Comparison of seismic, electrical resistivity, magnetic gradiometry and sonographic data in the Araguaia River, MT – Brazil

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Abstract

This work presents an analysis of geophysical methods applied in Araguaia River, Paraná Basin – Brazil. The field acquisition exhibits the performance of different shallow methods in describing the riverbed architectural facies and shows how each method behaves depending on the kind of interface. All survey lines were run along the main river channel: Responses were acquired at specific sites related to sandy sediments, rocky outcrops and gravel/coarse grain concentrated deposition. The combination of these geophysical data allows discussing methodology to describe geometry of sedimentary structures.

Introduction

The Araguaia River is the main tributary of Tocantins River, has a drainage area approximately of 380.000 km² and average discharge of 6.100 m³/s. It´s considered a river of low sinuosity, with islands, channels and tendency to braiding. In some sections, it shows a disposition tending to a unique channel, sometimes forming meanders. Its braiding index, however, is low, with a main channel and no more than one or two other channels. Islands and sand bars are the principal alluvial features along the channel (Latrubesse and Stevaux, 2002).

To date, the vast majority of river sedimentology study has relied on two main categories of observation: direct observation of shallow trenches, cut faces and cores or geophysical survey on dry and shallow regions of braid bars. The use of high-resolution seismic surveys has been shown a very useful tool for description of architectural facies of river sediments (Ianniruberto et al, 2012). The study of riverbed architectural macro forms may be improved with the combination of integrated geophysical methods.

This paper presents a comparison of different methods in detecting interfaces of depositional environments, usually related to unconsolidated sediments, rocky outcrops or gravel deposits. Joint interpretation of such data sets gives a more reliable and less ambiguous interpretation than any single method. Moreover, this kind of data set may be useful to test joint inversion algorithms (Hirch, 2008). Figure 1 illustrates the area of the survey, between the cities of Barra do Garças and Torixoréu (Mato Grosso State).

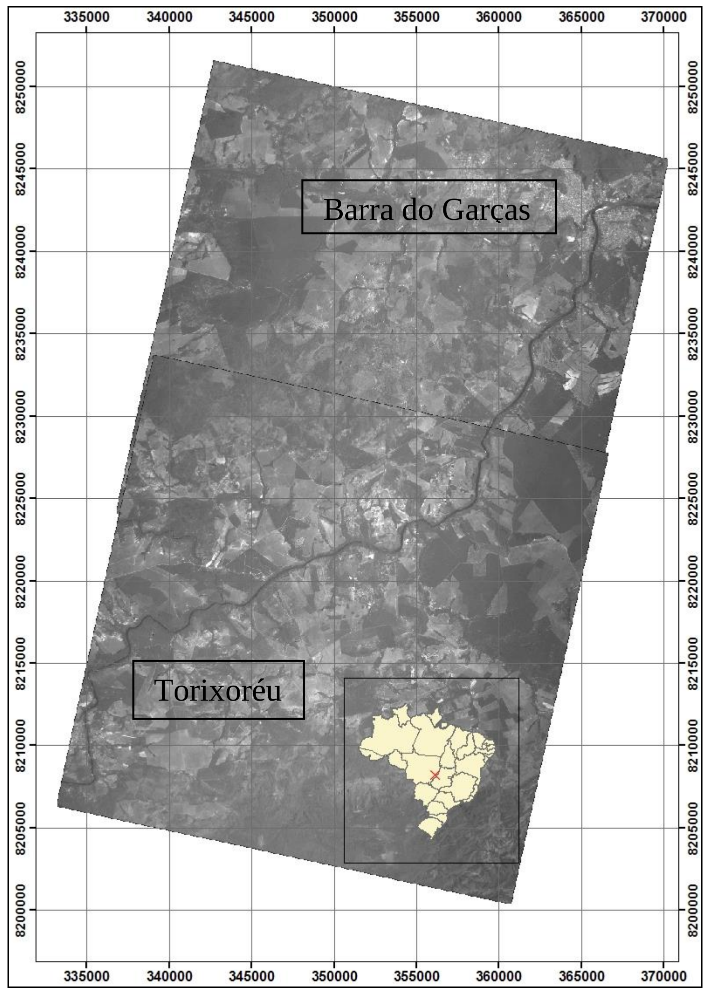

Figure 1: Location of the geophysical surveys along Rio Araguaia, Paraná Basin, Brazil, accomplished between the cities of Barra do Garças – MT and Torixoréu – MT. Reference Datum: WGS 1984. Projection system: UTM South, Zone 22. Image source: CBERS 2B HRC-INPE.

Geological Settings

The region of the study is related to the geological context of the Paraná Basin and covers its northern portion. The principal geological formations that occur in the geophysical surveys are Aquidauana, Furnas and Ponta Grossa. These units are made of depositional systems associated to alluvial, fluvial, lacustrine and eolian sedimentary environment with strong contribution of glaciation processes (Geisicki et al, 2000), besides regressive fossiliferous marine sediments – Formation Ponta Grossa.

Aquidauana formation, typically made of reddish stones, is usually recognized in the basin over the states of Mato Grosso and Mato Grosso do Sul. This formation outcrops an elongated patch in NNE direction and extends approximately 300 km long that cuts the whole state and show continuity to the north, in Mato Grosso state, and to south, in oriental Paraguay, where is recognized as Aquidaban Formation. This unit is composed, in a general overview, of sandstones made of several granulations, siltstones, mudstones, rythmites, clasty mudstones and reddish diamictites (sedimentary massive conglomeratic rocks, fulfilled with a fine grained matrix) with common medium-sized tractive sedimentary structures such as planar, tabular, tangential or fluted cross stratification, besides convoluted folds and plane parallel stratification (Geisicki et al, 2000).

The Furnas Formation is represented mainly by white quartzose sandstone, with a medium to coarse granulometry that exhibits cross stratification of several natures and postages. This unit may reach 250 meters of thickness and its white color is related to kaolinite clay mineral. The age of its basal portion is problematic and the deposition was possibly started at late Silurian. The Ponta Grossa Formation has a Devonian age and is constituted mostly by clay rocks (shale) rich in fossils (Milani et al, 2007). The figure 2 shows some examples of outcrops found in the field.

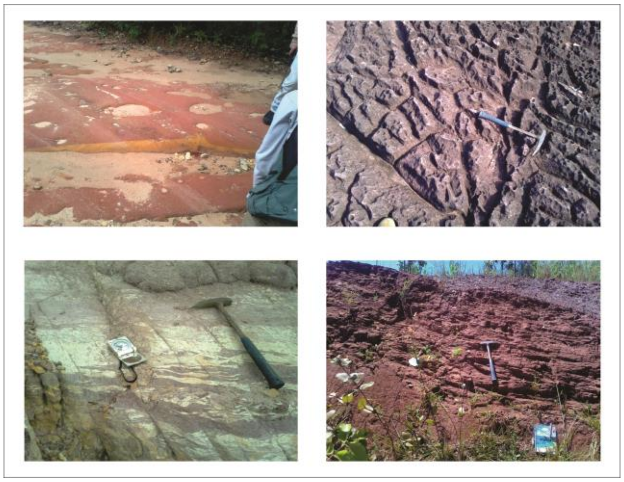

Figure 2:Examples of sandstones outcrops found in the alluvial terrace, near Araguaia River, MT.

Materials and Methods

The research aims applying distinct methods of geophysical surveys (seismic, sonography, electrical resistivity and magnetic gradiometry) with intention to verify the correlation between different equipment responses and the suggested anomalies.

The shallow seismic method was adopted using a high resolution seismic profiler (SBP) interfaced with a WADGPS (Wide Area Differential GPS) receiver and navigation suite. The Edgetech 3100P subbottom profiler, equipped with the tow-vehicle SB-216, was operated with a “chirp” pulse of bandwidth 2 – 15 kHz and about 10 cm resolution.

The sonografic survey was carried out with Edgetech Side Scan Sonar (SSS), equipped with the tow vehicle SSS 272TD that provided an accurate bottom mapping through acoustic pulses modulated at 500 kHz, 10 cm resolution and angular resolution up to 0,5 degree.

The electrical pathway was accomplished with dipole-dipole arrangement that was chosen for the attaining of higher resolution with a 2.5 m spacing electrode. The utilized equipment was composed of a multi-electrode resistivity imaging system Syscal PRO (Iris Instruments) with an floating cable made of 13 electrodes, 200 W – 400 W source and 2,5 A current intensity.

The magnetic gradiometry method is based on the measure of the differential magnetic field, originated by induction of a secondary field in minerals or objects as function of magnetic susceptibility of the supposed targets. Usually, anomalies are low with comparison to main components of the potential field and may be better determined with a proper arrangement of sensors disposed to form base lines in three dimensions. The equipment consists in a laptop for system control, magnetic gradiometer with 3 components, with absolute accuracy of 0,2nT, sensitivity of 0,01 nT and resolution of 0,001 nT.

Results

The geophysical survey performed in Araguaia river show different classes of sedimentological environment that may be related to the river transport energy. The main sediment class is composed basically by sandy dunes systems, detectable with continuity over hundreds of meters in the major part of the survey area. In local zones is possible to notice the intercalary of coarse grains/gravels and sand bars, depending on the tax of river transport energy. Near to the margins, is common the presence of outcrops features, as elongated stands clearly shown in side scan sonar imagery (figure 3).

The combined geophysical data provides an accurate way of interpreting data field acquisition and a better understanding of the geophysical characteristics and geometry of sediment layers. The figures listed above exemplify how each method responds due to the type of interface and its material present in the main river channel. Figure 3 illustrates the occurrence of sandy dunes and local

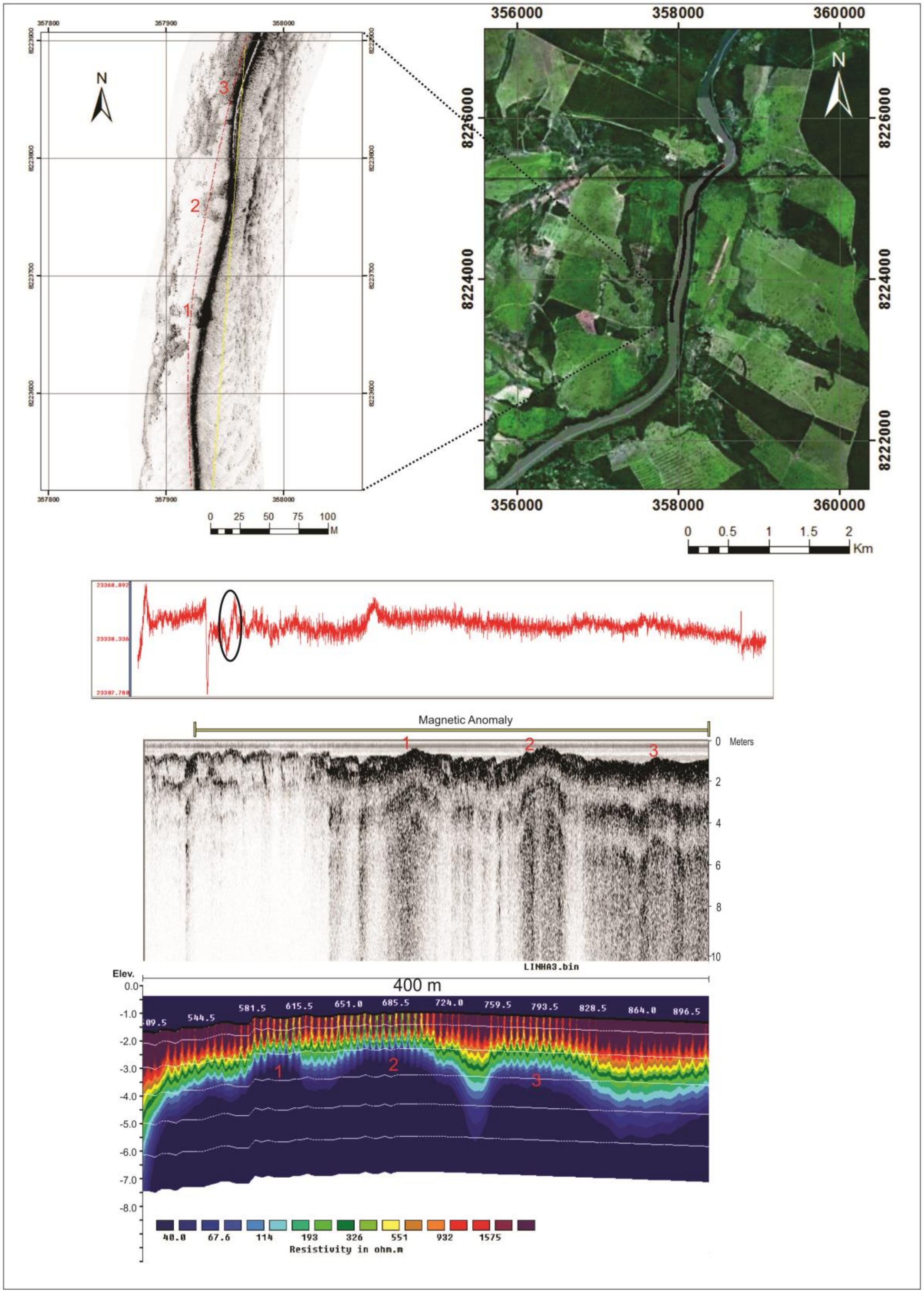

Figure 2: comparison of four different geophysical surveys: sonographic, geoelectric, seismic and magnetic gradiometer. It´s possible correlate same features in both geoelectric and seismic profiles, as outcrops along hundred meters.

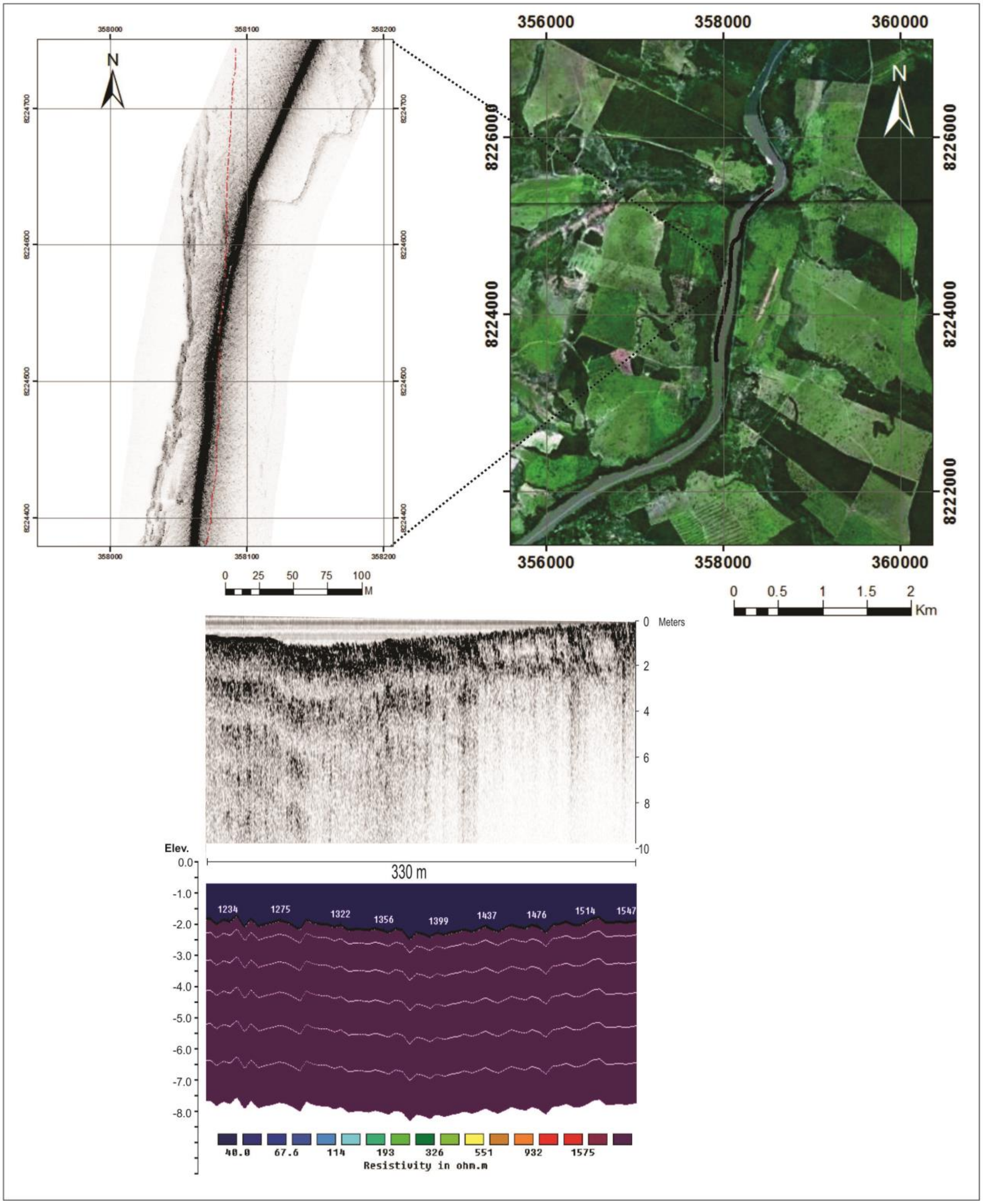

Figure 4: Relation between geoelectric and seismic methods. In this specific site, the resistivity profile shows that the sand covers exceeds more than 7 m, different from the seismic data, limited to a superior pack ranging 2 m thick.

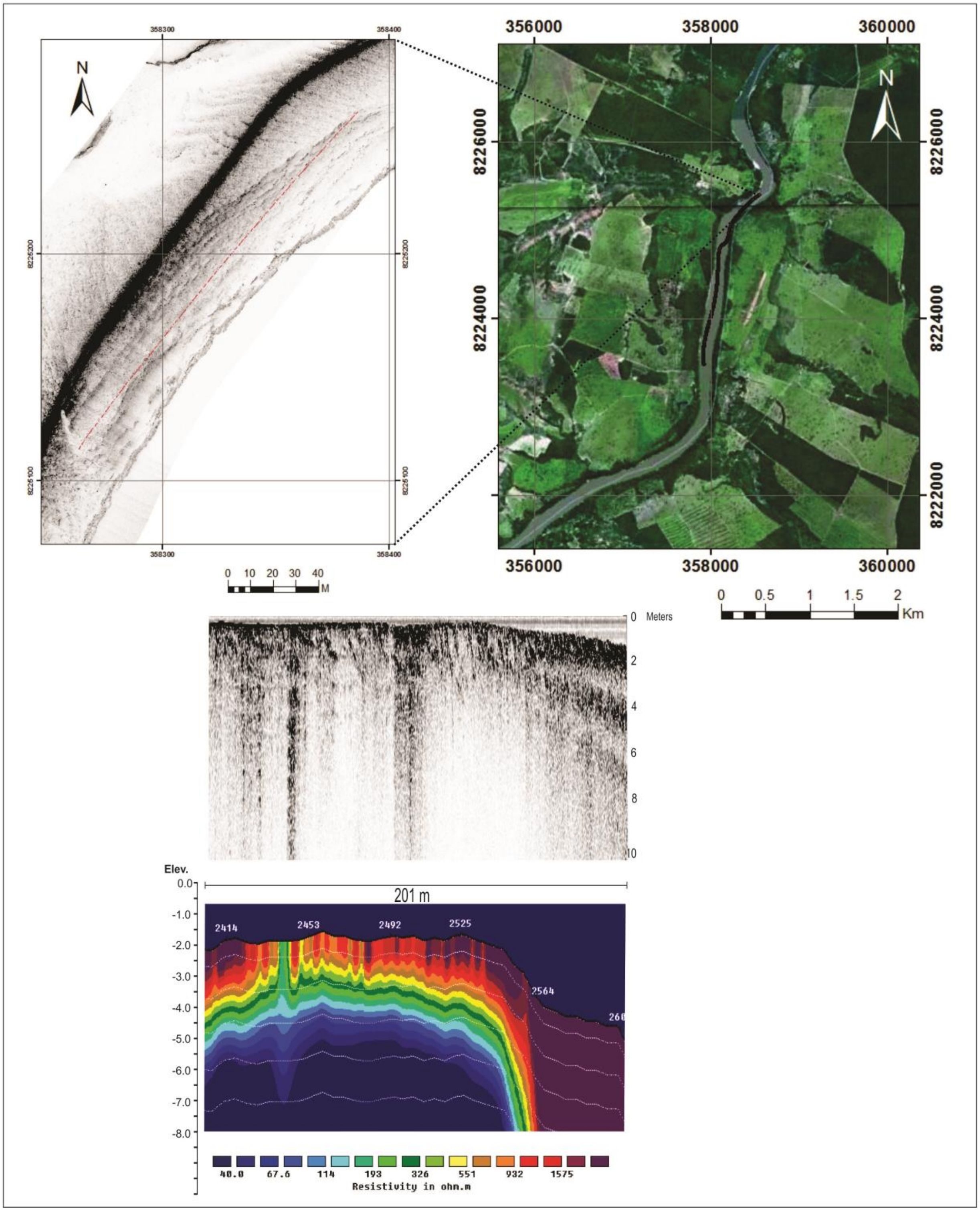

Figure 5: Comparison of methods in an interface area. At the end of the profile, the resistivity tends to higher values, with downdip morphology of more than 4 m thick, probably related to unconsolidated sediment, as seen in SSS imagery.

exposure of the rocky basement. In this case is possible to notice coherent responses of magnetic gradiometer, electrical resistivity, seismic and sonographic data. On the side scan images shown (figure 3, 4 and 5), are represented in “red” the navigation line of seismic transducer, in “yellow” the magnetic gradiometer navigation. The sonographic image in figure 3 presents texture of unconsolidated sediments interrupted by the presence of outcrops, related to rocky basement (event 1, 2 and 3). These features are easily recognized in seismic and electro-resistivity profiles, as highlighted in the figure. The seismic profile, as expected, shows higher impedance and absence of reflectors above the rocky outcrops and the geoelectric profile exhibits resistivity values lower than 100 ohms, expected for consolidated materials. The complex of psamitic dunes can be detected in both geoelectric and seismic methods, that show higher values of resistivity to the top layers (higher than 150 ohms) and clear continuity of emerged outcrop zones above psamitic covers (~ 2m thick), respectively. The magnetic anomaly is shown in the magnetic gradiometer profile, plotted within a black ellipsoid domain and should be probably related to a NW regional fault zone that cuts the river in this specific site.

The figure 4 presents a case of deposition related to unconsolidated material. The sonar imagery exhibits clear texture of sedimentation zone, notable in geoelectric profile with warm colors (high resistivity) with a thickness of more than 8 m. On the other hand, in the seismic section the same pack appears to scatter wave energy and brings information for only 2 m deep, showing shallow reflectors only.

In figure 5, the side scan sonar imagery maps an area of interface between stand rocky outcrop and unconsolidated sediment. The consolidated area in SSS is marked by stands lineation that may contain coarse grains/gravels probably generated by erosion currents in the river channel. The combined seismic and geoelectric profiles presents exactly this situation. The seismic profile, in the first 100 m represents high impedance and limited downdip structures reaching up to 2 m deep. The last 50 m indicates the presence of unconsolidated material, as seen. The geoelectric section in the first 100m shows low resistivity in the bottom and higher resistive material toward the top layers. In the end of the profile, occurs an enhancing of the resistivity, when comparing to the bottom layers at the beginning of the profile. The absence of basement rocks in the end of the profile reflects the enhancement of its resistivity, probably due to psamitic sequence pack.

Conclusions

The combination of geophysical methods has been very useful for sedimentological studies in the riverbed because it enhances the investigation, allowing analyses in different approaches and complements the previous traditional geological studies.

The seismic method provides a higher resolution profile compared to the geoelectric profile, although the second one had a better penetration of investigation (in this case approximately 8 m). The sonographic method performed by the Side Scan Sonar provides a good resolution for granulometric and rock differentiation analyses on plain view and the magnetic gradiometry is applied for the occurrence of magnetic/dense minerals and faults in the structural basement rocks.

It is known the occurrence of diamondiferous facies in the Araguaia River. The combination of these methods can be very useful on the evaluation of potential targets for diamonds exploration. Coarse grained and gravel sediments can be constrained by the seismic and sonographic methods while the magnetic gradiometric method highlights the occurrence of magnetic anomalies that could be linked to occurrence of guide minerals for diamonds exploration. The geoelectric method can provide complementary data in order to classify sediment types, sometimes attaining a better penetration.

Acknowledgments

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