Characterization of subsurface fault in Barreiras Aquifer Formation from geoelectrical and hydrogeological data – area of River Catu basin, NE Brazil.

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Abstract

This work refers to the studies developed in the area of River Catu basin, located in northeastern Brazil. The main objective was to characterize subsurface fault throw within the basin of the River Catu, southern coast of Rio Grande do Norte. The general methodology is the use of electric geophysical methods, particularly electrical resistivity, besides well lithologic profiles. In our research, the vertical electric sounding-SEV technique has been used to determinate and quantify fault throw. Using data from structural geology and tubular wells added to information geoelectrical data could create lithological profiles. The implementation and quantification of fault throw in the subsurface has obtained satisfactory results in the order of 10 to 30 meters. The hydrogeophysical profiles showed a tectonic-structural subdivision consistent with previous studies where it was possible to turn structural lineaments undefined into fault defined and quantified.

Introduction

This research was conducted in the area of River Catu basin, located on the south coast of Rio Grande do Norte, Northeast of Brazil, including the cities of Canguaretama, Goianinha, Tibau do Sul and Vila Flor-RN. (Figure 1). It has the main goal of characterizing subsurface faults, identifying throw trading-off morphotectonic alignment. The traces were based on geomorphology local anomalies (topography and hydrography). The basin area in question was chosen due to the elaboration of a preliminary model of Barreiras Aquifer's geometry (Rodrigues *et al.,* 2011), considering its hydrogeologic potencial in regard to public supply. Thus, the morphotectonic alignment, identified in previous studies (Nogueira *et al*., 2006; Rodrigues *et al*., 2011), motivated a higher investigation of tectonic-structural region using geoelectrical data. In this context, these alignments are characterized as faults, conditioned to the determination of throw according to the interpretation of the vertical electrical sounding-SEV and wells data. The research was funded by the "*Conselho Nacional de Desenvolvimento Científico e Tecnológico*" – CNPq (National Council of Scientific and Techological Development), and its project number is 573462/2008-9.

The area's lithostratigraphy consists of an outcropping sequence and another non-outcropping. The first one is represented by a crystalline basement and sedimentary rocks of mesozoic basin, including a carbonate layer below sandstone formations. The second involves the regional Cenozoic sedimentation, including Barreiras Formation and its quaternary coverage (Bezerra, 1998; Lucena 2005). The Barreiras Formation and the homonym aquifer is quite diverse in lithological terms, ranging from argillite to conglomerates, predominantly argillaceous sandstones. In quaternary coverage there is a highlight in the different generations of dunes, sandy coverage (associated with the paleo-gravels deposits), the alluvium and mangrove deposits. (Lucena, 2005).

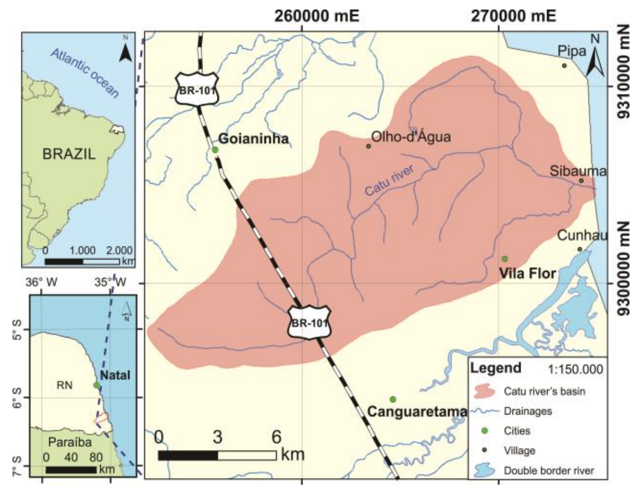

Figure 1: Location map of River Catu basin.

About the regional structure, previous researches characterized a complex structure brittle marked throughout the coastal sedimentary basin, where NE and NW has showed to be the most prominent (Bezerra, 1998; Bezerra *et al*., 2001; Lucena, 2005; Nogueira *et al*. 2006; Rossetti *et al.*, 2011). This structuring is characterized for presenting a transcurrent and normal kinematic, possibly associated with deformation sin-sedimentary Mesozoic and / or Cenozoic (Bezerra *et al*., 2001 Lucena, 2005). According to these authors, this context results from a stress field involving a maximum horizontal compression in E – W axis in early Neogene period and oblique compression in NE-SW and NW-SE directions. This compression has favored the formation of transcurrent dextral and sinistral structures (Nogueira *et al*., 2006).

However, preliminary studies performing morphotectonic alignments in River Catu Basin has evidenced morphotectonic alignments which were plotted equally based on hydrographic and topographic anomalies in directions NE and NW (Rodrigues *et al.*, 2011).

Although there are studies that describe the tectonic structures in the east band of Rio Grande do Norte (Bezerra, 1998; Bezerra *et al*., 2001; Lucena, 2005; Nogueira *et al*., 2006; Rossetti *et al*., 2011). The region still lacks of deeper neotectonic studies which should involve more geomorphological, hydrogeological and geophysical data.

This research tries to associate these morphotectonic alignments (considering its connotation with the regional brittle structuring) with fault conditioning the characterization of throw in the subsurface. So, this displacements will be highlighted for having a base variations of the top of substrate Mesozoic of Barreiras Aquifer's Formation, represented by sandstones to argillite composition calciferous. These possibly variations will be obtained from the preparation of hydrogeophysical profiles with information from lithological profiles of wells in the area and available models "resistivity x thickness" from the interpretation of SEVs.

Method

Table 1: Wells used to generate the profiles.

Wells	Coordinates		Depths (m)	NE (m)
	X	Y		
CANG 14	263436	9294406	50	18,34
FP-1369	263700	9298000	79	37,59
FP-730	262300	9306400	70	23
FP-858	260700	9295700	76	38,07

For preliminary characterization of subsurface fault throw was necessary to a roundup of tubular wells of the study area, for to obtain lithological and hydrogeological data including saturated thickness of the Barreiras Aquifer and unsaturated adjacent as well as depth of its basement hydrogeological (sandstone-argillite calciferous in depth) and also the static level. The table 1 shows the identification of the wells used in the preparation of hydrogeopysical profiles obtained in a database developed in the software platform Visual wells PRO 2.0v (Schlumberger Water Service) in the geophysics laboratory at Universidade Federal do Rio Grande do Norte (UFRN).

In some cases, there was no altimetry information about the wells, so it was necessary the attribution of this data from numerical models of the terrain (satellite image type SRTM - Shuttle Radar Topography Mission).

Through satellite image, topographic latter, and linked to the use of a GIS (Arcgis) it was possible to collect the altimetry data of wells, as well as gather data to generate topographic profiles of the planning lines for identification of fault throw (Figure 2).

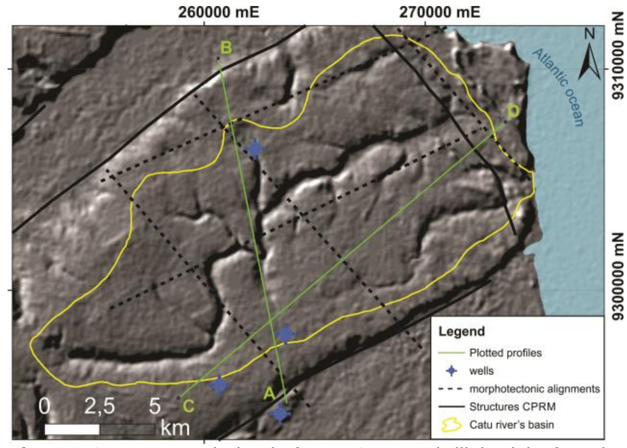

Figure 2: Image derived from SRTM (Hillshade) for the acquisition of elevation data. Lines AB and CD represents the profiles planned, while the dashed lines indicates the plotted morphotectonic alignment (Rodrigues *et al*., 2011).

Geophysical data used were from a geoelectrical survey, according to its notorious and important applicability in hydrogeology (Orellana, 1972; Astier, 1975; Custodio and Llamas, 1983; Kirsch, 2006; Feitosa *et al*., 2008), using the technique of vertical electric sounding (SEV) and electrode array Schlumberger type. This technique allows investigating the variation in resistivity with depth, since the flat and parallel layered model is valid to the study site. The field data (resistivity apparent curves) were interpreted in software WinSEV (WGeosoft), which provides, ultimately "electrical resistivity x thickness" models enabling the identification of point values of unsaturated and saturated thickness. The qualitative and quantitative refined analysis of SEV were based on calibrations geoelectrical of Lucena (2005).

Were performed 15 vertical electric sounding-SEV (table 2) distributed throughout the entire area of River Catu basin. The equipment used was the resistivity GEOTEST RD-300B. This equipment is characterized by minimizing the instability of readings due to electrode polarization phenomenon in addition of performing an electronic filtering the signal, that attenuates noise caused by telluric currents, among other causes.

The geoelectrical data processing for technique vertical electrical sounding intends to acquire an apparent resistivity curve that represents the variation of the physical parameter (ρ) as a function of depth. The interpretation of the curve must be according to the lithostratigraphycs models (Rodrigues *et al.*, 2011).

In the end, a reversal math with the proposal of calculating the layers number, its thickness and its resistivity. These solutions do not contemplate the indetermination from inverse problem ($\rho 1t1 = \rho'1t'1$). Very thin layers cannot be detected in curves of sounding at large depth (Rodrigues *et al.*, 2011).

Table 2: vertical electric sounding carried out in the River Catu basin.

SEV's	Coordinates		Unsaturated thickness (m)	saturated thickness (m)
	X	Y		
SEV 01	259948	9296646	20,55	43.3
SEV 03	257278	9298415	65,72	21.5
SEV 04	262757	9297930	27,89	64.1
SEV 05	260539	9308256	12,33	92.9
SEV 06	266251	9310920	19,46	21.2
SEV 07	269823	9310928	19	40.1
SEV 08	268370	9310058	5,04	79,9
SEV 09	270330	9304236	26,09	62.6
SEV 10	268304	9303375	7,29	77.7
SEV 11	266500	9301640	11,18	68.9
SEV 12	263523	9300966	24,65	34.8
SEV 13	260812	9303524	7,18	51.95
SEV 14	262745	9306840	21,1	41.4
SEV 15	265875	9307718	32,57	42.8
SEV 16	267062	9308822	2,91	93.7

Results

Linking geoelectrical and topographic data, with tubular wells data of the study area, allowed the elaboration of hydrogeophysical profiles identified as profiles A-B and C-D in figure 2. The profiles were designed and planned in order to intercept directions preferential of morphotectonic alignments previously characterized at area. The altimetric values are found related to sea level.

Throw were identified in the order of 10 to 30 m in A-B profile (Figure 03). To characterize the subsurface throw in the northwestern portion of the profile A-B was used geoelectrical data SEV 05 along with the FP-730 tubular well data. The base of the saturated thickness in 05 SEV has altimetry quota of -48.23 m while the top of the calciferous sandstone-argillite identified in FP-730 tubular well has altimetry quota of -19.50 m. In the southeast portion, were used geoelectrical data SEV 04, along with lithological information profile the Cang14 tubular well. The base of the saturated thickness (Barreiras Aquifer) in SEV 04 has altimetric quota -25 m while the top of the present calciferous in the Cang 14 tubular well has altimetry quota -40 m. Around profile A-B, it was possible to identify throw just correlating the variations of the base of the saturated thickness of SEV12, SEV13 and SEV 14 soundings.

The altimetric quota of base saturated thickness of the SEV's 12 and 14 have approximated values of the order of -11 m, while in the SEV 13, there was obtained the value of 2 m. In general was obtained throw in the central portion of the profile of approximately 11 meters. In the extremity, the throws are more expressive in order of 30 meters in the northwest region and 15 meters in the southeastern region.

In the C-D profile (Figure 04) were identified throws ranging from 15 to 25 meters. The southwest profile was used geoelectrical data of SEV 04 with the lithological profile data of FP-878 tubular well. The base of saturated thickness of SEV 04 has altimetry quota -25 m while the top of the calciferous, which is present in the FP-878 tubular well, has altimetric quota values of 3 m. Around this profile it was also possible to identify throws related only to variations in the base of the saturated thickness on the soundings SEV 12 and SEV11.

The altimetric quota of the base of saturated thickness of the SEV 12 is approximately -11m, while of the saturated base of SEV 11, is -30 m. Around SEV 10 and SEV 11 was also observed a slight quota variation on top of calciferous sandstone, although it had been not possible to characterize the fault. The fault characterized before are interpretative character normal.

Conclusions

The use of a multidisciplinary method, based on the analysis of geological, hydrogeological and geoelectrical data, was not only effective, but essential in characterizing subsurface fault throw in the context of a sedimentary aquifer. The results obtained in the Barreiras Aquifer in the eastern sector of the River Catu basin, showed a broad tectonic and structural control in various aspects of hydrogeological context. The variations of the geometry of the aquifer resulting from faults were evidenced by the relationship between the top of the Mesozoic sedimentary column non-outcropping (sandstone-argillite calciferous) and the saturated thickness base, information obtained from of lithological profile, local tubular wells geoelectric soundings.

The implementation and quantification of fault throw in the subsurface were initially guided by the distinction of morphotectonic alignments previously identified. These last ones morphotectonic alignments were defined by topographic anomalies and drainage network, including springs and abrupt inflections in the course of rivers. Thus, the definition of fault and no more morphotectonics alignment, held quantification from subsurface throws which are on the average of 10 to 30 meters.

This structural partition observed in hydrogeophysical profiles is influenced by the kinematics of normal local faults as interpretative mode, although transcurrent components must integrate this context. These last ones transcurrent components, however, have not been characterized in this study. The faults were defined in A-B profile in addition to the measures of throws, due to the presence of topographic lows on the limits of profile. These topographic lows are correlated with grabens in the SW-NE direction, resulting of a transtensional regime and marked by the Jacu River's valley (north) and Curimatau River's valley (south).

However, it emphasizes the necessity of using new geoelectric surveys throughout the area, particularly around of SEV 04 and Cang 14 well for possible characterization of fault in subsurface or just oscillation topography of calciferous sandstone-argillite.

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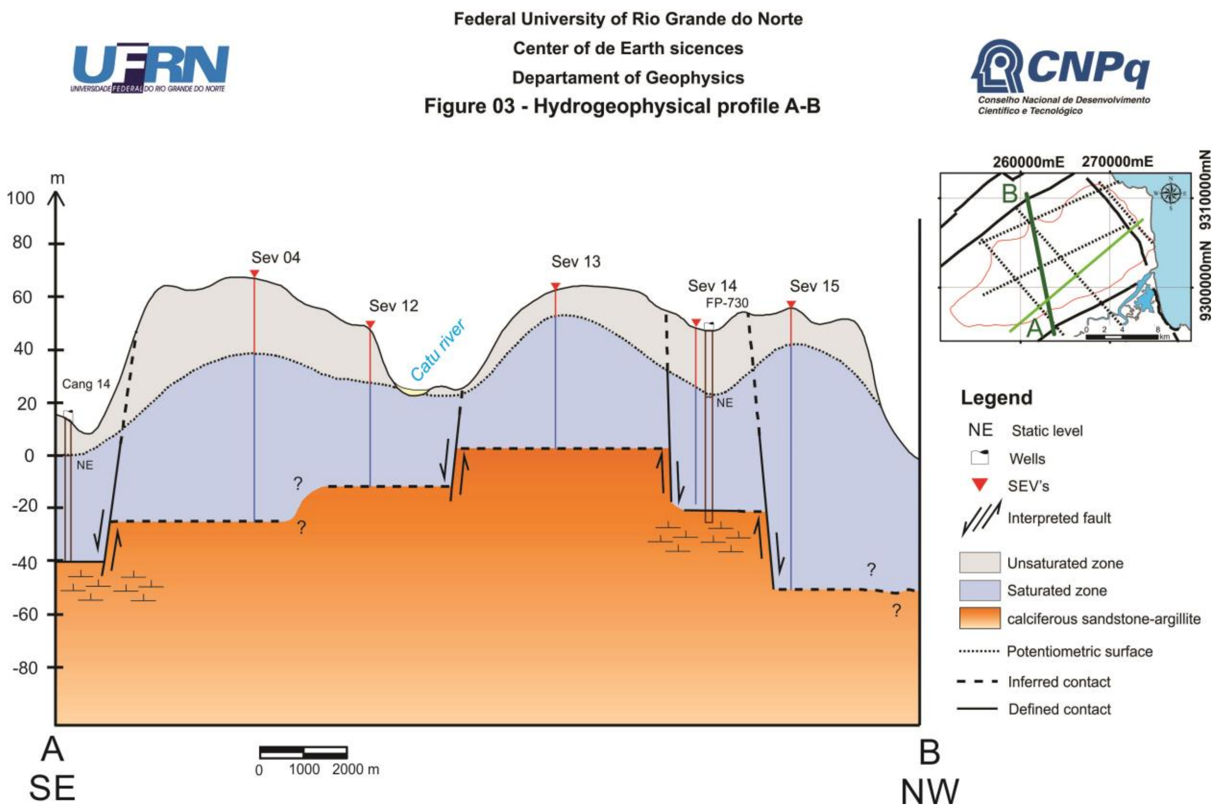

Figure 03: Schematic hydrogeophysical profile used for identification and quantification of fault throw.

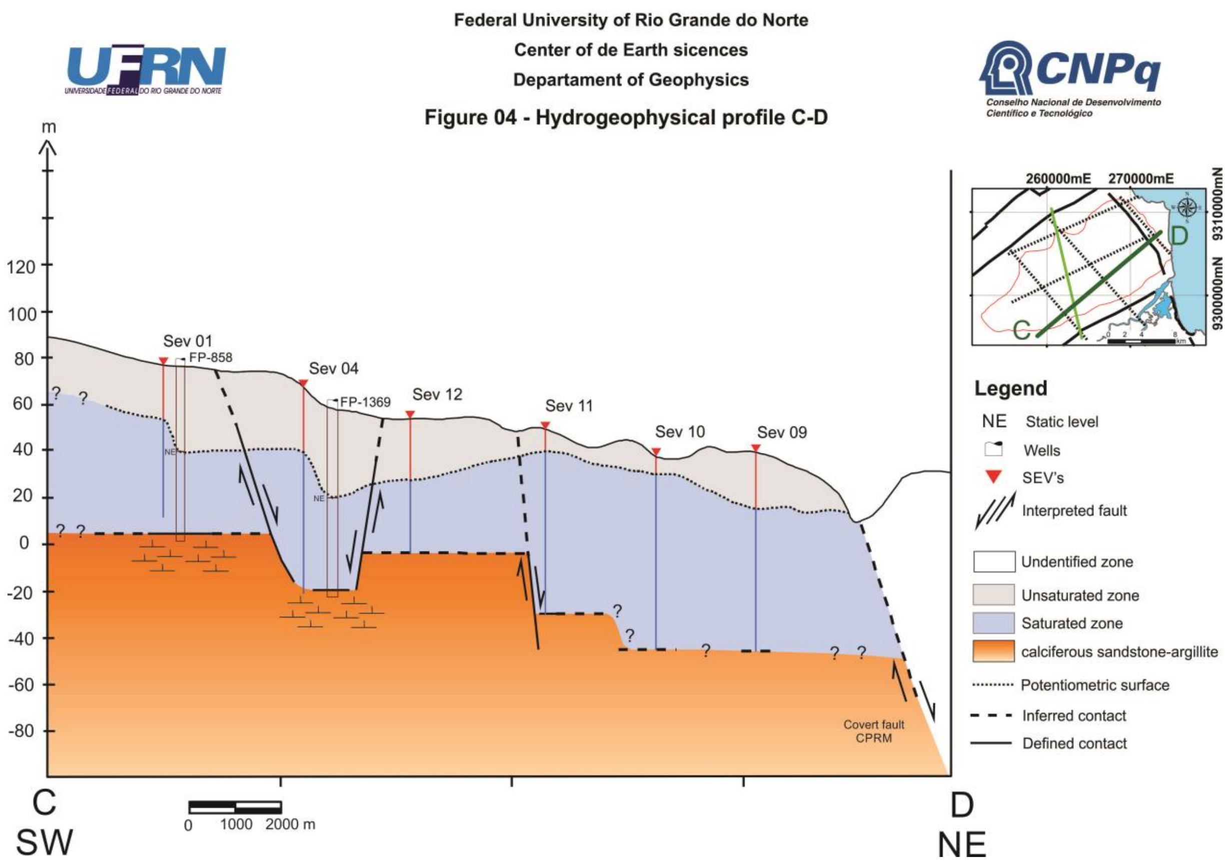

Figure 04: Schematic hydrogeophysical profile used for identification and quantification of fault throw.