

Radar and resistivity surveying in Saschiz

Report for Atelier Undaverde srl.

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Tartalóm

Introduction.....	3
Geophysical surveying.....	3
Description of the methods.....	3
GPR survey.....	3
Resistivity measurement	4
Data processing	4
Results	5
Main square.....	5
Parking area.....	5
Summary	6
Main square – eastern part	6
Main square – western part	6
Parking area.....	6
Supplements.....	12

Introduction

In the first half of March we carried out geophysical surveying in the center of Saschiz in order to map the subsurface conditions. Our contractor, the Atelier Undaverde srl. is responsible for the new design of the village center, and they want to know about archaeological objects in the subsurface in order to take them into account during the design.

Geophysical surveying

We made measurements in two areas in Saschiz: 1) in the main square of the village and 2) in an empty land beside the school along the road No.13 (Fig. 1). The second area from now will be called „Parking area”. In both areas we applied two methods: 1) Ground Penetrating Radar (GPR) and 2) Resistivity measurements. We made the GPR survey using instrument Mala Ground Explorer with 160 MHz shielded antennas, and we made the resistivity measurements with instrument ARES. We made the surveying in local coordinate system, which was transformed into Stereo70 coordinate system by measuring the Stereo70 coordinates of a few fitting points using RTK GPS. We made the GPR survey along lines in two perpendicular directions. In the main square in WNW-ESE direction the spacing between the survey lines was 0.5 m, and in NNE-SSW direction the spacing was 1 m (Fig. 1). In the Parking area in NNE-SSW direction the spacing between the survey lines was 0.5 m and in the perpendicular direction it was 1 m. The resistivity measurements were also made along lines. We measured only a few lines in order to check the results of the GPR survey, and especially to obtain information from below the penetration depth of the radar waves.

Description of the methods

GPR survey

The transmitter antenna of the GPR transmits radar waves into the ground. If the velocity of the waves in the subsurface changes, the waves are reflected back to the surface. The receiver antenna detects the reflected waves. We move the instrument on the surface along a line and the instrument record the arrival times of the reflected waves at every 10 cms horizontal distance, and finally we obtain a „time structure” of the subsurface. The velocity of the waves is calculated from so called diffraction hyperboles and the time section is converted back to depth section using the velocity. The survey is made along parallel lines and the depth sections obtained along the lines are put beside each other, and thus we can map the subsurface structure in 3D. The results are presented in depth horizons. In these horizons the amplitude of the reflected waves is shown.

The radar waves attenuate in the subsurface. The penetration depth of the waves depends on the electric resistivity of the subsurface material and the frequency of the antennas. In case of low resistivity the waves attenuate quickly, that is the penetration depth is very shallow. Before GPR surveying we made a resistivity measurement, which showed that in the upper 1 m the resistivity was 40-80 ohmm and below was 10-20 ohmm. We expected 1 m penetration depth.

The half-wavelength of the waves of the 160 MHz antenna emitted by the transmitter is 30 cm. It means that we can resolve objects, which are larger (thicker) than 30 cm.



Figure 1. Location of the survey areas in Saschiz.
Red line: main square, yellow line: "Parking area"

Resistivity measurement

The electric resistivity is also measured along lines. We push steel electrodes into ground. We inject electric current into the ground through two electrodes, and we measure the voltage between two other electrodes. From the measured voltage and current we can calculate the resistivity of the subsurface. If we increase the distance between the current electrodes the current goes deeper and we obtain the resistivity of the material located deeper. Making the measurement using many electrodes we can determine the resistivity distribution of the subsurface. Based on the resistivity distribution we can guess the type of the subsurface material. E.g. rocks and building materials have high resistivity, soil and clay have low resistivity. In the present survey the electrode separation along the lines was 1 m.

Data processing

Radar data were processed with software ReflexW 3D and 3D Vision. Data were t_0 corrected, amplitude corrected, background noise was removed, bandpass filtered, hilbert transformed, migrated and depth converted.

Measured resistivities were inverted into model resistivities using RES2DINV.

Results

The radar images in different depths in the main square and in the Parking area are presented in Supplement 1 and Supplement 2, respectively. We did not interpret every depth slice, because they can be classified into three groups (depth: 0 – 0.4 m, depth: 0.4 – 0.8 m, depth below 1 m). We interpreted these groups, which are presented in the following.

Main square

In shallow depths, in the uppermost 0.4-0.5 m, the radar images are influenced by the surface objects (Fig. 2). We can identify the present day walking pathways as dark stripes (see also Supplement 1, 0.1-0.3 m slice). Those flower beds, which we were able to survey, also appear as dark patches. We were not able to survey in the rose beds and in the area of the fountain. These areas are blank. The western part of the main square is darker than the eastern part. It is darker due to higher reflectivity, which is probably due to stones located near to the surface.

In 0.4-0.8 m depth different structures are present (Fig. 3). These structures do not have a sign in the surface. They represent the former structure of the main square. In the eastern part of the square, below the park, dark stripes are visible, which are connected to two circular objects. The southern circle is a former well (well 1 in Fig. 3). The other circular object is not a closed circle, because it is partly covered by the present day fountain. This might have been a second well (well 2? in Fig. 3). There is a wide dark grey stripe east to the tower's wall and the present day road. We interpret this stripe as the former road, which was probably paved. In the western part of the main square, except the canals and a dirt road going to the gate of a house, no structures are visible.

In larger depth (deeper than 1 m), except the former road in the eastern part of the square and the canals in the western part, no structures are visible (Fig. 4 and Supplement 1). The eastern part of the square becomes light grey, which means that there are no reflections. According to the resistivity sections the resistivity is medium (40 – 50 ohmm) and high (100 ohmm) in the upper 1 m (Fig. 5). Those areas where the resistivity is high correspond to reflections in the radar images. Below 1 m the resistivity reduces to less than 20 ohmm. It is too low and the radar waves are attenuated in this depth. No structures are visible in the low resistivity part of the sections. In the western part of the square there are reflections even from 1.5 m depth (see Supplement 1, 1.3-1.5 m slice). However, these reflections do not form structures. These reflections are probably caused by stones and rocks transported here by the nearby creek.

Parking area

The Parking area is functioned as a depo of demolished material as shown by the concrete blocks and bricks on the surface. The radar images do not reveal structures, therefore we did not interpret them (Supplement 2). There is a white patch in the middle in the northern part of the area. This is a reflection free area, which appears from 0.2 m depth downwards. There the resistivity is low resulting in very shallow penetration depth of the radar waves (Fig. 6). Probably this is the original surface in the area, located here in shallower depth. This surface is about 1 m depth in other places, because the reflections disappear below this depth. The black dots are caused by metal objects, which are strongly reflective. They also derive from the rubbish.

Summary

We carried out GPR survey in the main square and in the Parking area. The radar surveys were accompanied with resistivity measurements along lines. The results of the different methods are in agreement with each other. Materials characterized by relatively high resistivity also generate reflections in the radar images.

Main square – eastern part

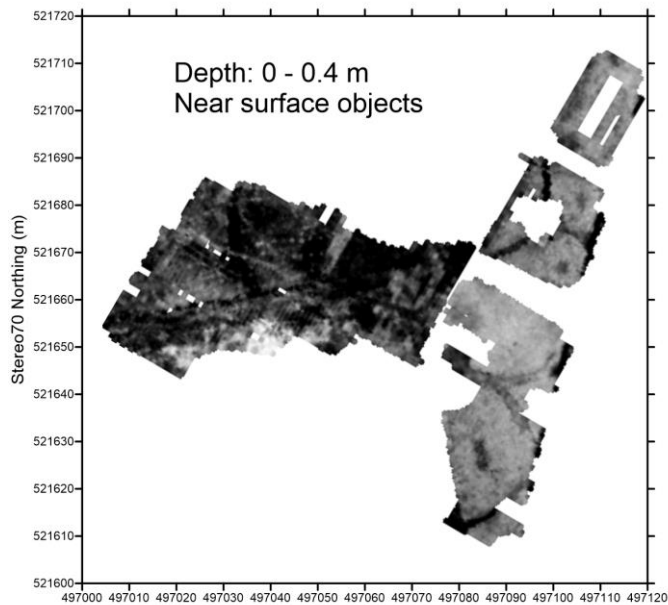
Radar waves were able to image, in general, the upper 0.8 – 1 m of the subsurface. The main square can be divided into an eastern part, where a park is located now, and a western part, which is an empty place covered by grass. The structure of the uppermost 0.4 m below the park agrees with the surface structure of the park. The structure in the depth range of 0.4 – 0.8 m is completely different from upper 0.4 m. In the 0.4 – 0.8 m depth range we were able to detect former walking paths, a well and probably a second well. The second well is partly located under the fountain in the park. The former road crossing the main square probably run further to the east relative to the present day road, which is running just beside the fortified wall. Below 0.8 – 1 m depth the radar is not able to image any structure. Resistivity sections show that below this depth the structure is natural.

Main square – western part

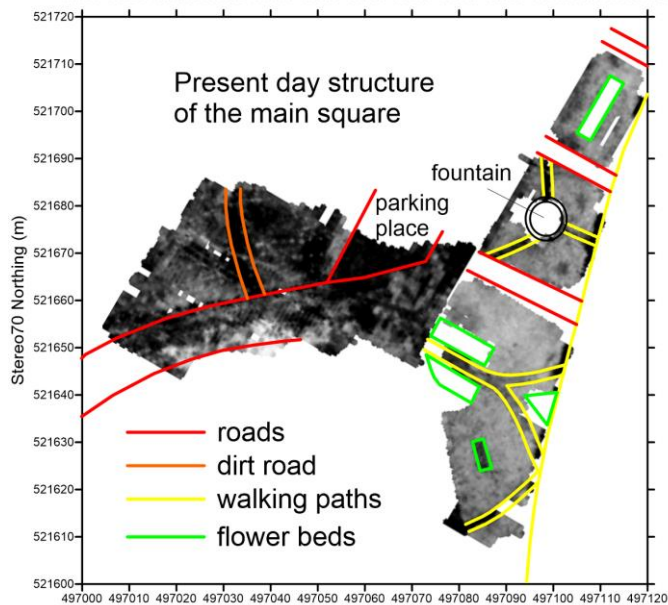
In the western part we were not able to detect regular structures, except canals. In this part the penetration of the radar waves is higher, because the resistivity is higher. We interpret the irregular reflections and high resistivity as the manifestations of hard rocks deposited by the nearby creek.

Parking area

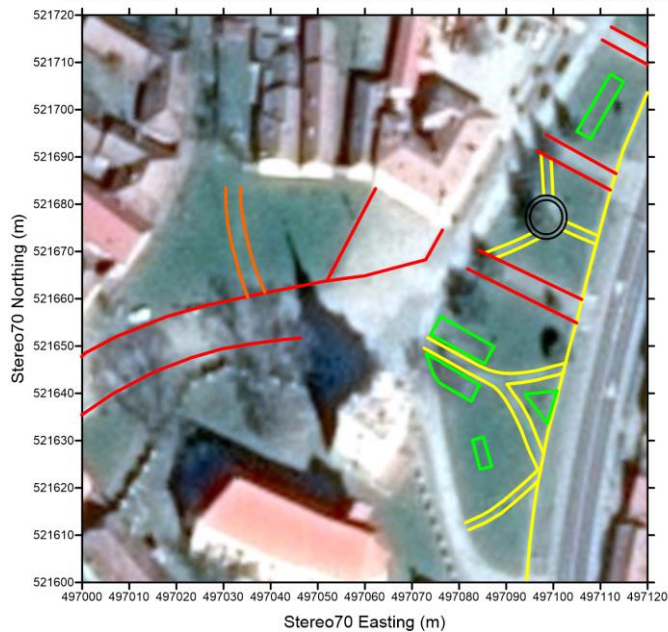
In the Parking area the upper 1 m consist of waste material as concrete, brick, metals, etc. It does not have an internal structure. The radar is not able to image any structure below it, because the underlying material has a low resistivity and the waves attenuate in it. Resistivity sections do not show structures in the low resistivity part of the sections until 3 m depth.



Radar image

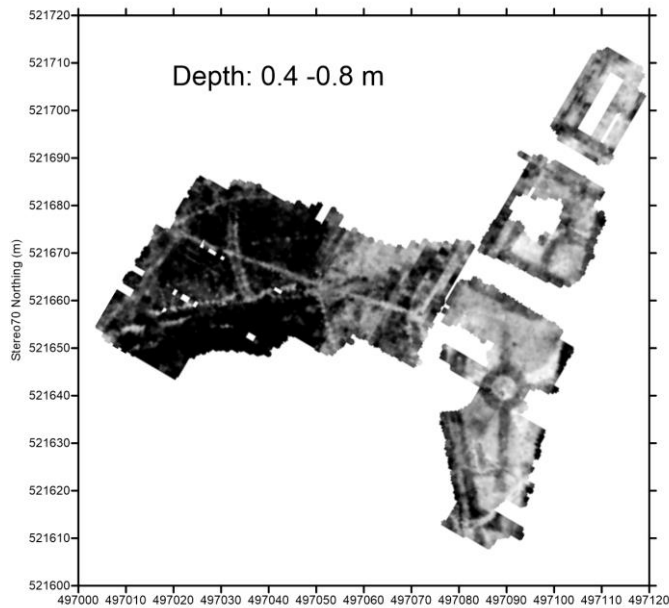


Interpretation of the radar image

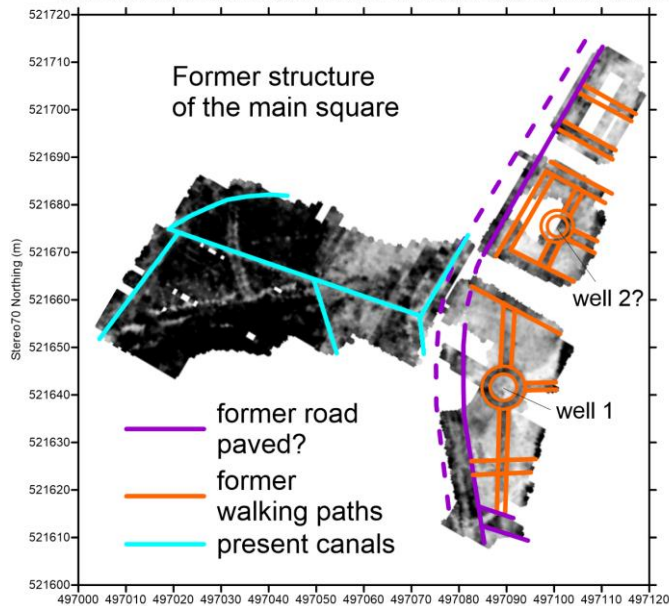


Interpretation of the radar image overlaid on Google aerial photo

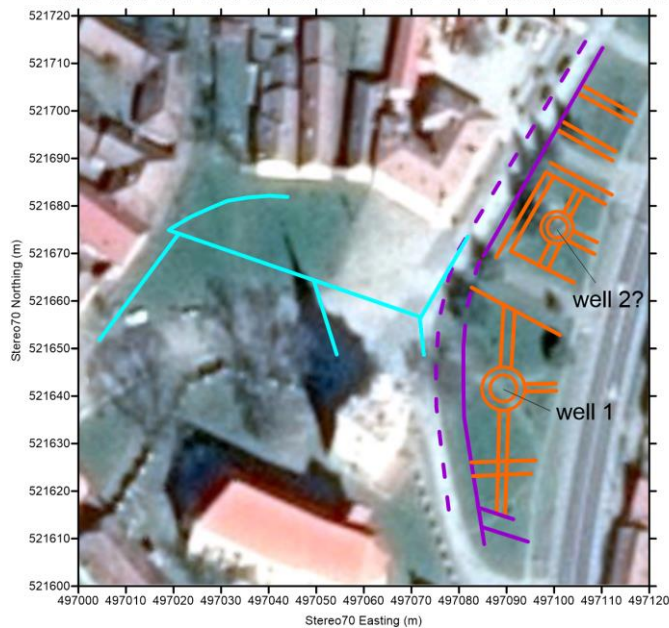
Figure 2.
Radar image at depth 0.1 – 0.3 m
representing the uppermost 0 – 0.4 m
depth interval, and its interpretation



Radar image

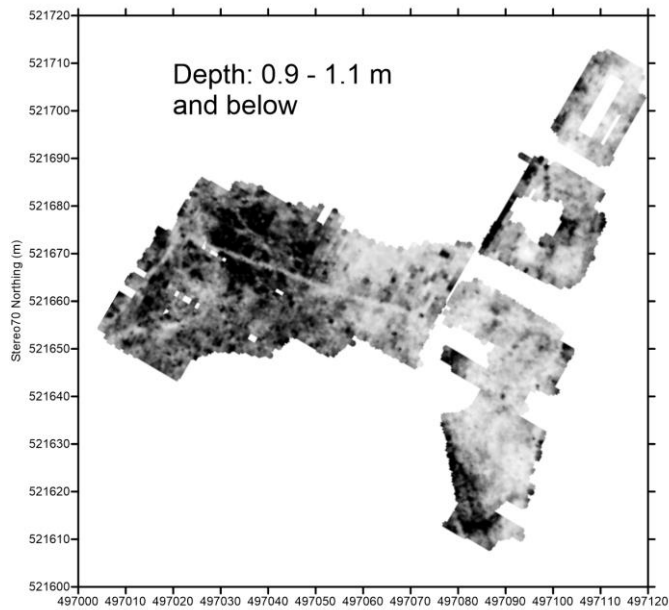


Interpretation of the radar image

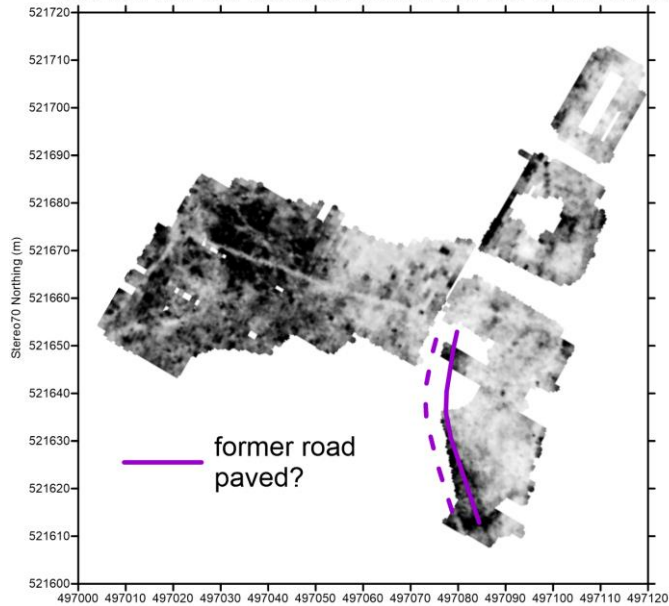


Interpretation of the radar image overlayed on Google aerial photo

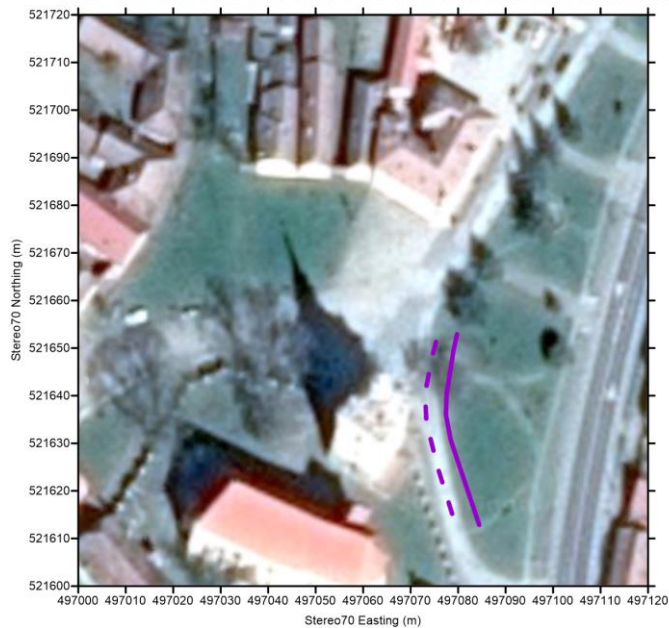
Figure 3.
Radar image at depth 0.4 – 0.6 m representing the 0.4 – 0.8 m depth interval, and its interpretation



Radar image



Interpretation of the
radar image



Interpretation of the
radar image overlayed
on Google aerial photo

Figure 4.
Radar image at depth 0.9 – 1.1 m
representing the depth range below 1 m,
and its interpretation

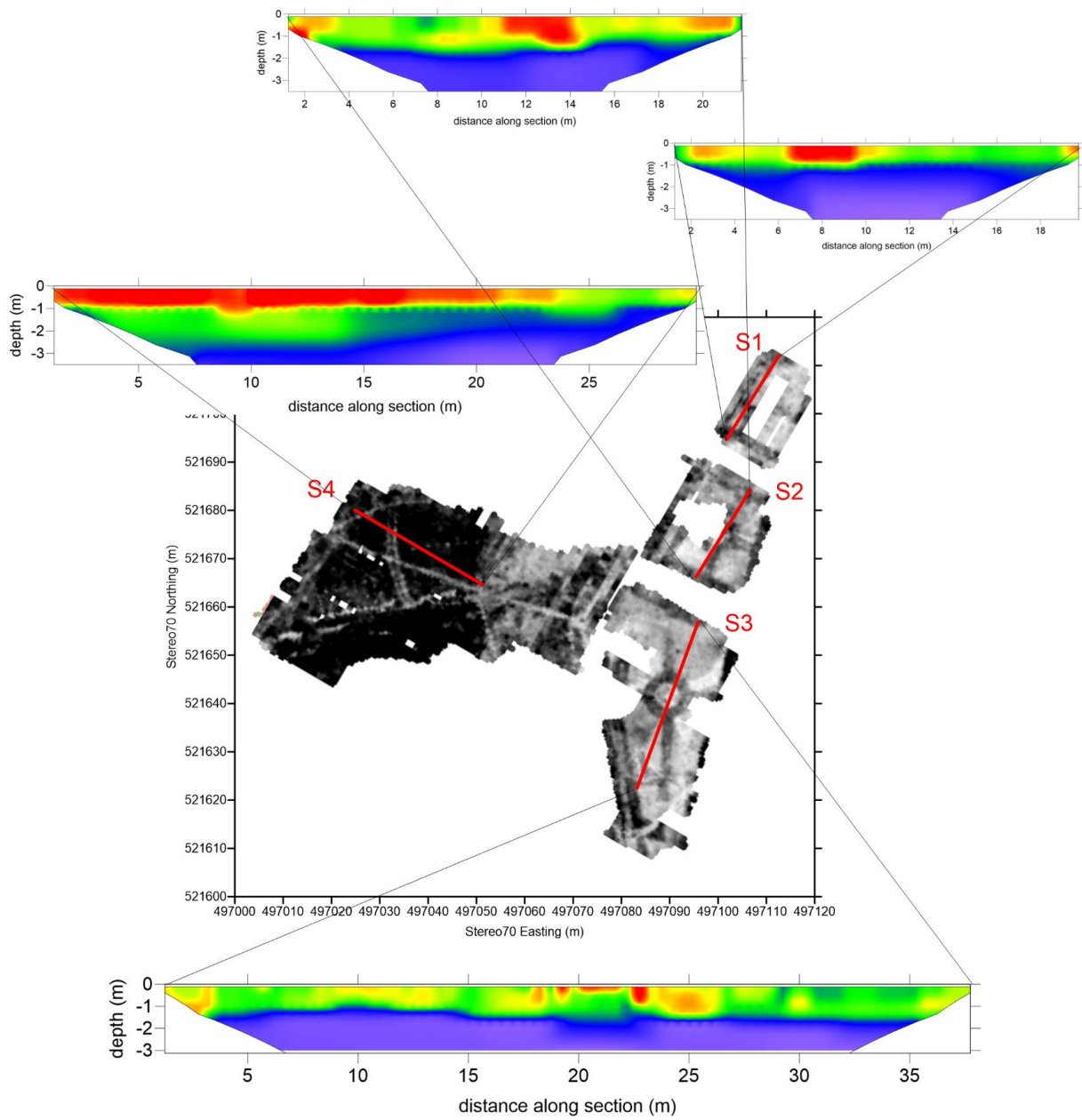


Figure 5. Resistivity along depth sections in the main square.

Red: resistivity higher than 100 ohmm

Green: resistivity 40 – 50 ohmm

Blue: resistivity: 10 – 20 ohmm

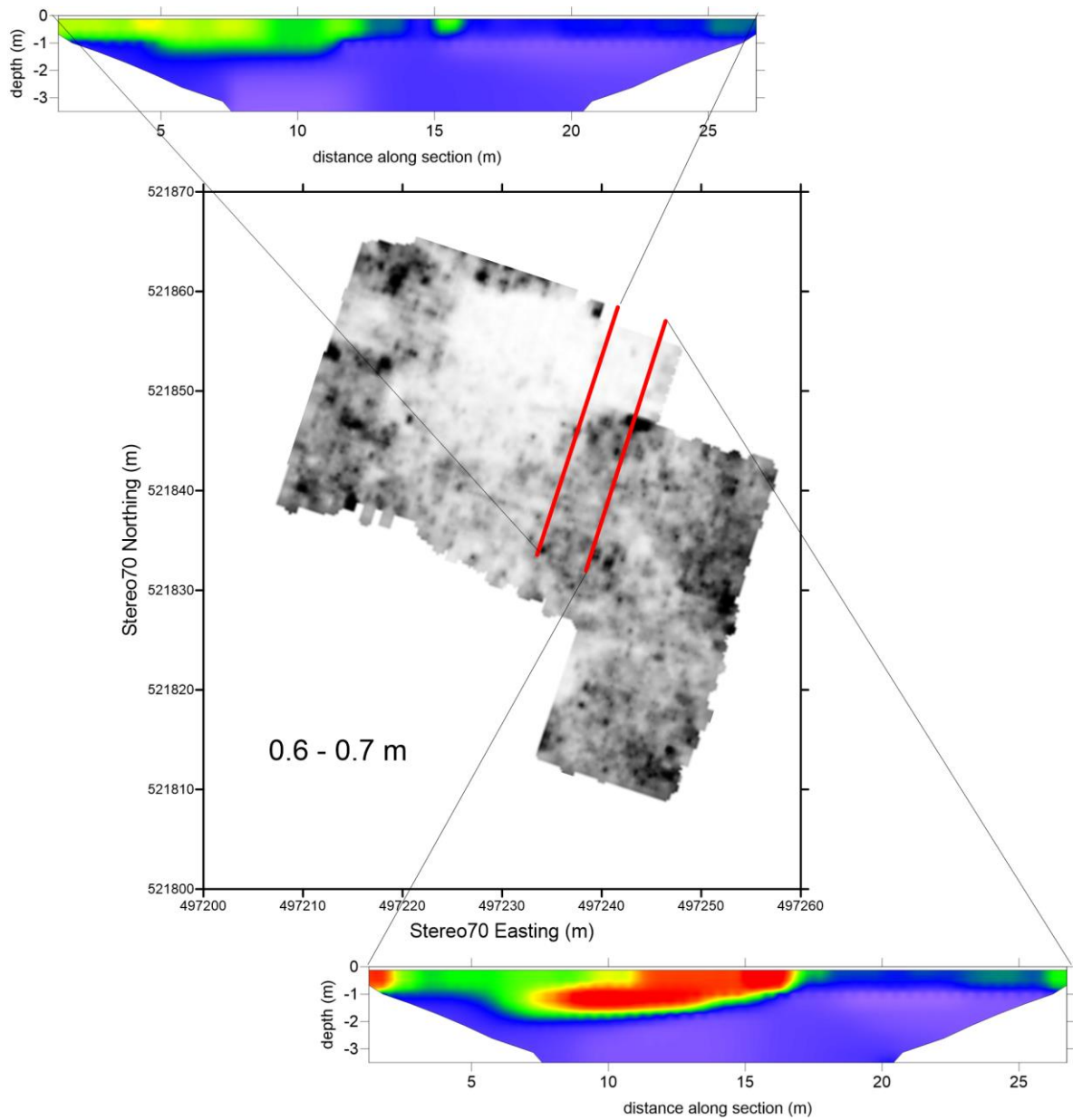


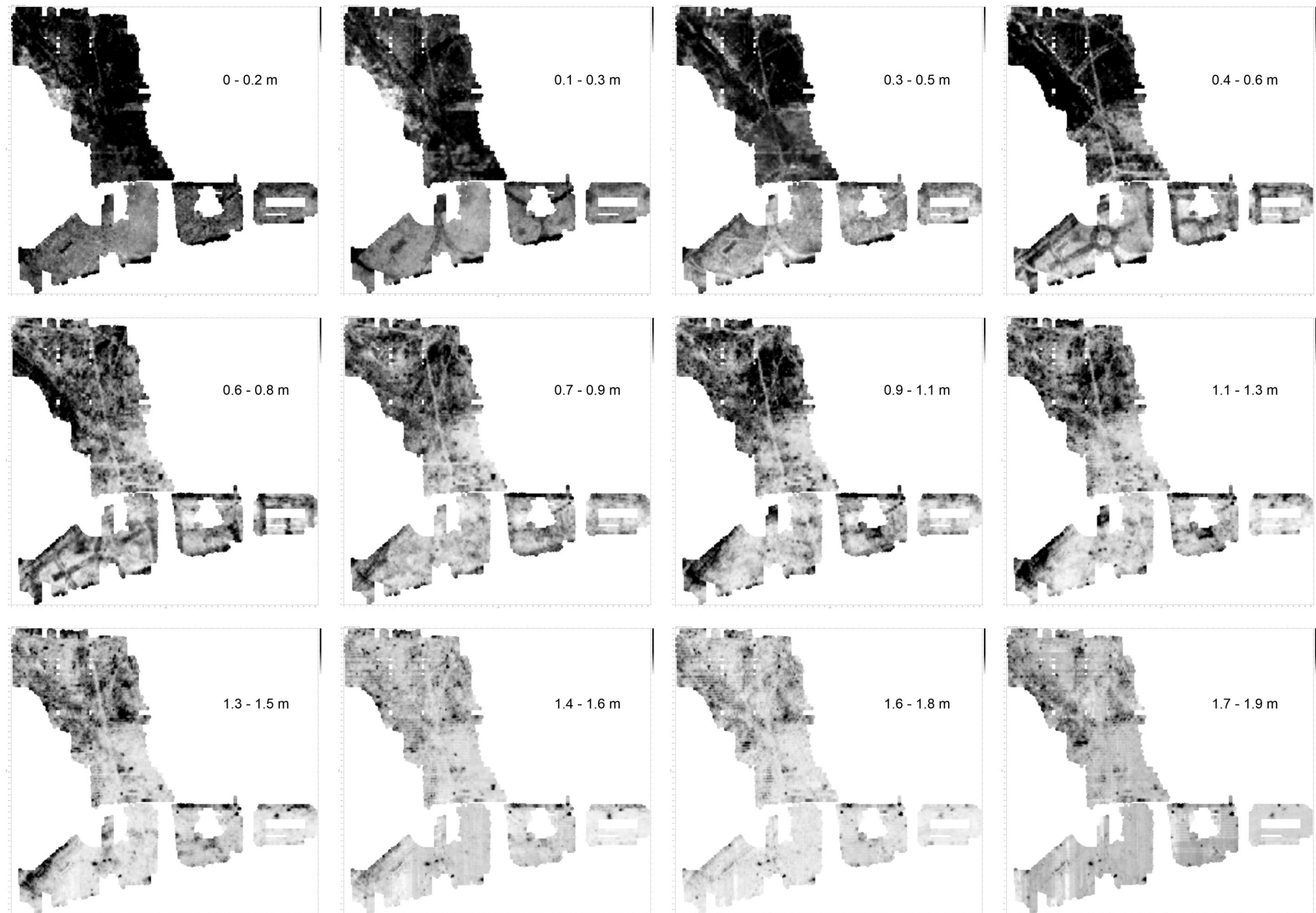
Figure 6. Resistivity along two depth sections in the Parking area.

Red: resistivity higher than 100 ohmm

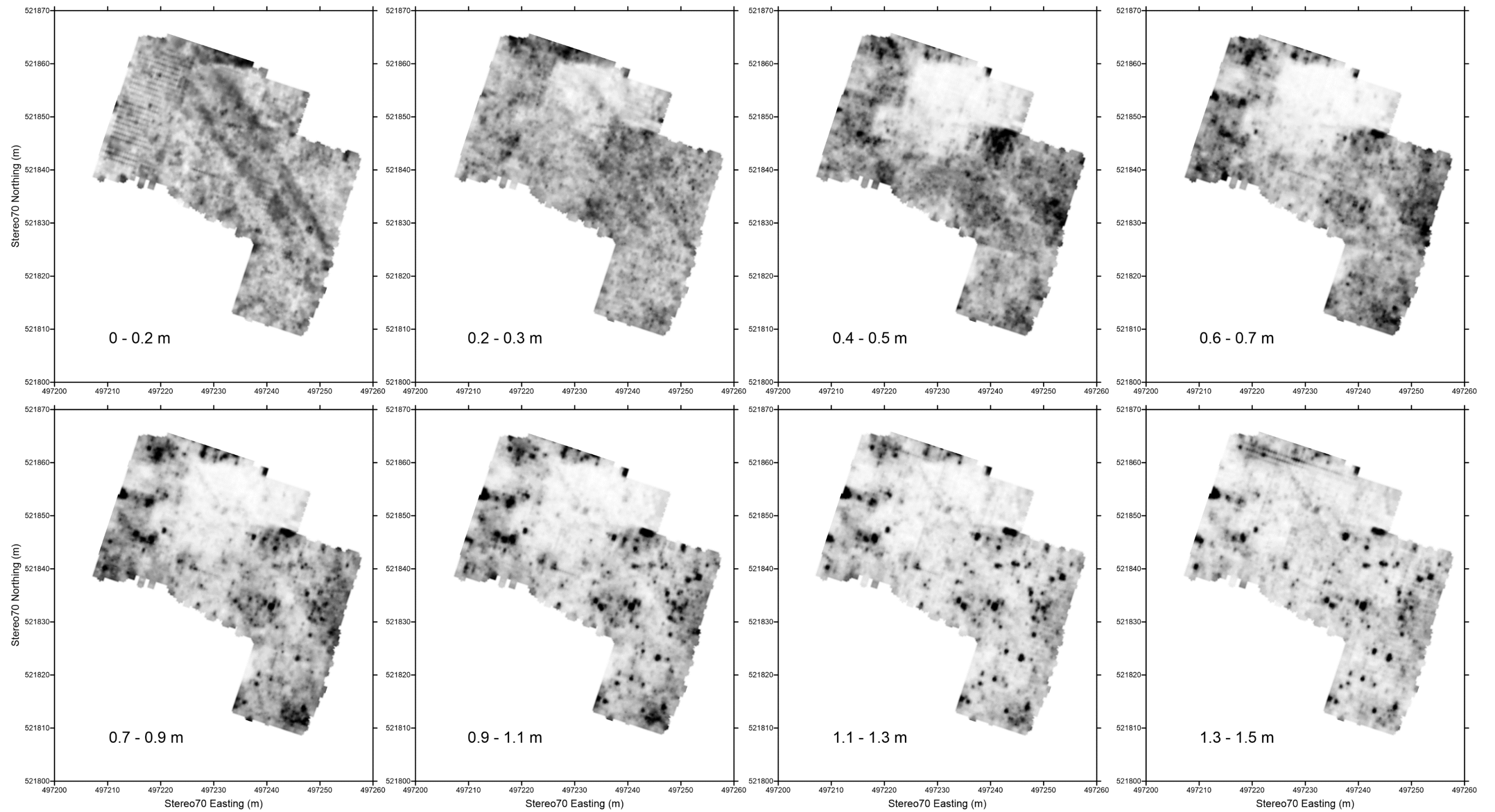
Green: resistivity: 40 – 50 ohmm

Blue: resistivity: 10 – 20 ohmm

Supplements



Supplement 1. Radar images at different depths in the area of the main square.



Supplement 2. Radar images in different depths in the Parking area.