GPR and electrical resistivity applied to detect small tunnels

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This paper was prepared for presentation at the 8th International Congress of The Brazilian Geophysical Society held in Rio de Janeiro, Brazil, 14-18 September 2003.

Abstract

Geophysical prospection using electrical resistivity and GPR methods were accomplished on an area above three tunnels (40 cm depth; 10 cm diameter and 2m long) dug in a terrain constituted by soils associated with tertiary sediments (red sandy clay). The main target was to study the possibilities of geophysical methods for detecting small tunnels in urban environment.

As practical application took place a study with those two integrated geophysical methods (GPR and electrical resistivity) in one of the patios of the House of Detention (Carandirú) in São Paulo being possible to identify a tunnel that was used in the past as prisoners' escape, showing that the method is effective and feasible of being used.

Introduction

The purpose of this work was to verify the viability of the use of geophysical methods (ground penetrating radar - GPR and electrical resistivity) for identification of small tunnels with diameters larger than 0.5 m and located to depths up to 5 m.

In a previous work three tunnels were dug (2 m long, 10 cm diameter at 40cm depth), located in the campus of Institute of Technological Research, São Paulo, where the massive land is constituted by soils associated to tertiary sediments (sandy clay of red pain).

In this site with controlled tunnels, GPR measurements were made using a 1 GHz antennae with a transmitter-receiver separation of 11 cm. GPR data was collected at 2 cm intervals.

The electrical resistivity method used was the pole-pole profiling. Three pole-pole profiles were collected using an AM spacing of 20 cm. Inversion of this data using RES2DINV produced the inverted resistivity section shown below.

Results

The FIGURES 1 and 2 show the sections of GPR and electrical resistivity on two of the three tunnels. As it can be seen, only one of the tunnels could be detected by GPR.

Using the software GPRMAX2D, a theoretical section of GPR was generated (FIGURE 3) simulating two tunnels placed in soils with different electrical conductivity and permittivity.

In FIGURE 3a, where the medium has high electrical resistivity and low permittivity, the anomaly produced by the tunnel can be seen while in the FIGURE 3b where the tunnel is, the medium has low electrical resistivity and high permittivity and no anomaly produced by the tunnel can be observed.

The changes in the values of the electrical resistivity and permittivity of the medium in that the tunnels were situated can be the reason that just one of the tunnels have been detected by GPR.

In the electrical resistivity sections an anomaly could be observed in each of the tunnels.

Practical application

A practical study with the purpose to detect tunnels using those two methods (GPR and electrical rsistivity) was accomplished at the House of Detention (Prison of Carandiru) located in São Paulo city once many tunnels used by prisoners to escape, were discovered in the past.

In a patio of one of the pavilions where the soil is constituted by loamy embankment, deposited over sediments alluvium, 3 geophysical profiles were accomplishment: GPR measurements were made using a 100 MHz antennae and data was collected at 10 cm intervals; three pole-pole profiles were collected using an AM spacing of 1 m.

The FIGURES 4 and 5 illustrate the results.

GPR sections (FIGURE 4) and electrical resistivity profiles (FIGURE 5), show anomalous features that can be directtly correlated to tunnels dug by prisoners in the past but nowadays, filled .

Conclusions

The integration of those two geophysical methods, from one side, the GPR with it´s advantageous properties like high resolution and survey speed and its immediate results, even considering some limitations (electric characteristics of the soil or rock), and the electrical resistivity by its best resolution constitute a viable and feasible methodology of being used for detection of small tunnels in urban area.

References

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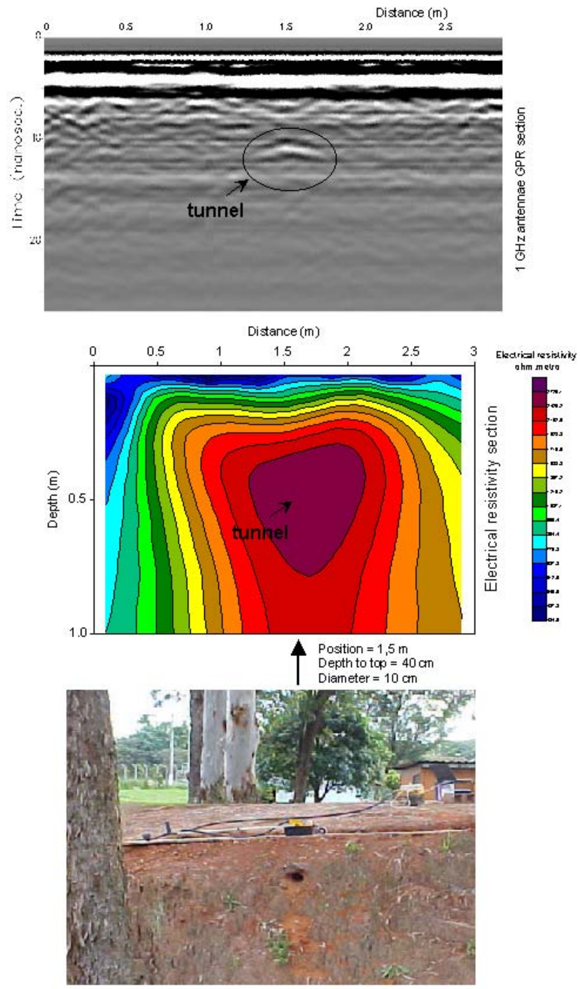

Figure 1 – The above figure is one of the tunnels dug in IPT. The GPR section shows a hiperbolic anomaly over the tunnel and the electrical resistivity profiling section shows a region of high resistivity coincidente with the tunnel.

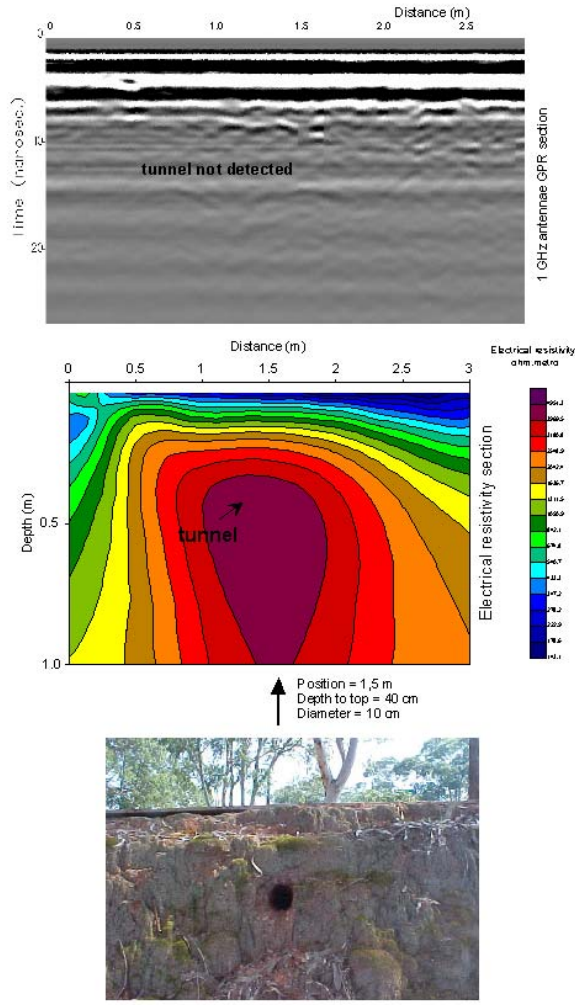

Figure 2 – Figure of another tunnel dug in IPT. No anomaly due to the tunnel is observed in the GPR survey line while the electrical resistivity profiling section shows a region of high resistivity coincidente with the tunnel.

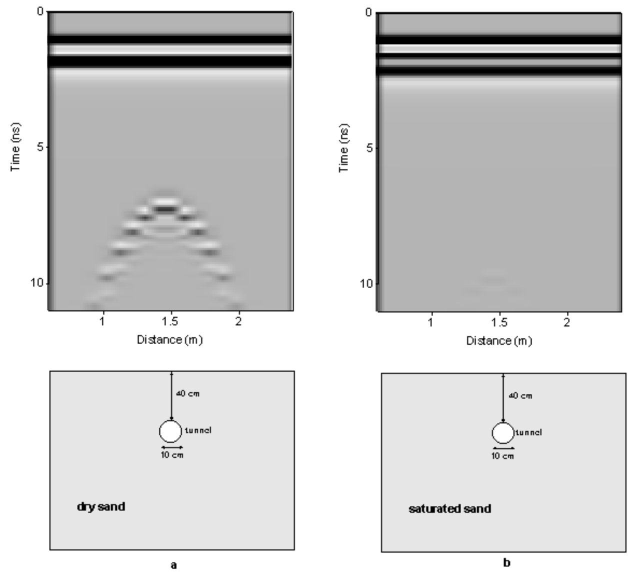

Figure 3 – Simulated GPR scan and representation of the geometry of the model a) dry sand and b) saturated sand. Note that no anomaly is produced by the tunnel when the medium has high conductivity like saturated sand.

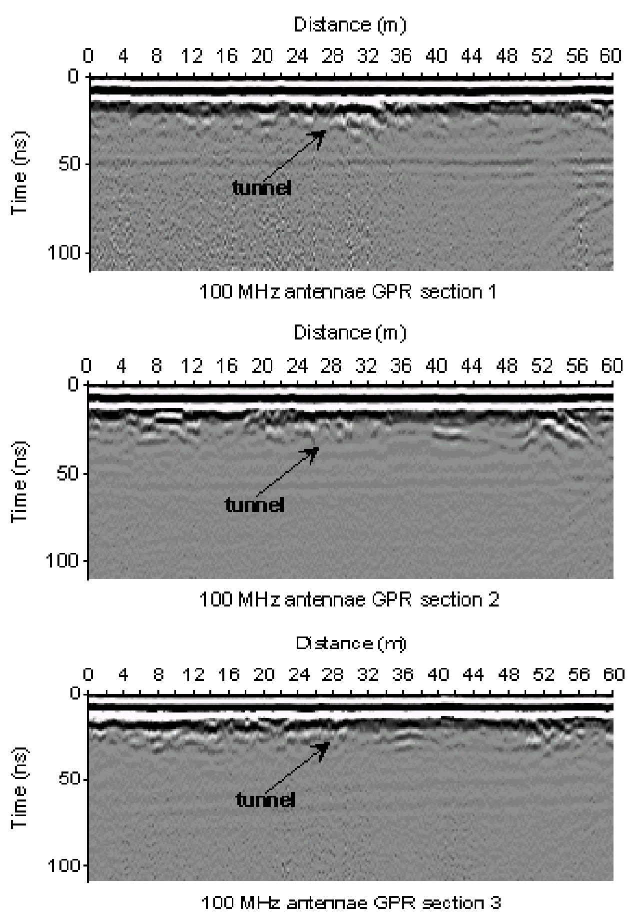

Figure 4 – Three GPR survey lines showing the position of the tunnel located in Prison of Carandiru.

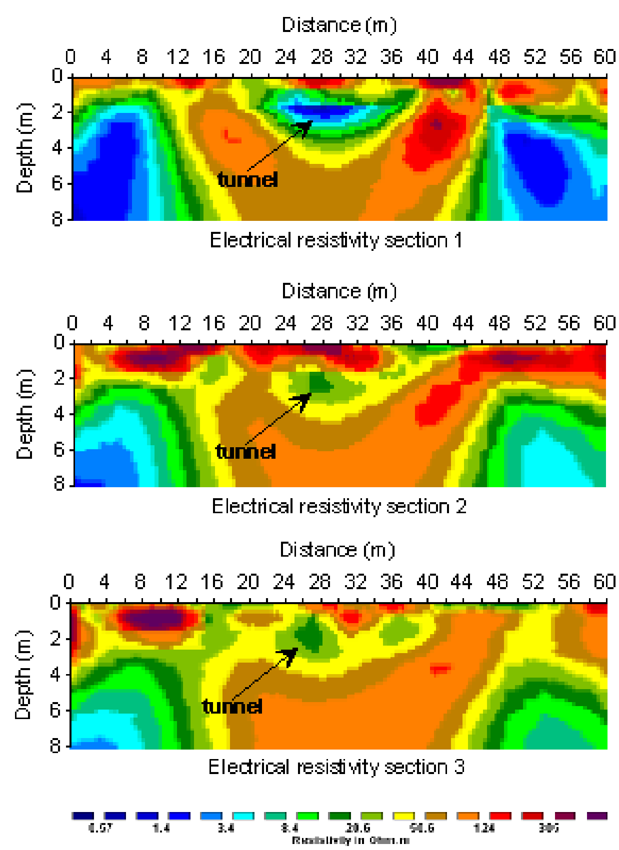

Figure 5 – The inverted model of the field data of pole pole profiling in Prison of Carandiru showing the position of the tunnel.