2D/3D Electrical Resistivity Tomography (ERT) Applied to Preliminary Economic/Geoelectrical Evaluation of the Jandaira and Açu Formations in the SW Border of the Potiguar Basin, Rio Grande do Norte, Brazil.

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Abstract

Electrical resistivity tomography (ERT) was applied in the west part of the Potiguar Basin (near the Olho d' Água region) in the state of Rio Grande do Norte. The main objectives were to apply this method in the field and use some modern processing and interpretation techniques. This research was also aimed to achieve better geoelectrical resolution of two important geological formations for industry and groundwater resources.

Introduction and Regional Geology

Since 1952, the Potiguar Basin has been the subject of research and explorations related to the oil and gas industry. However, the occurrence of limestone in the Jandaíra Formation has broad applications to consider. The Jandaíra Formation (Apodi Group) consists of carbonate rocks from the Cretaceous period, with outcrops in the Apodi Plateau (Fig. 1), where there is an occurrence of interest for shallow geophysical investigations. The homogeneous and compact layers of the Açu Formation (sandstones) are almost horizontal, continuous, and have great potential for exploitation of groundwater (Souza, 2005). As a result, in this part of the Potiguar Basin, the limestone and shale of the Jandaira Formation assume great importance for the fruit industry due to the large groundwater requirements.

The Potiguar Basin is a rift formed in the Neojurassic period, during the separation of the South American and African plates. Its origin is associated with the creation of the South Atlantic Ocean and is linked to a series of neocomian and intracontinental basins, comprised of an important rift system in northeastern Brazil (Matos, 1992).

In this region, the Tabuleiro do Norte and surrounding areas have improved considerably. Companies in the cement industry have begun leasing large areas due to the Jandaira's limestone. Therefore, the objective of this research is to apply geological and geoelectrical characterization of the Jandaíra Formation units comprising the occurrence of limestone with economic interest in the Potiguar Sedimentary Basin. The principal aim of this research is to identify limestone geoelectrically by using electrical resistivity tomography and the thickness of the Jandaira Formation, which can be an important role for hydrogeological supplies. The Açu Formation is the most favorable groundwater system, since the quality and great possibilities amount for the most diverse purposes, while its depths can cause problems for small farmers.

Consequently, a site area located near the west border of the Potiguar Basin has been covered with the acquisition of 2D geophysical data, processing, inversion and interpretation of multi-electrodes, resulting in high resolution electrical investigations. Figure 1 shows a detailed geological map involving the studied region and an image illustrating a 3D view of the same region.

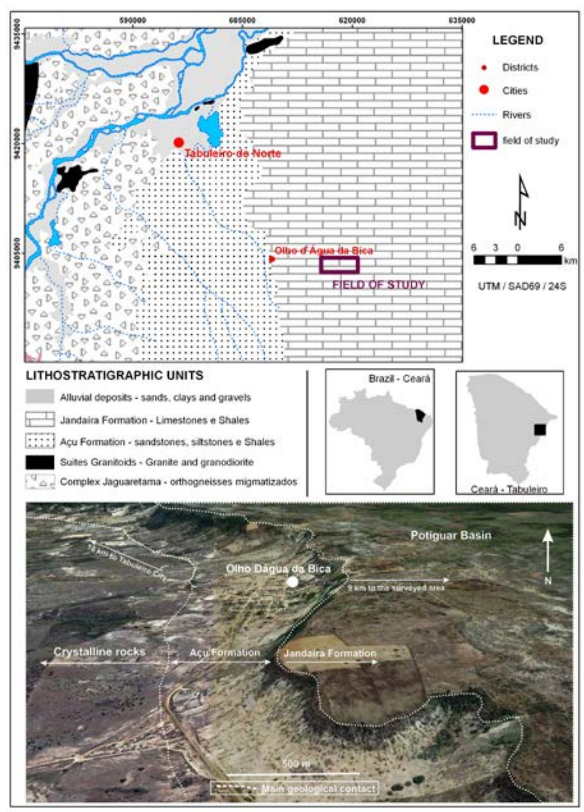


Figure 1: Geology of the Study Area (Potiguar Basin) and location of ERT sections.

Methodology (Electrical Resistivity Tomography)

Electrotomography imaging techniques such as ERT are now widely used in environmental and engineering problems (Pellerin, 2002). ERT produces spatial models of subsurface resistivity distributions, from which features of contrasting resistivity may be located and characterized. Methodologies for ERT data collection and modeling are described widely in literature (Slater et al., 2002; Dahlin et al., 2002; LaBrecque et al., 1996). During the course of an ERT survey, multiple electrical resistance measurements are made. In this case, the ERT data was collected using an AGI SuperSting R8 IP system attached to 42/84 stainless steel electrodes via multi-core cables. Two sections were measured at 840m long for regional evaluation. Figure 2 shows a schematic illustration of site position sections located 9km east of the Potiguar Basin border (Figure 1).

Four sections were made using the dipole-dipole method. The length of the four parallel sections (Laj 7,2,5,6) were 420m (W-E direction) with electrode spacing of 10m (Fig. 2). The separation of each section was 15m. The resistivity data was processed and inverted using commercial software such as Res2dinv (Geotomo Software), Earthimage 2D (Advanced Geoscience, Inc.), and Zondres2D (Zond Geophysical Software).

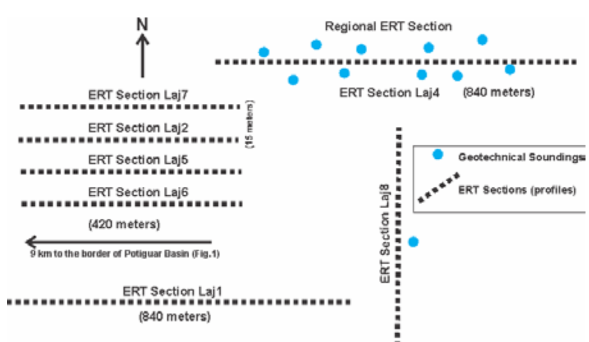


Figure 2: Schematic illustration showing the position of all ERT sections in the site area.

During processing, we evaluated the amount of data acquired in each survey. The data acquired proved to be an excellent quality data with contact resistances ranging between 400Ω to 1600Ω (an acceptable contact resistance value is often below 5000Ω, ideally below 2000Ω). The contact resistance is an excellent indicator of data quality, and it can also help identify problems in electrodes inside the array. Figure 3 shows an example of the contact resistance chart for the Laj1 section.

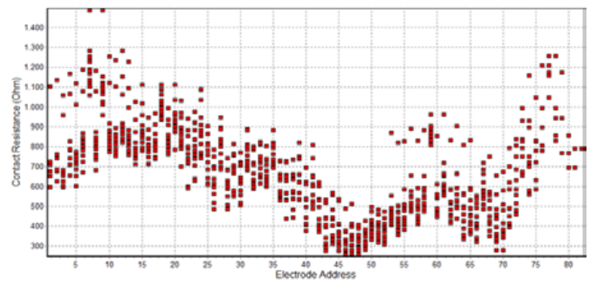


Figure 3: Contact resistance chart as an example for Laj1 section. The contact resistance in ohms is very good for each electrode address.

Another way to evaluate the data quality after the inversion process is the analysis of the convergence and data misfit. This means to evaluate the convergence curve of inversions in terms of interaction numbers and RMS errors. Figure 4 shows an example of a Crossplot of measured versus predicted apparent resistivity data showing a positive correlation between the measured apparent resistivity and the predicted apparent resistivity, the RMS error, and the L2 results. Several other mechanisms of inversion evaluation were used as the L2 norm as it indicates a worthy convergence. It is also another measure of data misfit (Figure 4).

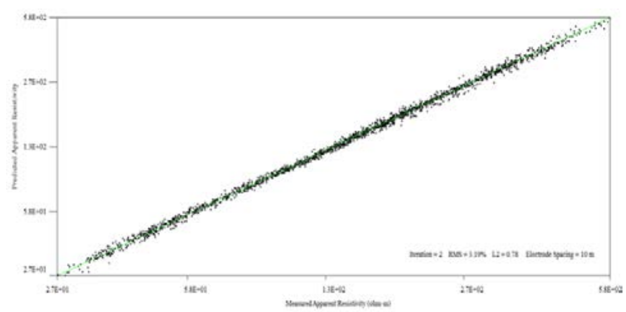


Figure 4: Crossplot of measured versus predicted apparent resistivity data showing a positive correlation, the RMS error, and the L2 results.

Inversions of the surface datasets were carried out with 3D inversions using a 3D constrained smoothness, nonlinear, least-squares algorithm (Loke and Barker, 1996) in which the forward problem was solved using the finite difference method. On the other hand, the least squares method with regularization is used for inverse problem solution. Regularization increases solution stability and allows receiving smoother resistivity and potential distribution. A starting model is produced, which, in these cases, was a homogeneous half-space, for which a response is calculated and compared to the measured data. The starting model is then modified in such a way as to reduce the differences between the model response and the measured data. These differences are quantified as an RMS error value (< 3%) with 15 iterations.

Results and Discussion

The 2D ERT results are given in Figure 5 as a model with a series of four 2D inverted/interpreted resistivity sections, showing the interior of the model. The 3D block (Figure 6) was constructed with these four sections, but they were inverted using a 3D method.

Based on this interpretation, the area consists of some argillaceous limestones, characterized by relatively low resistivity (20Ωm) and sand/gravels (>34/40ohm.m) in shallow depths that contrast with a relatively conductive geoelectrical horizon (6-35Ωm) between 0 and 15 meters in depth. Another resistivity contrast occurs below 30 meters, showing a more resistive geoelectrical horizon (>28/45Ωm); this horizon is compatible with the porous limestone, shales and siltstones of Jandaira Formation. An interface/transitional horizon can be seen near 44 meters in depth showing the beginning of a more resistive horizon (>60-80ohm.m). This last imaged horizon can be associated with a transitional zone to the compact sandstones of Açu Formation (the principal aquifer system, probably after 70 meters). The electrical contrast between these material types permits us to distinguish between them in the 2D section and 3D resistivity images.

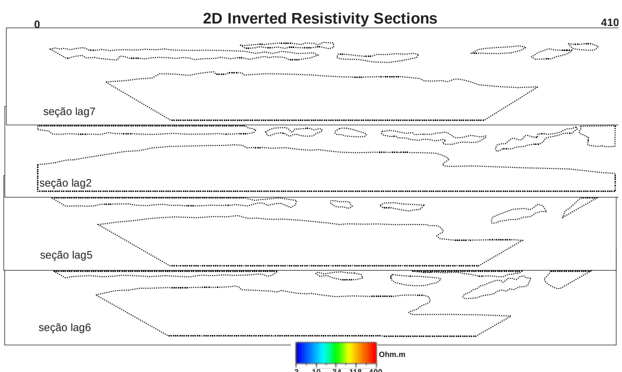
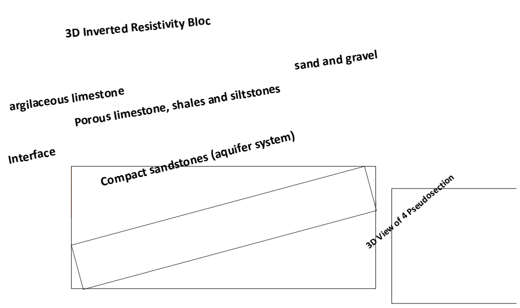


Figure 5: The four 2D inverted and interpreted resistivity sections.



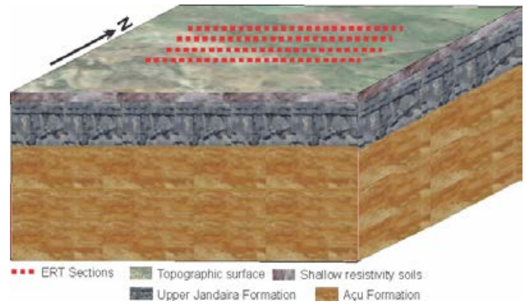


Figure 6: 3D resistivity blocks, parallel sections, and dynamic slices compared with the geological interpretation.

With a regional purpose we conducted also an ERT section more expressive in dimensions in its lateral and depth of investigation. Figure 7 shows an inverted/interpreted 840 meters ERT section (position in figure 2) showing all the geoelectrical horizons mentioned above. Another way to show the ERT resolution is shown in figure 8, but more ERT/geological information is need because there are not any information's from drilling near the area. This figure shown a beautiful possibility to present a sinkhole and a crevice-type cave observed by a depression most conductive and a centered most resistive zone.

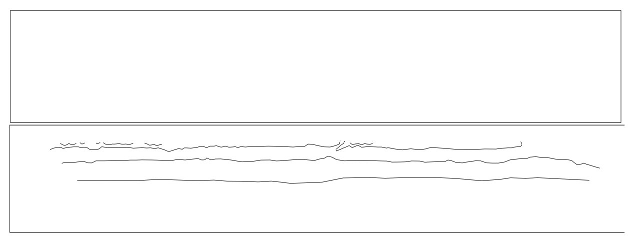
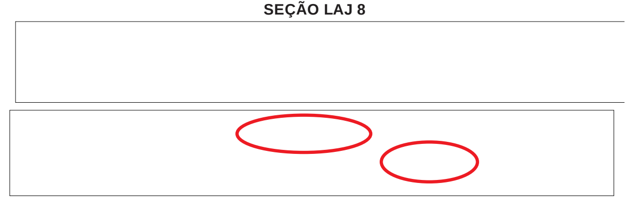


Figure 7: Inverted/Interpreted Laj 4 Section (figure 2) with 840 meters length (84 electrodes).



Preliminary Conclusions

This preliminary research about ERT acquisition, processing and inversions in this part of the Potiguar Basin could send geoelectrical information with a positive resolution in the evaluation of shallow depths (~100m). The three principal geoelectrical horizons were identified, and they could be comparable with geological/lithological subsurface horizons. Most likely the three identified horizons were the limestone from the Jandaira Formation, the sandstone from the Açu Formation, and an interface contact zone between them. The softwares used have great resources for processing and inversion of ERT data as well as data quality assessments. Numerous other details of ERT imaging analyzed here should be the subject of further researches in that area.

References

Dahlin, T., Bernstone, C., Loke, M.H., 2002. A 3-D resistivity investigation of a contaminated site at Lernacken, Sweden. Geophysics 67 (6), 1692–1700.

LaBrecque, D.J., Miletto, M., Daily,W., Ramirez, A., Owen, E., 1996. The effects of noise on Occam's inversion of resistivity tomography data. Geophysics 61 (2), 538–548.

Loke, M.H., Barker, R.D., 1996. Practical techniques for 3D resistivity surveys and data inversion. Geophysical Prospecting 44 (3),499–523.

Matos, J.P.L., 2009 - Estudo Geofísico e Geológico ao longo de uma seção transversal ao rifte da Bacia Potiguar – RN/CE

Pellerin, L., 2002. Applications of electrical and electromagnetic methods for environmental and geotechnical investigations. Surveys in Geophysics 23 (2–3), 101–132.

Slater, L., Binley,A.,Versteeg, R., Cassiani,G., Birken, R., Sandberg, S., 2002. A 3D ERT study of solute transport in a large experimental tank. Journal of Applied Geophysics 49 (4), 211–229.

Sousa, J. F. & Vidal, F. W. H. 2005. Rochas Carbonáticas. In: Rochas e Minerais Industriais do Ceará. Editora Funcap. p. 49-66 p