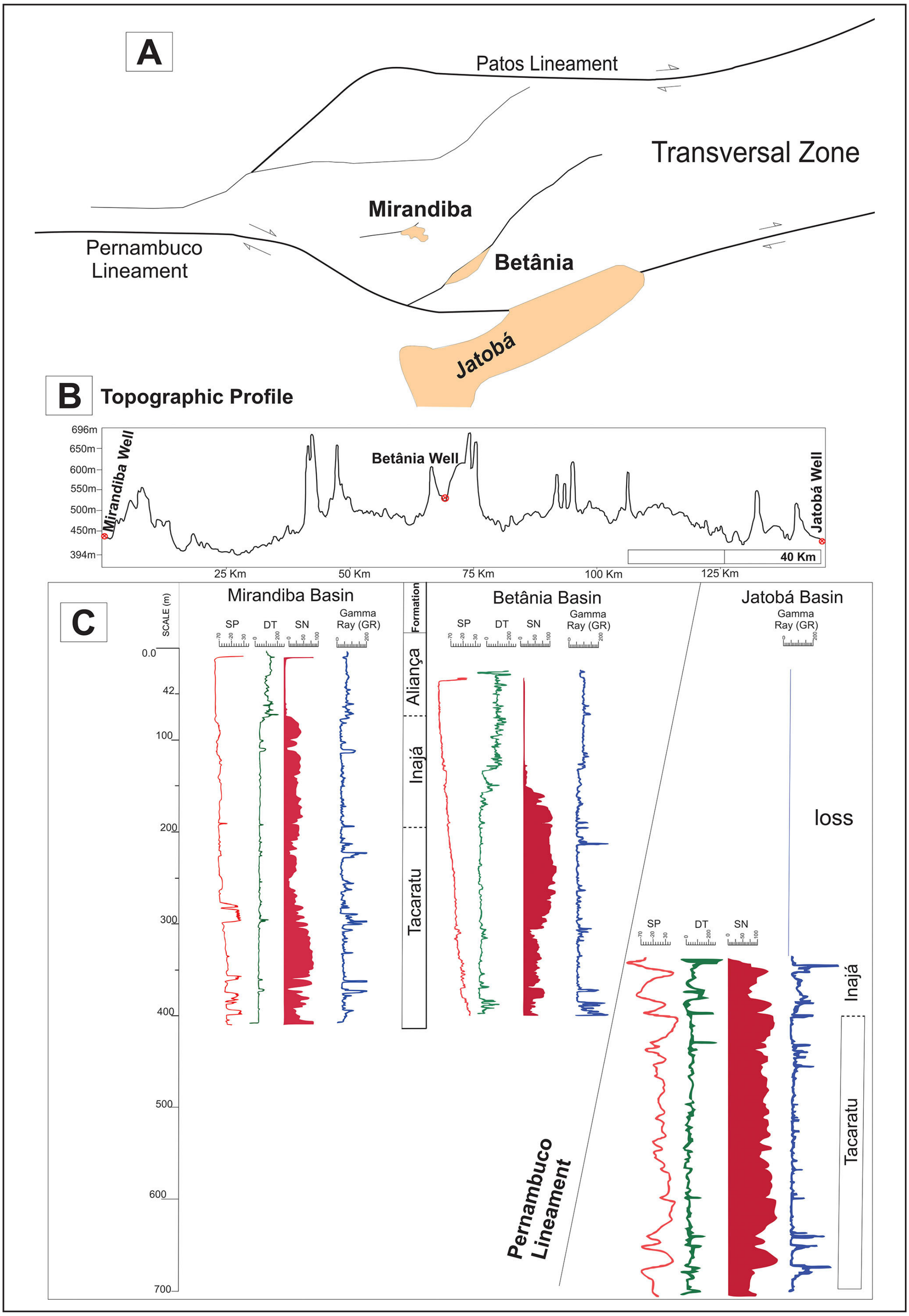


FIGURE 16. A) Simplified tectonic framework of the Mirandiba, Betânia and Jatobá basins. B) Topographic profile of 144km along the drilled wells; C) Correlation of gamma-ray log profiles.

basin. On the other hand, the Tacaratu Formation is dispersed in these basins without well-defined limits, see the example of the Poço do Icó sedimentation described above, where its limits are 10 km from the limits of the Mirandiba Basin. The Tacaratu Formation, however, belongs to the Paleozoic sequence and is the sedimentary remnant that occurs as a substrate under the basins (Milani et al. 2007).

8. Conclusions

The structural system that gave rise to the Mirandiba Basin has the maximum compression tensioner oriented to NE-SW and the distention to NW-SE. It has a depth of around 400 meters and the depressions formed by tectonic events were filled by Post-Tacaratu sedimentation. The Tacaratu Formation is the unit that occurs most extensively in the Mirandiba Basin, consisting of 5 facies: (Sp, St, Sl, Sh and Gp) deposited in a braided river system with all the architectural elements formed within the main channel. The Inajá Formation has a facies association (Sm, Sr, Fsm, Fl) of the upper shoreface and Sh facies representing the foreshore in a shallow-marine environment. The Aliança Formation facies (Fl, Fm, Co) described features pointed to a lacustrine environment. The Salvador Formation is distinguished by the basin border conglomerates (Gcm) interspersed with sandstones (Sm) and pelites (Fl) representing the rift phase. For the Marizal Formation, its 5 facies (Gm, Sm, Sh, Sp, Sl) were deposited in an alluvial fan environment.

The Salvador and Inajá Formations added here to the stratigraphic chart of the Mirandiba Basin provide important insights for both a better geological recognition of the basin and hydrogeological potential, since the Salvador Formation represent the rift stage in the basin and was not described up to date and the Inajá / Tacaratu represent the most significant aquifer in the basin.

The gravity alignments that are associated with the basin are those of possible WNW-ESE direction and their associated structures that deformed and crystallized the sandstones of the Tacaratu Formation, reinforcing the hypothesis of correlation with a Phanerozoic tectonic event. The NNW-SSE direction and evident truncation relationship with the alignments correlated with Precambrian events indicate that its origin is attributed to younger events.

The comparison with other basins (Jatobá and Betânia) pointed out that the layer of ferruginous sandstone stands on the top of the Tacaratu Formation is common in all of them. We interpreted these layers based on the peak of Gamma-ray, U-bearing red sandstones and ferruginous concretions as rollfront deposits formed by shallow and oxidizing paleofluid circulation relative to the basin inversion or the extension that precedes or mark the establishment of Cretaceous interior basins.

The Mirandiba Basin has well-defined lithostratigraphy and may be directly correlated with the Jatobá Basin and some other interior basins. The geometric and kinematic arrangement identified in the structures, as well as the specific gravity geophysical data suggest that the basin has a semi-graben type shape and that it was developed by a pull-apart structural system.

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