GPR on city roadways: two case studies with feedback from trial trenching

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Abstract
GPR surveys were performed in dense urban areas in France. Underground utilities and the narrow width of the streets can make GPR really challenging for archaeological features detection. The relevance of GPR compared to trial trenching is discussed.

Keywords
archaeological prospection; multi-channel GPR; urban areas; utilities

Introduction

Ground penetrating radar (GPR) has been widely used for decades for utilities detection (Gabryś et al. 2019) and is being increasingly used in urban areas to evaluate presence of archaeological remains, especially in a led-development archaeological context (Paez-Rezende and Hulin 2021). This non-destructive method - whose relevance is no longer to prove for the detection of buried remains (Goodman 2008) - seems appropriate in this context where trial trenching can be burdensome as it requires a stripping step of the asphalt and subsequently the modification of the road traffic. This is especially true with the new multi-antenna GPR devices that can be towed with no impact on the local road traffic. However, the urban context has some limitations that counterbalance these aspects (Trinks et al. 2009; Masini et al. 2020). Firstly, utilities can be extremely numerous (water, gas, electricity, optic fiber, some of which are unknown and/or disused). All of them could obviously be very inconvenient in detecting something else, not to mention that trenches installation may have partly destroyed the archeological remains. Moreover, roadway maintenance may also create heterogeneities of the upper layer of the road. Lastly, the narrowness of the streets is a drawback for identifying archaeological structures as we may only cross a small section of them. Here we present a collection of GPR data we obtained in two French cities and we discuss the pros and cons and when it is appropriate or not to implement GPR in urban areas, especially for surveying the roadway.

Materials and methods

For these studies an *Impulse Radar Raptor* multi-channel GPR with 450 MHz antennas spaced by 8 cm – either in its manual (8 channels) or towed system (18 channels, Fig. 1) was used. A GNSS Trimble R4S device has been associated, occasionally replaced by a Trimble S5 total station for crowded environments. We used the *Condor* Software to process the data and create the depth-slices and *GPRSlice* to visualize B-scans. We acquired the GPR datasets during the spring of 2022 in Limoges and Cherbourg. The geophysical survey was carried out prior to the trial trenching in Limoges; whereas in Cherbourg the trenching was already in progress during the GPR acquisition. We covered more than 6.5 km of streets in Limoges (the roadway, roundabouts and intersections) and about 1 km in Cherbourg (roadway, sidewalks and some lawns). In both cases, we did not stop the traffic during the acquisition.

Fig. 1: Towed 18-channels Raptor GPR with GNSS positioning in Cherbourg.

Results

Over the kilometer of road mapped in Cherbourg, three areas with potential archaeological anomalies are identified with high confidence level. On the most convincing, a medieval tower, its rampart and counterforts are clearly detected at a depth of 60 cm. Multiple reflections which could be linked to a cemetery are also seen 100 cm below the ground surface. A trial trench carried out a week after the GPR acquisition confirms the presence of the rampart and the cemetery (Fig. 2).

In Limoges, GPR results reveal a set of Gallo-roman remains in a street close to the city center (Fig. 3). Most of them appear deeper than a meter despite the presence of several pipes. Remains were expected in this area based on the results of an excavation performed in the 1970s. On the other 6 km, no archeological features can be clearly identified and no remains are known from previous excavation or ancient maps. Feedback from the on-going trial trenching will certainly be of great interest.

Discussion

The results presented here have to be balanced with the totality of the surveyed area. The utilities density increases considerably as one approaches the city center and consequently masks many of the archaeological anomalies. The archaeological remains observed below tens of pipes in a street of Limoges (Fig. 3) is an exception. In most of the cases, the density of utilities is such that it is not possible to state the presence of remains underneath. In Cherbourg, the three interesting areas from an archaeological point of view are all located on a road surrounding the city center and less affected by underground utilities. Moreover, some sections of walls observed in the trial trenches are not visible on the GPR dataset. At most, some areas can be flagged as potentially interesting areas populated with reflections of unknown origin.

Surveying a street is especially challenging as it is a convenient path for utilities and it offers a very narrow, incomplete view of the subsurface. The *a priori* information is also of prime importance. In both cities studied, most of the anomalies are found in areas already identified as high archaeological potential areas. Even a simple presumed indi-

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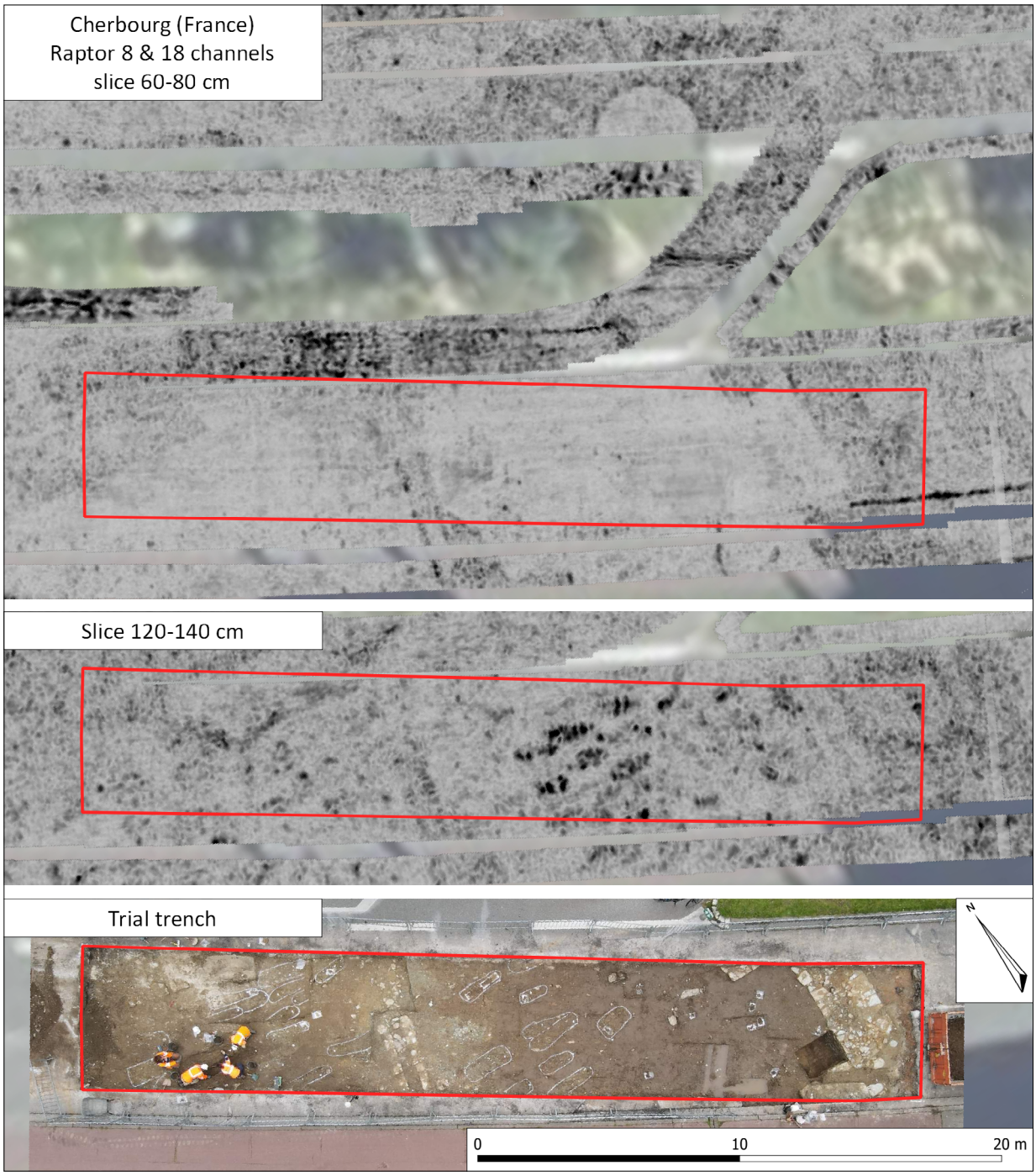

Fig. 2: Part of the results of the GPR survey in Cherbourg: depth-slice at about 60-80 cm, 120-140 cm, and the trial trench (drone photography, J.-L. Lamache). IGN orthophoto background.

cation of the remains can be of great importance to discriminate a wall from a pipe, especially considering the number of unknown and/or disused utilities. Given the frequently weak and noisy data under the numerous utilities network, the distinction may not be possible on the B-scan basis.

Conclusion

The multi-channel GPR has a strong potential for urban archaeology. It allows a fast acquisition of high definition images of the subsurface even on roadways. This approach

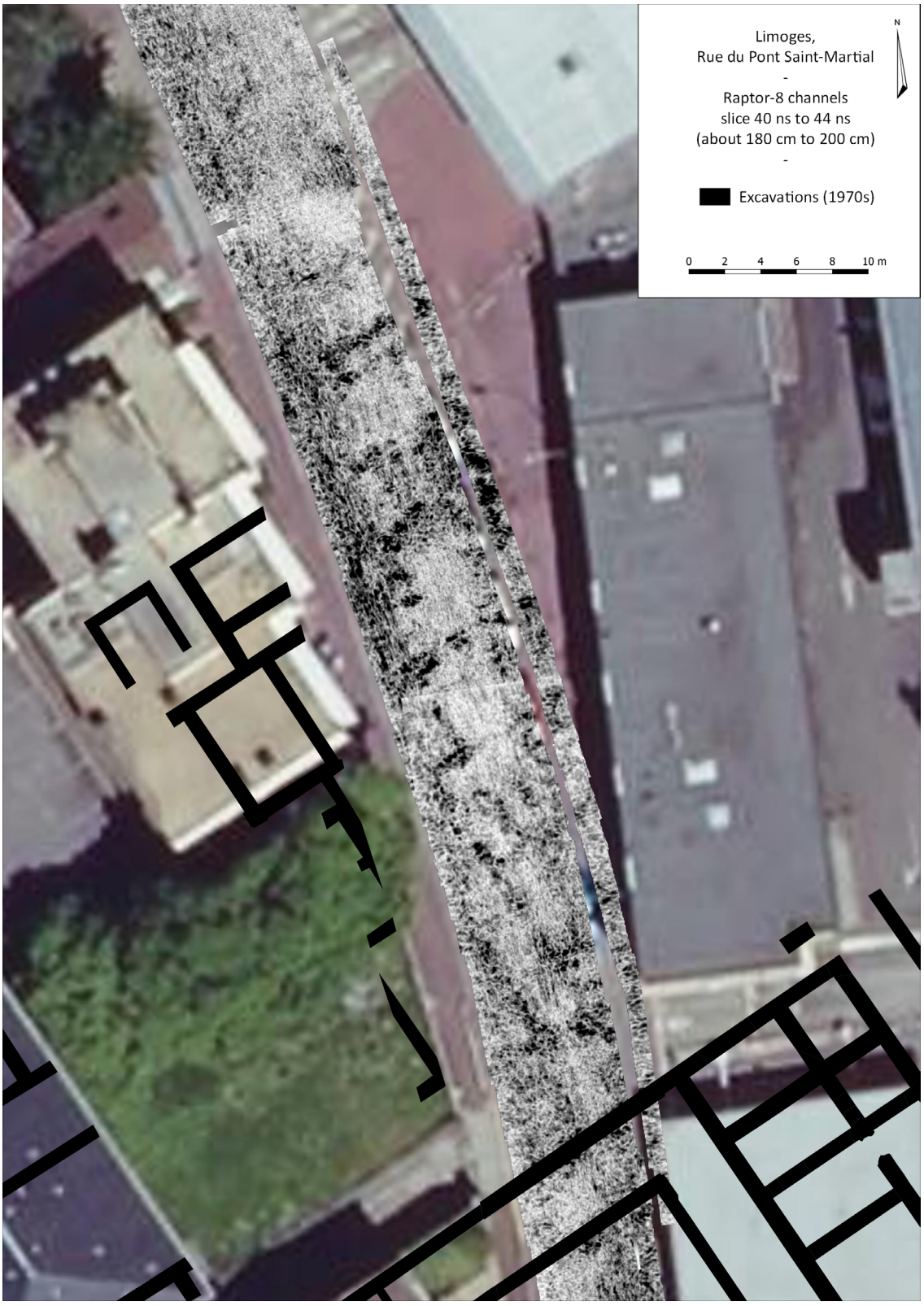

Fig. 3: Part of the results of the GPR survey in Limoges: slice from 180-200 cm overlapping the results of 1970's excavations. IGN orthophoto background.

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is particularly suitable for preventive/rescue archaeology. Surveying large urban areas, such as squares, may be often relevant. However, for road surveys, the use of GPR should be considered more carefully. It is likely to get only a map of the utility network, even if this knowledge remains of primary interest for choosing the location of the trenches in the case of preventive/rescue archaeology. GPR should be preferred on wide streets, where the number of known utilities is moderate. Reflections that are initially difficult to interpret based only on GPR data can be identified by the trial trenching and still provide useful information afterward to have an extended view of the features.

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