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Real 3D surveying of archaeological sites

Description of the problem

When mapping areas where targets are of unknown size, shape and orientation it's usually difficult to gather data dense enough to get a good picture of what's hidden underneath. Precise positioning is also a common problem.

This note shows an effective method for mapping larger areas, with line spacing small enough to prevent information loss and with a system that lend itself to precise positioning of each profile. This way of dense data collection combined with precise positioning is not available, practically, when standard, off-the-shelf equipment is used. In other words, this note describes a state of the art technology for detailed subsurface investigations such as archaeological mapping.

We make no conclusions about the archaeological artefacts found whatsoever; this is solely a description of an advanced technique for collecting and processing of GPR data.

Equipment used

The equipment consisted of a 400MHz, 16 channel antenna array, mounted on a John Deere tractor, a Malå array control unit, a total station, a prism for tracking the array position and a laptop for data collection, see Figure 1 below. Processing and interpretation were done with WTI software, a Matlab package especially developed for interpretation of real 3D data.

Figure 1. Equipment used: radar array (mounted on a John Deere tractor) and a total station.

The Site

This study were performed at a site called Kungsgården quite central in the city of Skellefteå (close to the Gulf of Bothnia, in the north of Sweden) and is believed to be a former harbour from the 14th century on the shore of the Skellefteå River. Today the site is approximately 3m above the river surface. Minor excavations have been carried out earlier, but we did not know the findings prior to the radar mapping.

In Figure 2 the site conditions are shown. The lawn was reasonable flat with a maximum height difference of about 6m within the area scanned with the array. The site was partly soaked with water and had some linear features on the surface, which also shows up in the radar images. Due to the convenient conditions it was possible to collect the whole dataset with the total station in one single position.

Investigation method

With a single antenna it's often not possible to position survey lines with sufficient precision to allow for 3D processing. 3D processing requires the line spacing to be no larger than ¼ of the centre wavelength, measured in the soil. With this requirement fulfilled no information will be lost due to spatial aliasing. On the contrary, when using a single antenna, spatial aliasing between the different lines is usually the rule, making any attempt of 3D processing impossible. The array used had a channel separation of 8 cm and the data was binned to 10cm cubes. The array unit has paint bottles placed in one of the corners in order for the driver to mark the actual path and thus ease full coverage of the area.

Figure 2. During the survey the total station tracks the prism located on the antenna array.

Critical elements

Since the site was somewhat "bumpy" with small ditches, the prism was placed in a low position to minimize the positioning error due to the fact that the array did not follow the ground perfectly. Also the driver of the cart needs to take great care of overlapping the swats of the array. Holes in the coverage will result in artefacts in the processed data.

The total station should be positioned with care so that line of sight can be established safely during the whole survey. When selecting the position one should not only think about the survey, but also on what traffic in terms of pedestrians and vehicles to be expected during the survey. It's important to mark the fix points used for the total station set up, in order to be able to continue the survey if the total station is being moved by accident during the survey.

With the total station set up, one should locate landmarks, which can help later positioning of interpreted features. In this case we mapped the road as well as fix points for the local city co-ordinate system.

Results

In Figure 3 a top view, at 15cm depth, is shown. The two green rectangles denoted A and B are presented in more detail below. Already from a first glance at one depth, it's obvious that there are many linear, man-made structures on the site.

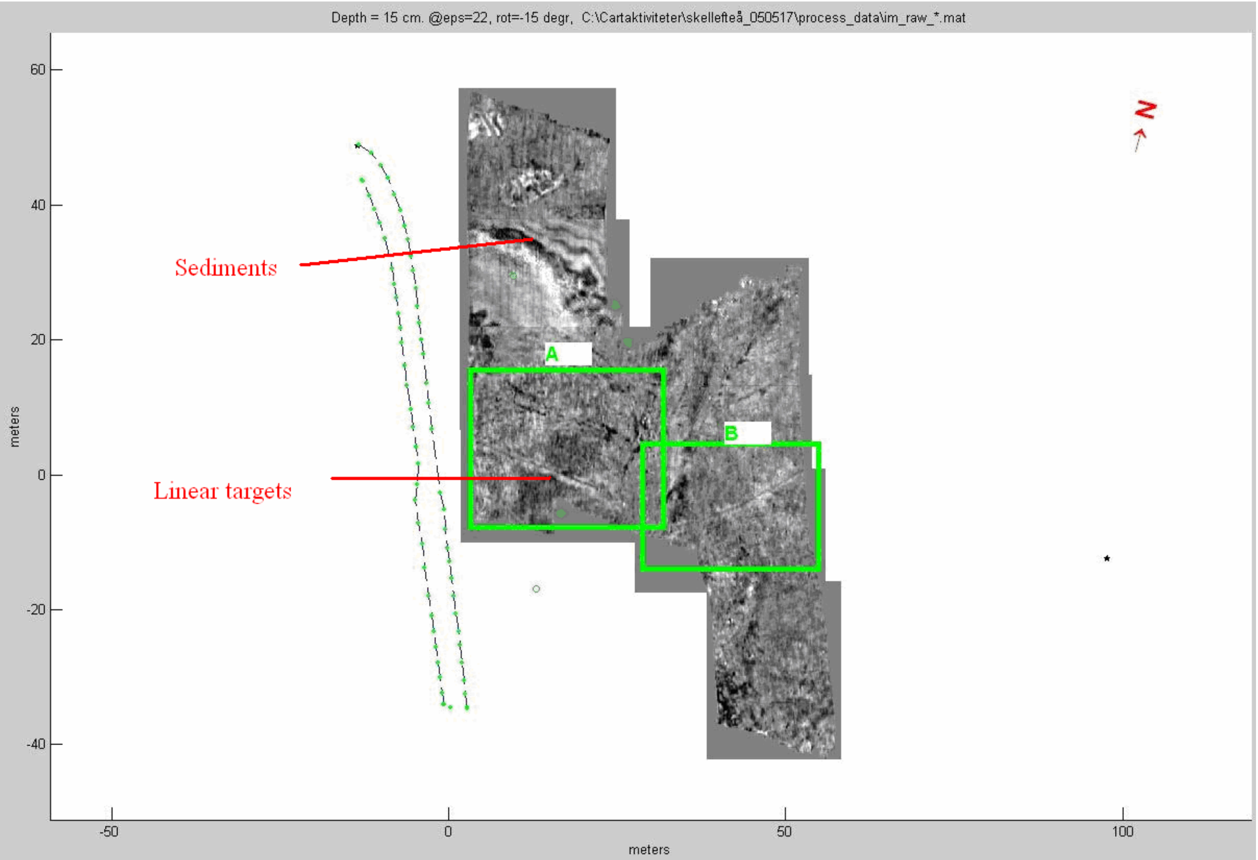

Figure 3. Top view at 15 cm depth. Linear structures as well as areas of backfill or sediments are easily identified.

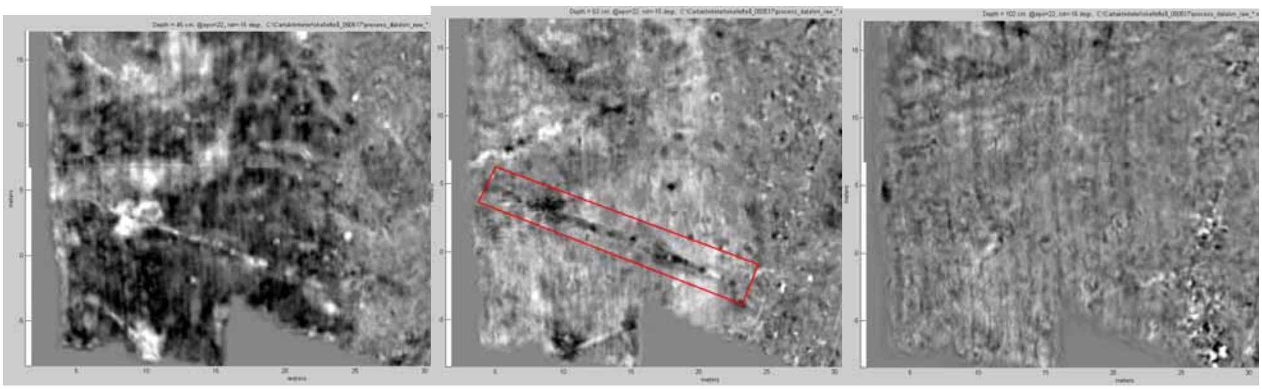

Figure 4. Slices of area A at depth 45, 63 and 102 cm. Note the linear structures at the first two depths

From Figure 4 it's clear that most of the man made structures are located within the first meter of soil at this location. There is an interesting feature to be seen in figure 4; a linear structure in the centre (marked) seems to follow a line of point reflectors. It is unlikely that this is a structure from recent times, since, to our knowledge, no modern infrastructure is designed in this way.

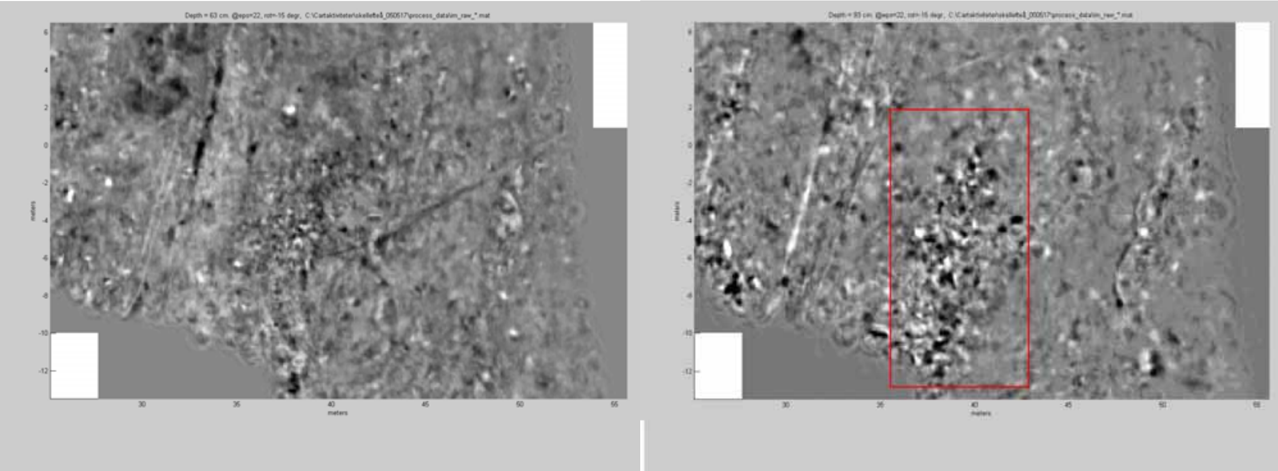

Figure 5. Slices of area B at depth 63 and 93 cm, note the cluster of point reflectors in the centre of the deeper slice.

Discussion

The survey covered 2500 m^2 and took effectively 6 hours, including mobilisation and transportation, with two operators. The post processing took about 3 hours.

Obviously the array approach is more expensive, due to the equipment cost, than a traditional, single antenna, approach. But this is somewhat imaginary since a survey with a single antenna with the same data density would be practically impossible, and if carried out, actually more expensive.

Given the details and reliability in the final interpretations/data, it should be clear that array surveys have the potential of being an efficient and fast method for this kind of investigations where the demand for detailied results are high. In fact the interpretation process becomes much easier since the data gives an overview during the whole interpretation process. For example the cluster of point targets in figure 5 would be difficult to distinguish from line targets if the line spacing were large; there would be no way of identifying the area as filled with point reflectors. On the other hand, the sediments in the top section of figure 3 would be easily distinguished with a single antenna approach.

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