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Geophysical Survey of the Grand Place in Brussels - An Example of Prospection in an Urban Context

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Summary

In urban contexts geophysical prospection faces specific difficulties resulting from the limited size of the available areas, the presence of numerous sources of both geophysical and electromagnetic noises, the soil surface material and eventually crowd. At the Grand Place in Brussels GPR and electrostatic (capacitively coupled resistivity) surveys were associated. The low resistivity of the clayed substratum limits GPR to very shallow depths, which is compensated by the use of three different offsets for the electrostatic arrays corresponding to 1, 1.5 and 2 m depth of investigation. The underneath features anterior to the end of the XVII century can thus be evidenced.
Introduction

Within the framework of the programme “Voir sous les pavés” (Seeing under cobblestones) directed by François Blary (ULB) and Michel Dabas (CNRS-ENS), a survey has been achieved to detect and map archaeological features in Brussels. The survey was carried out at the ‘Grand Place’ and neighbouring streets including the courtyard of the City Hall. The central square was rebuilt after the 1695 bombardment (by Louis XIV’s army). Texts exist about the previous plans of the city but their indications are not sufficiently precise to locate buildings and delineate their general pattern.

In urban context, geophysical surveys face specific difficulties: (1) physical and regulation constraints limiting the size and accessibility of the study areas, (2) the surface material which should remain undamaged, (3) the presence of numerous and potentially strong sources of electromagnetic or mechanical noises, (4) the geophysical noise corresponding to the presence of objects or features at the surface or just beneath it disturbing measurements and, in the Grand Place case, (5) the presence of tourist crowd that complicates the social acceptance. In such conditions, it is mandatory to be able to distinguish between archaeological features and contemporary disturbing targets, by comparing results of different methods based on different physical phenomena and having different volumes of investigation.

Methods and instruments

Two complementary geophysical methods were applied: Ground Penetrating Radar (GPR) and the electrostatic method (also called capacitively coupled resistivity, CCR) (Flageul et al. 2013). The first aims at a precise location of all transition in electromagnetic properties and necessitates a fine measurement mesh. The second aims at 3D imaging the electrical resistivity variations with a mesh in relation to the size(s) of the array. The combination of these two methods is known to be relevant; it has already been applied with full success in urban contexts (Dabas et al. 2000).

Two commercial advanced multi-antennas GPR have been used: the ‘Stream-X’ working at 200 MHz central frequency and the ‘Stream-C’ working at 600 MHz (both instruments from IDS GeoRadar). They are both presented in action in Figure 1.

Figure 1 Multi-channel GPR units used to scan the Grand Place: (left) IDS Stream-X 16 channels, (right) IDS Stream-C 33 channels.

The used electrostatic multi-pole is a new prototype, called MP3, which has one injection dipole (AB) and three measuring dipoles (M1N1, M2N2, and M3N3) set up as illustrated in Figure 2. The three channels allow investigating over three increasing thicknesses of terrain, around 1, 1.5 and 2 m. The poles are made of copper wire gauze inserted in the two parallel PVC bands pulled together by the operators.
For all the instruments, measurement positions were followed and recorded using a robotic total station (Leica TS16) that continuously delivers a position at 1 Hz rate. Stream-X (VV dipole polarization) collects 15 radar profiles with mutual spacing of 12 cm within 1.68 m wide swaths. The total shift between adjacent swaths is 1.8 m. Stream-C (VV+HH dipole polarization) technical features translate in a 4.35 cm minimal spacing between radar profiles, and swaths shift around 1 m. This GPR unit integrates 23 dipoles oriented along the in-line direction, and 9 dipoles oriented along the cross-line direction (i.e. both vertical and horizontal polarization). In the MP3 the three channels data are registered at 0.0488 m sampling step and the separation between adjacent profiles is around 1 m.

Results

Figure 3 Apparent resistivity maps at Grand Place (Local coordinate system in meter).
Resistivity measurements showed the existence of a highly conductive layer clayed (12 Ωm) at a relatively shallow depth (< 2 m). This has been verified by an electrical sounding achieved by inserting nails between the cobbles of the courtyard. Consequently the thickness of the layer(s) between this substratum and the contemporary surface layer looks rather limited which is quite surprising at the centre of a long time inhabited town. Figure 3 shows the three apparent resistivity maps of the Grand Place; an important decrease from channel 1 to channel 3 values can be observed but also significant lateral variations which show the layout of ancient remains.

**Figure 4** Stream-C 600 MHz wave amplitude distribution at -25 cm b.g.l

**Figure 5** Stream-C 600 MHz wave amplitude distribution at -50 cm b.g.l.
As a consequence of the low resistivity, the depth explored by GPR is limited to around 1 m. This difficulty adds with the high density of contemporary targets in this part of the city, as it can be observed in Figures 4 and 5. They exhibit underground utility networks more complex than expected and previously documented both in terms of quantity and location of underground ducts.

Conclusion

Having collected geophysical data and performed relevant processes for the very complex GPR data, a phase of modelling and inversion has to be conducted to better constrain the physical characteristics of the present features and to identify the archaeological ones. This step will be associated to a detailed confrontation both with the documentary information and with all the observations that might have been made during former engineering works at this place.

As an assessment of our first interpretation of the results, one must underline that (1) despite the lack of spatial resolution, resistivity data were able to map quickly the main structures but also to identify the presence everywhere in the surveyed area of a very clay rich conductive level, possible witnesses of the swamp that extended there; (2) GPR data proves to be the best for small dimensions structures and for utilities.

We believe that the good achievement of this project is due to the integration of the archaeologists at every stage of the process. Thanks to cross-analysis with historical documents, an important contribution to the knowledge of the genesis of this historic center of the Capital of Europe was already attained and will be improved soon.

Acknowledgments

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References
