Boulders mapping by using resistivity imaging survey

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Abstract

São Paulo city is mostly settled on a sedimentary basin and its basement is formed by pre-cambrian rocks, mainly gneiss. With the urban expansion these pre-cambrian areas have been occupied by important enterprises that impose relatively deep excavations, including underground parking lots, subway tunnels and stations. One of the problems encountered is the detection of boulders that prejudice the chronogram and increase the final cost of the work.

The evaluation of the presence of boulders is typically defined using refraction seismic and the results are not always very precise and the use of Ground Penetrating Radar (GPR), common in several countries (e.g. Smith and Jol, 1995), is limited in tropical environments due to the thick weathering covering and the high attenuation of the signal. MASW (Miller et al.,1999) could be applied but is a time consuming technique and with relatively poor horizontal resolution (Yinhe et al., 2008). Nowadays, with the availability of multielectrode resistivimeters, it is possible to intensively survey an area by several profiles relatively fast and at low cost. This paper presents an application of resistivity in Brazil, where it was used to identify the presence of boulders, to locate and even calculate the size of them.

Introduction

The area studied is in Barueri, a municipality close to São Paulo city, where the implantation of deep foundations is sometimes difficult due to the presence of boulders of gneiss, the rock that predominates in that region. The gneiss is normally overlaid by weathering mantle (weathered soil and regolith) of more than ten meters thick, but some boulders of different sizes may be present in the soil. Those boulders may have a volume of several cubic meters and jeopardize the direct investigation program. The area of the survey was approximately 2500 m^2 (50x50m) where a building with four levels of underground parking was projected.

The objective of the study was to locate the presence of boulders and to predict its size in order to calculate the cost of their removal.

Method

Resistivity method has been used for almost a century and its principles and applications are well defined (e.g. Orellana (1972), Dobrin (1981), Parasnis (1986), Sharma (1986), Robinson and Çoruh (1988), Telford, Geldart, and Sheriff (1990).

The dipole-dipole array was used in this resistivity survey. The distance between electrodes was AB=MN=2.5m and AB=MN=5m with ten levels of investigation. The distance between the sections was typically 2 meters, wherever the area permitted. Twenty six parallel sections were carried out. A 48 multielectrode resistivimeter was used and allowed to acquire the data without changing the array to complete the acquisition of each section. With such density of information we hoped to detect variations of resistivity that could be related to the presence of boulders.

The raw data was processed using the software RES2DINV (Abem, 1998) and Surfer 8 (Golden Software). While the first is specific for inversion of resistivity and IP data, the second is generally used to interpolate spatial data. The results of the inversion process were exported as XYZ data and interpolated to improve the visualization.

The RES2DINV uses a fast and efficient technique for data inversion, developed by Loke and Barker (1996a, 1996b) and Degroot-Hedlin and Constable (1990) and is based on the least square and the smoothness-constrained methods. Theoretically it provides a 2-D subsurface model free from the distortions presented in the pseudo-sections, and those due to the electrodes array adopted.

The 2-D modeling system of the software divides the subsurface into rectangular blocks, and the values of resistivity and chargeability for each block are calculated, and related to the points assumed in the pseudo-section. The optimization method reduces the difference between the measured and the calculated values, and adjusting the values for each block. The distribution and size of the blocks are generated automatically by the software so that the number of blocks does not exceed the measured points (except when the user imposes this condition).

The final depths of the blocks, i.e. the calculated depths of the investigation levels are approximately those proposed by Edwards (1977) for the largest distance of the electrodes array, and are about half of those proposed by Hallof (1957) for pseudo-sections. The user may also adjust these depths if direct information is available.

In order to obtain a global picture of the resistivitiy distribution in the area surveyed it is possible to draw maps using the modeled data. Typically one specific investigation level is highlighted after analyze of all the data. If required, resistivity variation over depth can also be assessed and pictured (GALLAS, 2000).

Results

The inverted data were presented in resistivity sections and Figure 1 shows three typical results. The chromatic scale was standardized to allow comparison between the section and facilitate the visualization. Considering the geology of the area, three basic resistivity levels were correlated to specific material mechanical resistance (Figure 2). Resistivities lower than 500 Ω.m were correlated to unconsolidated sandy-silt (result of the weathering on gneiss); resistivities between 500 and 1500 Ω.m were correlated to residual soils, and values of resistivity higher than 1500 Ω.m were associated to weathered and sound rock.

In order to facilitate the interpretation, 6 maps were generated and showed the resistivity distribution at different depths (1.1, 2.8, 4.9, 7.8, 10.3 and 13.2m below ground level). They are presented in the Figures 3, 4 and 5.

The association of the high resistivities regions of the maps allows visualization of the size of the boulders with depth. This is noted mainly in the coordinates 40,20. The boulder increases in size and resistivity (correlated to mechanical resistance) from 1.1m to 2.8m; reaches the highest values of resistivity at 4.9m; then decreases both in size and resistivity value (while deriving to the coordinates 50,30), not being visible in the 13.2m map. The same association is possible to be made for the other high resistivity occurrences. The high resistivity observed in the 13.2m map may be related to the surface of the basement.

If borehole or excavation data becomes available, it will be possible to refine the interpretation associating specific geological description with the resistivity values and extrapolating this to the whole studied area .

Conclusions

The objective of the study was to locate the presence of boulders and to predict its size in order to anticipate foundation problems and eventually calculate the cost of boulder removal. An intense resistivity survey was carried out in the area of interest and the boulders locations were detected as well as their distribution over depth. The method was found to be simpler, more precise and less expensive than the typically used refraction seismic methodology. After the survey, the results were used to redesign the parking lot, minimizing rippability costs.

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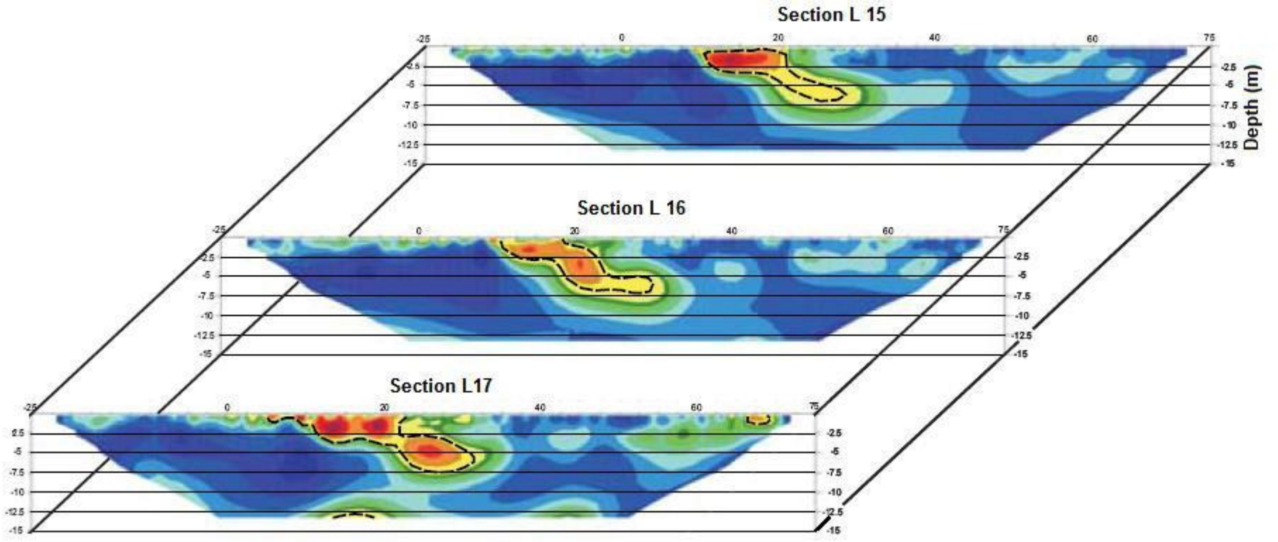

Figure 1 – Typical resistivity profiles showing the anomalous high resistivity values (center of the sections) associated to the boulders occurrence.

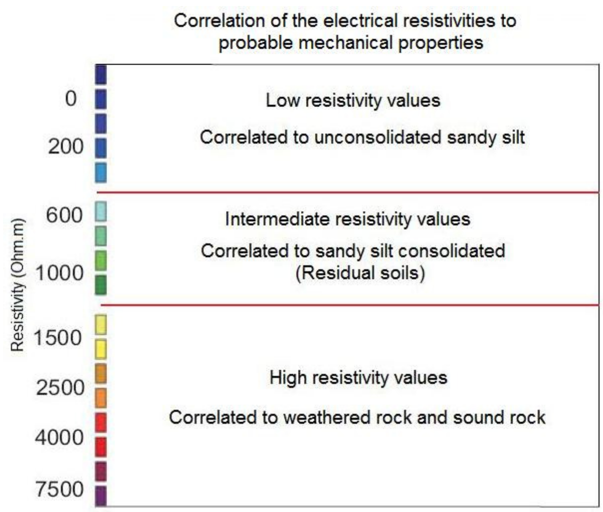

Figure 2 –Resistivity Intervals and respective interpretation related to the mechanical resistance

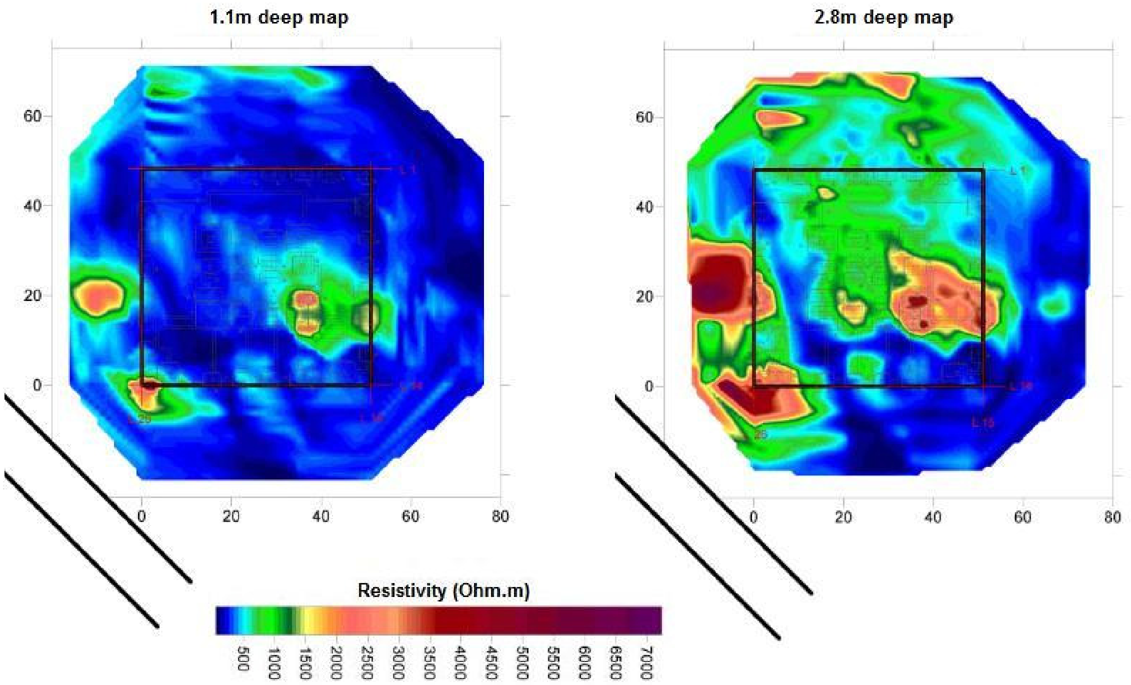

Figure 3 – Maps for 1.1m and 2.8m bgl. It is possible to observe the size of the high resistivity anomalies.

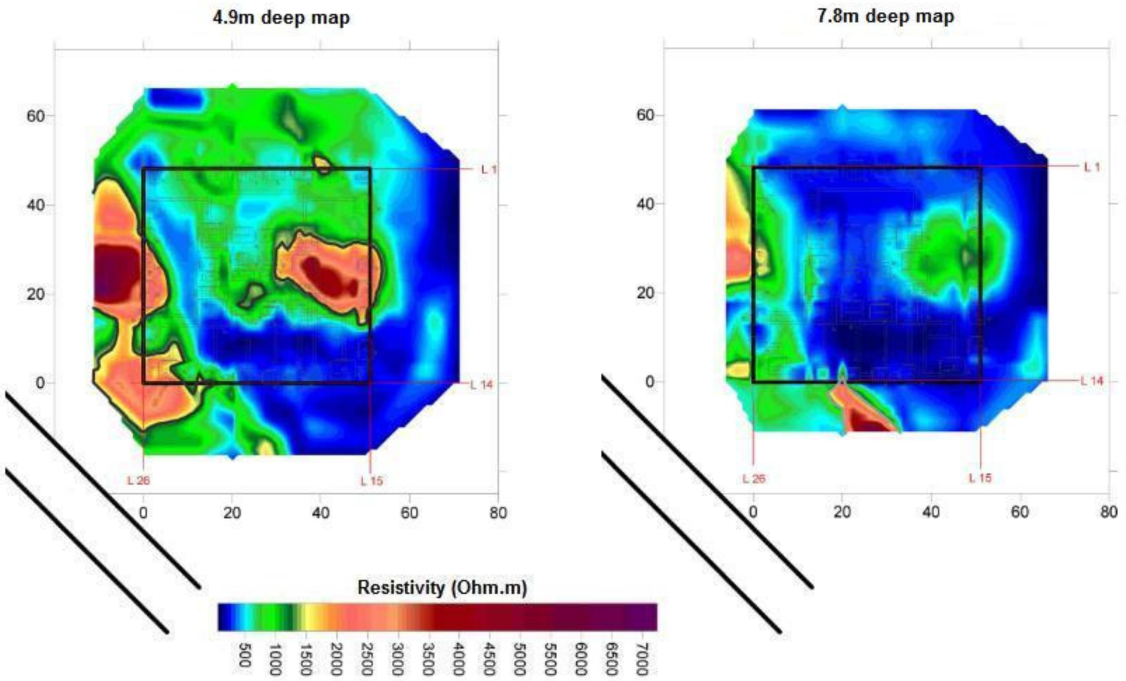

Figure 4 – Maps fort 4.9m and 7.8m bgl. It is possible to observe the position and size of the high resistivity anomalies.

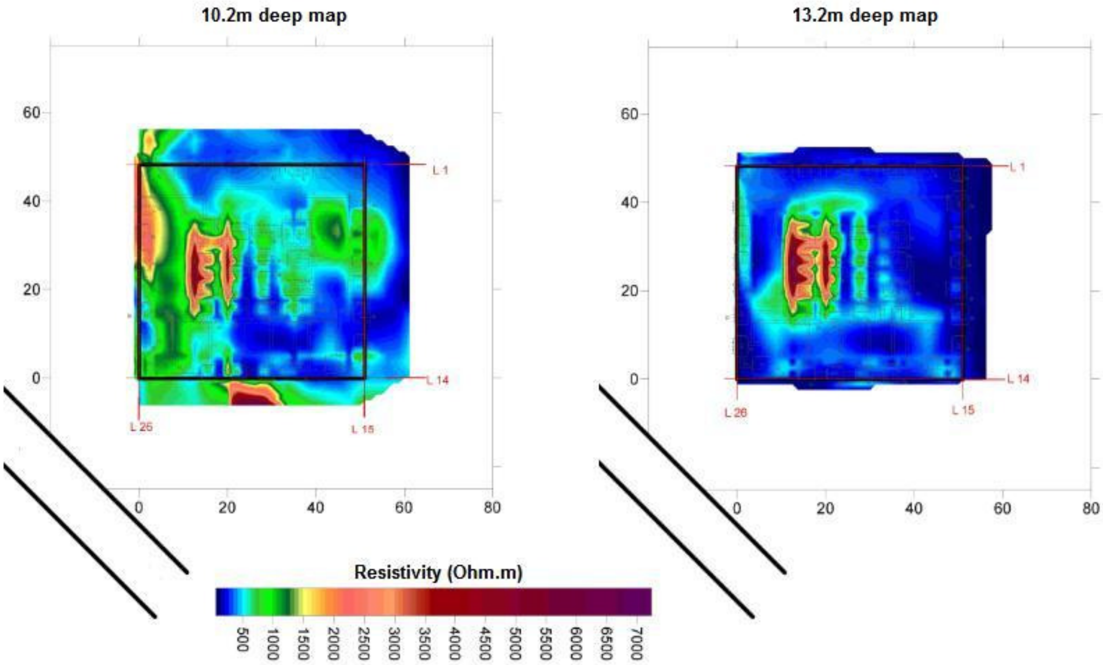

Figure 5 – Maps for 10.2m and 13.2m bgl. The high resistivity anomalies may be due to the basement..