Bakalis

Archaeological Background

Magoula Bakalis seems to have been inhabited since the prehistoric period, specifically from the Final Neolithic and beyond. However, as the Acropolis of the later city of Pherai was placed on the hilltop, it is very difficult to detect evidence relating to the prehistoric occupation. However, the continuous habitation from the Final Neolithic in this place and the subsequent development of one of the four most important cities of Thessaly shows that the habitation was successful and important through time.

Satellite Remote Sensing and Historical Aerial Photography Survey

A Quickbird image from 15 June 2009 and a GeoEye-1 image from 4 May 2010 were used for satellite remote sensing at Bakalis (Figures 1-2). The Quickbird has an off-nadir angle of 7.6° and a ground sampling distance (GSD) of 0.62 m (panchromatic) and 2.49 m (multispectral), and the GeoEye-1 has an off-nadir angle of 9.9° and a ground sampling distance (GSD) of 0.50 m (panchromatic) and 1.81 m (multispectral). In addition to the satellite imagery, an aerial photograph from 26 August 1960 with a scale of 1:15,000 and one from 1977 (date unknown) with a scale of 1:15,000 were used (Figure 3) in the analysis.

The environment around Bakalis is largely urban, since the prehistoric mound lies at the northwestern edge of the modern village of Velestino. The site is surrounded by some agricultural fields and a church. Velestino was the location of the ancient Greek settlement of Pherai; therefore, there is a high probability that surface anomalies from remote sensing will be from historical periods. The topography north of Bakalis rises gradually with many hills and streams. Elevations around Bakalis range from 130-150 masl, while the mound itself rises to an elevation of nearly 160 masl. Several other prehistoric settlements are located in the same area. These include Velestino 3 (Mati) (1.5 km to the northeast), Nikonanou (2.8 km to the northeast), and Velestino 4 (Visviki) (3 km to the east). The prehistoric tell is only 700 m away from the extra-mural sanctuary of Zeus Thavlios, which was an important cult site for the classical Greek city of Pherai. Cultivation in the nearby agricultural fields is predominantly wheat and corn. The historical air photographs show that the local environment and land use around Bakalis have not undergone significant changes. Some field boundaries and field orientations are different in the 23 August 1960 aerial photograph. The urban area of Velestino extends slightly more to the north and northwest than it did 50 years ago..

Satellite remote sensing within a 1 km radius around Bakalis produced good results (Figures 4-5). However, the majority of features correspond to features from the ancient Greek settlement, such as buried road systems and architecture. The habitation mound is obvious in the satellite imagery, but no surface anomalies were extracted from remote sensing.

Figure 1. Bakalis from a 15 June 2009 Quickbird image

Figure 2. Bakalis from a 4 May 2010 GeoEye-1 image

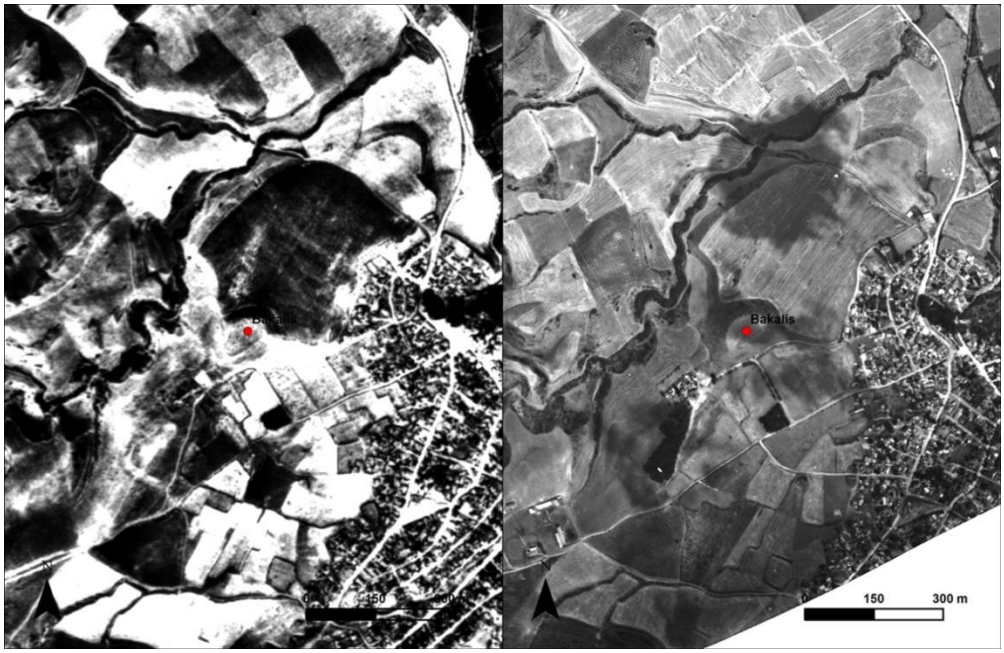


Figure 3. Bakalis from aerial photographs taken 26 August 1960 (left) and 1977 (right)

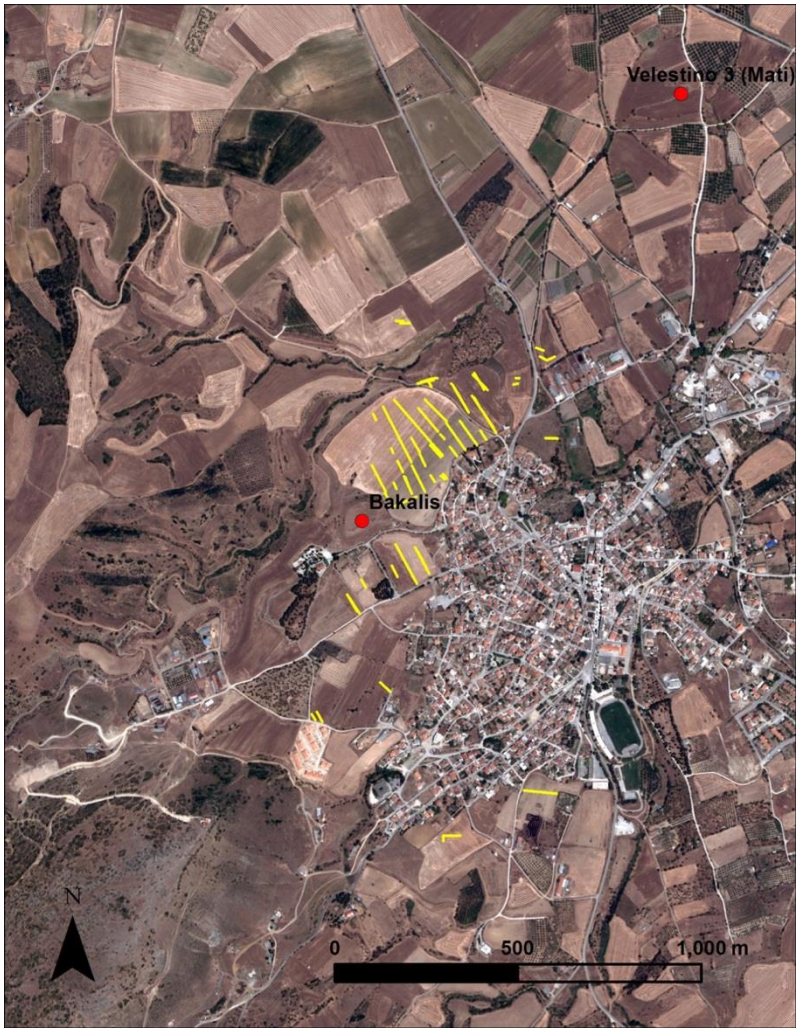


Figure 4. Crop marks from the 4 May 2010 GeoEye-1 image within a 1 km radius around Bakalis

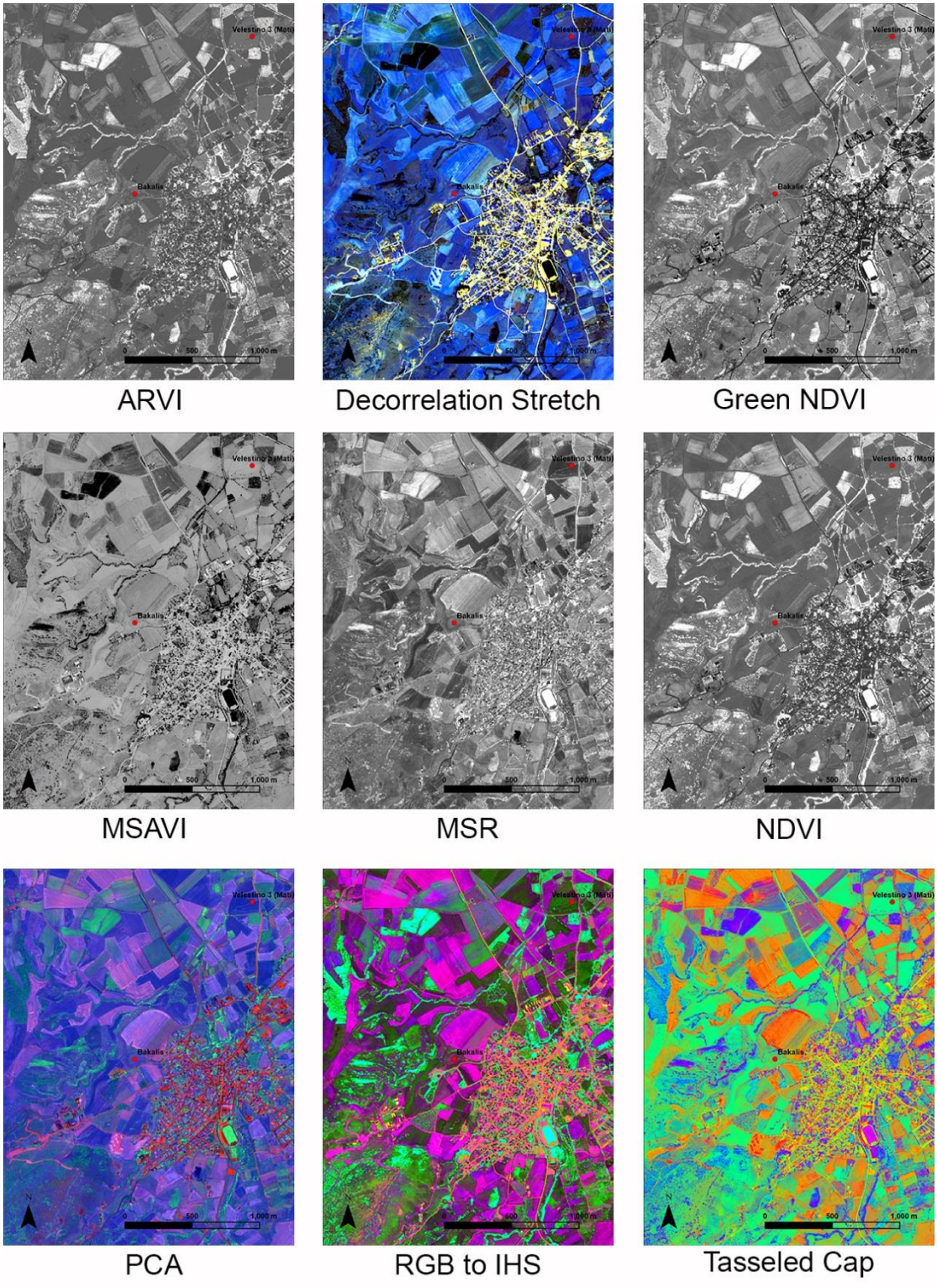


Figure 5. Spectral filters and vegetation indices applied to the 4 May 2010 GeoEye-1 image around Bakalis

Remotely Piloted Aircraft Systems (RPAS) Survey

A low altitude aerial survey over Bakalis produced a number of interesting results. In particular, the wild vegetation regime on top of the magoula's plateau did not impede the identification of some marks with regular (mostly rectilinear and rectangular) shape (Figure 6), occurring predominantly on the Southern and Eastern edges of the elevated field, overlooking to the rest of the Classical/Roman city.

Figure 6: Bakalis plateau with crop-marks highlighted in red.

These linear shapes are defined by areas where the vegetation did not grow (Figure 7) as much as in the surroundings. This may suggest the presence of buried structures and so leads to the interpretation of the vegetation marks as built features. They correlate exactly with results from the geophysical surveys (see below), especially from Ground Penetrating Radar (GPR) data, which supports such an interpretation. Many more similar traces could be identified in the images and in the final ortho-mosaic, but their partial overlapping with walking and light-machinery paths suggested a more conservative approach to their interpretation.

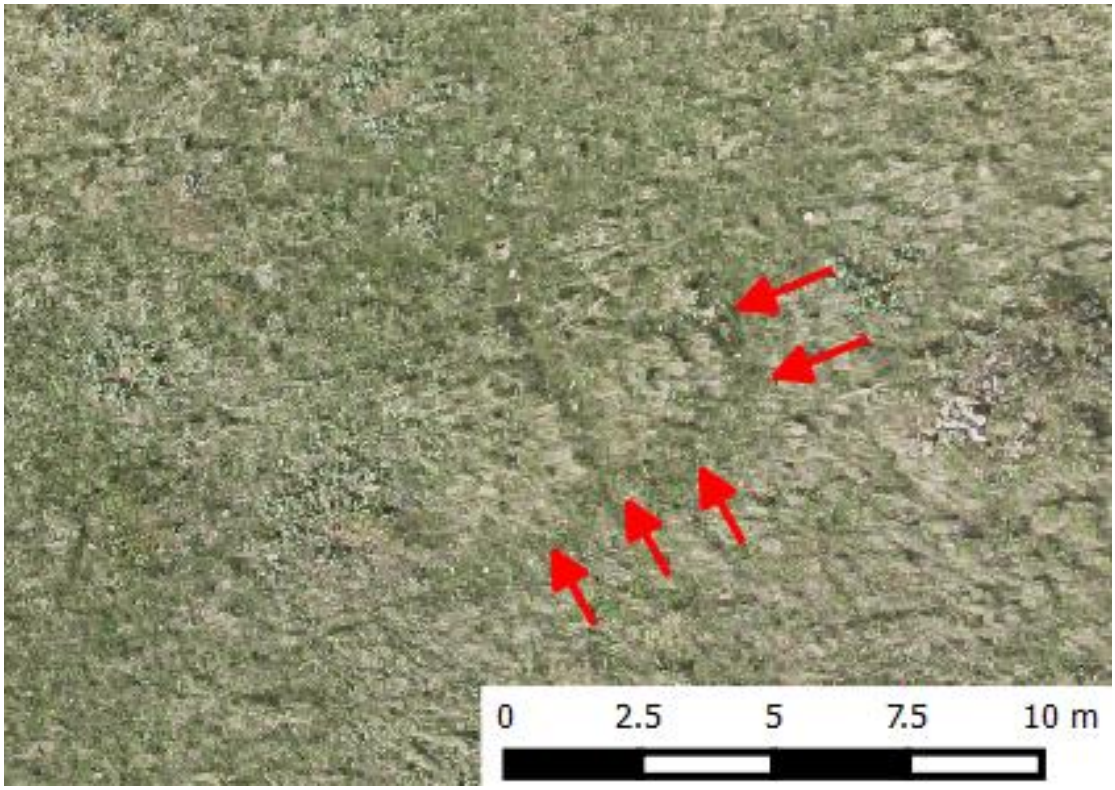


Figure 7: Detail of one of the vegetation-marks (the south-western most one from Figure 6) with red arrows highlighting some of the linear features. Despite the apparent differing orientation of the identified structures, the short side for these possible buildings seems to consistently be around 3.4 to 4 meters.

Geophysical Prospection

Geomagnetic Survey

Geomagnetic prospection conducted on top of the Magoula Bakalis produced satisfactory results despite the various occupation phases of the site. (Figure 8). Highly magnetic structures created intense magnetic anomalies with clear dipolarity and they are probably caused by preserved structures (marked A1 to A17 in Figure 8). The dimensions of the buildings range from 3x4m to 5x7m and most of them are clustered to the center of the top of the hill, at higher elevations, manifesting a preferable orientation towards the NW-SE direction. Only structures A16 and A17 seem to be located to the lower elevations to the SE section of the hill. To the west, a couple of linear anomalies (B1 and B2) extend towards the E-W direction and seem to confine a very intense amorphous magnetic anomaly within an area of 17x18m. To the north side of B1, a large elongated building (A5) exists with dimensions of 5x12m. At the same time, there seems to be an absence of clearly defined architectural residues to the far west side of the hill. Two parallel anomalies (B5) running for more than 31m in the west-southwest east-northeast direction, seem to be

a later addition to the geomagnetic inventory or they can be interpreted as a short road system leading to the core of the settlement.

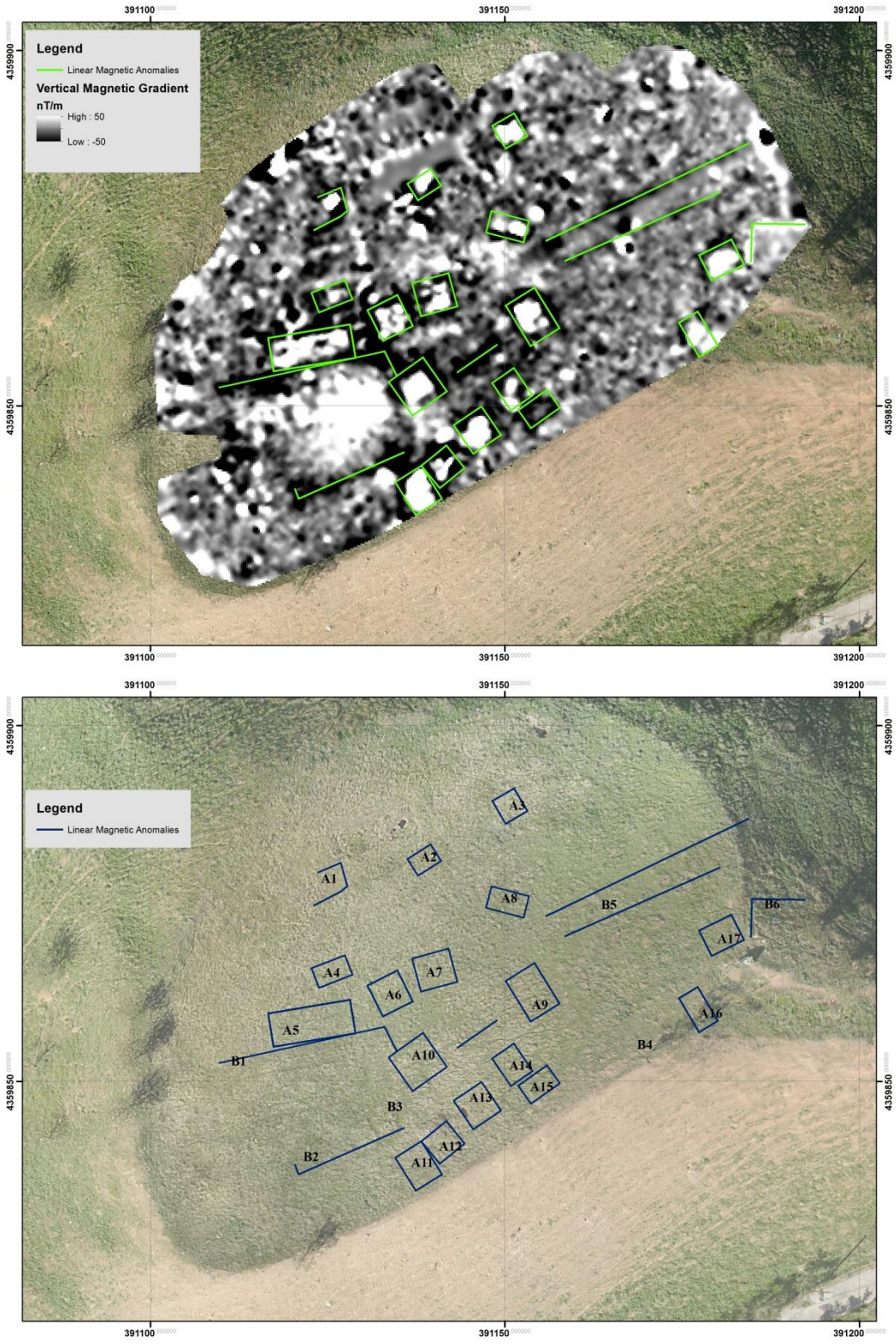


Figure 8: Geomagnetic results from Bakalis

Electromagnetic Induction Survey

Electromagnetic (EM) data are also exploitable for archaeological purposes. Structures A2 and A13 are indicated as high magnetic susceptibility anomalies in the EMI measurements (Figure 12). On the three different depth layers of soil conductivity (Figures 9, 10 and 11) investigated, features B3, A13, A15 and B4 can be clearly identified as low conductivity anomalies. Special emphasis has to be given to feature B3 which is located to the SE of the very intense magnetic anomaly defined by B1 and B2. B3 outlines a rectangular shape anomaly of about 7x8m in area extent, while an elongated anomaly of about 2.4m in width extending to the NE for more than 16m seems to be associated with the particular structure. Finally, traces of the magnetic anomaly B1 can also be observed in the EMI measurements as a low conductivity feature (Figure 13).

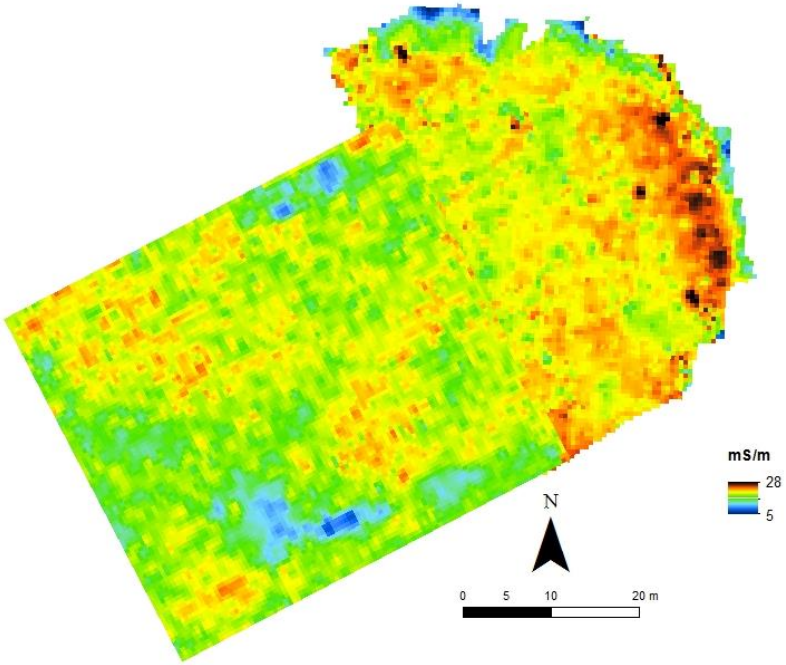


Figure 9: Electrical conductivity (CMD, VCP configuration) for 0-0.3 m depth

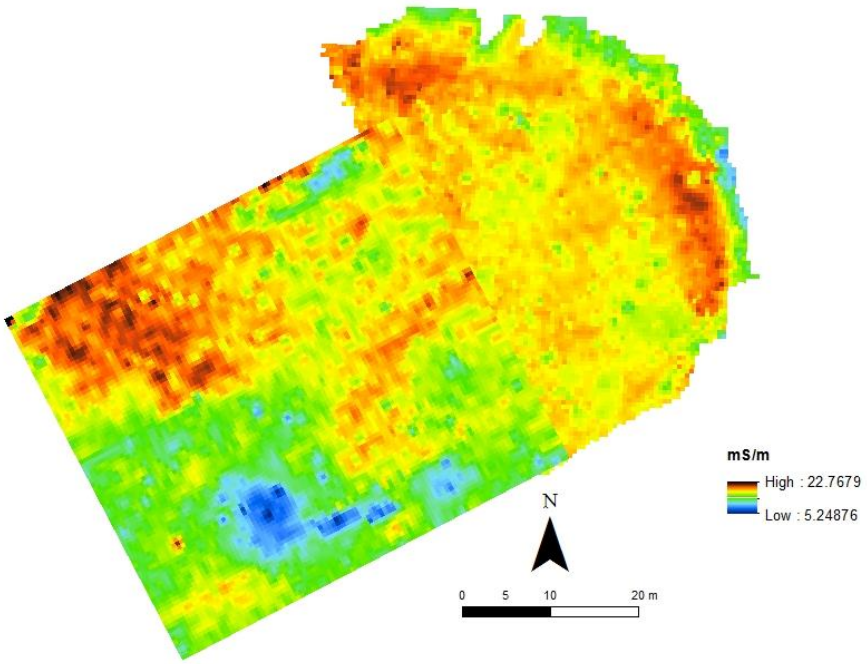


Figure 10: Electrical conductivity (CMD, VCP configuration) for 0-0.7 m depth

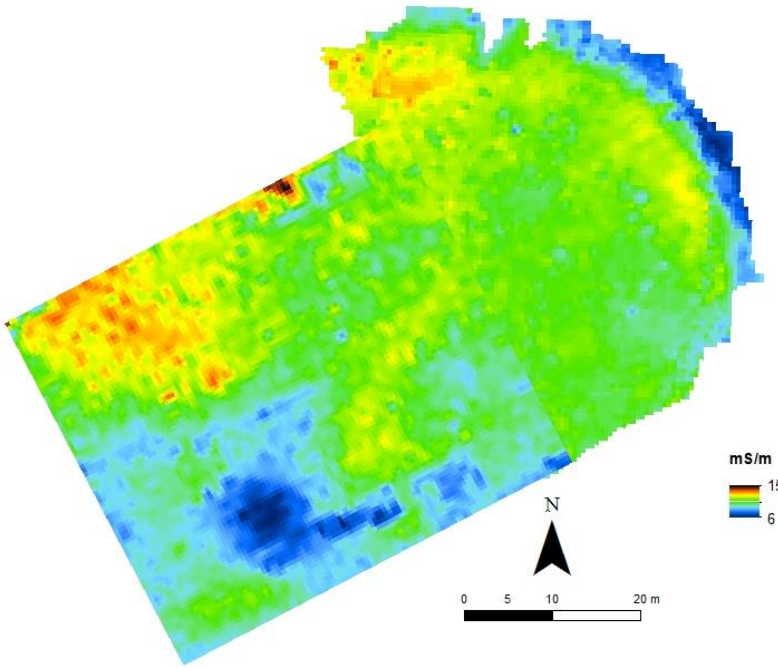


Figure 11: Electrical conductivity (CMD, VCP configuration) for 0-1.3 m depth

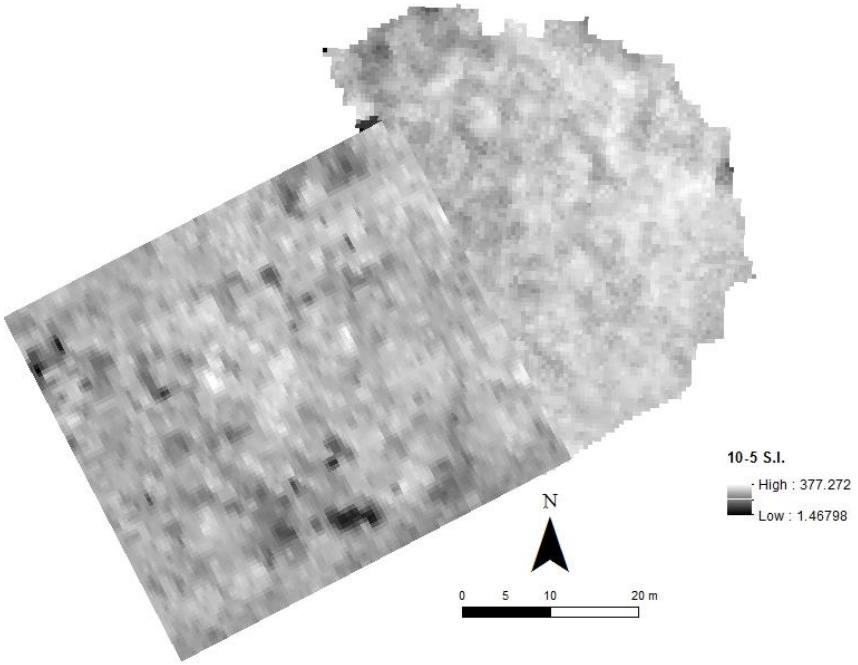


Figure 12: Magnetic susceptibility (CMD, VCP configuration) for 0-1.3 m depth

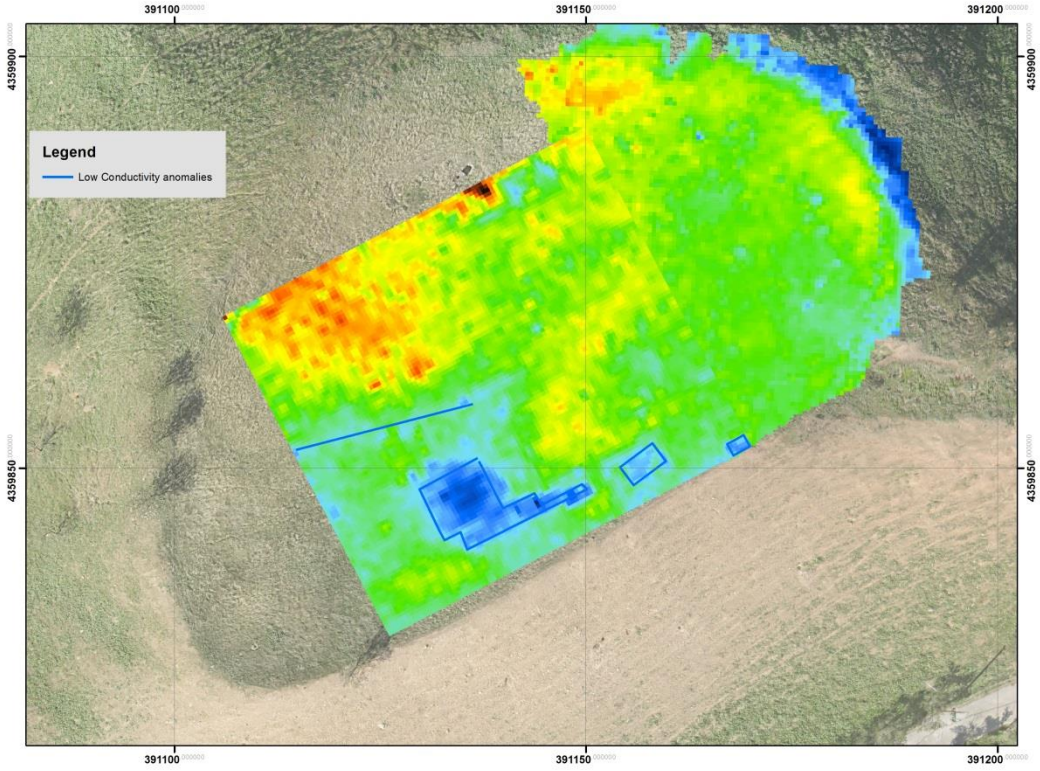
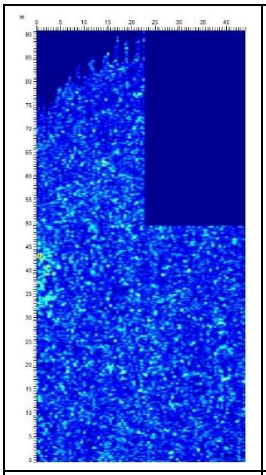
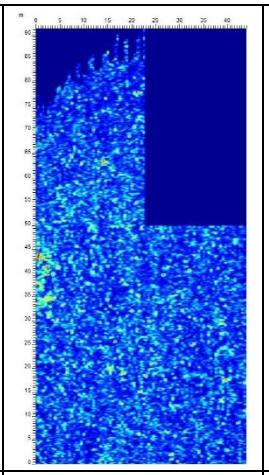
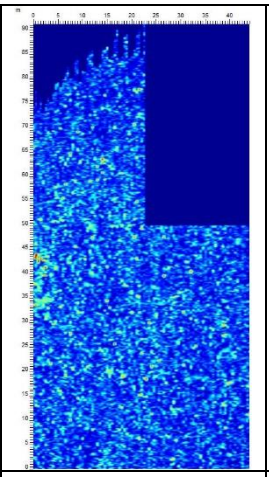
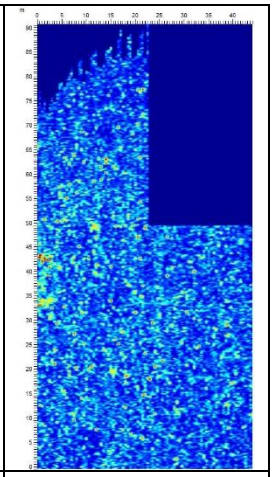
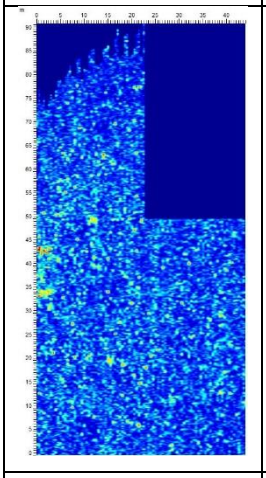
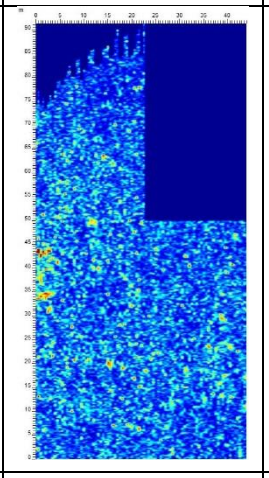
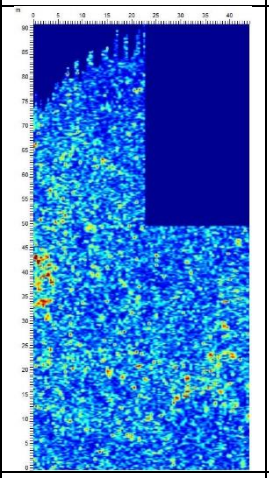
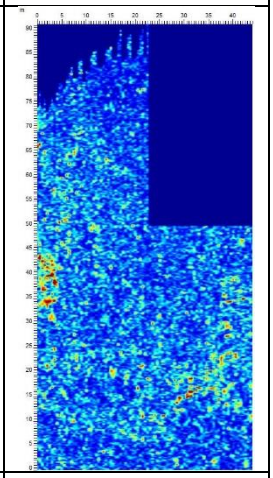


Figure 13: Low soil conductivity (CMD, VCP configuration for 0-1.3 m depth) anomalies.

Ground Penetrating Radar Survey

The survey grids of GPR were set at the top of the natural hill of Bakalis and data were collected using Noggin GPR equipped with a 250MHz, in parallel transects. The depth slices from the surface and up to 2.0m depth are presented in Table 1. The area covered is ~2875m^2 and consists of two grids, Bakali 1a and Bakali 1b. In the case of Bakali 1a, the GPR scan lines were expanded beyond the initial survey grid, towards the edge of the cliff. The processing flow is: Repick first break (15%), Dewow, Background average subtraction, Bandpass filter (Fc1=40 % Freq,Fp1=80 % Freq,Fp2=120 % Freq,Fc2=160 % Freq). In the case of Bakali 1b the GPR scans were limited within the survey grid while the filters and corrections that applied are:Trace reposition, Repick first break (15%), Dewow, Background average subtraction, Bandpass (Fc1=40 % Freq,Fp1=80 % Freq,Fp2=120 % Freq,Fc2=160 % Freq).

The obtained results are noisy within the range of 0-80cm and do not exhibit any strong anomalies. Below this depth a few strong features appear that become clearer at the range of 100-170cm. Those features are better shown in the 3D GPR models of Figure 14 and are further analyzed in the following paragraphs.

			
0-10cm	10-20cm	20-30cm	30-40cm
			
40-50cm	50-60cm	60-70cm	70-80cm

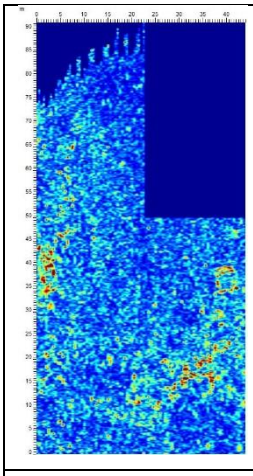
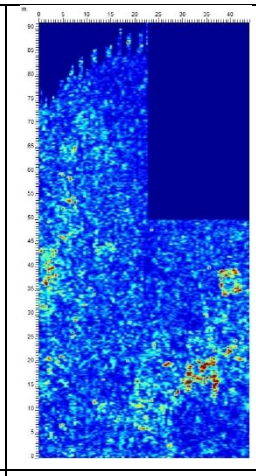
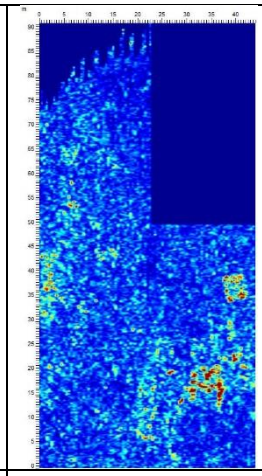
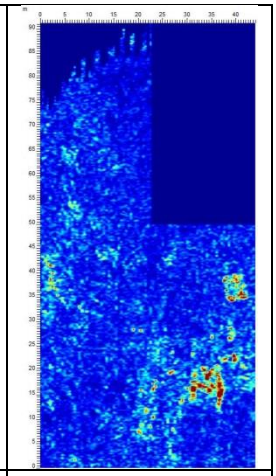
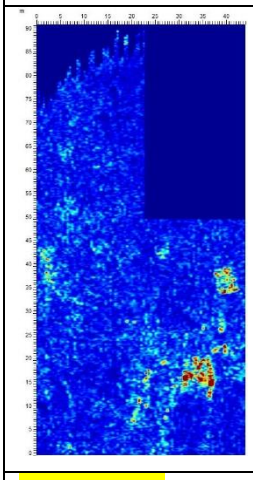
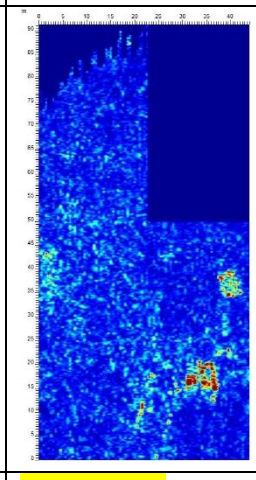
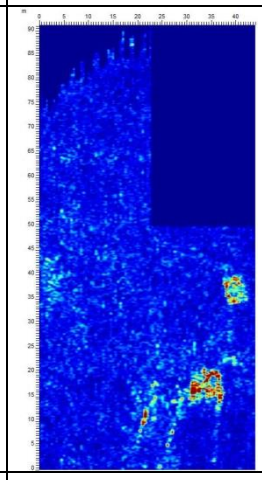
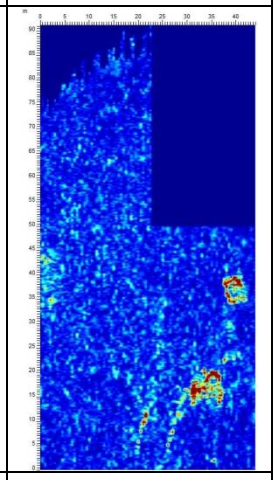
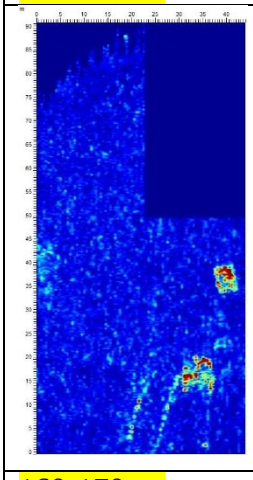
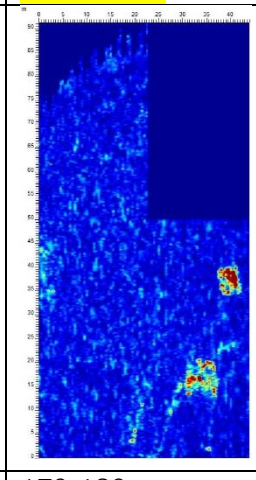
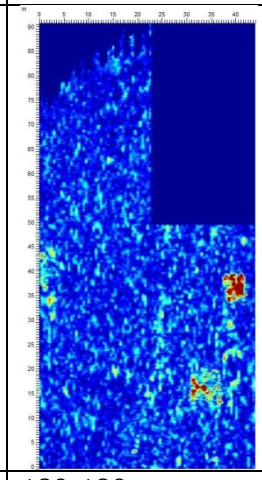
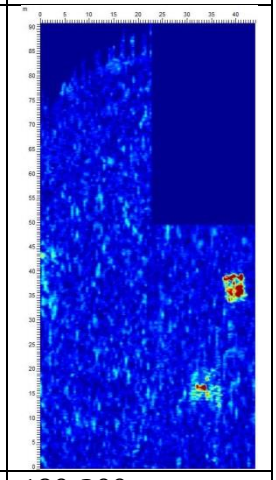
			
80-90cm	90-100cm	100-110cm	110-120cm
			
120-130cm	130-140cm	140-150cm	150-160cm
			
160-170cm	170-180cm	180-190cm	190-200cm

Table 1: GPR depth slices for the grids Bakalis 1a and 1b, with 10cm thickness.

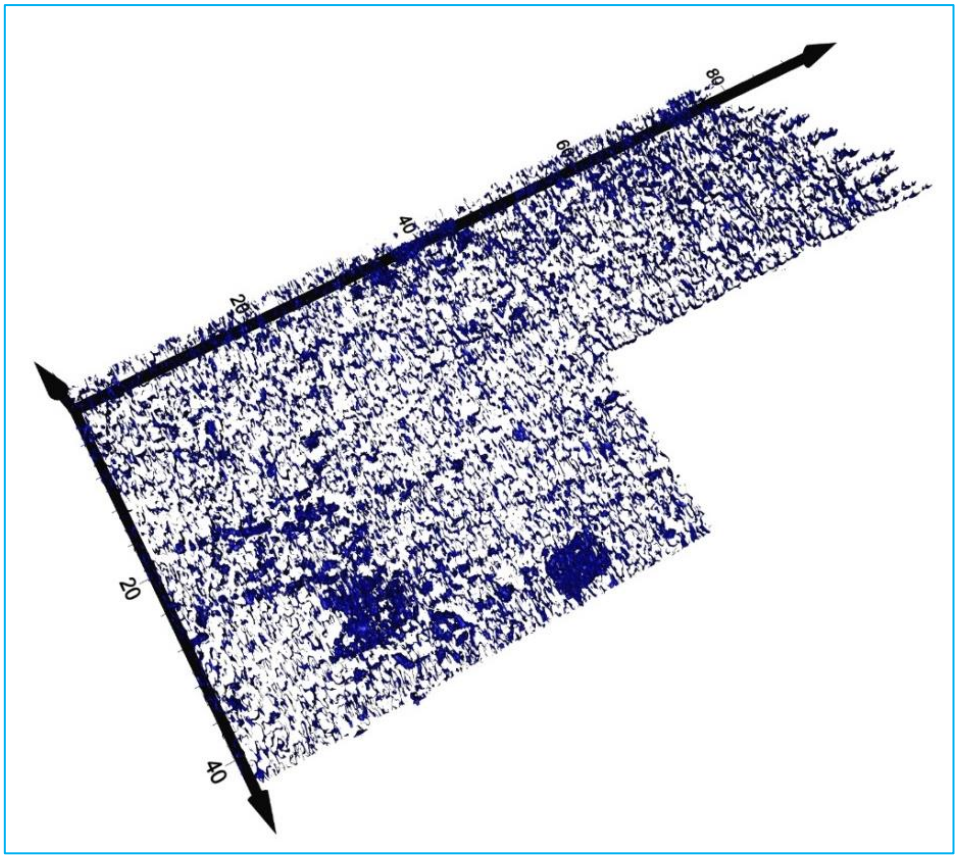


Figure 14: A perspective of the 3D GPR model at the area of Bakalis.

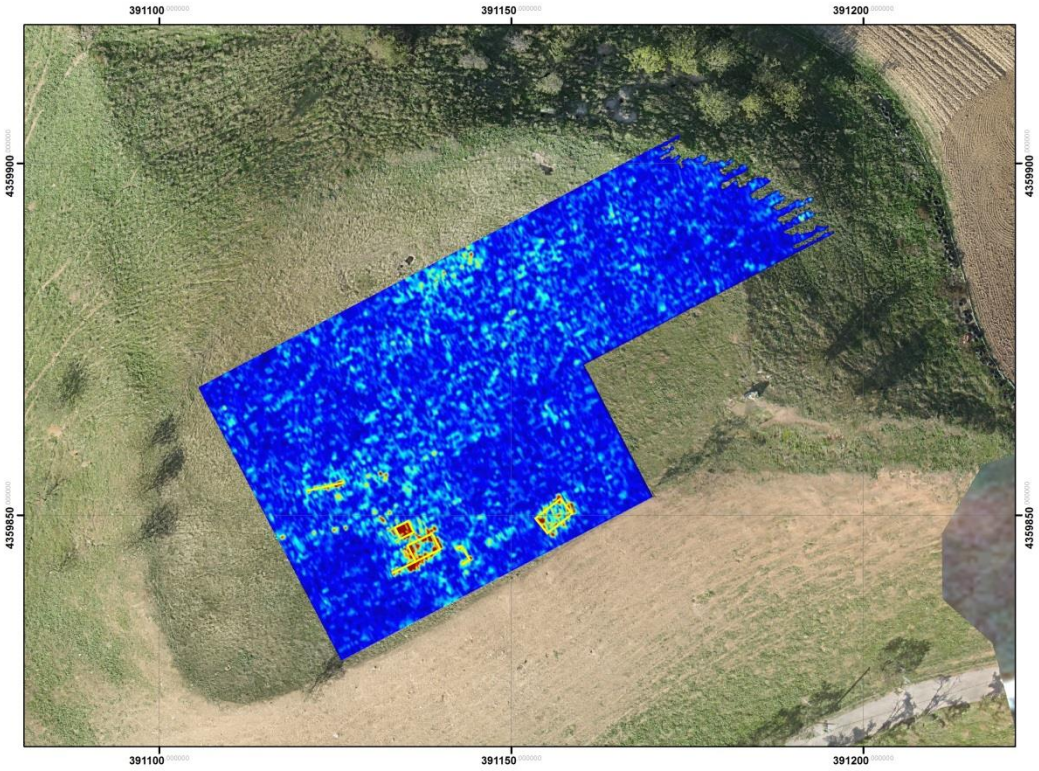


Figure 15: Strong reflectors identified by the GPR measurements in the area of Bakalis.

Figure 15 illustrates the rectified GPR slice at 130-140cm and the strong reflectors identified by the GPR survey. The expansion towards the NE cliff of the hill did not show any anomalies that could be attributed to a fortification wall – despite some suggestions from the EMI survey. On the other hand, three well-defined anomalies are visible on the SW side of the GPR grid.

A linear feature with orientation almost W-E that appears from 120cm and up to 180cm from the surface and is more likely that belongs to part of a wall that has been identified by the magnetic and EMI data (feature B1). Its extension towards the east is also suggested but it is relative fuzzy in the GPR slices. The group of anomalies B3 describes two well defined rectangular anomalies with high contrast in their electrical properties. Those features are not clearly visible in the magnetic results indicating low contrast in their magnetic properties. Even if the particular structures seem to be distinct, they fall within the rectangular region defined by the EMI low conductivity. Sections of B2 are also visible in the specific region. Finally, A15 describes another rectangular anomaly that is visible as a strong solid anomaly from 80-200cm. This could indicate a rectangular structure with a collapsed roof or filled with material from collapsed walls. This feature is also visible in both the magnetic and EMI conductivity showing the same orientation but with a slight offset in its spatial location.

Integration of Geophysical Results

Magoula Bakalis is located at the NW fridges of the modern village of Velestino and based on the archaeological finds it seems to have been inhabited since the prehistoric period, specifically from the Final Neolithic and beyond. However, as the Acropolis of the later city of Pherai was placed on the hilltop, it is very difficult to detect evidence relating to the prehistoric occupation. However, the continuous habitation from the Final Neolithic in this place and the subsequent development of one of the four most important cities of Thessaly shows that the habitation was successful and important through time. This has to be emphasized as the mound is surrounded by two streams (Makalo rema to the north and Maluko rema to the south flowing NE) and it is in a close proximity to a spring at Kastraki hill providing water not only for the inhabitants of the area but also for cultivation of the fertile plains around the settlement.

A Quickbird image from 15 June 2009 and a GeoEye-1 image from 4 May 2010 were used to investigate the regional environmental settings around the settlement. In addition to the satellite imagery, an aerial photograph from 26 August 1960 with a scale of 1:15,000 and one from 1977 (date unknown) with a scale of 1:15,000 were used in the analysis. A number of features have been identified through aerial and satellite imagery but due to the intense habitation of the area during the Classical period, it is most probable that the features identified belong to the historical periods. This is especially evident to the flat properties to the east of the mound, where a number of parallel streets and architecture of historical periods has been identified either through geophysical prospection or excavation methods. Despite the chronological relevance of the features, even the RPAS survey on the hill was able to identify a few targets suggested by the vegetation marks occurring predominantly on the Southern and Eastern edges of the elevated field and overlooking to the rest of the Classical/Roman city.

The geophysical survey at magoula Bakali employed magnetic (SENSYS-MX), EMI (MiniExplorer CMD) and GPR (Noggin Plus 250MHz) techniques covering the total area of the flat-topped prehistoric mound. Highly magnetic structures created intense magnetic anomalies probably caused by preserved structures (marked A1 to A17), having dimensions ranging from 3x4m to 5x7m. Structures A2 and A13 are also indicated as high magnetic susceptibility anomalies in the EMI measurements. To the west, a couple of linear anomalies (B1 and B2) extend towards the E-W direction and confine a very intense amorphous magnetic anomaly within an area of 17x18m. Traces of the magnetic anomaly B1 can also be observed in the EMI measurements as a low conductivity feature, but also to the GPR data which indicate a vertical extent of it between 120 to 180cm below the surface. To the north side of B1, a large elongated building (A5) exists with dimensions of 5x12m. On the three different depth layers of soil conductivity investigated, features B3, A13, A15 and B4 can be clearly identified as low conductivity anomalies. Special emphasis has to be given to feature B3 which is located to the SE of the very intense magnetic anomaly defined by B1 and B2. B3 outlines a rectangular shape low conductivity anomaly of about 7x8m in area extent, while an elongated anomaly of about 2.4m in width extending to the NE for more than 16m seems to be associated with the particular structure. Within the extent of B3, the GPR data describe two distinct rectangular anomalies with high contrast in their electrical properties. Those features are not clearly visible in the magnetic results

indicating low contrast in their magnetic properties. Finally, A15 describes another rectangular anomaly that is visible as a strong solid anomaly from 80-200cm. This could indicate a rectangular structure with a collapsed roof or filled with material from collapsed walls.

Most of the structural remains seem to be clustered at the center of the top of the hill, at higher elevations, manifesting a preferable orientation towards the NW-SE direction. Only structures A16 and A17 are located to the lower elevations to the SE section of the hill. Whatever the case, the clustering of these features does not form a well-defined intra-site settlement pattern but is rather dispersed in terms of their spatial distribution.

Similarly, there seems to be an absence of clearly defined architectural residues to the far west side of the hill. Two parallel anomalies (B5) running for more than 31m in the west-southwest east-northeast direction, seem to be a later addition to the geomagnetic inventory or they can be interpreted as a short road system leading to the core of the settlement.

Figure 13: Depiction of anomalies from different methodologies

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