Depositional Architecture of Fluvial Deposits in the Resende Basin Identified With Radargrams (*GPR*).

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Abstract

The knowledge of the depositional architecture of sedimentary rocks to create predictive models for exploration and exploitation of economic minerals as well as for environmental purposes is of paramount importance. Ground penetrating radar (GPR) method has been proven to be very effective to map quickly and cheaply shallow geological structures using outcrops. The results of the investigations presented here refer to the depositional architecture of the sandy tertiary Resende Formation at the pull-apart Resende basin state of Rio de Janeiro. The antennas used for data acquisition were 100 MHz and the sampling grid was 5mx5m in a rectangle area approximately 40mx70m. A denser grid 1mx1m was used in a smaller area of the rectangle to have an accurate definition of the model. Processing the lines with software conventionally used for seismic data showed very effective, which radargrams were matched with three wells with continuous cores and gamma-ray logs; therefore, a good understanding of the architecture of the fluvial braided system was reached. The vertical cycles of 2-3 meters are filling channels with apparent width ranging from 20 to 34 meters and sand bars are approximately 10 meters width and length estimated 3 times their widths. The whole system is aligned in a direction from W-SW to E-NE in agreement to the paleocurrents presented by Ramos (2003).

Key Words: GPR, Resende basin, architecture, fluvial braided channels

Introduction

One of the main challenge in the exploration and exploitation processes of some economic material, such as hydrocarbon and water, as well as for environmental activities, is the knowledgement of the architecture and geometry of the geologic rock bodies bearing the minerals. Once one know this model the exploration becomes more precise and optimized. An easy and cheap way to reach such model is the application of the GPR method in shallow and analog geologic structures easily found in outcrops, elaborate models and apply them in the subsurface. Some works have used this method to map geologic structures (Ékes & Friele, 2003) and (Heinz & Aigner, 2003). Here, an outcrop of the sandy Resende Formation in the pull-apart Resende basin (Figure 1), state of Rio de Janeiro, was investigated.

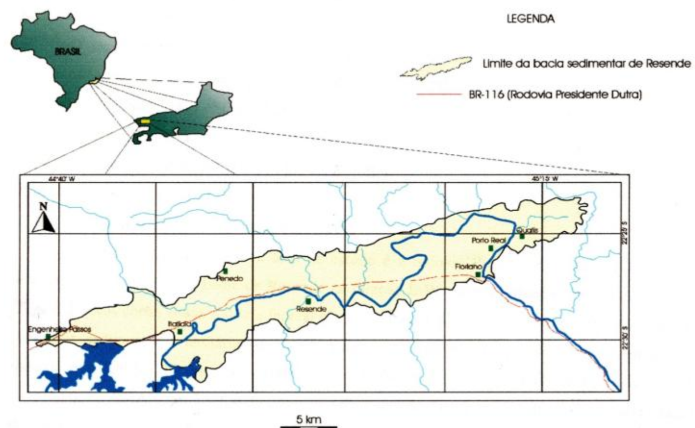


Figure 1- Location map of Resende basin. The study area is close to Porto Real town at the right end of the basin. (Araujo Jr. 2003).

Sedimentologic works have already been done at this area by Ramos (1989, 2003), where a detailed description of the sedimentary facies and vertical succession of them demonstrated that the depositional system consists of a complex braided channels and bars. The objective of the GPR analysis is to verify the geometric architecture of the sedimentologic sandstone bodies, mainly the widths and interrelation between channels and bars. The braided channels and bars of the Resende Formation were deposited Iná lacustrine basin with the discharge of alluvial fans sandy rivers to the basin. The thickness of the sandy/conglomeratic cycles ranges from 1 to 3 meters consisting of a poorly sorted sandstone with conglomerate at the bottom of them. Their composition is predominantly arcosian and prone in festoon cross-beds with medium size (Ramos, 1997, 2003). The use of softwares for seismic to process GPR data was also very effective.

Method

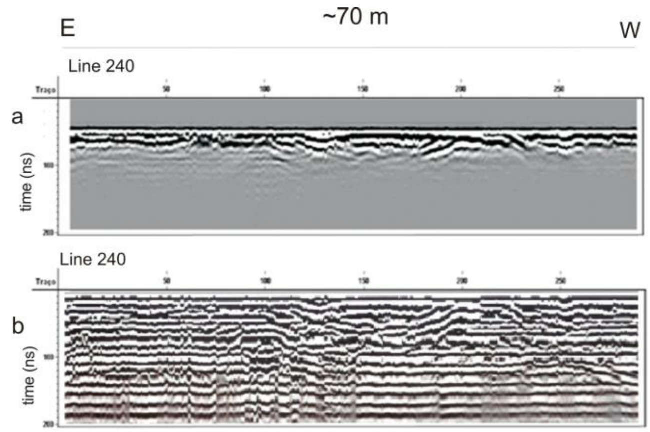
The GPR is a geophysic method that uses electromagnetic waves (EM) with high frequency (10 to 2000 MHz) which consists of a continuous pulse emission from the surface to the subsurface. When the wave reach an interface that separates two medium with contrasting electromagnetic properties it is partially reflected toward the surface, where it is recorded (Dias, 2007). The penetration of the signal in the subsurface is controlled by the geologic facies which has its specific electric and magnetic properties such as: electric conductivity (σ), dielectric permittivity (Є) and magnetic permeability (μ). Therefore, the reach of the signal depends on the used frequency and the investigated material.

The equipment used in this work was manufactured by Ramac/Mala Geoscience (Sweden) which consists of a central control unit and transmitter and receptor bi-statics antennas with frequency of 100 MHz.

The *GPR data* were acquired using the mode *COS* with initial *offset* values (S_1) 0.5 m and continuous spacing (S_2) 0.25m. The investigated area is a rectangle with its longer side oriented E-W, approximately 1.400 square meters. The grid consisted of 13 E-W lines and 9 N-S transversal lines with 5m spaced. The grid was refined between lines 254 and 251 with lines spaced one meter only (11 lines E-W and 11 lines N-S), are that encloses the wells.

Data were initially processed with the software *GRADIX* (Interpex,1996) having the following processing steps: zero time correction, dewowin filter, trapezoidal pass-band, *AGC* gain, mixing and the reformat of *.rd3 extension files, using DOS/Windows to the extension *sgy. The header was generated with the software Vista 2D/3D 4.00, to define the field geometry. This software recognizes the GPR data and automatically converts them to a scale used in seismic. Also, the effect of the direct wave displacing (air) of time from 0 ns to 40 ns was corrected. As example, one can see the radargram of line 240 (Figure 2a) before processing and after processing (Figure 2b) with GRADIX software (Interpex,1996). In the interpretation step the software Petrel Seismic Interpretation® was used, however, it is essential that the geometry of log acquisition be previously implemented in the software.

The gamma-ray (GR) logs ran in three wells, PRG1, PRG2 e PRG3, 6m spaced from each other, have depths approximately of 50m each, much deeper or thicker than the GPR data resolution, around 5m thick. The GR logs were correlated with rock cores of the same wells with sedimentary facies defined by Almada (2007). The GPR data used for interpretation were from the interval ranging from 0 to 100 ns (0 to 5 m) that could be correlated laterally. Below this depth the presence of multiples and low resolution prevent a reliable analysis

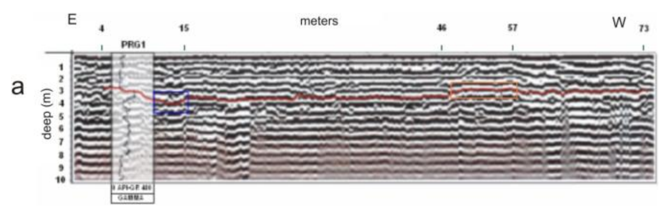


Figures 2a and b - In a, line not processed which presents a small tdepth resolution. In b, the same line processed with the software Gradix. Visualization at deeper portion were much involved

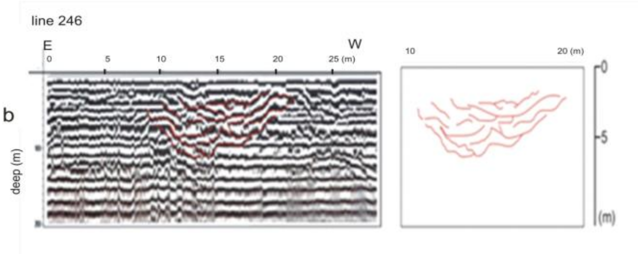
Results

The main results of this work can be summarized as follow:

- The depositional system consists of fluvial braided channels and bars with their axis oriented W-SW to E-NE. This direction is approximately along the rectangle that has na E-W orientation along the longer side.
- The channels which have depths/thicknesses ranging from few decimeters to 5 meters (a function of their position in the system, according to previous work, had their apparent width determined in this work, which range from 20 to 34 meters (Figures 3a and 3b). The actual width is a little smaller because the GPR radargrams are obliqúe to the general orientation of the channels and bars; therefore, they are not ortogonal to the channels (Figure 5). Also, in figure 3a, it is clear the transition from channels (negative relief-reflectors) to bars (positive relief-reflectors) at the position 46m, typical features of the braided system.

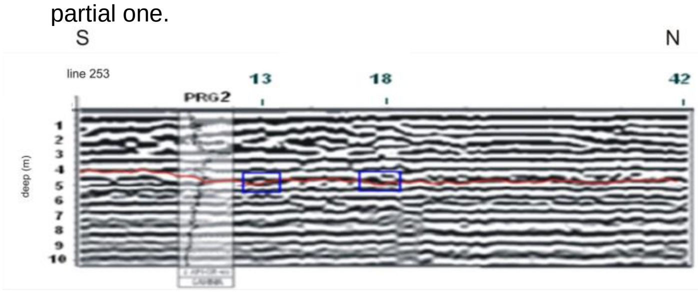


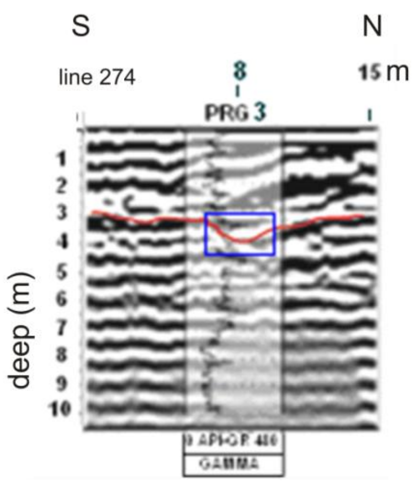
- *Figure 3a - Observe a shallow channel fill which bottom is at 1.5m. The apparent width is approximately 33 m. The actual width is small because the section is crossing diagonaly the paleodrainage which is to NE Laterally the channel is limited by longitudinal bars. The gamma-ray peak marks the bottom of the lower channel level up to 3.5 m.*



- *Figure 3b - E-W Line showing a nice.channel fill complex (upper-center portion of the section) approximately 20m width and 5m deep.*

- The depositional cycles of sandstones are smaller than the GPR resolution (Figures 4a and 4b). One can see that the gamma-ray spikes, due to fine and argilacceous sediment mark the top of these cycles which to some extent correlates well with the radargram reflectors.
- It can be clearly observed in figures 4a and 4b the presence of reflectors dipping to the South, that is, represt beds that onlap the North flank of the channels. The Southern border of the channels are not present at the GPR lines because the line is a partial one.





Figures 4 a and b – Two lines spaced 30 m, both transversal to paleodepositional direction, showing the onlap of beds toward the North flank of the channel. The South flank of the channel is not shown. GR curve presents various cycles with a good correlation with the radargram reflectors. Between 13 and 18m (in figure a) is present a sand bar that separates two channels.

- The model for the whole area is shown in figure 5, which is the result of interpretation of all lines with all spacing. Here the surface around 5 meters deep presents the sedimentary architecture of channels and bars oriented preferentialy E-NE/W-SW (darker colors). This structure which is the channel complex, disappear toward the East because it becomes shallower, therefore, in this area it was eroded. It can be also observed that the width of the braided system is that already mentioned 20-34m

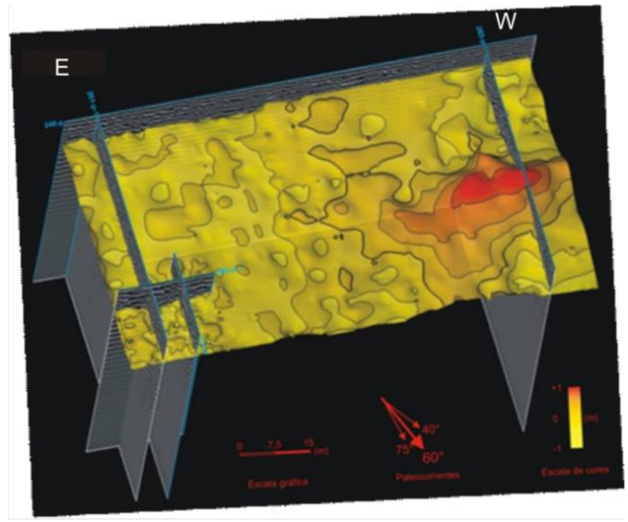


Figure 5 – Image presents the bottom surface.of the channels and bars up to 5m deep. Observe the general orientation of paleocurrents to E-NE, the same orientation of the fluvial valley (dark colors). Some longitudinal bars and few transversals can be observed beside the channel.feature.

Conclusions

The GPR method applied to shallow structures in outcrops is actually an excellent way to determine the depositional architecture of rocks. The problem of compatible scales between radargrams and logs in the wells is also essential to understand the limit of the sedimentary units, as well as the information supplied by rock cores. The use of softwares conventionaly used for seismic to process GPR data was also very effective. The low content of shales, high ratio between channel width/ channel depth are good evidence of a fluvial braided complex, confirming previous interpretation. The apparent width of channels ranges from 20-34meters, whereas the bars have widths around 10 meters (Figure 3a). The lenght of the bars which is much longer than the width was estimated three times their width.

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