Riksantikvarieämbetet

Delrapport 4!

Survey report

Ground Penetrating Radar survey for Archaeological Prospection in Nyköping 2006

Methodology, data acquisition, results, interpretation

Diarienr: 424-00275-2007

Immo Trinks & Lars-Inge Larsson

Photo title-page: Immo Trinks
Pär Karlsson operating the ground penetrating radar system in the town centre of Nyköping (Quarter Åkroken).

Contact information:
Riksantikvarieämbetet
UV Teknik
Instrumentvägen 19
126 53 Hägersten

Table of contents

Sammanfattande antikvariska kommentarer

Under en vecka i juli 2006 genomförde Riksantikvarieämbetets Avdelning för Arkeologiska Undersökningar en georadar undersökning av delar av två kvarter i centrala Nyköping. Uppdragsgivare var Länsstyrelsen i Södermanland. Arbetsprocessen och insamlad data har beskrivits i rubricerad rapport. Agneta Åkerlund vid nämnd länsstyrelse har vidare lämnat önskemål om en sammanfattande antikvarisk tolkning utifrån de resultat som redovisas i rapporten. Detta dokument är ett försök att tillmötesgå detta. Detta dokument följer de områdesbenämningar och den ordningsföljd som återfinns i rapporten.

Område Mejeriet, nedre delen

I mätdata från området syns tydligt spår efter rör- eller elledningar samt i nordväst spåren efter den grävda kanal som runnit genom området och som kan ses i stadskartan över Nyköping från 1888. I den norra delen syns en tydlig cirkulär anomali som först uppträder på ca 0,60 meters djup och som sedan kan följas ned till knappt 2 meters djup. Denna anomali är inte helt lätt att tolka men utgör troligen spåren efter en brunn eller kulvert från historisk eller modern tid. I den centrala delen av mätområdet finns spår efter två rektangulära strukturer som troligen är spår av två byggnader. Dessa kan ses på ett djup från ca 1,50 meter och ned till ca 2 meter. Med tanke på djupet och att de ligger orienterade efter något annat än dagens gatunät så utgör dessa troligen spår efter byggnader från en äldre fas i stadens historia.

Mest utmärkande för området är dock snarast frånvaron av anomalier och identifierbara strukturer. Utifrån våra mätningar ger området intryck av att de övre ca 1,50 metrarna är kraftigt omrörda. Exempelvis så har det in på 1900-talet, längs med Bruksgränd, stått ett större boningshus men av detta syns inte ett spår. I mätdata upphör i princip alla spår vid ca 2,30 meters djup. Det kan betyda att kulturlagren upphör på denna nivå och följs av naturlig lera. Mätningarna motsäger inte att det i leran kan finnas arkeologiskt intressanta fynd eller strukturer men de är i sådana fall av sådan art att de inte kan ses med hjälp av georadar.

Område Mejeriet, övre delen

I mätresultatet syns tydligt ett flertal rör- eller elledningar som går genom området. Relativt ytligt, på ca 0,2-0,3 meters djup, i områdets södra kan också spåren efter förmodligen två mindre byggnader ses som två rektangulrära avtryck. Dessa är från relativt sen tid, troligen 1900-tal.

Området domineras av spåren från en tidigare större byggnad som funnits på platsen. Byggnaden är troligen från slutet av 1800-talet eller från början av 1900-talet. Grundmurarna från denna byggnad syns från ca 0,50 meters djup och syns sedan tydligare och tydligare nedåt med rumsindelningar i det som var byggnadens källare. Byggnadens grundmurar kan följas ned till ca 3 meters djup.

Sammanfattningsvis är alltså området hårt utschaktat genom den tidigare byggnaden med källare samt genom dragning av rör- och elledningar genom området. Intressant arkeologi kan fläckvis finnas bevarat i områdets östra delar även om mätningarna med georadar inte har kunnat påvisa några tydliga strukturer från äldre faser. Det kan möjligen också finnas någon bevarad arkeologi under den stora byggnaden även om det verkar mindre troligt.

Åkroken, övre delen
Området uppvisar en stor mängd anomalier och tolkningsbara strukturer. Ytligt kan en mängd nedgrävningar av rör- och elledningar ses och från ca 0,50 meters djup och ned till ca 2 meters djup domineras området av spåren från byggnader med källare som nästan samtliga är direkt identifierbara på 1888 års stadskarta. Särskilt tydligt är spåren efter byggnader längs Västra Kvarngatan. I mätdata syns också tydligt den tidigare Rådhusgränden. I mätdata kan inte ses några strukturer som tydligt avviker från existerande gatunätsstrukturen och som därmed skulle vara tydligt äldre än de identifierade byggnaderna.

Sammanfattningsvis är alltså stora delar av området urschaktat i samband med uppförandet av de byggnader som mätningarna och kartmaterialet påvisar. Äldre lämningar kan möjligen återfinnas i de ytor där det inte funnits nedgrävda källare samt i ytorna mellan husen även om georadarmätningarna inte kan påvisa sådana äldre strukturer. Det är inte heller omöjligt att det kan finnas arkeologiskt intressanta spår även under de nedschaktade källargrunderna.

Åkroken, nedre delen
Den nedre delen av Åkroken ger intryck av att vara relativt orörd av sent historiska och moderna aktiviteter. Det kan också vara så att för den delen som omfattar parkeringen att detta område kan vara nedschaktat i samband med anläggandet av parkeringen och att senare tiders spår på det sättet försvunnit. I mätdata finns självfallet spår av rör- och elledningar. I framför allt den norra delen av området uppträder en mängd spår från ca 1 meters djup efter strukturer som verkar vara byggnader. Samtliga av dessa byggnader har en annan orientering än dagens gatunät och kan närmast jämföras med det äldre gatusystemet som syns på en stadskarta från 1665. Dessa strukturer kan i vissa delar sedan följas ned till ett djup av ca 2,20 meter och detta indikerar att det rör sig om strukturer som är från ca 1600-talet eller äldre.

Sammanfattningsvis verkar alltså den nedre delen av Åkroken vara relativt orörd om man är på jakt efter bevarade äldre delar av staden. Kulturlagren verkar fortsätta ned till ca 2,20-2,30 och följs därefter av lera. Våra mätningar utesluter inte att det kan finnas intressanta arkeologiska lämningar i detta lerskikt.

Sammanfattning
Mätning med georadar gjordes i delar av två kvarter i centrala Nyköping. Mätningarna visar i detalj att det finns stora urschaktningar från rör- och elledningar samt från byggnader troligen byggda under 1800-talet i övre delen av Mejeriet samt i övre delen av Åkroken. I dessa delar finns förmodligen spår av äldre faser i stadens historia men att det endast fläckvis är bevarat mellan och i enstaka fall under urschaktningarna. Mätningarna vid nedre delen av Mejeriet visar på ett område med få strukturer vilket indikerar att området kan vara omrört. På ca 1,50 m djup finns dock svaga spår som kan tolkas som strukturer tillhörande äldre delar av stadens historia. Mätningarna i den nedre delen av Åkroken visar på att det området är relativt fritt från senare tiders påverkan och att det tydligt finns strukturer efter bland annat byggnader som är från 1600-talet eller äldre.

Georadar metoden har tydligt visat sig användbar för att värdera förutsättningarna för bevarade strukturer i en medeltida stad. Metoden kan också användas för att uppskatta kulturlagrens tjocklek. Undantag är mycket blöta områden, exempelvis närmast Nyköpings ån, med högt lerinnehåll som effektivt begränsar georadarsignalens penetrationsförmåga.

1 Introduction

In July 2006 the prospection unit of the *Archaeological Excavation Department* of the *Swedish National Heritage Board* conducted Ground Penetrating Radar (GPR) measurements in the town centre of Nyköping in order to investigate the presence of historic and archaeological structures in the ground. The selection of survey areas was based on a pre-site visit by Lars-Inge Larsson and the author on May 23rd 2006.

During five days of field work an area of 4700m² was surveyed with very high resolution. In order to be able to geo-reference the GPR data the location of all survey areas was exactly measured using a tachymeter and geodetic fix points obtained from the local land survey office. The GPR measurements were conducted by Pär Karlsson, Lars-Inge Larsson and the author. The GPR data was processed by Alois Eder-Hinterleitner (*Central Institute for Meteorology and Geodynamics*, Vienna) using specialized software. Data analysis and interpretation of the GPR data was performed within a Geographical Information System (GIS). Historical maps of the area were obtained and used with the GPR data for the identification and interpretation of anomalies.

The map shown in Figure 1.1 and the satellite image (Figure) 1.2 give an overview of the survey areas in the town centre of Nyköping south of *Västra Kvarngatan*. The site *Åkroken* in the west is subdivided into two sub-areas due to large elevation differences between them: the upper part consists of the upper parking place which is covered with tarmac, while the lower part comprises the lower car park (asphalt covered) and the bordering green space by the river with grass and sand surfaces. The survey site *Mejeriet (upper part)* is a sand covered car park located between two buildings. The site *Mejeriet (lower part)* comprises a small parking place and mostly open, grass covered green space north of the river, as well as a sand covered road and foot path. The sizes of the surveyed areas are listed below.

Site name	**Area [m²]**
Mejeriet (lower part)	1000 + 230
Mejeriet (upper part)	650
Åkroken (upper part)	988 + 556
Åkroken (lower part)	465 + 817
Total area	**4706**

The satellite image in Figure 1.2 and the maps in Figures 1.3 and 1.4 cover all the same area at the same scale. Figure 1.3 and 1.4 display historical maps from the years 1888 and 1665, respectively. Of great interest are the past presence of buildings and constructions at the surveyed locations. The oldest available, detailed map of the town centre of Nyköping dates from the year 1665 (Figure 1.4). It shows two differing street systems, the older irregular system and the newer regular layout.

The suggested survey area *Verkstaden* between *Folkungavägen* in the east and *Behmbrog* in the west was not considered worthwhile surveying since considerable disturbances of the GPR signal would have been caused by side reflections from metallic objects next to the survey area (Figures 1.5 & 1.6). Furthermore, the relatively small are had been intersected and disturbed by a trench for cable or pipe laying, rendering the imaging archaeological structures in this limited area using GPR difficult or impossible.

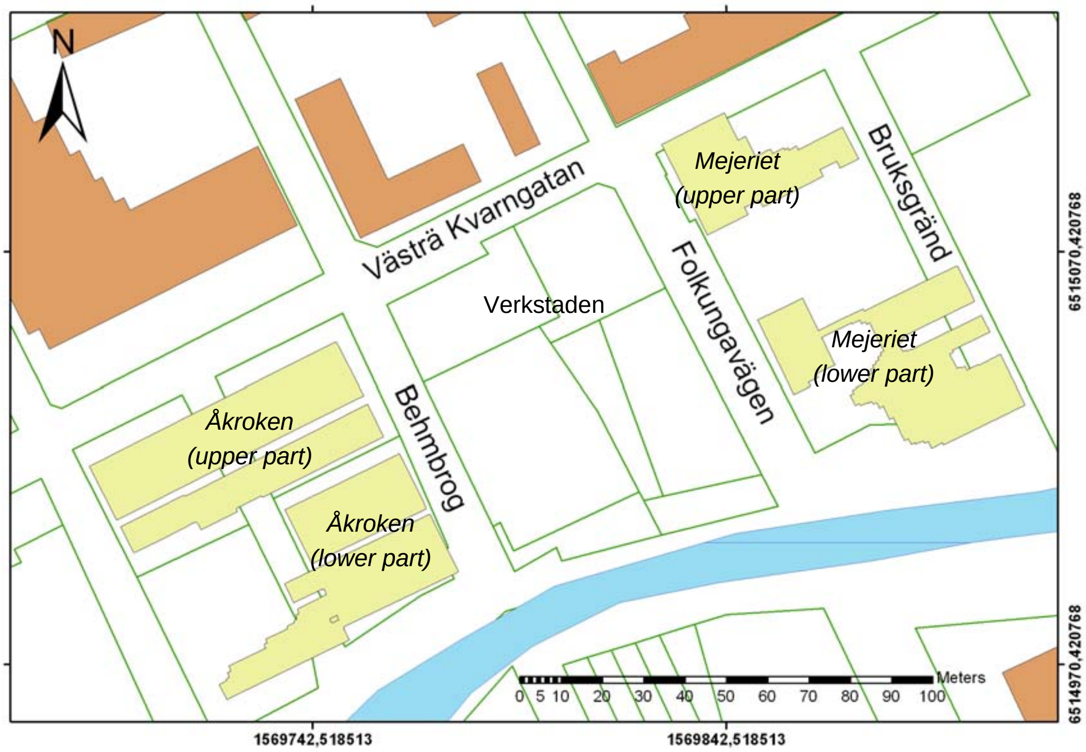

Figure 1.1: Map of the town centre of Nyköping showing the GPR survey areas (marked in yellow colour).

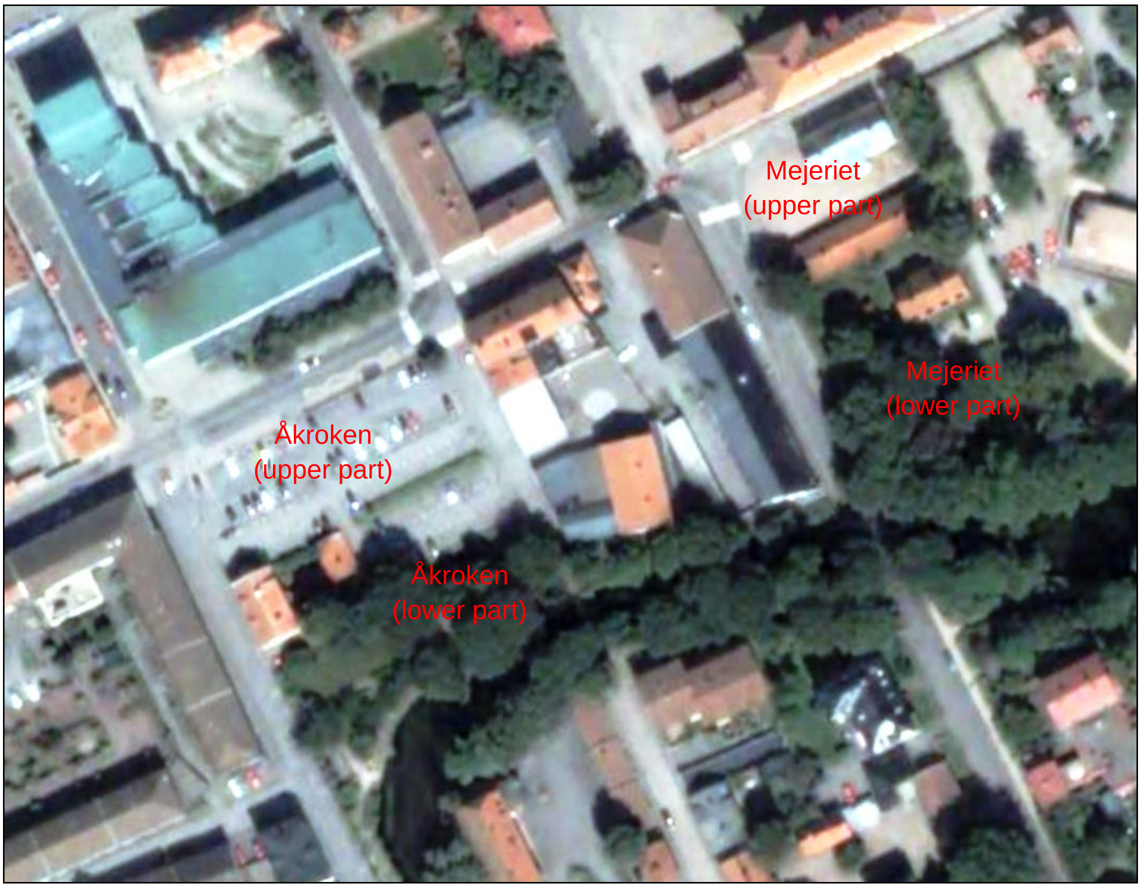

Figure 1.2: Satellite image of the town centre of Nyköping showing the survey areas. Image source: *Google Earth*

Figure 1.3: Historic map of year 1888 showing the town centre of Nyköping.

Figure 1.4: Historic map of the year 1665 showing the town centre of Nyköping.

Figure 1.5: Photograph showing the accessible area in the quarter *Verkstaden.* Note the metallic doors, containers, stairs, patio, balustrade and reinforced concrete structures, as well as the traces in the tarmac cover, indicating cable or pipe trenches.

Figure 1.6: Photograph showing the same area as Figure 1.5 from the opposite direction.

The following section provides a short introduction to the methodology of archaeological prospection using GPR surveying. In Section 3 the measured data for the different survey areas and their interpretation are presented and discussed separately.

How to use this report

The data presented in this report is best viewed by opening the PDF file in Acrobat Reader and displaying one page at a time or using the full-screen display mode. The paper copy of this report contains a DVD including the report in electronic form in PDF format in the folder “Report”.

A self contained *Power Point* presentation of the data can be found in the subfolder “PowerPoint_Presentation”, including animations of the data in form of AVI-movie files.

The original GPR data and its geometry information are included in the folder “Original Data”.

The result of the GPR data processing is contained as GPR depth-slices of 5cm, 10cm and 20cm thickness in form of geo-referenced TIFF images in the folder “Processed Data” and corresponding sub-folders “5cm”, “10cm” and “20cm” for each of the four survey sites *Mejeriet (lower part)*, *Mejeriet (upper part)*, *Åkroken (upper part)* and *Åkroken (lower part)*.

The folder “GIS Data” contains the geo-referenced GPR data and its interpretation in form of depth-slice TIFF images, maps, and shape-files in *ArcGIS* format. The project file “Nyköping_Georadar_2006.mxd” can be read and opened with *ArcMap 9.1*.

Further data analysis and use of the data is possible within a Geographical Information System (GIS), e.g. *ArcView*, *ArcMap* or *ArcExplorer*. For example to obtain the exact coordinates or dimensions of structures and anomalies of interest it is recommended to load the data (shape files, geo-referenced TIFF images) into *ArcView*, *ArcMap* or *ArcExplorer* and to use the cursor and the measuring tool. To display the coordinates in *ArcExplorer* at the bottom left corner of the main-frame choose View/Display Scale Bar.

The freely available GIS viewer software *ArcExplorer* for viewing and printing of the data is contained in the subfolder *ArcExplorer* “ArcExplorer Software”. The *ArcExplorer* software is as well available from
http://www.esri.com/software/arcexplorer
for Windows 98/2000/NT/XP, Macintosh, Solaris, AIX, HP-UX and Linux operating systems. On Windows operating systems run the *ae2setup.exe* program to install *ArcExplorer 2*. On all other systems choose the Java Edition *ArcExplorer 9.1*.

Always work with the original GPR depth-slice data. The interpretations contained in this report and on the DVD shall only highlight prominent features and structures. The depth-slice images contain considerably more detail and information. Depth-information of the data is relative and a function of the velocity used in the time-to-depth conversion. In the generation of the depth-slices shown in this report a velocity of 10cm/ns has been used throughout.

2 Description of the Ground Penetrating Radar method

Ground Penetrating Radar, Ground Probing Radar (GPR) or Georadar is a geophysical measurement method that allows the investigation of the shallow subsurface. A GPR antenna is used to send electro-magnetic waves into the subsurface. These waves are reflected from structures such as large stones, old foundations of buildings, pits, ditches or interfaces of geological layers. The reflected radar waves that are returning to the surface like an echo are recorded with the GPR antenna and used to generate an image of the subsurface.

The GPR technique

GPR antennas used for archaeological prospection typically emit an electro-magnetic signal with an average frequency between 100 and 1000 Megahertz (MHz), similar to radio stations. In general, it can be said that the higher the frequency, the shorter the wave-length of the electro-magnetic wave. The wave-length is defining how well we can resolve structures in the subsurface: a shorter wave-length of higher frequency is able to "see" smaller objects. On the other hand, high frequency electro-magnetic waves suffer more from damping of the signal, compared to electro-magnetic waves with longer-wave lengths and lower frequency.

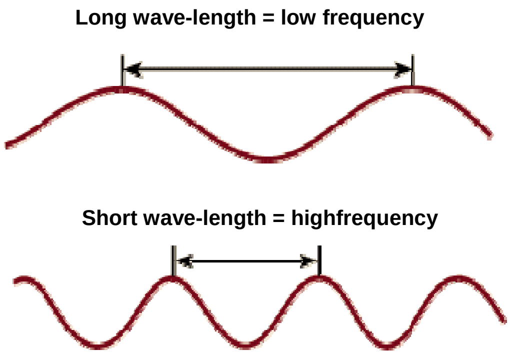

Fig. 2.1: Sketch, showing a low frequency signal of long wave-length (top), and a high frequency signal of short wave-length (bottom). Similar to acoustic waves, the low frequency range has less attenuation and travels further. It is a well known phenomenon that the low frequency bass of music penetrates walls and ceilings in buildings while the high frequency tones are filtered out.

The frequency dependent damping has the effect that the amplitude of the electro-magnetic signal decreases, the further the signal travels through the ground. Low frequency signals are better suited to look deeper into the ground than high frequency signals. Thus, for the selection of the antenna with the right frequency for our survey we need to make a compromise between penetration depth and desired resolution. Antennas with different frequencies are available (e.g. 100, 200, 250, 300, 500, 800, 900, 1000 MHz), and a 500 MHz antenna is often a good choice for archaeological investigations down to a depth of about 2 to 3 metres with 15cm to 20cm resolution.

The penetration depth and resolution of the georadar method does not only depend on the frequency of the antenna used, but as well on the soil properties at the measurement location. The physical properties of the ground determine the velocity and attenuation of the electro-magnetic waves. In particular, the electrical conductivity of the soil can have a great effect on the radar waves.

Soils with high clay content, or soils that contain a large amount of conductive water, are difficult to investigate with georadar. The uppermost layers of such soils soak up the energy of the electro-magnetic waves and prevent the energy to travel deeper. Sandy soils allow much better depth penetration. Fresh-water in itself poses no problem to GPR investigations. It is possible to conduct a radar survey from a boat, by suspending the antennas into the water of a lake or by placing them on the floor of a rubber-boat. In that case the electro-magnetic waves penetrate through the water into the sediment underneath. Similarly, it would be possible to measure on the frozen surface of lakes in winter time, for example to search for harbour constructions or wrecks in shallow water regions, that are inaccessible during summer due to reeds or other seasonal plants.

How is a GPR survey conducted?

Before a georadar survey is undertaken it is important to determine the specific conditions of the measurements site. Each project is different and requires the use of an antenna of suitable frequency and a carefully designed measurement grid. If linear structures, such as walls or ditches, are the target, it is best to measure perpendicular to the expected structure. Regular survey areas with equally long profiles allow faster, cheaper measurements, while survey areas that contain obstacles, such as trees, bushes, walls or fences, cause delays.

Fig. 2.2: Pär Karlsson operating the *Sensors & Software Noggin Plus* 500 MHz antenna mounted in the *SmartCart* for the survey of the upper parking place *Åkroken* in Nyköping. The data logger with integrated monitor is fastened in a carrier frame in front of the operator. Two profile lines with 1m separation distance are visible on the ground. The antenna is pushed along these lines and in between them with a GPR profile spacing of 25cm. Every 5cm along the profile a GPR trace is recorded.

While the GPR antenna is pulled over the surface an electromagnetic source signal is emitted into the ground. The antenna will then "listen" for fractions of a second and record the returning signal which has been reflected or refracted in the subsurface. For each measurement position along the profile line a *time-series* of amplitude values ("*GPR trace*") is recorded. It is important that the data is measured with very dense trace spacing (5cm in profile direction; 25 cm profile spacing).

How does GPR data look like?

Each GPR trace is a time-series of amplitude values of the reflections of the electromagnetic GPR signal, recorded with the receiver antenna, some time after emittance of the source signal from the source antenna, at a specific antenna location.
Each GPR profile consists of a large number of GPR traces. These traces can be plotted as an image with the profile distance as horizontal axis and the recording ("listening") time as vertical axis (Figures 2.3, 2.4). Such an image is called a "*GPR section*" or "*GPR profile*".

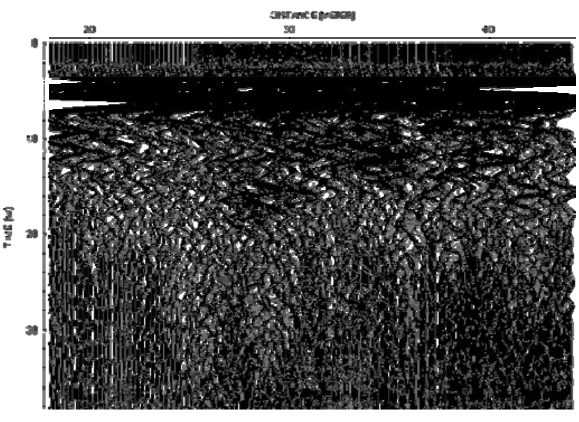

Fig. 2.3: A GPR section consisting of many GPR traces. The vertical axis is showing the two-way travel time of the GPR signal, and the horizontal axis denotes the distance along the profile.

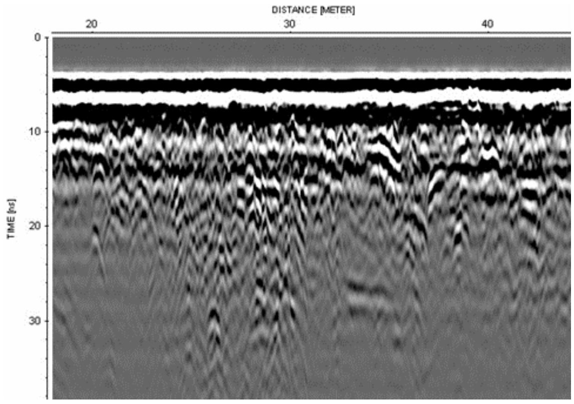

Fig. 2.4: The same data as in Fig.2.3 displayed using grey-scale colour values between negative, minimum amplitude (white) and positive, maximum amplitude values (black).

It is common to record many parallel GPR sections by measuring with the GPR antenna in zig-zag mode along parallel profiles across the survey area. The *cross-line* distance between the sections should be 25cm. The *inline* distance of traces in direction of the profile should be 3cm.

The individual GPR sections are merged into a three-dimensional (3D) data volume (Figure 2.5). Data values between the profile sections are interpolated in order to obtain a comparable sample density in inline and cross-line directions.

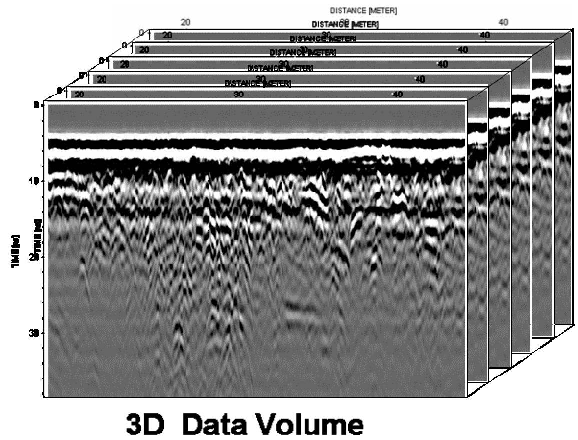

Fig. 2.5: Set of parallel GPR sections. This set of two-dimensional (2D) GPR sections can be merged into a three-dimensional (3D) data volume through interpolation between the sections. Normally, the sections are measured in zig-zag mode by pulling or pushing a GPR antenna back and forth over the survey area along parallel, equally long profile lines.

Such a 3D data volume can be cut like a cake in all directions. Slices of equal recording time, so called *time-slices*, can be generated by cutting the 3D data volume horizontally (Figures 2.6, 2.7).

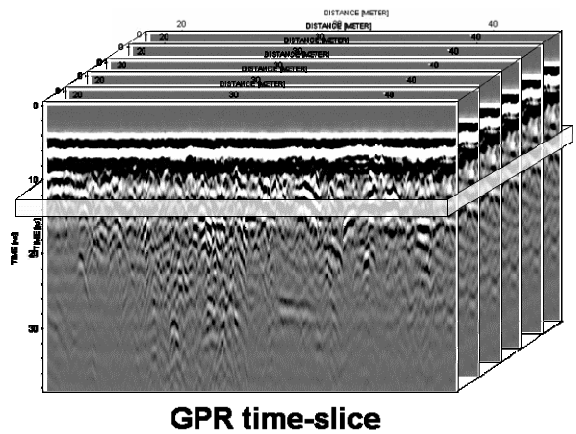

Fig. 2.6: A horizontal slice cut through the 3D data volume with travel-time as vertical axis is called a time-slice, since all data values have the same two-way travel-time value.

If the velocity of the electromagnetic waves in the subsurface is known, the 3D data volume can be converted into a 3D block with depth as the vertical axis. Then it is possible to generate *depth-slices*, which show the reflecting structures at a certain depth or within a certain depth range. Often an average velocity is used for the time-to-depth-conversion (e.g. 10cm/ns). It should be noted that in the case of an average velocity used, depth variations of up to 50%, compared to the real depth, can remain present in the data.

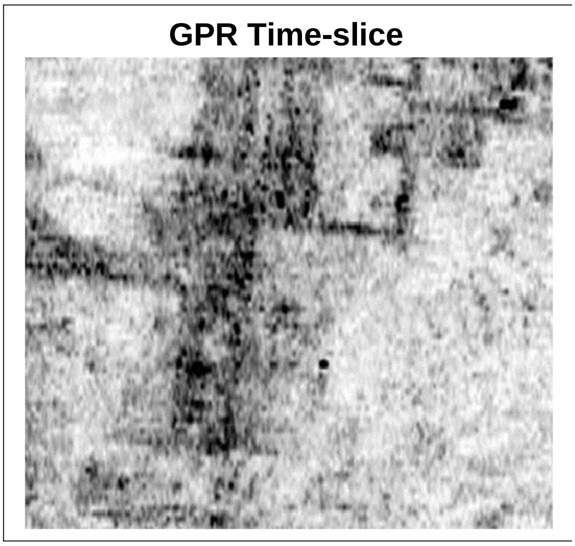

Fig. 2.7: A time-slice showing cables, or pipes, and the foundation walls of medieval buildings. This data example is not from Nyköping.

Structures in depth are best recognizable by analyzing a series of depth-slices. From a series of depth-slice images an animation (simple movie) can be generated. Then the viewer can observe the emergence and change of different structures with increasing, or decreasing depth.

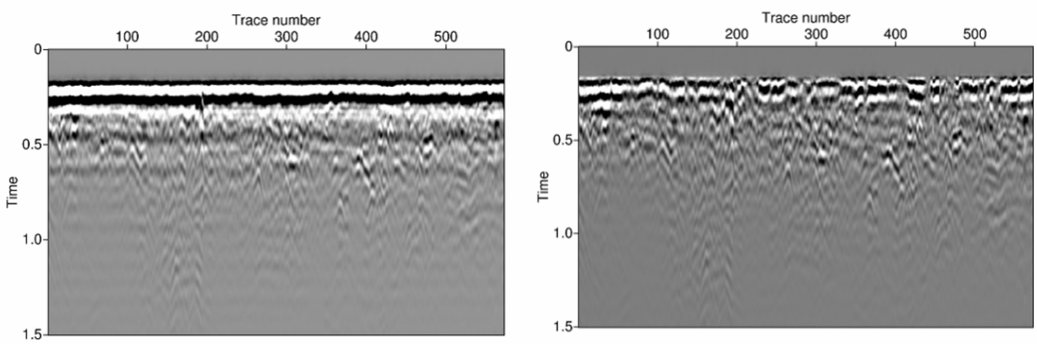

Fig. 2.8: GPR profile before (left) and after average trace removal (right). This process suppresses the direct-wave and reveals the reflections in the uppermost section. Furthermore, signal-ringing is removed from the data.

Other common GPR data processing steps are the removal of the *average trace*, or *background removal.* This process removes signal-ringing in the data and allows to image the uppermost region of the data, which otherwise would be hidden by the high amplitudes of the *direct-wave.* The *direct-wave* is the wave that travels directly from the source antenna to the receiver antenna, which are often located both inside the same GPR antenna box. The direct-wave is the first signal that is recorded by the receiver antenna. Since the direct-wave is of several ns length, it covers the reflections that occur in the uppermost layers of the subsurface.

What objects can GPR detect?

Under the right conditions georadar can be used to detect the foundations of buildings, canalisation pipes, pits, ditches, graves, cavities and geological structures such as layer interfaces and faults.

It is important to realize that the GPR method cannot guarantee the detection of objects or structures, particularly if they are small in size (relative to the wave-length used), if their physical properties do not differentiate them from the surrounding material or if the soil conditions are adverse.

Under the right conditions georadar can be used to detect the foundations of buildings, canalisation pipes, pits, ditches, graves, cavities and geological structures such as layer interfaces and faults.

It is important to realize that the GPR method cannot guarantee the detection of objects or structures, particularly if they are small in size (relative to the wave-length used), if their physical properties do not differentiate them from the surrounding material or if the soil conditions are adverse.

Under the right conditions GPR measurements allow the archaeologist to obtain an image of structures that are hidden in the subsurface without digging. GPR surveying, similar to magnetic prospection, is a non-destructive method. In addition to the structural information obtained through magnetic prospection, GPR measurements provide information about the relative depth of the structures. If the velocity of the radar waves in the subsurface is known, the absolute depth of structures seen in the GPR data can be determined.

The results of georadar measurements can be used to plan excavation activities efficiently in regard of costs and time. GPR measurements make it possible to target interesting structures and to excavate selectively with the benefit of prior knowledge.

Suggested reading

- Conyers L., Goodman D., 1997. *Ground-penetrating radar: an introduction for archaeologists.* Walnut Creek, Calif., AltaMira Press.

- Gaffney C.F., Gater J., 2003. *Revealing the buried past: geophysics for archaeologists.* Tempus.

- Leckebusch J., 2003. Ground-penetrating Radar: A Modern Three-dimensional Prospection Method. *Archaeological Prospection*, 10, 213–240.

- Leckebusch J., 2005. Use of antenna arrays for GPR surveying in archaeology. *Near Surface Geophysics*, 3, 109-113.

3 Description of GPR survey and discussion of the results

This section describes the technical details of the GPR survey as well as the location of the individual survey areas. For each survey area the data interpretation is presented and the results are discussed. An archaeological interpretation is suggested wherever possible. An overview of all survey areas is given in Figure 1.1.

The GPR measurements were conducted using a manually operated *Sensors & Software* 500MHz *Noggin Plus* mounted together with a *DVLIII* data logger onto a *SmartCart* (see photo title page). An odometer attached to one of the cart wheels was used for accurate positioning of the data along the profile. The antenna was pulled along up to 50m long profile lines that where marked every meter. If the geometry of the survey area required shorter profile length than 50m, the length of the profiles was reduced and measured to the nearest meter marking. Prior to the measurements the odometer was calibrated along a 50m profile.

In case of the parking spaces the survey area had been cleared of vehicles in order to enable access to the entire area. The survey areas were staked out using three 50m long measuring tapes. For each survey area at least three reference points were measured with a geo-referenced total station.

For all measurements the data recording length was set to 80ns at 512 samples. Assuming a constant velocity of the GPR signal in the subsurface of 10cm/ns this setting corresponds to a maximum investigation depth of 4m. The inline trace interval was set to 5cm and the cross-line profile distance was 25cm for all survey areas, except the small area in the north-west of *Mejeriet (lower part)*, which was surveyed with 50cm cross-line sample spacing. The internal trace stacking was set to a value of 4.

The weather remained dry and warm throughout the entire period of field work.

Data processing was conducted by Alois Eder-Hinterleitner (*Institute for Meteorology and Geodynamics*, Vienna). The time-to-depth conversion of the GPR data for the generation of depth-slices was performed with a constant velocity of 10cm/ns for all survey areas.

3.1 Survey site *Mejeriet (lower part)*

The survey site *Mejeriet (lower part)* is located between *Folkungavägen* in the west, *Bruksgränd* in the east, the river in the south and the first building in the north (Figure 3.1.1). The area is covered with lawn, a sand road and foot path and a sand covered parking space south of the building.

Figure 3.1.1: Photograph showing survey site *Mejeriet (lower part).*

In past times this area was part of *Nyköpings bruk*, a large brass production and metal treatment site. Information signs in the area (red posts in Figure 3.1.1) contain a photograph showing the mansion of the brass mill (Figure 3.1.2b). A picture taken from approximate the same view point can be seen in Figure 3.1.2a.

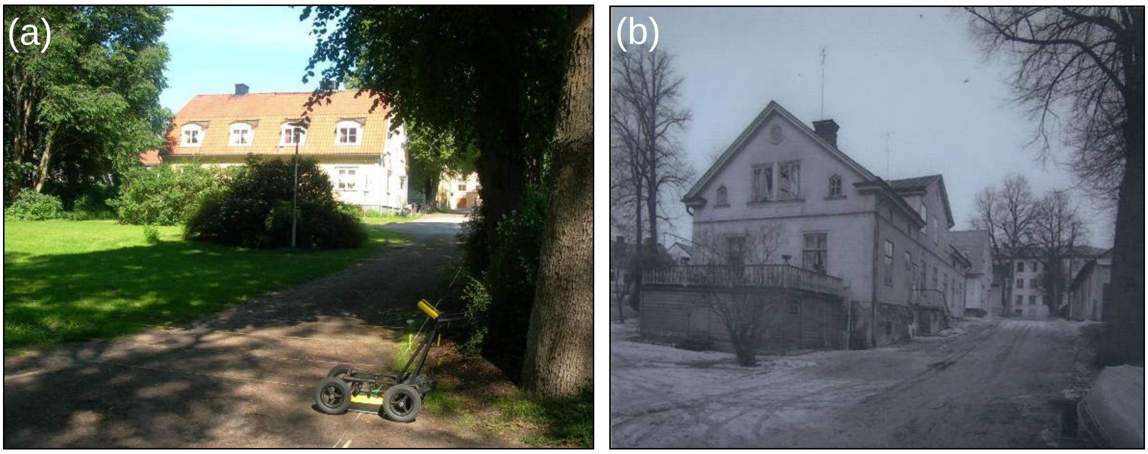

Figure 3.1.2: (a) Photograph showing the orientation of the GPR profiles and the baseline of the survey along the eastern edge of *Bruksgränd.* (b) Historic photo taken from approximately the same point of view showing the mansion of the brass mill in the foreground. In the background the same building as shown in (a) can be seen. Photo: O. Hagelroth 1962, Sörmlands Museum.

Figure 3.1.3 shows the survey site from the pedestrian entrance at *Folkungavägen.* The footpath covered with sand is well visible in the GPR data. A smaller survey area located adjacent to *Folkungavägen* was measured separately with a cross-line profile spacing of 50cm (Figure 3.1.4).

In Section 6.1 Figures 6.1.1 to 6.1.30 show depth-slices of 10cm thickness between 0m and 3m depth of the GPR data measured at this site.

Interesting structures contained in the data of the survey site *Mejeriet (lower part)* are presented below. An interpretation of the anomalies is attempted and possible causes suggested.

Figure 3.1.3: Photograph showing survey site *Mejeriet (lower part)* from the pedestrian entrance at *Folkungavägen*.

Figure 3.1.4: (a) Photograph of the most western part of the area east of *Folkungavägen*: view from the south. (b) Photograph of the same area as shown in (a): view from the north. The survey lines with one meter separation can be seen on the ground. This part of the survey area *Mejeriet (lower part)* was surveyed with 50cm profile spacing, while the larger area to the east was surveyed with 25cm cross-line spacing.

Figure 3.1.5 presents an interpretation of anomalies and structures in the GPR data. The information form different depth-levels are merged into one 2-dimensional map. It is necessary always to consult the data in form of the depth-slices shown in the Abstract, or even better in form of an animation. The interpretation shall merely guide to, and illustrate prominent features. Areas of high, intermediate and low reflectivity are drawn in the interpretation, as well as anomalies that can clearly be interpreted as utilities (e.g. cables and pipes), surface features such as path or roads. Incoherent linear features visible in the data that are difficult to interpret have been drawn as thin black lines.

The selected depth-slices shown in Figure 3.1.6 to 3.1.11 illustrate the interpreted anomalies with increasing depth.

Figure 3.1.6 clearly shows the anomaly caused by the foot path that enters the survey site in the south-west from *Folkungavägen*, as well as the dark structures in the north-western area, which may be caused by a utility trench.

Figure 3.1.7 shows utilities in the northern part of the survey area as dark, reflective structures.

Figures 3.1.8 and 3.1.9 show a highly reflective dark band in the north-western part of the survey area which is likely to be caused by the remains of the small creek that is visible in the historic map of the year 1888 in this area (see Figure 1.3).

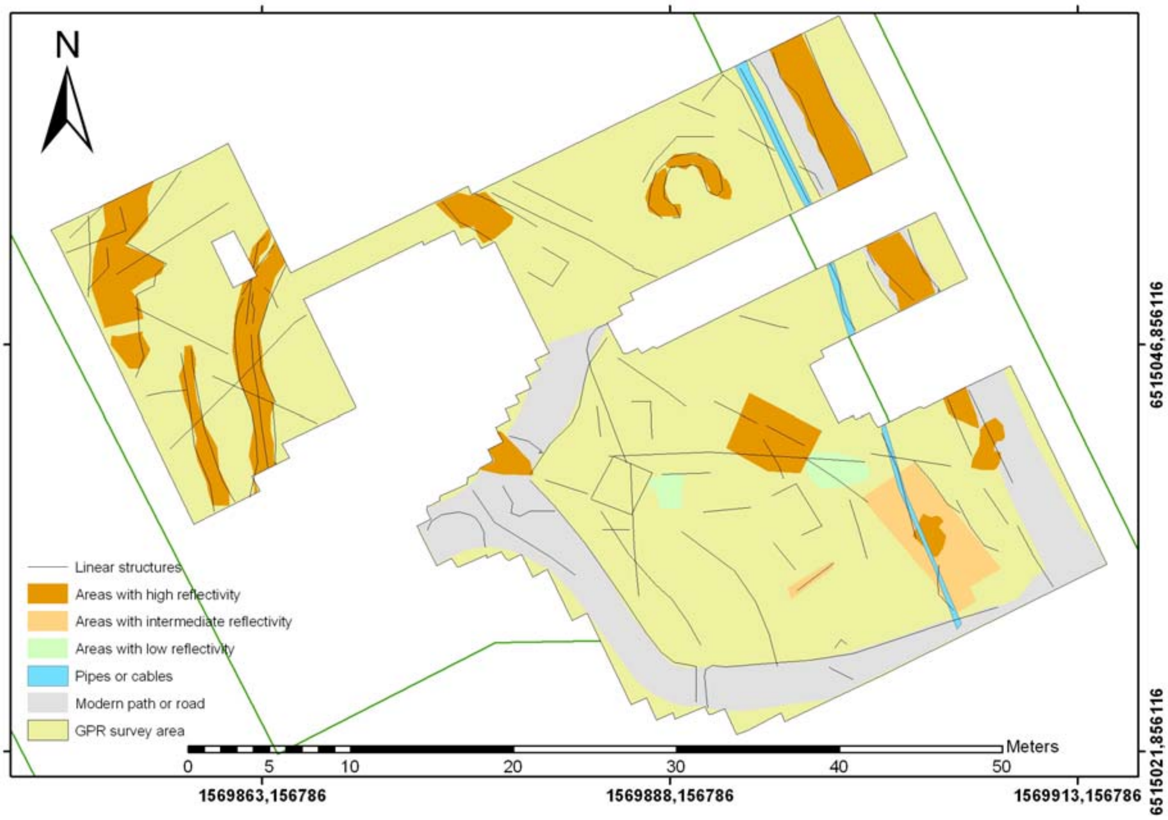

Figure 3.1.5: Interpretation of the GPR data recorded at the survey site *Mejeriet (lower part).*

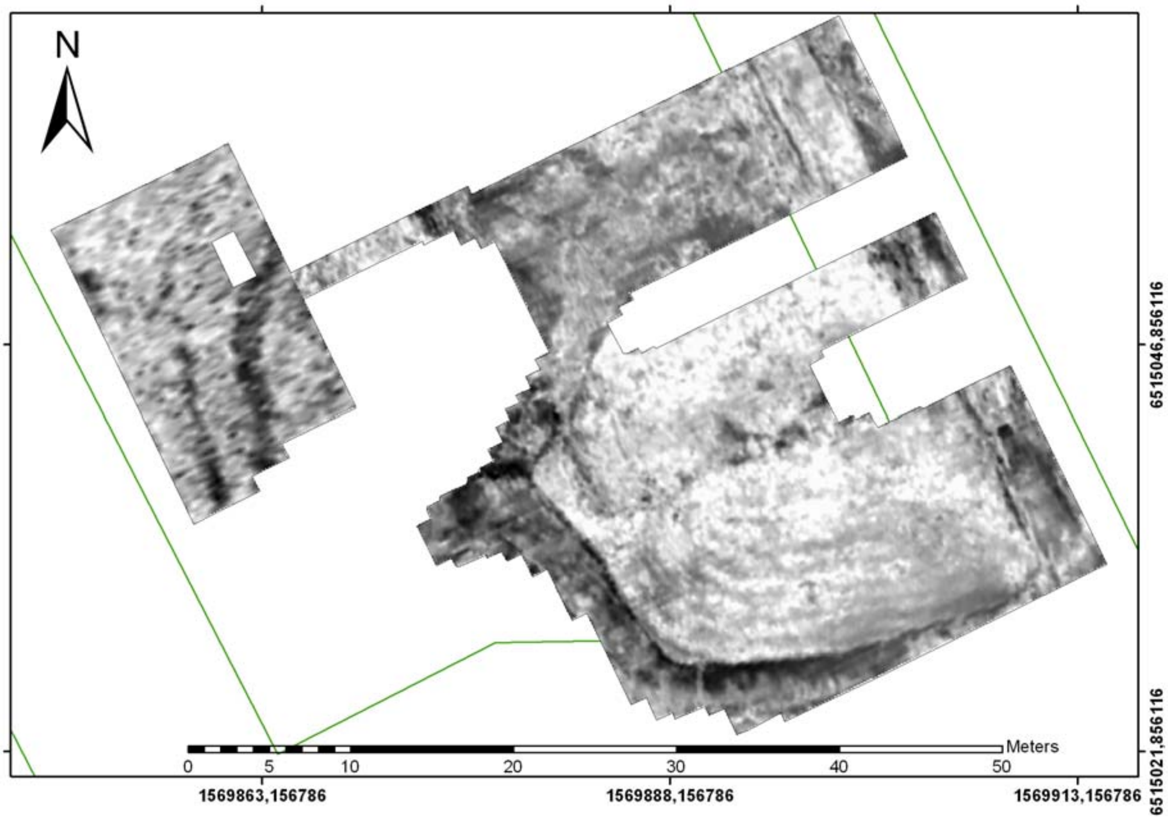

Figure 3.1.6: GPR depth-slice (10-20cm) of the survey site *Mejeriet (lower part).*

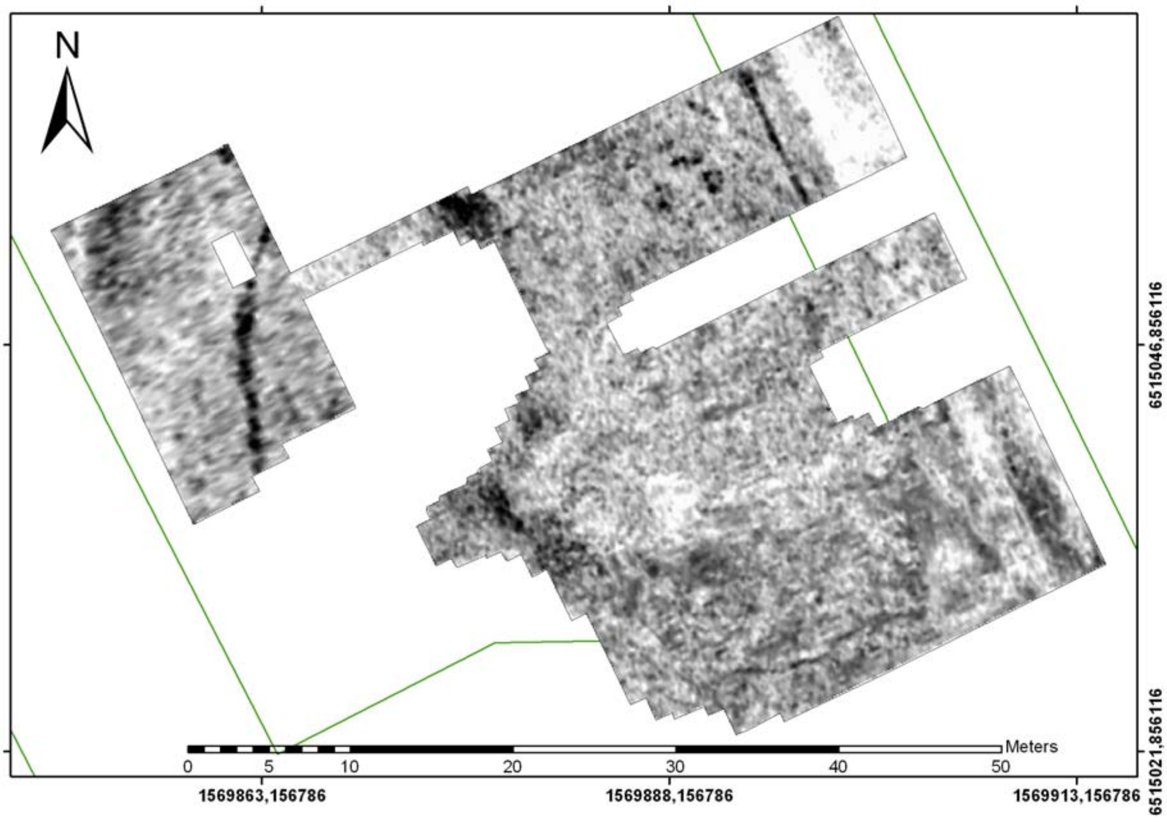

Figure 3.1.7: GPR depth-slice (60-70cm) of the survey site *Mejeriet (lower part).*

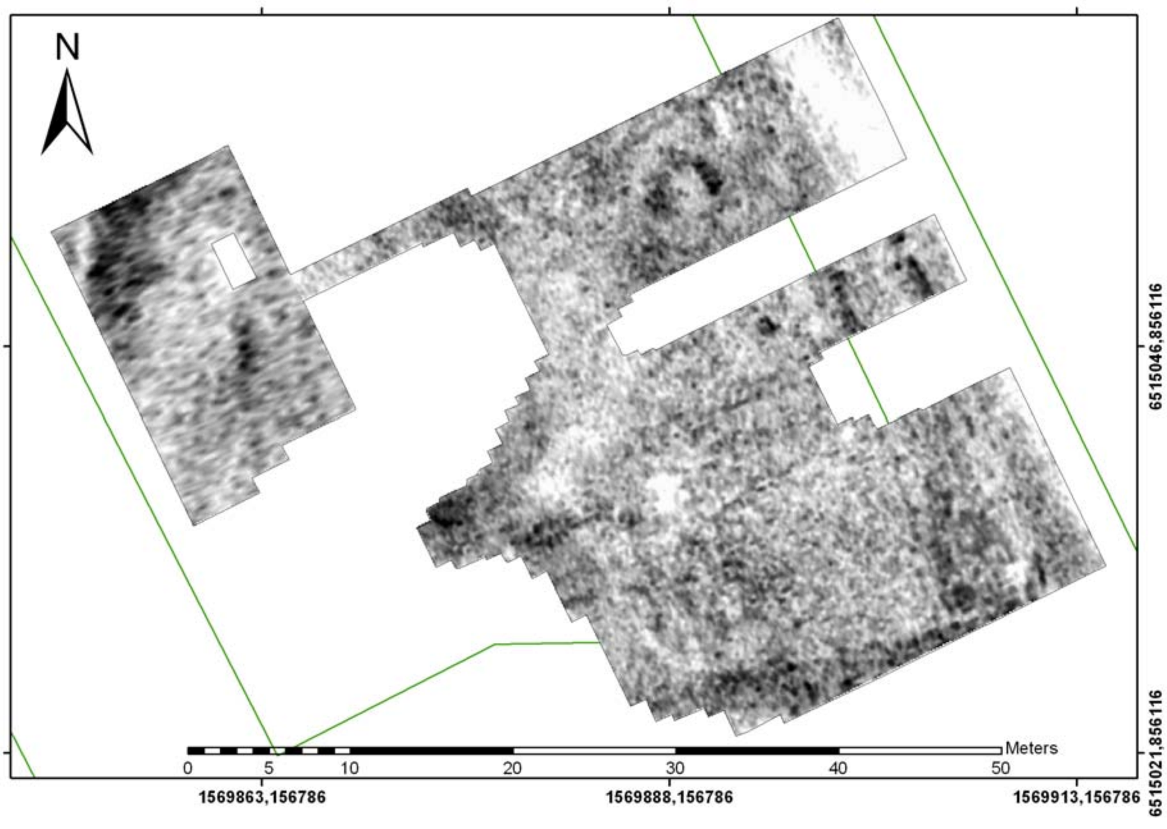

Figure 3.1.8: GPR depth-slice (90-100cm) of the survey site *Mejeriet (lower part).*

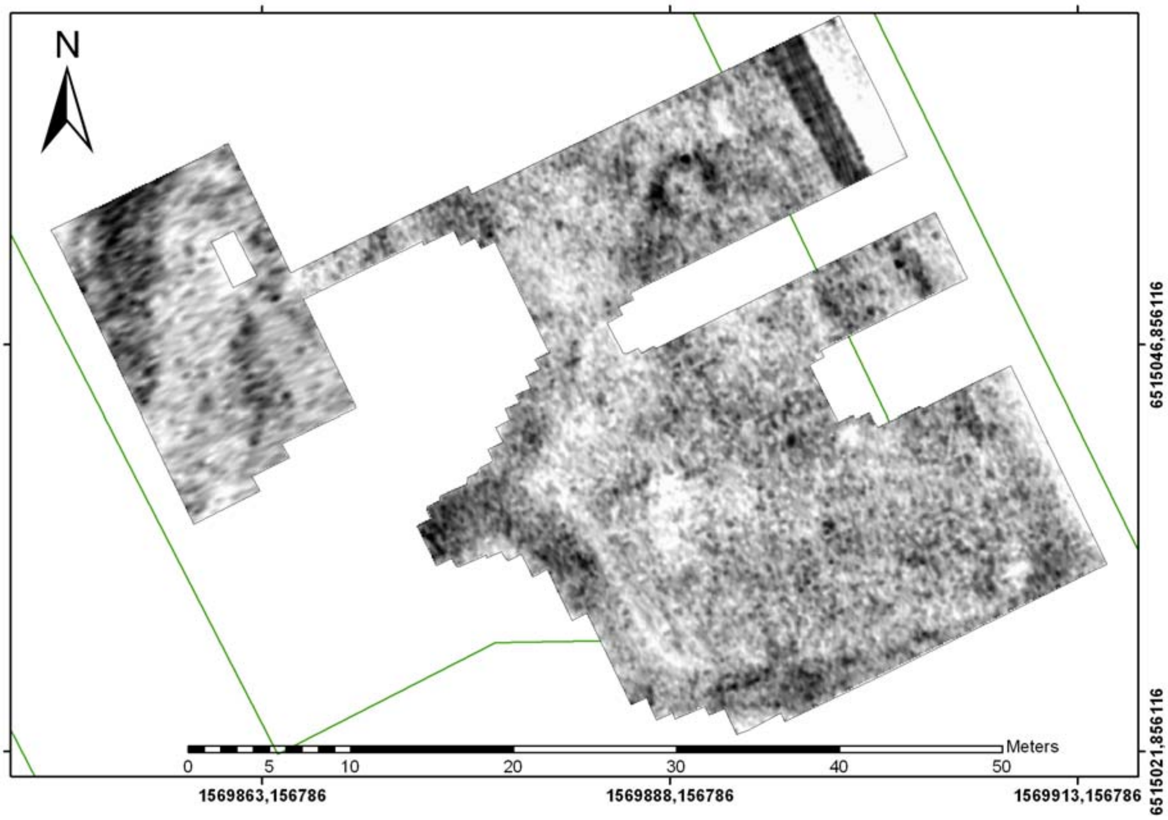

Figure 3.1.9: GPR depth-slice (120-130cm) of the survey site *Mejeriet (lower part)*.

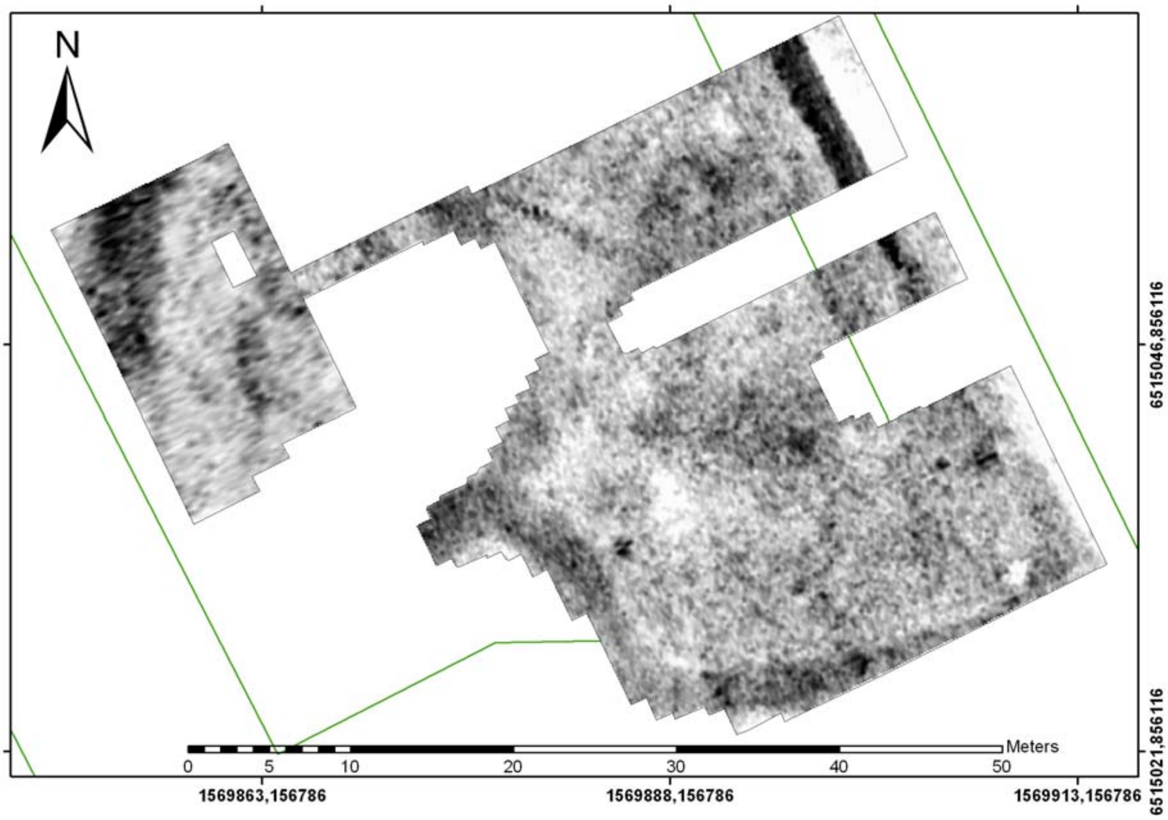

Figure 3.1.10: GPR depth-slice (150-160cm) of the survey site *Mejeriet (lower part)*.

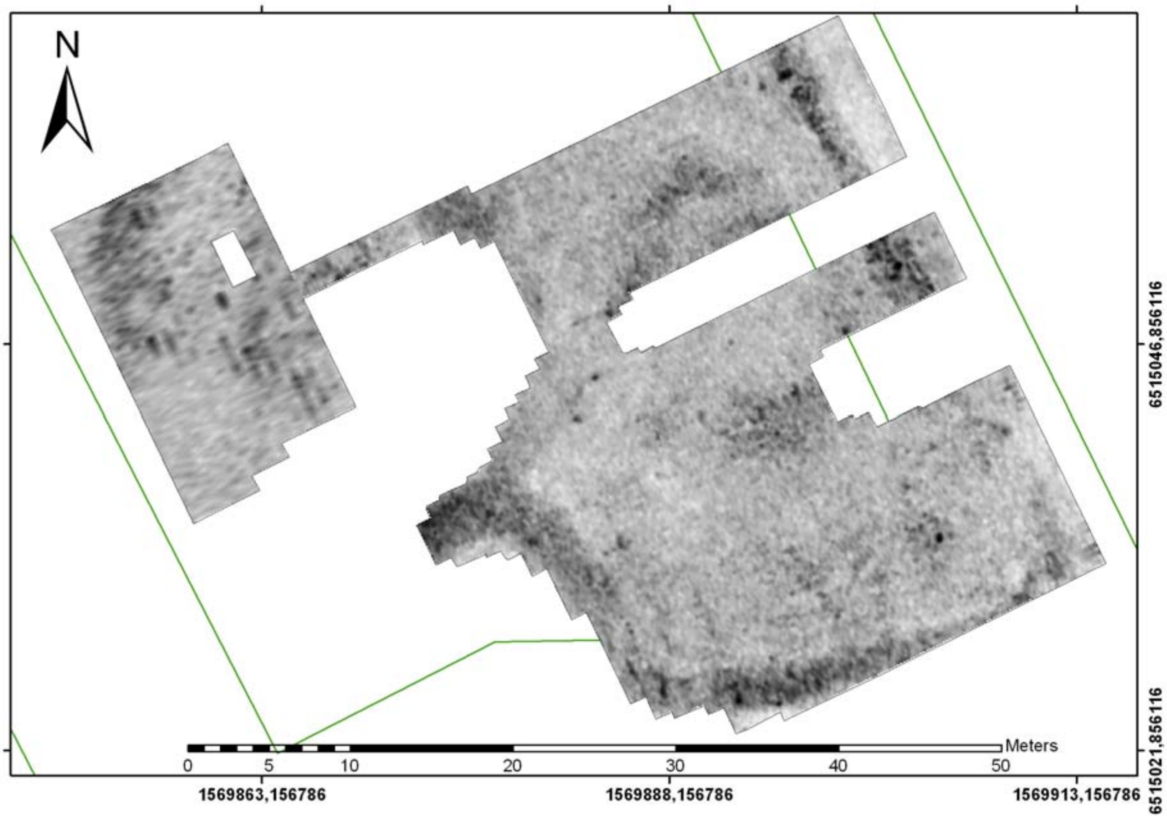

Figure 3.1.11: GPR depth-slice (220-230cm) of the survey site *Mejeriet (lower part)*.

Figure 3.1.7 shows in the south-east part of the survey area a rectangular structure that is marked in the interpretation as “Area with intermediate reflectivity”. This structure may have been caused by a building at this site.

Figures 3.1.7 to 3.1.9 show a dark, ring shaped structure in the area of the parking space just south of the building that is visible in Figure 3.1.1.

Figure 3.1.10 furthermore shows a possible pipe, cable or trench in that area running from west-north-west to east-south-east.

Figure 3.1.11 illustrates the signal strength at about 220-230m depth (assumed GPR signal velocity of 10cm/ns). Only little coherent structure is visible at this depth. This could be due to the signal having reached the bottom of the cultural layer. However, it is possible that non-reflective structures are present at this or greater depth. The lack of signal can not be interpreted as absence of archaeological structures. However, the homogeneous grey areas suggest that the underlying clay layer has partly been reached at the approximate depth of 220-230cm.

3.2 Survey site *Mejeriet (upper part)*

Survey site *Mejeriet (upper part)* is located between two buildings south of *Västra Kvarngatan* and between *Folkungavägen* and *Bruksgränd*. The site is a currently used as a parking place covered with sand (Figure 3.2.1 & 3.2.2).

Figure 3.2.1: Photograph of the survey site *Mejeriet (upper part)* as seen from *Folkungavägen*.

Figure 3.2.2: Photograph of the survey site *Mejeriet (upper part)* looking towards *Folkungavägen*.

The map depicted in Figure 1.3 shows the large *Mejeri* building on this site. Figure 3.2.3 shows manhole cover, indicating canalisation pipes in the area.

All GPR depth-slices of 10cm thickness from this site can be found in the Appendix 6.2. Selected depth-slices are shown in Figure 3.2.5 to 3.2.15. An interpretation of the data is shown in Figure 3.2.4.

The topmost depth-slice (Figure 3.2.5) shows traces of the pedestrian footpath at the corner *Folkungavägen - Västra Kvarngatan.*

Figure 3.2.3: Photograph showing manhole cover at the survey site *Mejeriet (upper part).*

At an approximate depth of 40-60cm we can see a cable or pipe underneath the footpath along *Västra Kvarngatan* and a highly reflective area in the eastern part of the site, crossed by linear anomalies (Figure 3.2.6 & 3.2.7).

Figure 3.2.8 shows the emergence of wall structures at a depth of approximately 70-80cm. These structures become clearer expressed at greater depth as shown in the depth-slices in Figures 3.2.9 to 3.2.13. Between the walls areas of reduced reflectivity are contained.
Below 230m depth only strong reflective structures are visible (Figures 3.2.14 & 3.2.15).

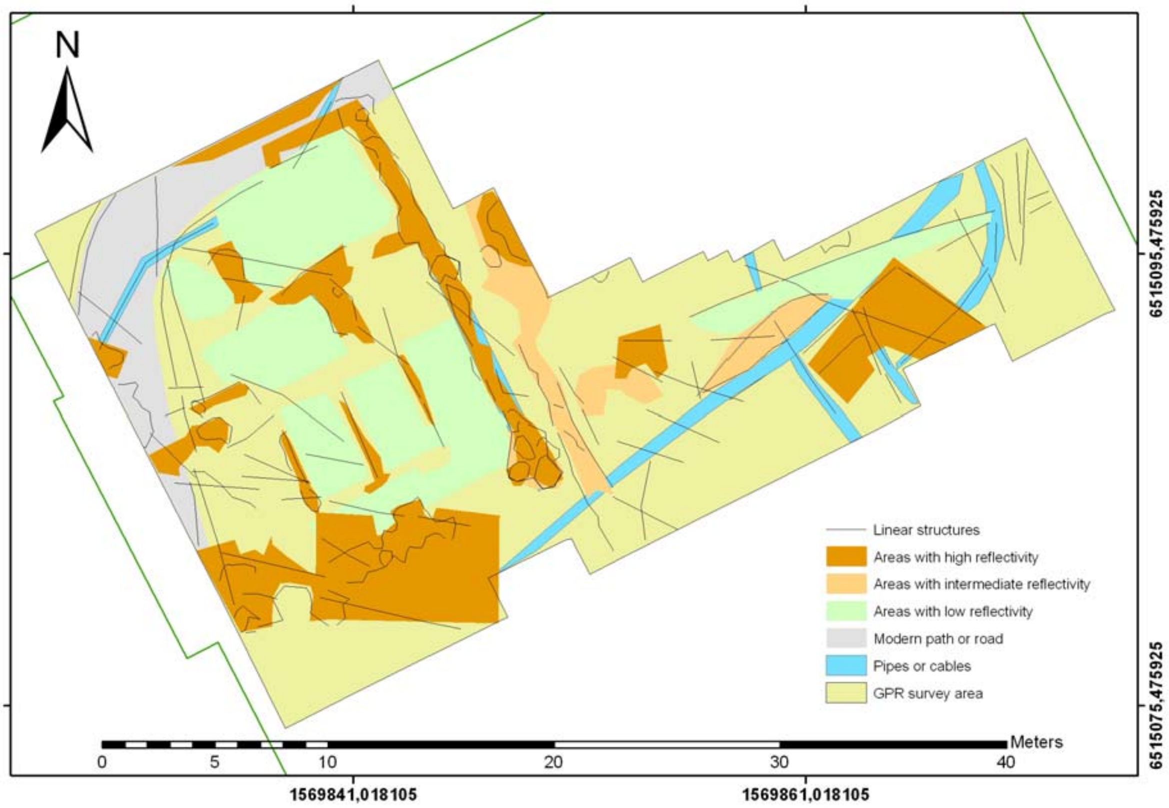

Figure 3.2.4: Interpretation of the GPR data recorded at the survey site *Mejeriet (upper part)*.

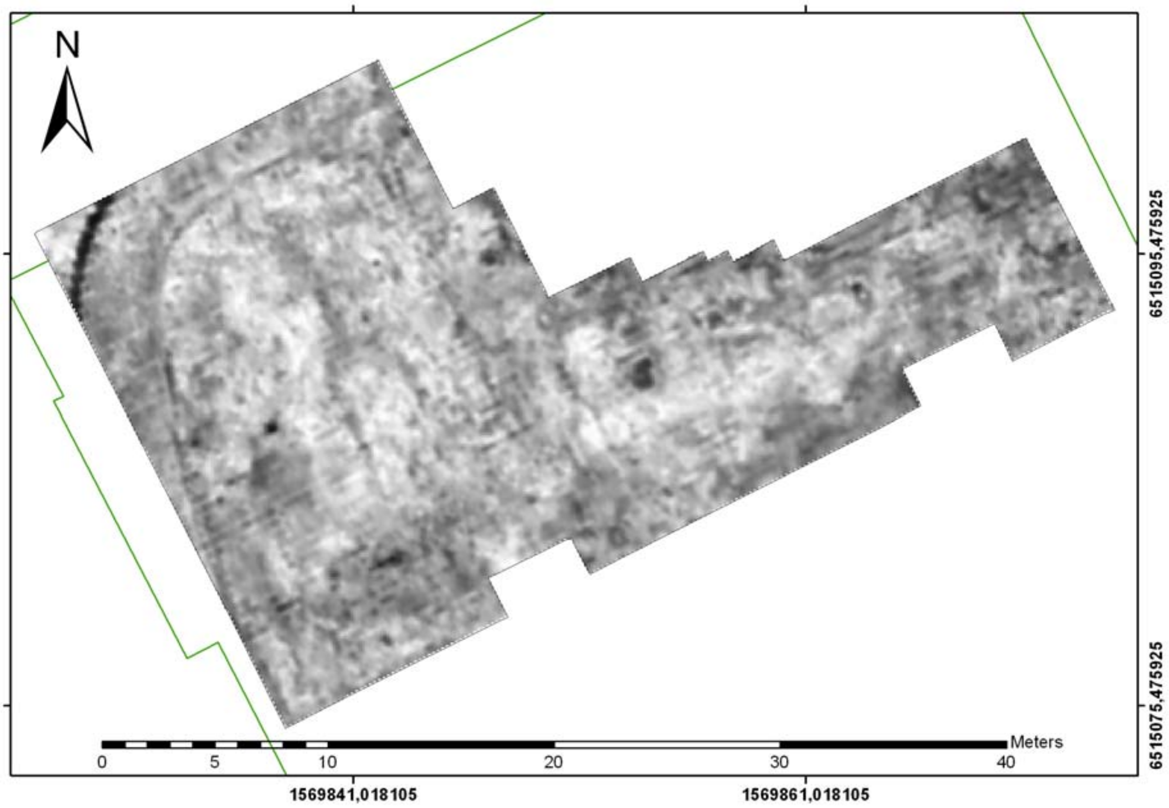

Figure 3.2.5: GPR depth-slice (0-10cm) of the survey site *Mejeriet (upper part)*.

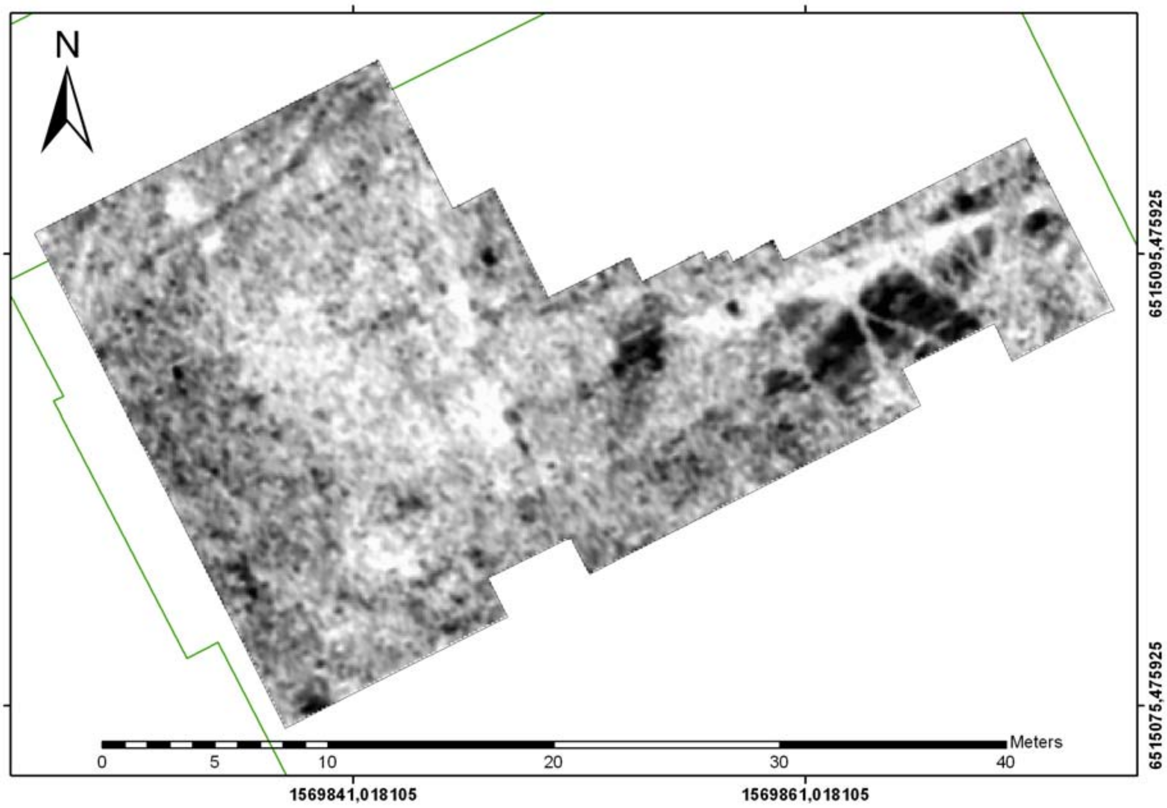

Figure 3.2.6: GPR depth-slice (40-50cm) of the survey site *Mejeriet (upper part)*.

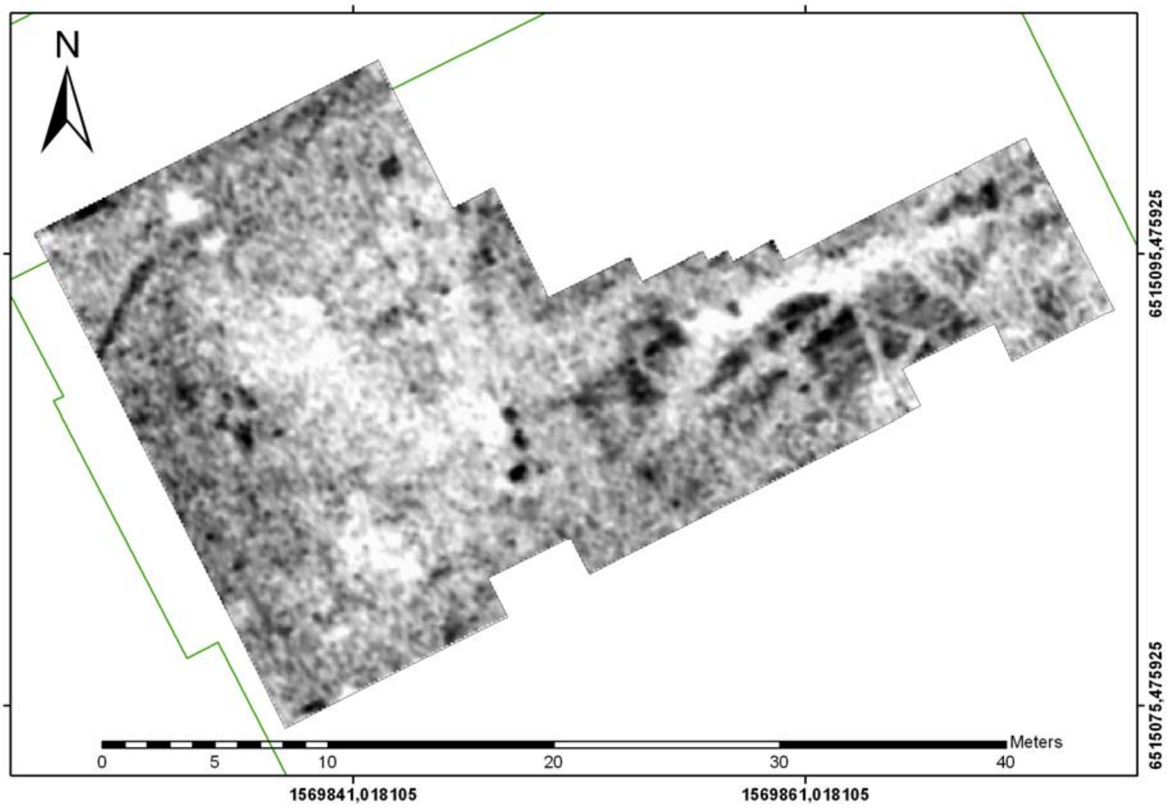

Figure 3.2.7: GPR depth-slice (50-60cm) of the survey site *Mejeriet (upper part)*.

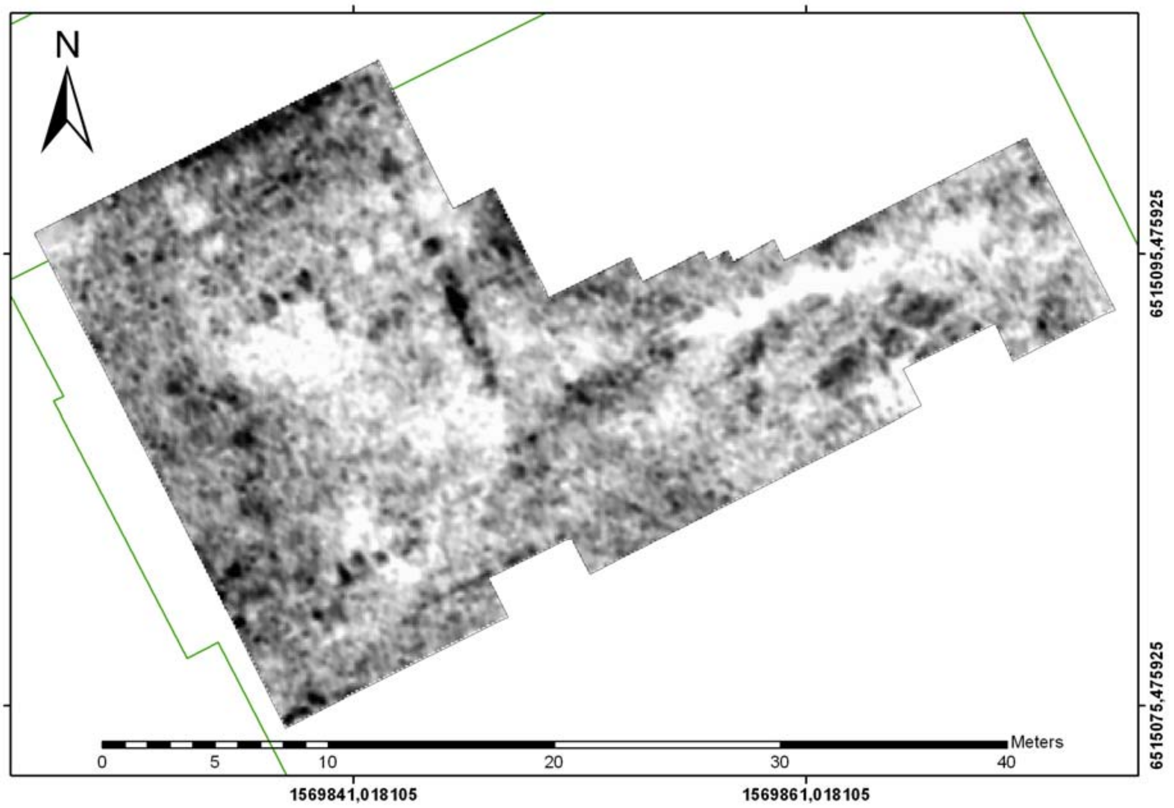

Figure 3.2.8: GPR depth-slice (70-80cm) of the survey site *Mejeriet (upper part).*

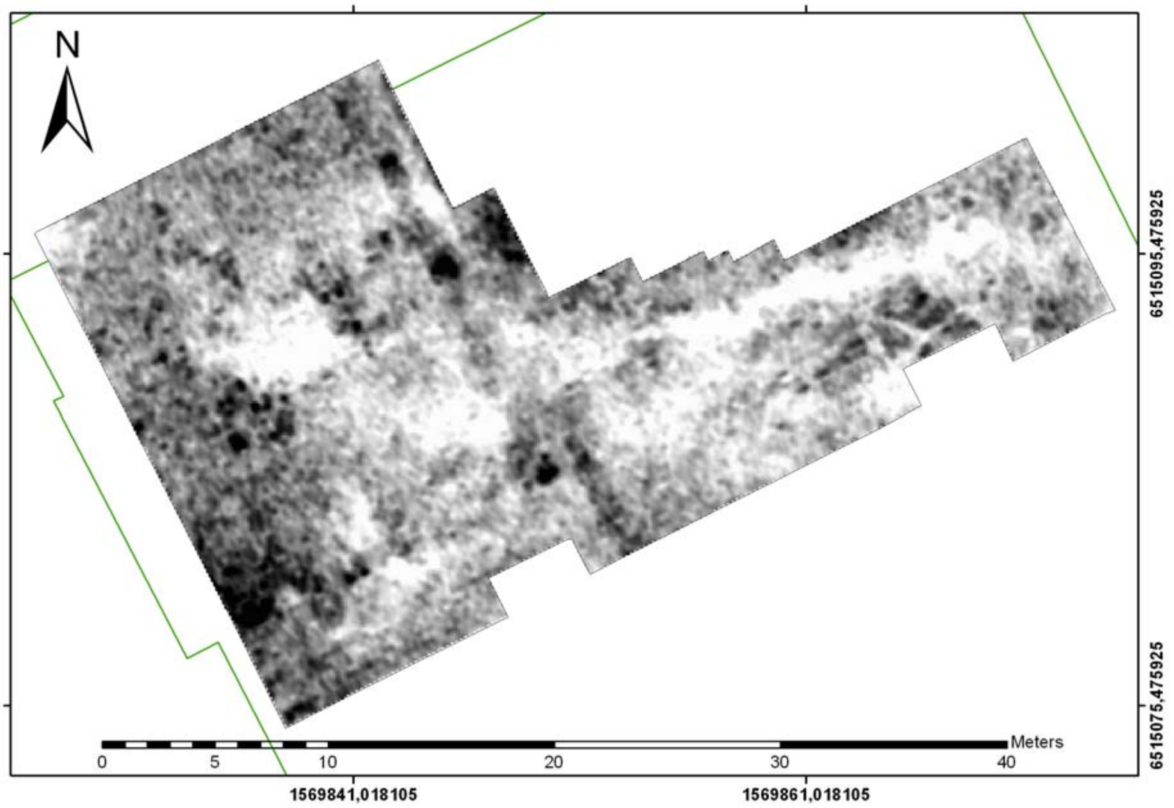

Figure 3.2.9: GPR depth-slice (90-100cm) of the survey site *Mejeriet (upper part).*

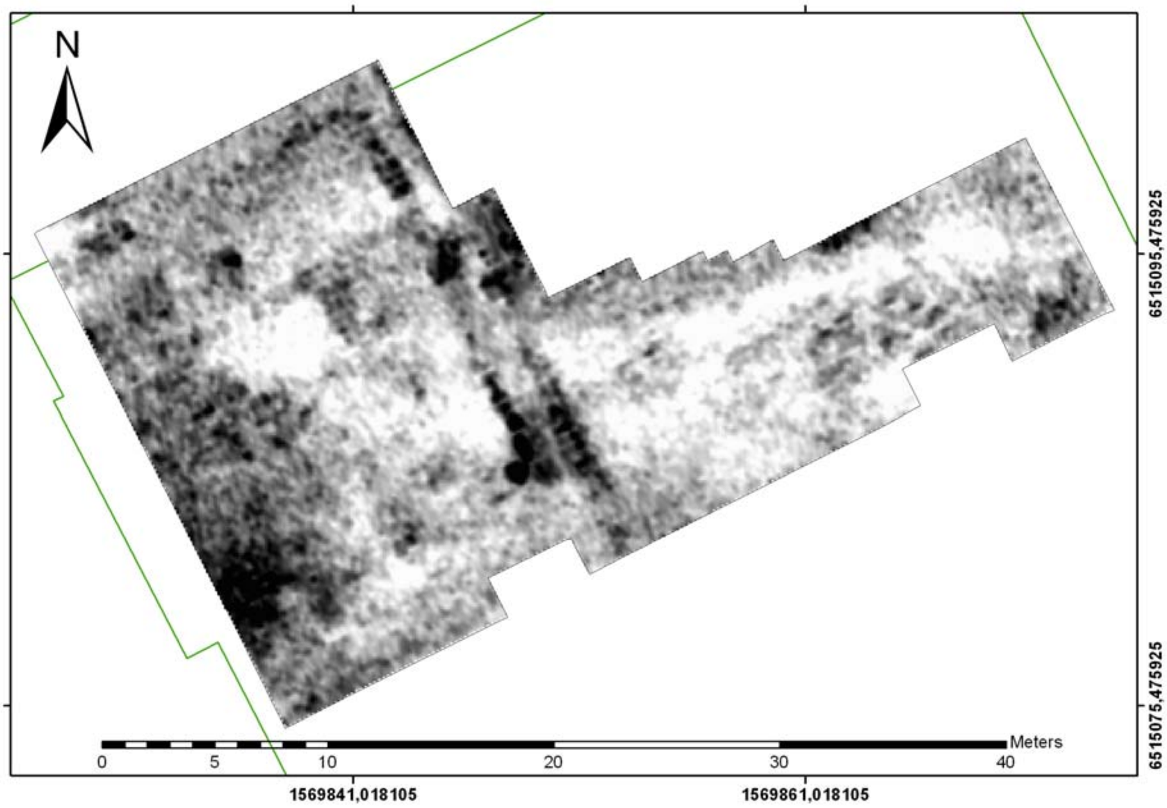

Figure 3.2.10: GPR depth-slice (110-120cm) of the survey site *Mejeriet (upper part)*.

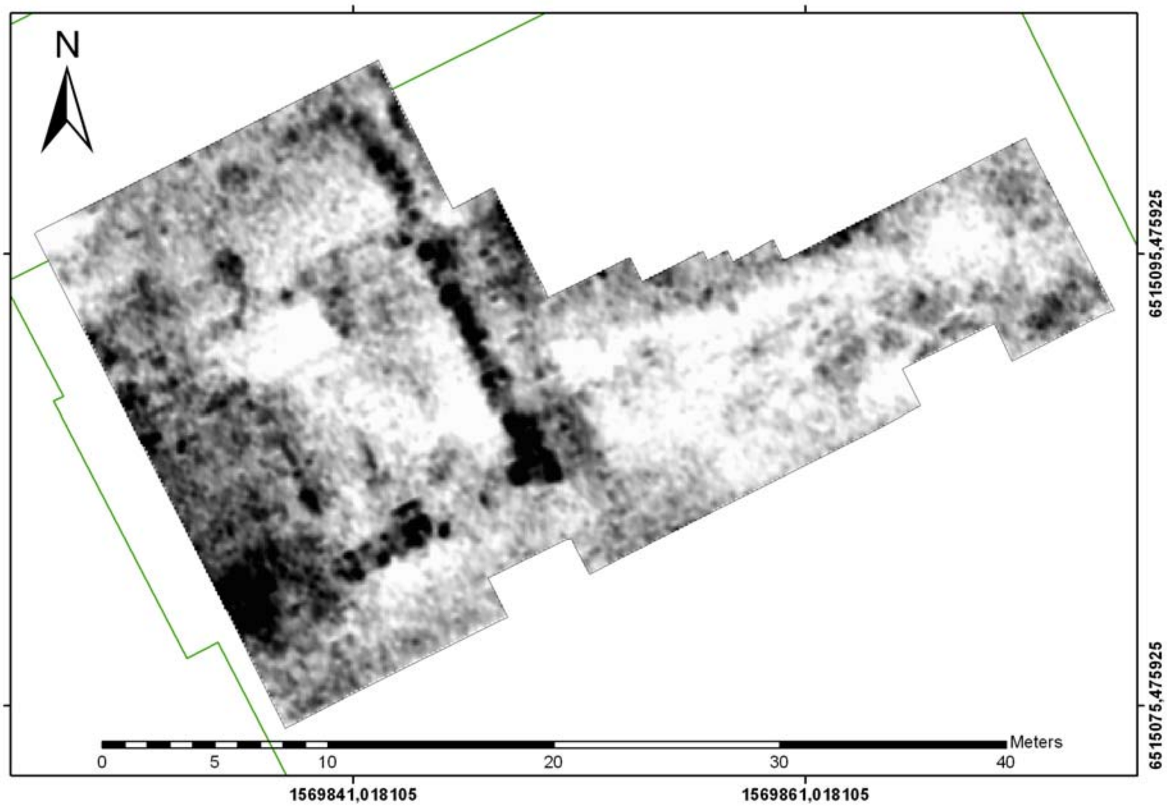

Figure 3.2.11: GPR depth-slice (130-140cm) of the survey site *Mejeriet (upper part)*.

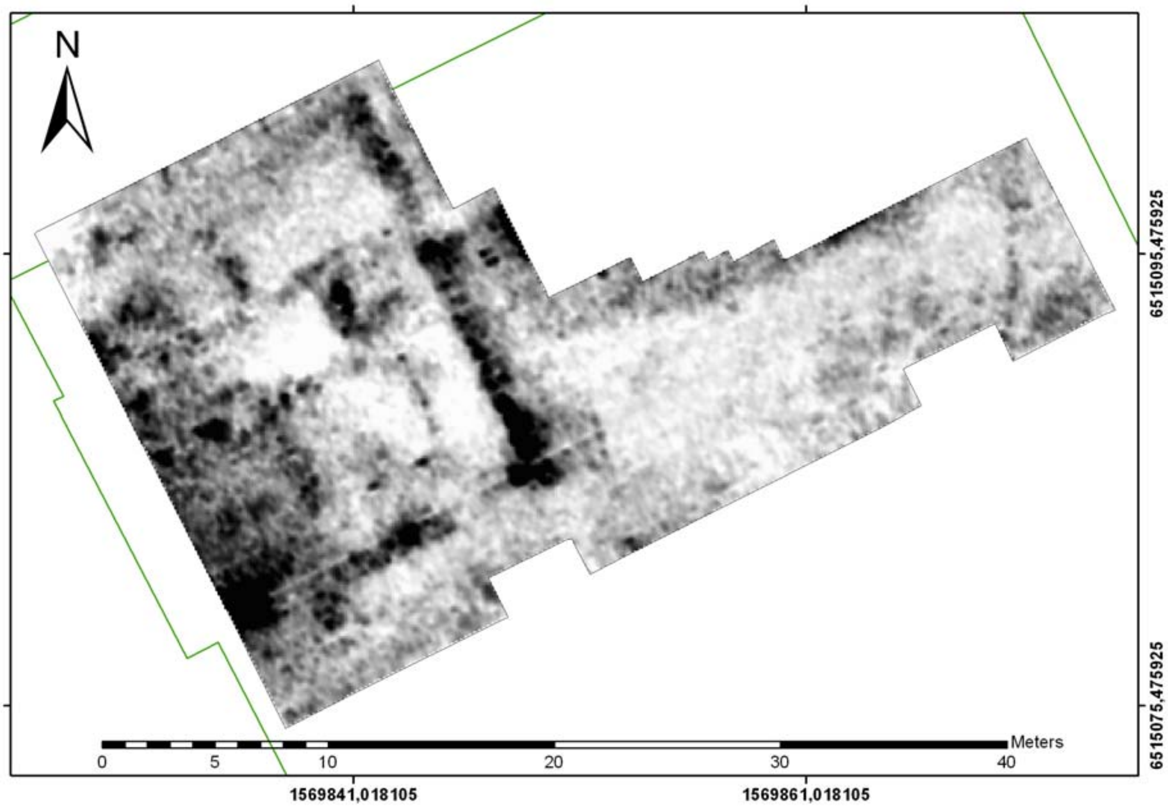

Figure 3.2.12: GPR depth-slice (160-170cm) of the survey site *Mejeriet (upper part)*.

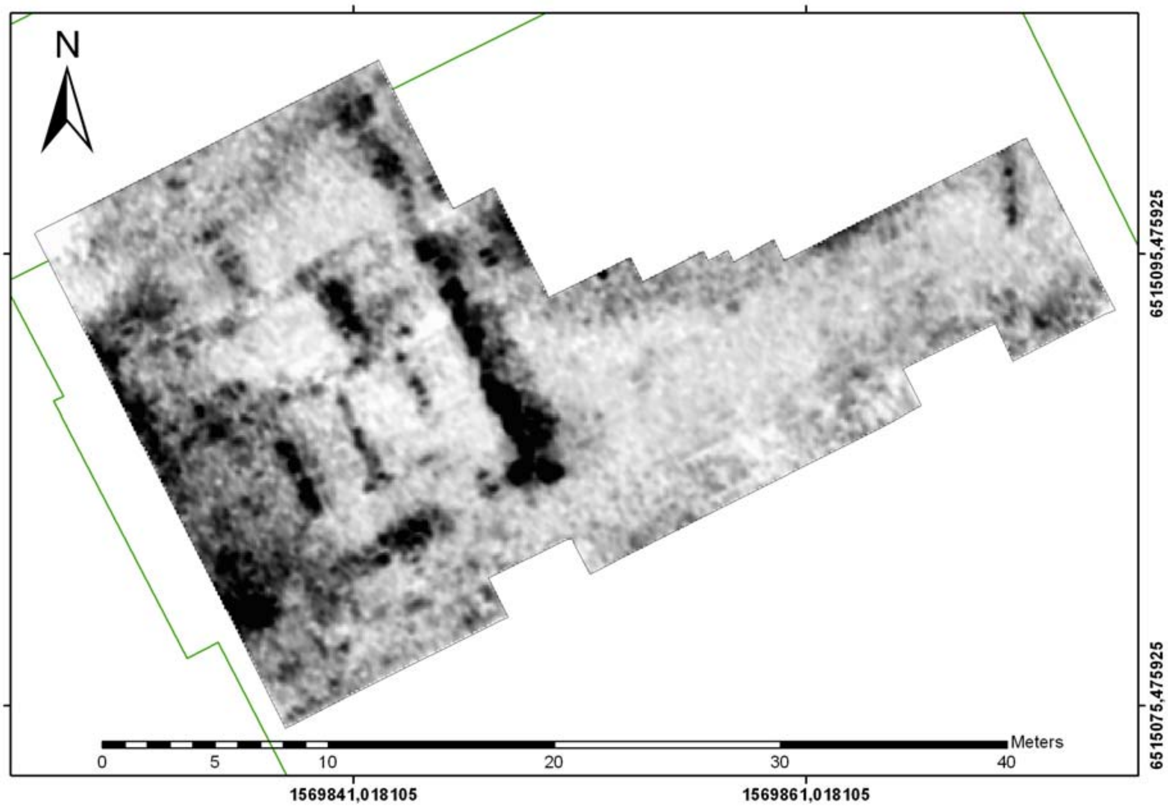

Figure 3.2.13: GPR depth-slice (180-190cm) of the survey site *Mejeriet (upper part)*.

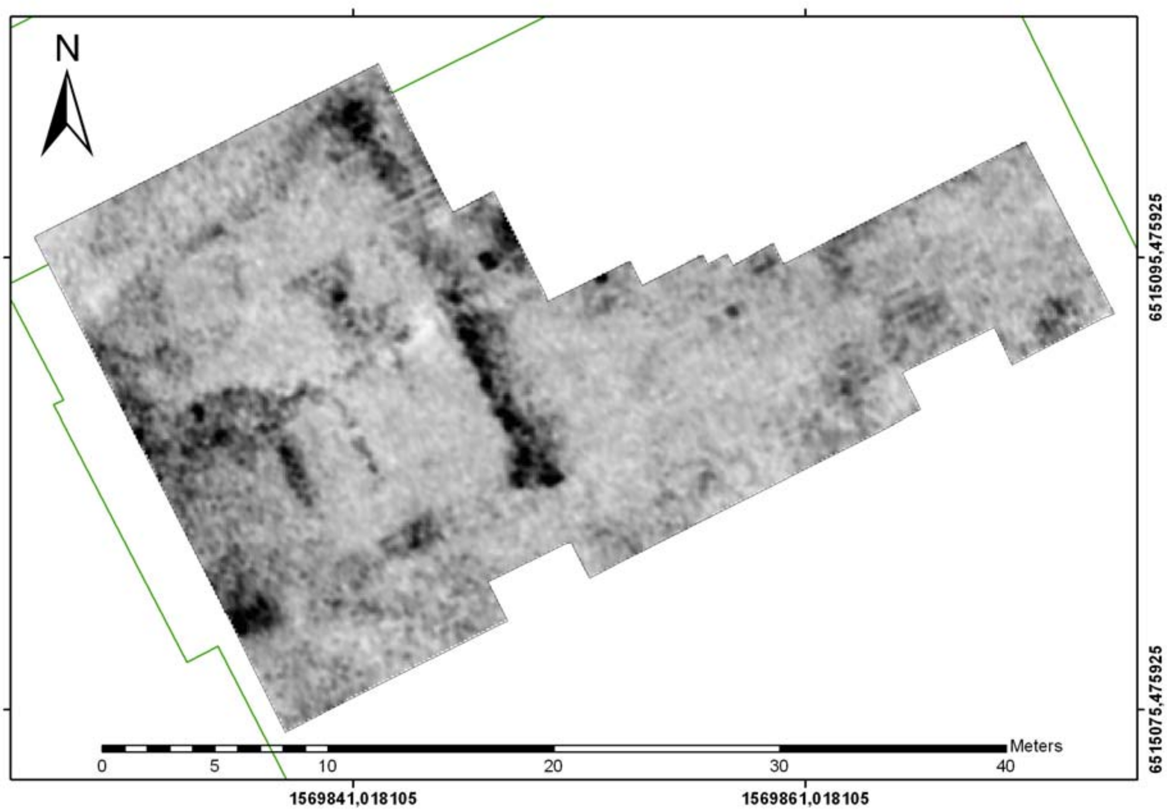

Figure 3.2.14: GPR depth-slice (230-240cm) of the survey site *Mejeriet (upper part)*.

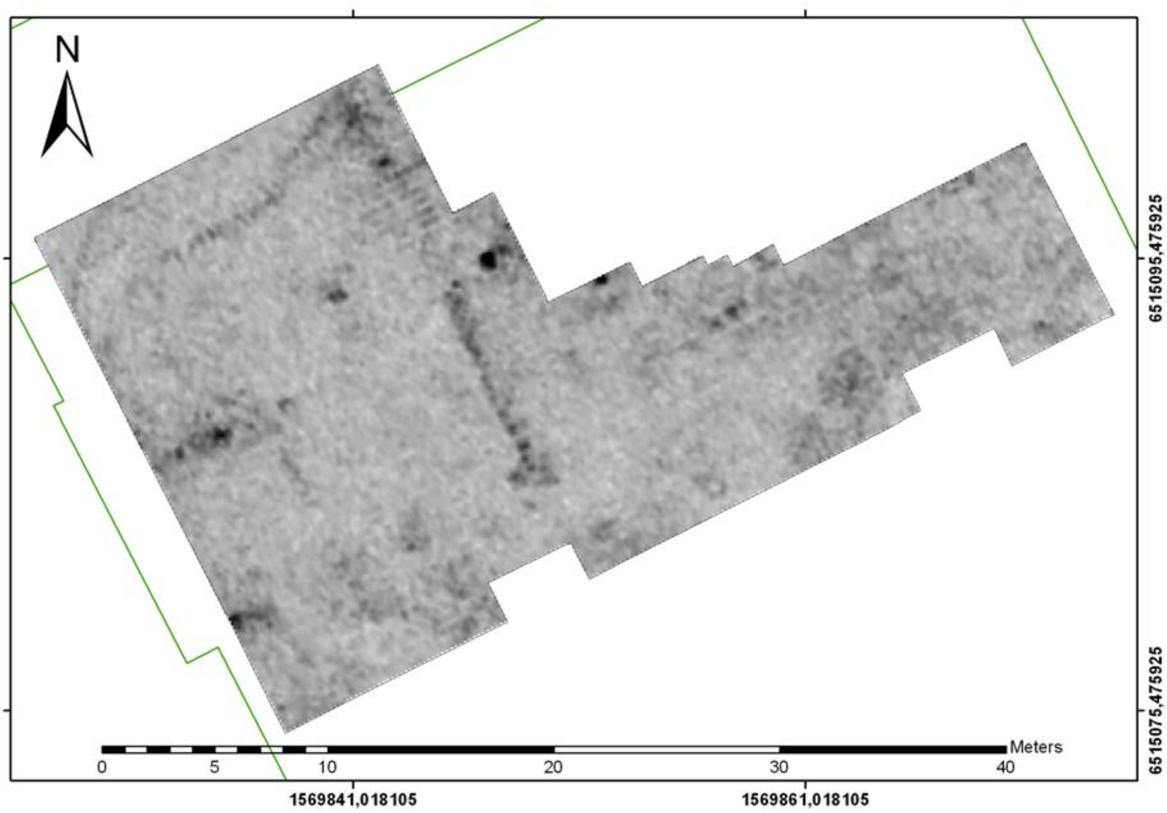

Figure 3.2.15: GPR depth-slice (290-300cm) of the survey site *Mejeriet (upper part)*.

3.3 Survey site *Åkroken (upper part)*

The survey site *Åkroken* is divided into an upper and a lower part due to a large elevation difference between them. The upper part consists of the first two double rows of parking place as shown in Figure 3.3.1.

Figure 3.3.1: Survey site *Åkroken (upper part)* comprises the area with two double rows of parking spaces at about the same elevation level. This photo shows the view of the survey area from the west. The parking place had been cleared of cars for one day in order to allow GPR measurements on the entire area.

Both the northern and southern part of this site were surveyed with the 500 MHZ antenna and 25cm cross-line spacing within one day (see photo on title-page). The northern sub-areas of the survey site *Åkroken (upper part)* measures approximately 67m by 15m, while the southern spans over 67m by 9m. The corresponding GPR depth-slices are listed in Appendix 6.3 (Figures 6.3.1 to 6.3.30).

Both areas are covered with tarmac. The asphalt shows several signs of intrusions. Electricity cables have been dug into the ground crossing both areas perpendicular to their long axis. The surface expression of these cable trenches can be seen in Figures 3.3.2 and 3.3.3. It is expectable that underground electric power cables as well supply the street lamps at the site. Indications for sewer pipes exist (Figure 3.3.3).

The corresponding depth-slice images of 10cm thickness each are listed in Appendix 6.3 (Figure 6.3.1 to 6.3.30).

Figures 3.3.2 and 3.3.3 show utility trenches and visible intrusions in the area.

An interpretation of the major structures contained in the data is shown in Figure 3.3.4.
Figures 3.3.5 to 3.3.18 display some of the most prominent structures.

Figures 3.3.5 to 3.3.7 show structures caused by cable and cable trenches close to the surface.
In Figures 3.3.7 to 3.3.9 an excavation pit in the north-east of the survey area can be seen. The outline of known earlier excavation pits can be seen in Figure 3.3.19.

Figures 3.3.10 to 3.3.16 show structures of buildings contained in the subsurface.

Little signal is reflected from below 220m depth as visible from Figures 3.3.17 and 3.3.18.

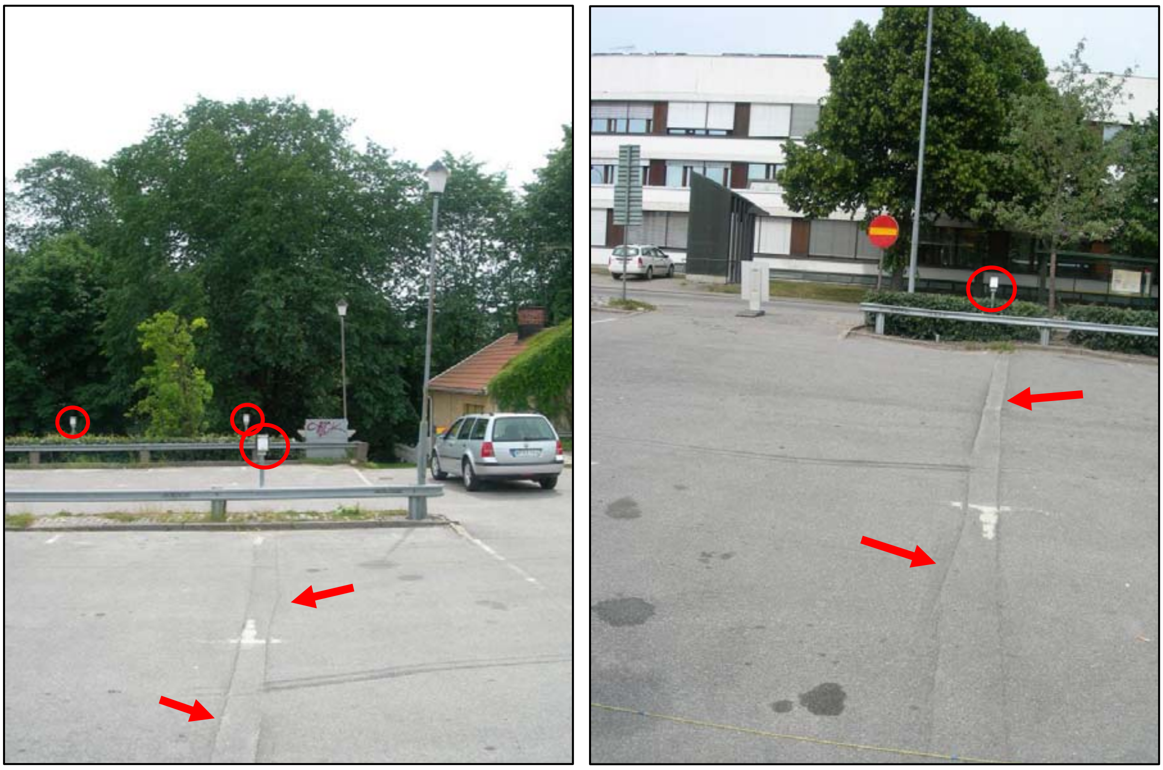

Figure 3.3.2: Presumably an electric cable for the supply of the car park's power sockets (marked with circles) had been placed in the trench visible in these figures. View to the south (left) and view of the same surface structure to the north (right).

Figure 3.3.3: Trench intrusion in asphalt surface in the south-western part of survey site *Åkroken (upper part)* and manhole cover (photo left). Indication for sewer pipes in the subsurface can be seen as well in the right photo.

Very good agreement between some of the structures shown in the map from the year 1888 and the data is shown in Figures 3.3.20 and 3.3.21.

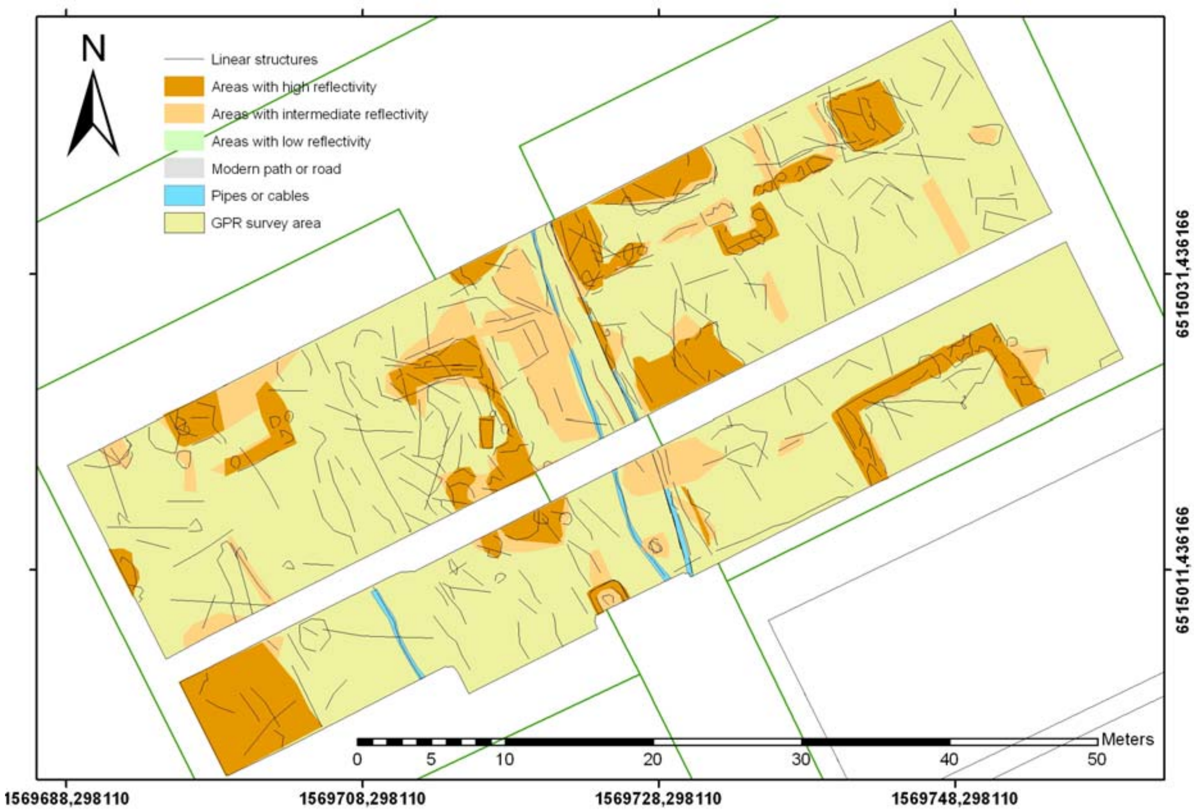

Figure 3.3.4: Interpretation of the GPR data recorded at the survey site *Åkroken (upper part).*

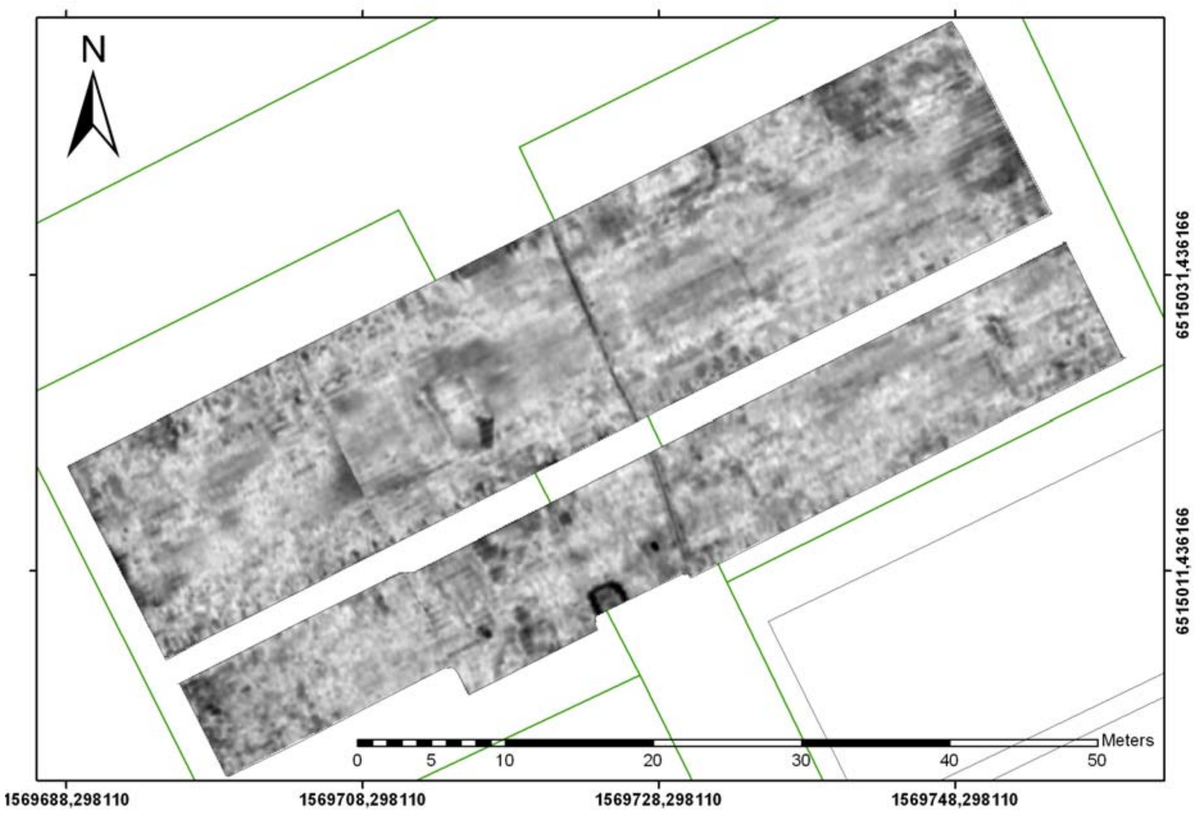

Figure 3.3.5: GPR depth-slice (0-10cm) of the survey site *Åkroken (upper part).*

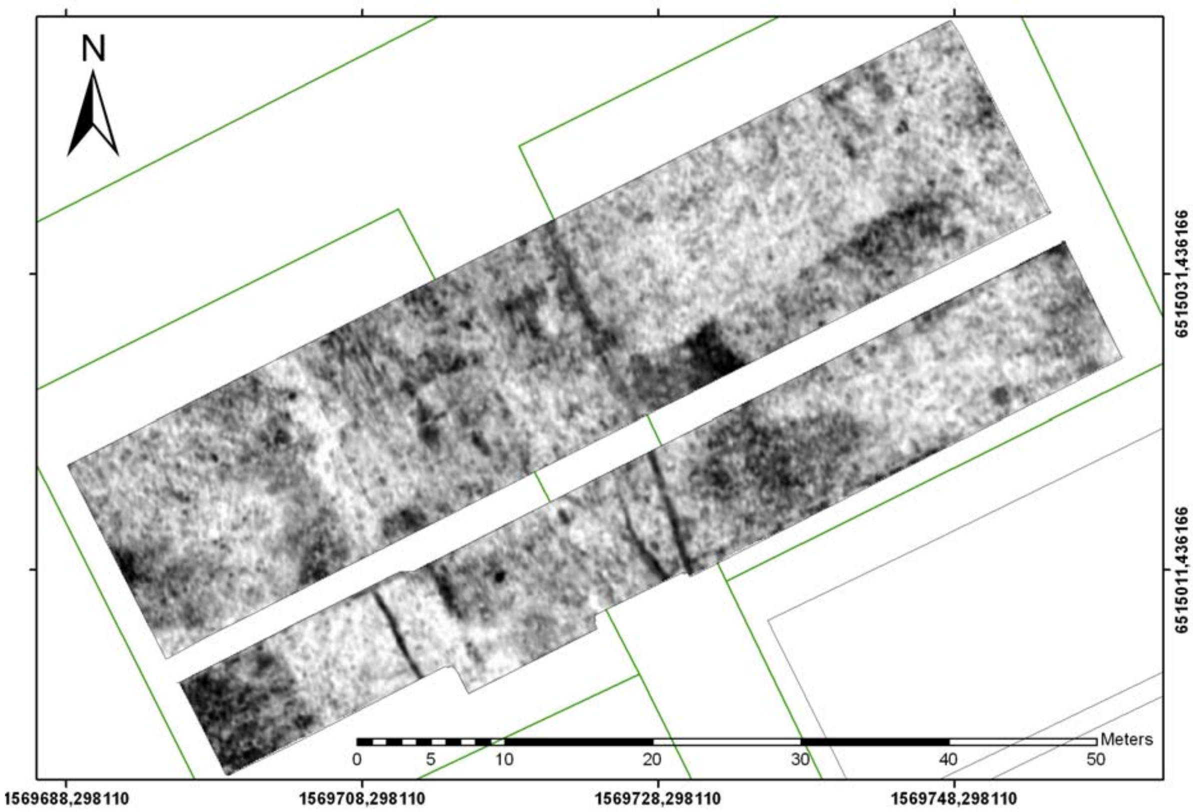

Figure 3.3.6: GPR depth-slice (30-40cm) of the survey site *Åkroken (upper part)*.

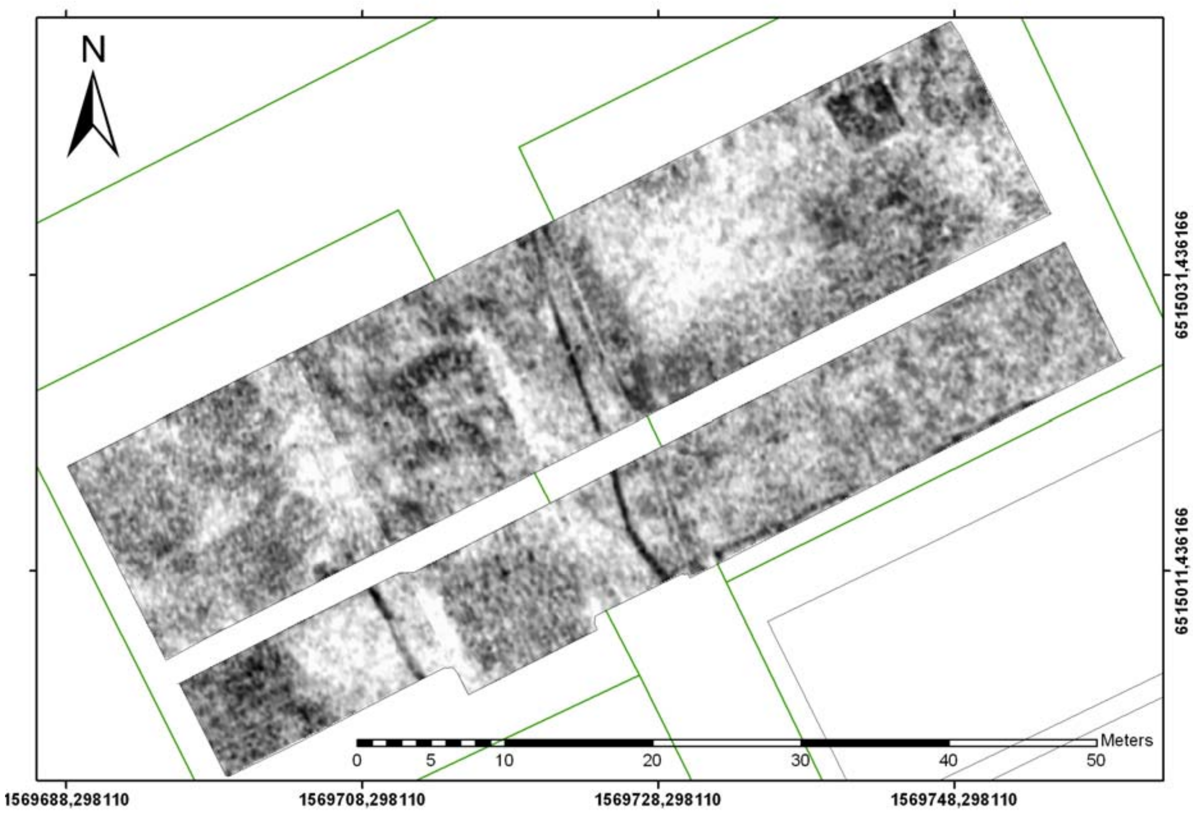

Figure 3.3.7: GPR depth-slice (40-50cm) of the survey site *Åkroken (upper part)*.

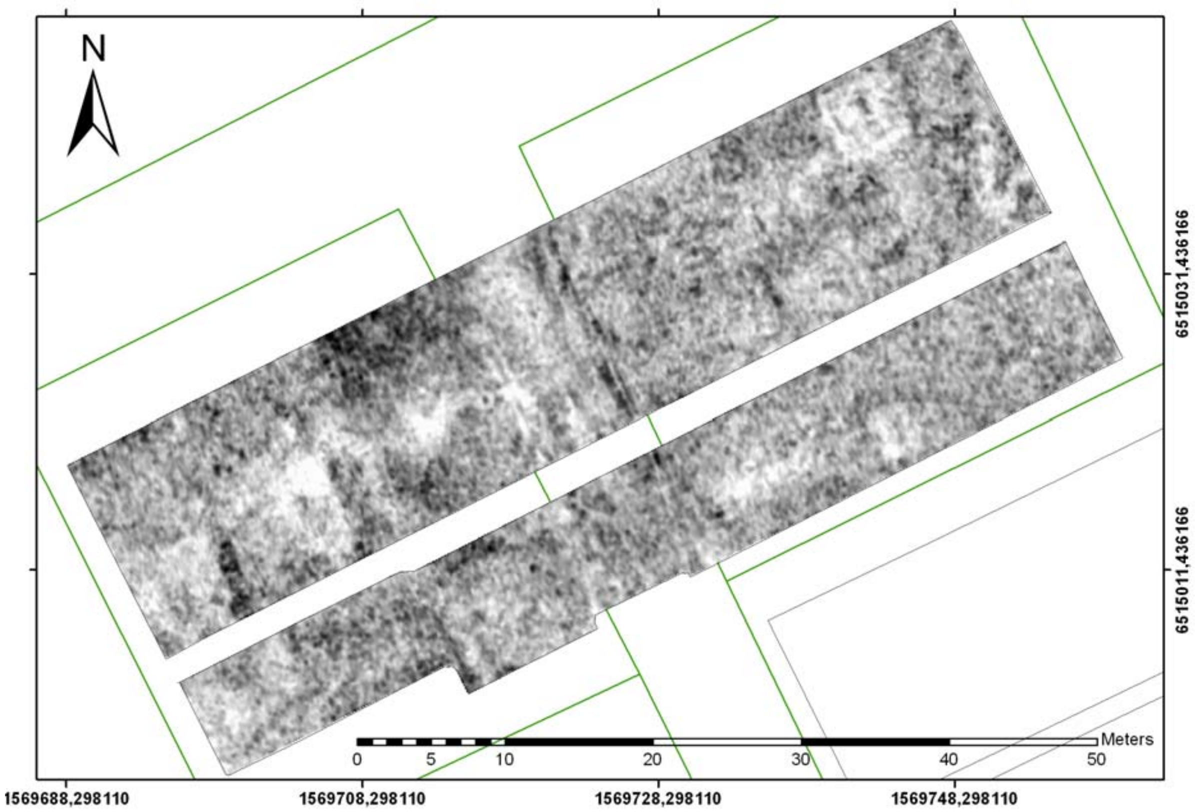

Figure 3.3.8: GPR depth-slice (60-70cm) of the survey site *Åkroken (upper part).*

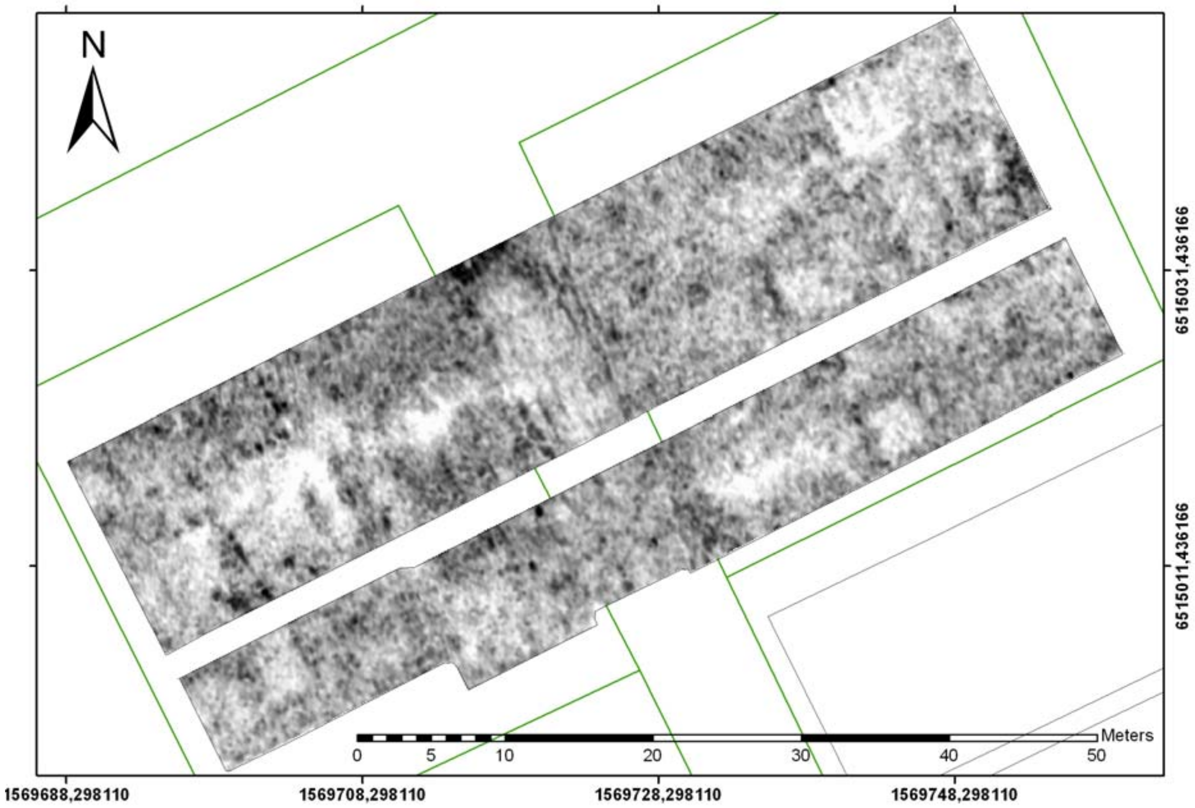

Figure 3.3.9: GPR depth-slice (70-80cm) of the survey site *Åkroken (upper part).*

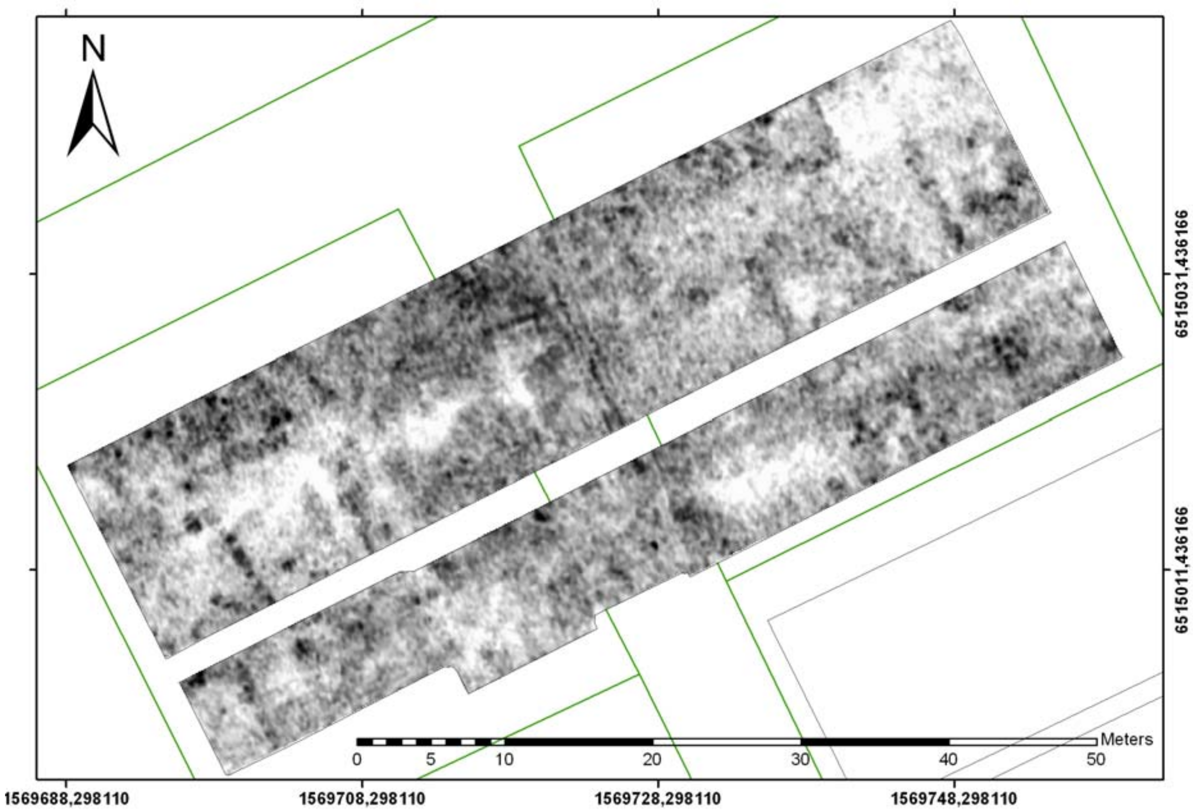

Figure 3.3.10: GPR depth-slice (80-90cm) of the survey site *Åkroken (upper part).*

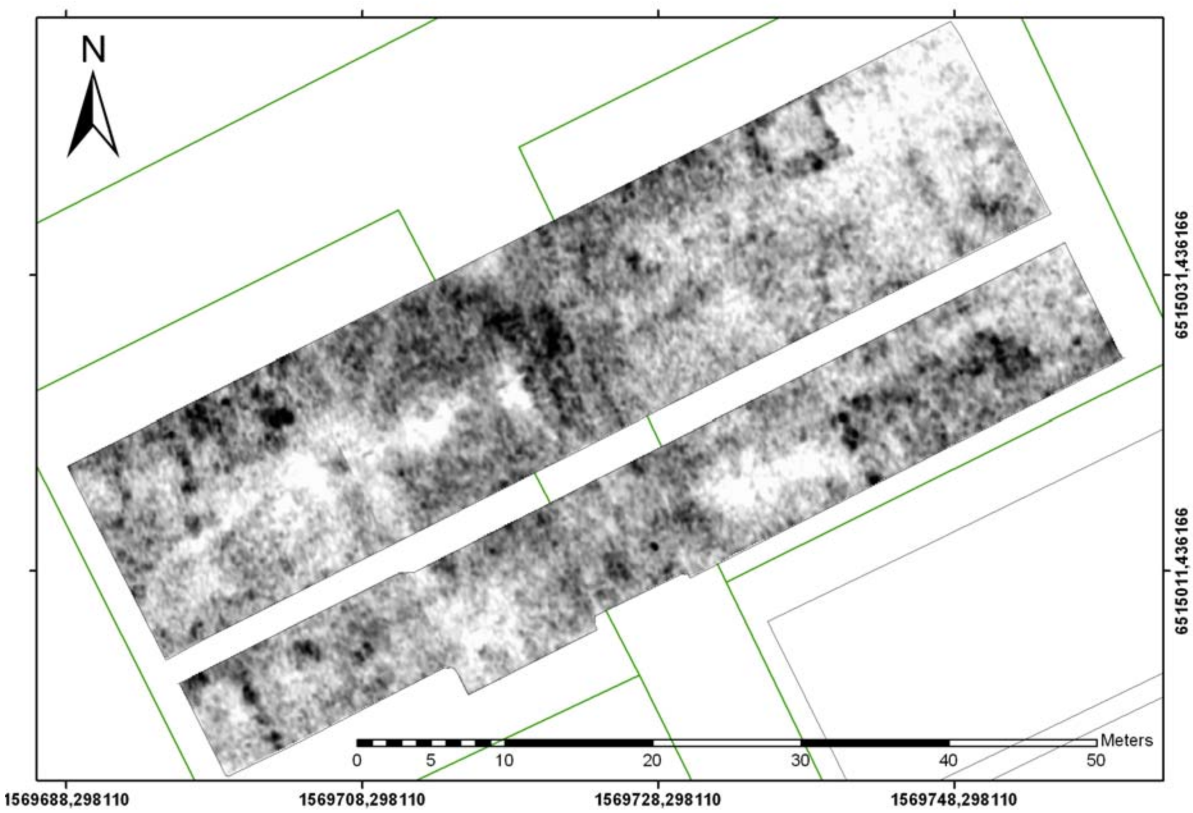

Figure 3.3.11: GPR depth-slice (90-100cm) of the survey site *Åkroken (upper part).*

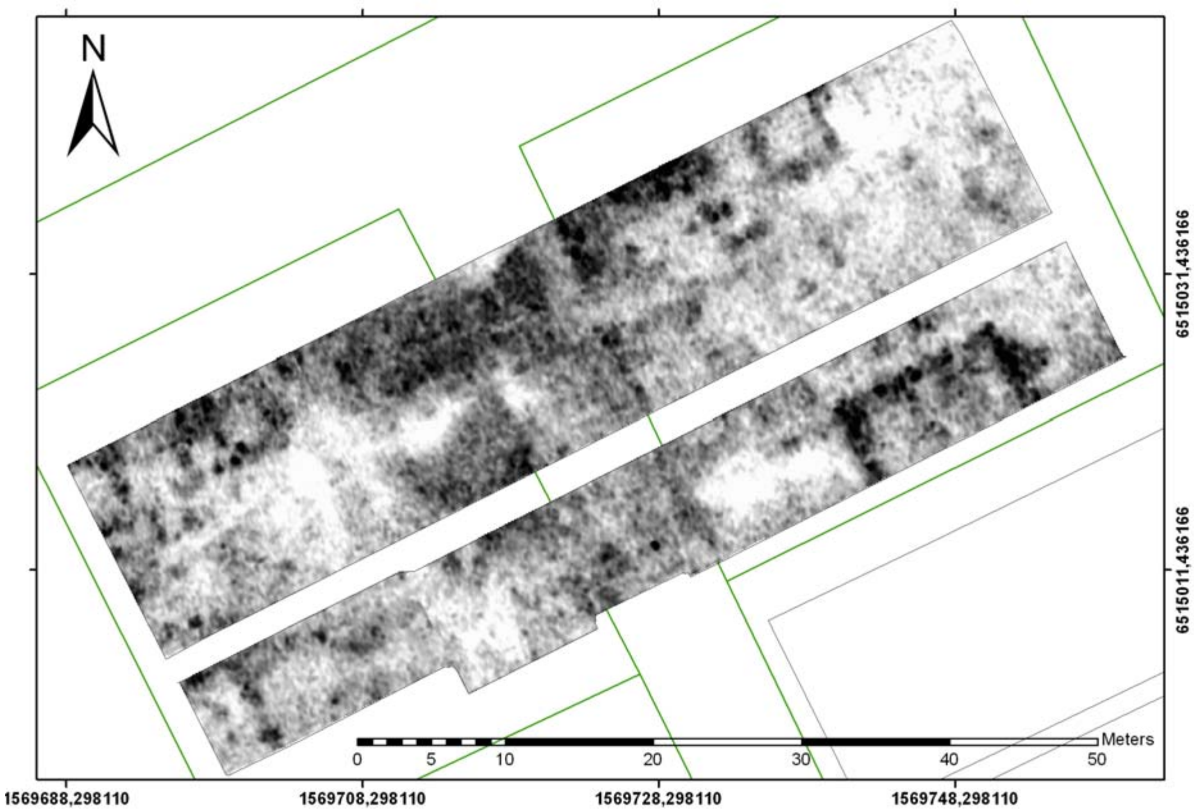

Figure 3.3.12: GPR depth-slice (110-120cm) of the survey site *Åkroken (upper part)*.

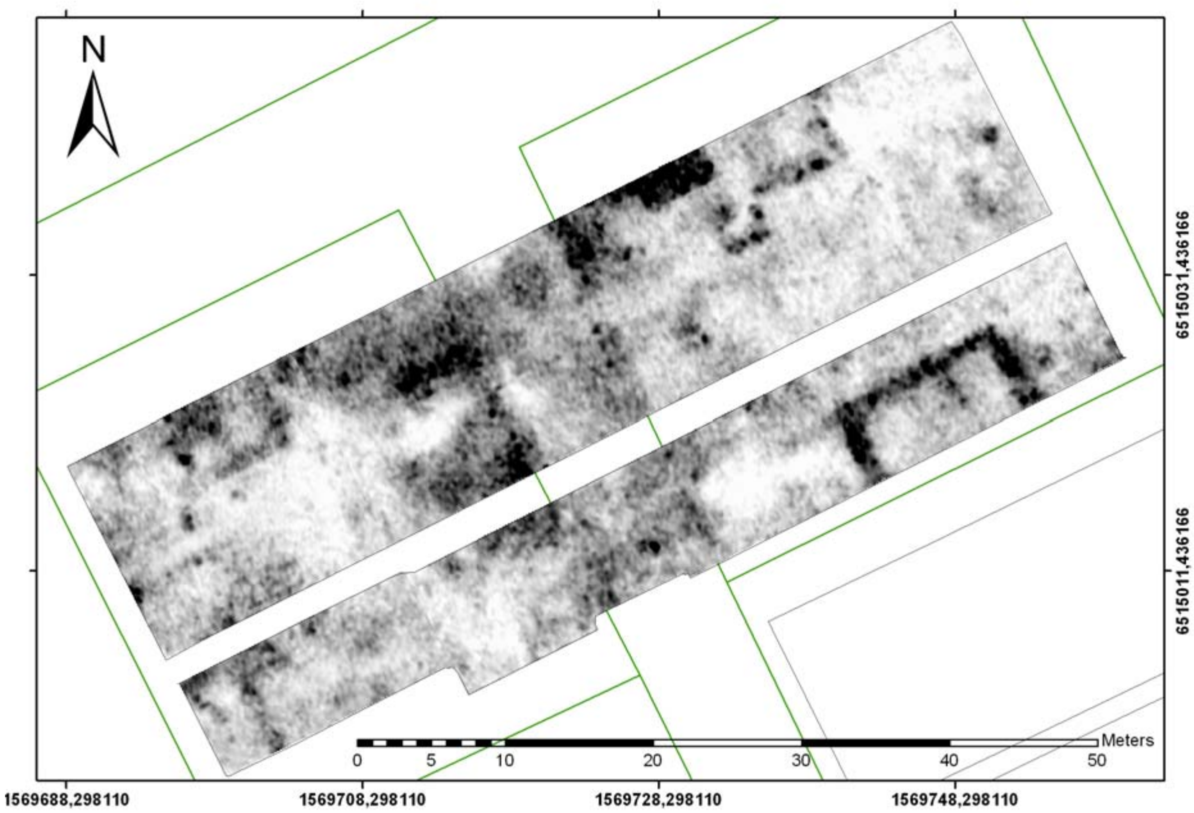

Figure 3.3.13: GPR depth-slice (130-140cm) of the survey site *Åkroken (upper part)*.

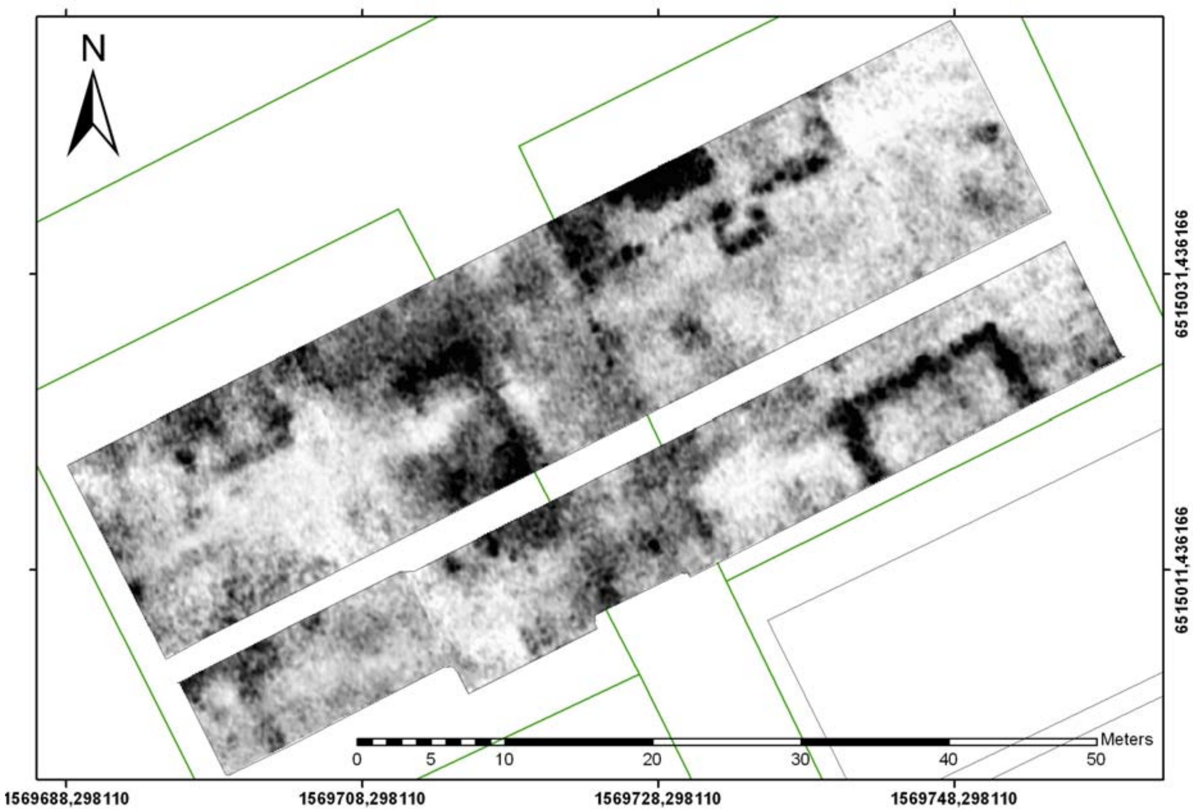

Figure 3.3.14: GPR depth-slice (140-150cm) of the survey site *Åkroken (upper part)*.

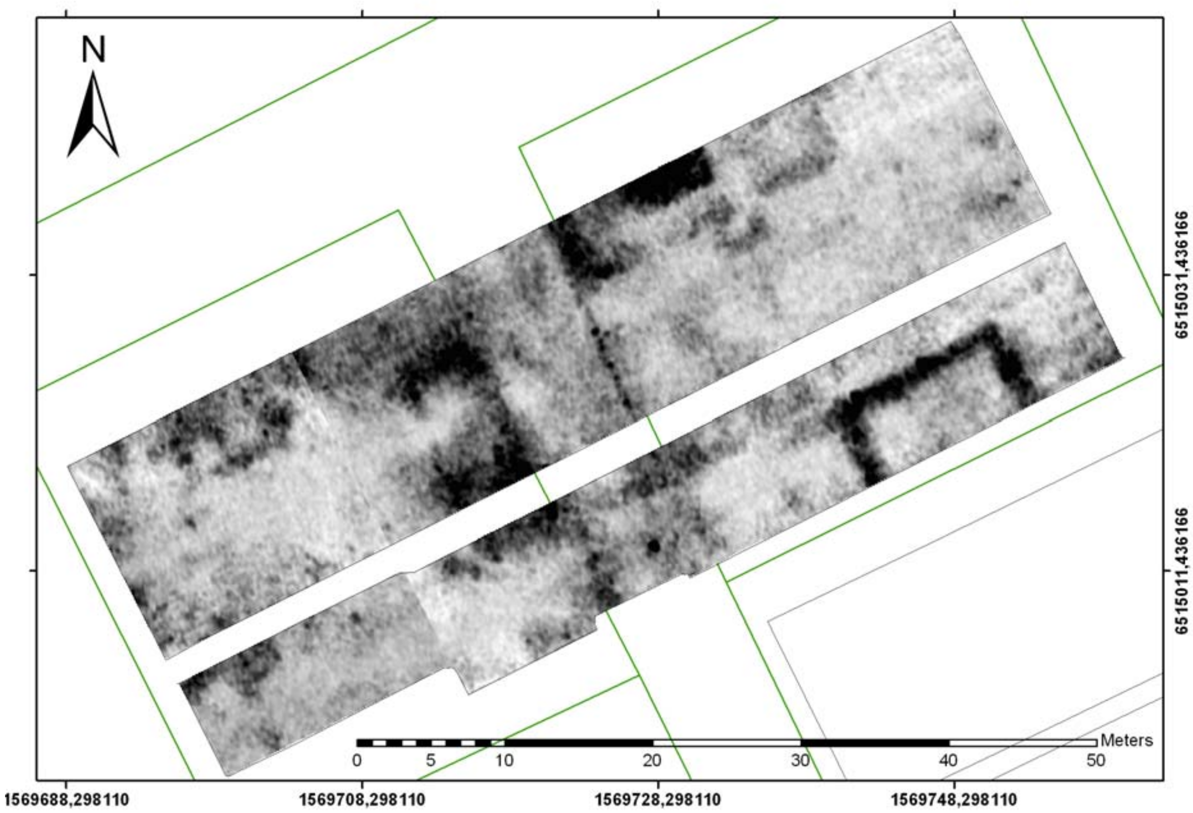

Figure 3.3.15: GPR depth-slice (160-170cm) of the survey site *Åkroken (upper part)*.

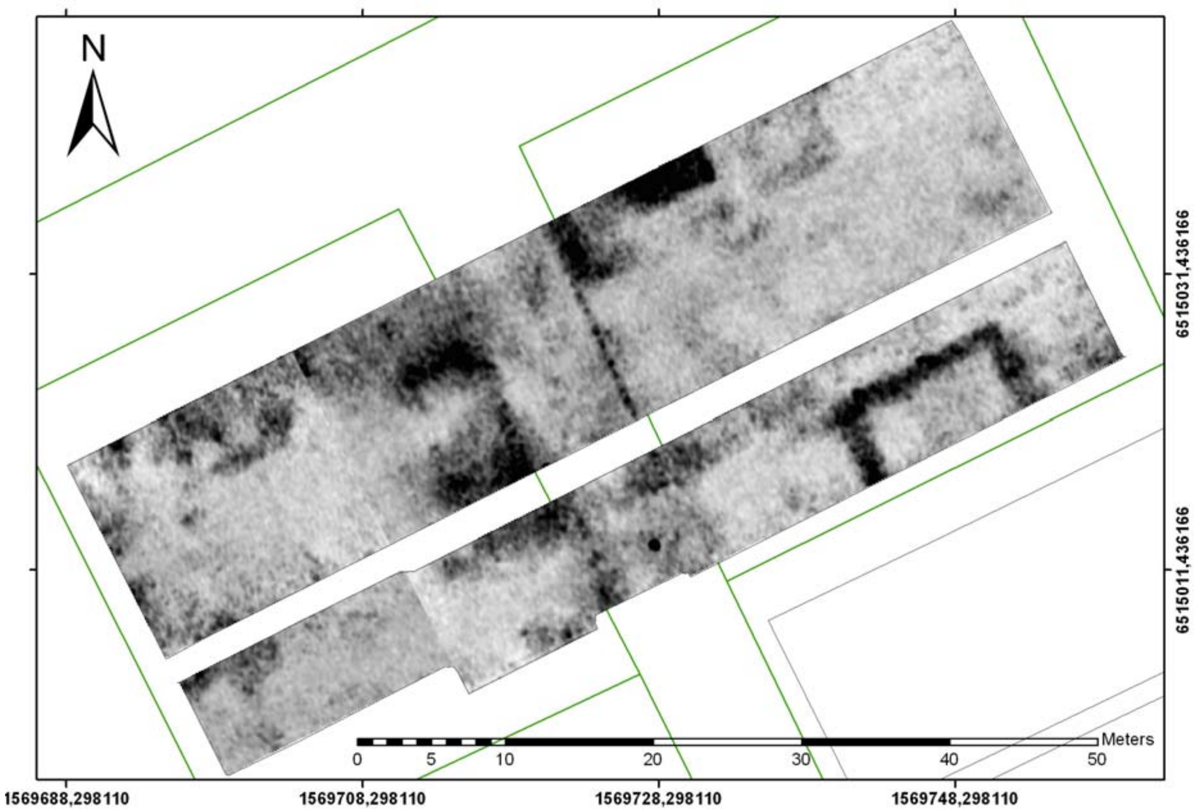

Figure 3.3.16: GPR depth-slice (170-180cm) of the survey site *Åkroken (upper part)*.

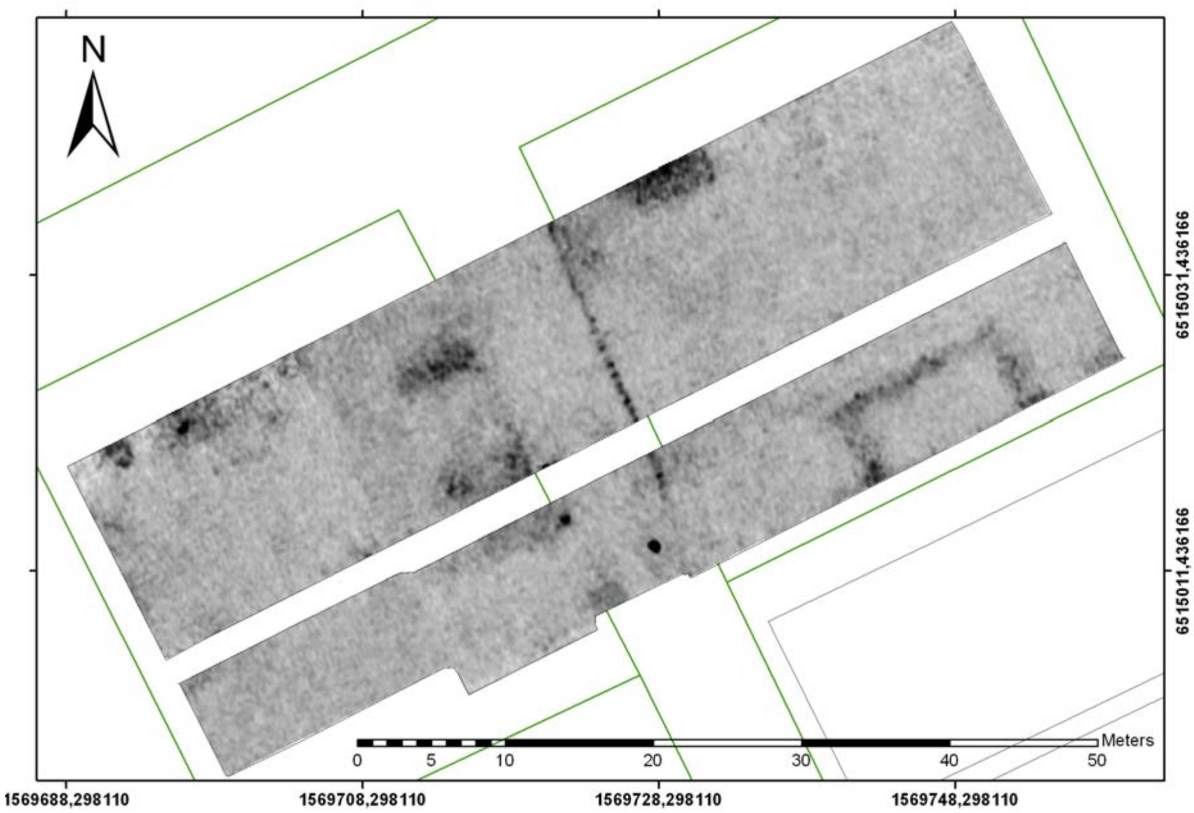

Figure 3.3.17: GPR depth-slice (220-230cm) of the survey site *Åkroken (upper part)*.

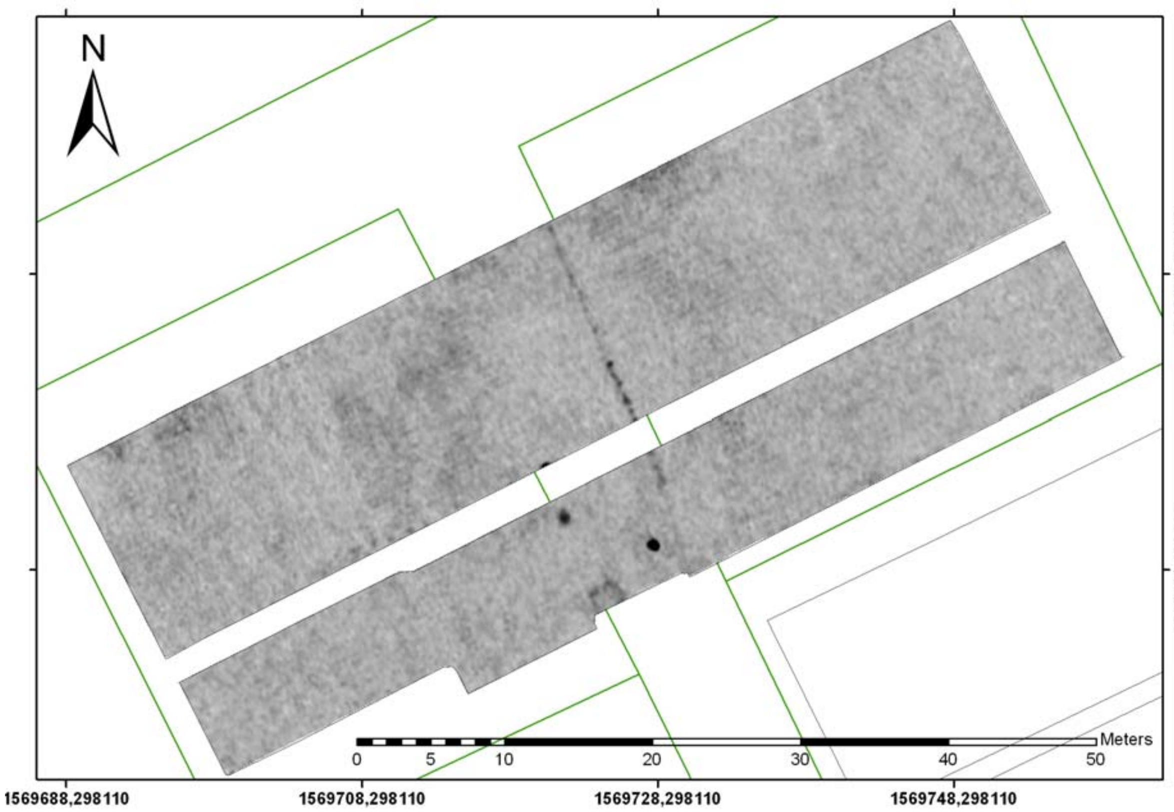

Figure 3.3.18: GPR depth-slice (280-290cm) of the survey site *Åkroken (upper part)*.

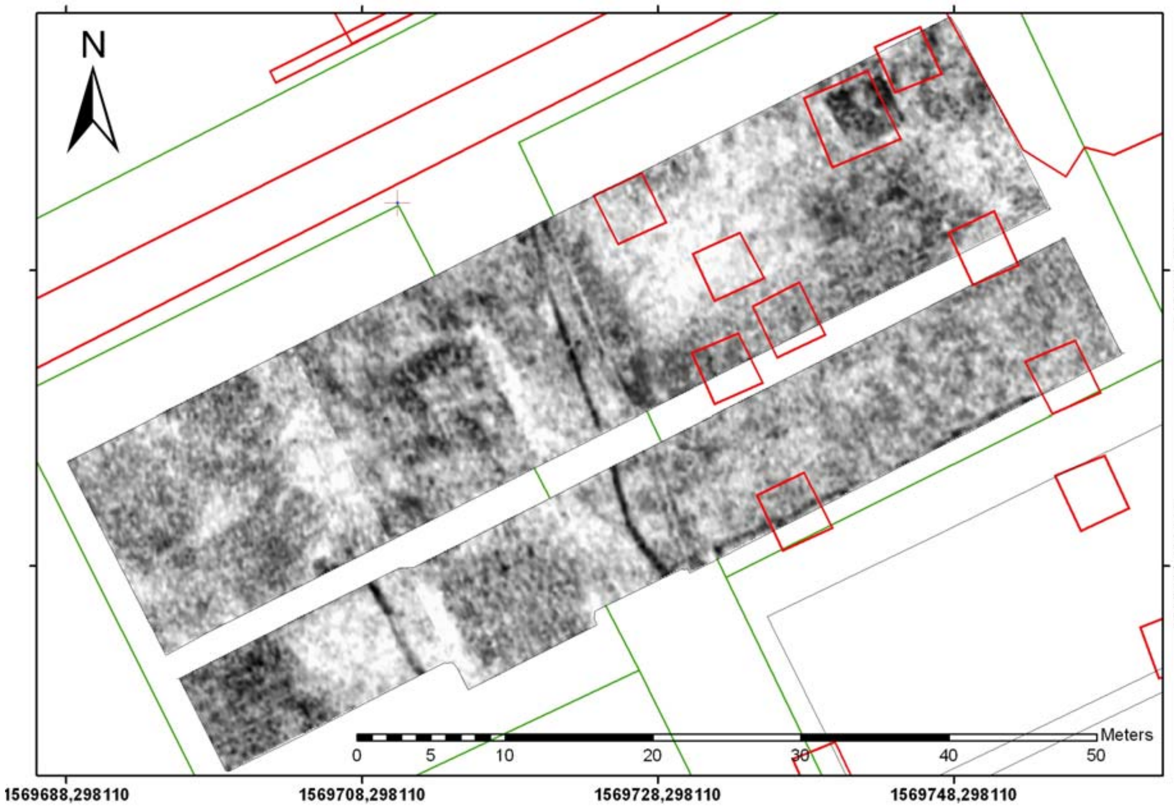

Figure 3.3.19: GPR depth-slice (40-50cm) with older excavation trenches superimposed in red.

Figure 3.3.20: Section of the historic map from year 1888 (see Figure 1.3).

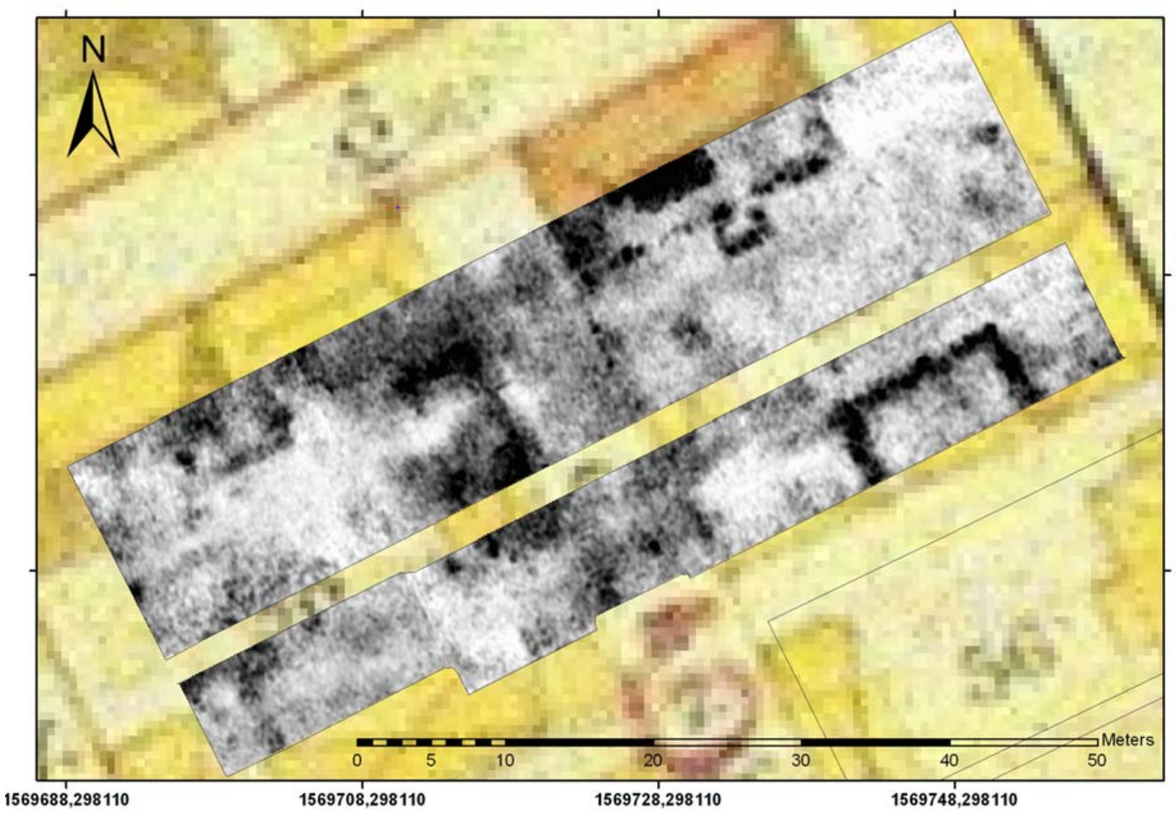

Figure 3.3.21: Section of the historic map from year 1888 with GPR depth-slice (140-150cm) superimposed. Very good agreement between the GPR data and the map can be observed for the red house and *Radhusgränden*, which divides the quarter. The strong wall structures in the south-east of the survey area do not match the structures visible in the map.

3.4 Survey site *Åkroken (lower part)*

The survey site *Åkroken (lower part)* comprises the lower parking space (Figure 3.4.1), and the adjoining green areas south and south-west of it (Figures 3.4.2, 3.4.3 and 3.4.4).

Figure 3.4.1: Lower parking place in quarter *Åkroken*. This area except the ramp to the upper car park is part of the survey site *Åkroken (lower part)*.

Figure 3.4.2: Green area between the car park shown in Figure 3.4.1 and the river.

Figure 3.4.3: The same area as shown in Figure 3.4.2 from the west. The tracks of the GPR cart are visible in this photo.

Figure 3.4.4: Small green area in the western continuation of the area shown in Figure 3.4.2, just north of the river bend.

The corresponding depth-slice images of 10cm thickness each are listed in Appendix 6.4 (Figure 6.4.1 to 6.4.30).

Figure 3.4.5 provides an interpretation of the most prominent structures in this survey area, which can be seen in Figures 3.4.6 to 3.4.17.

Figure 3.4.6 shows the anomaly caused by the footpath.

Figures 3.4.7 and 3.4.8 show a cable or pipe crossing the survey area.

Figures 3.4.9 to 3.4.15 show building structures contained in the subsurface of the area.

Figures 3.4.16 and 3.4.17 show the reduction of signal strength with depth, indicating a lack of reflecting structures.

Figures 3.4.18 and 3.4.19 show that the orientation of some of the structures contained in the data appears to coincide with the layout of the town centre as shown in the map from the year 1665.

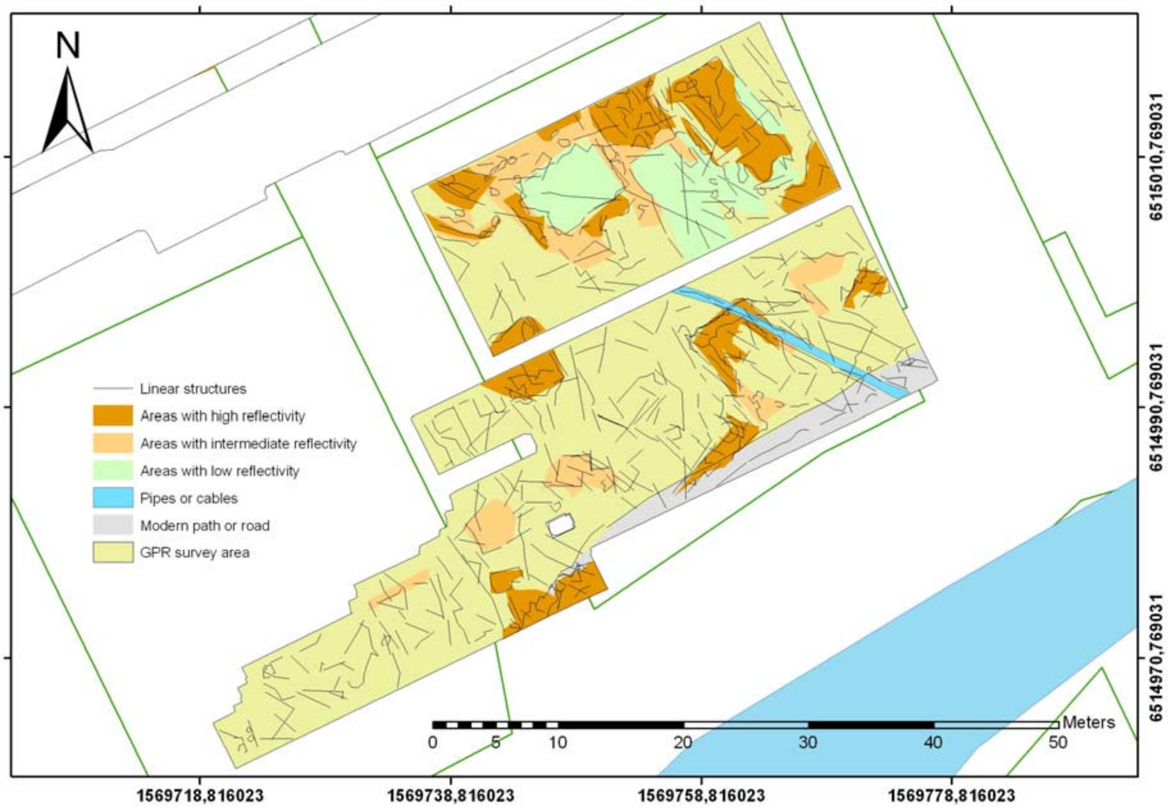

Figure 3.4.5: Interpretation of the GPR data recorded at the survey site *Åkroken (lower part).*

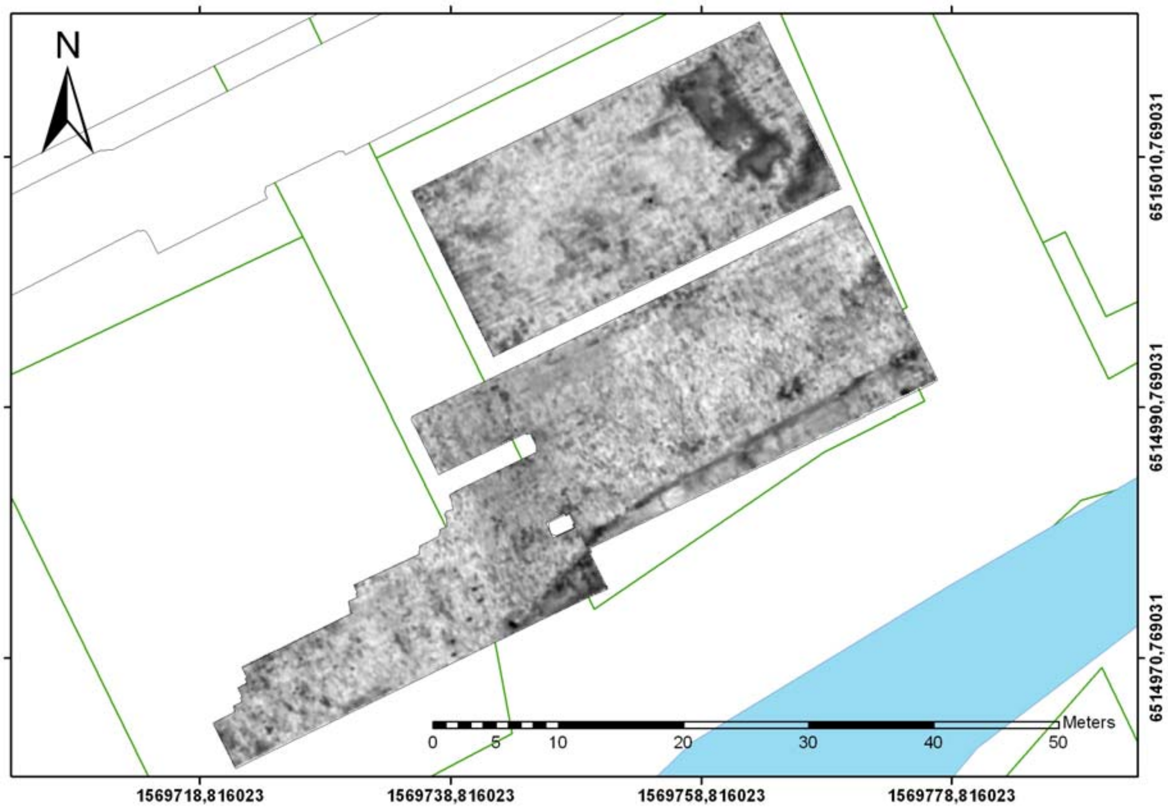

Figure 3.4.6: GPR depth-slice (0-10cm) of the survey site *Åkroken (lower part).*

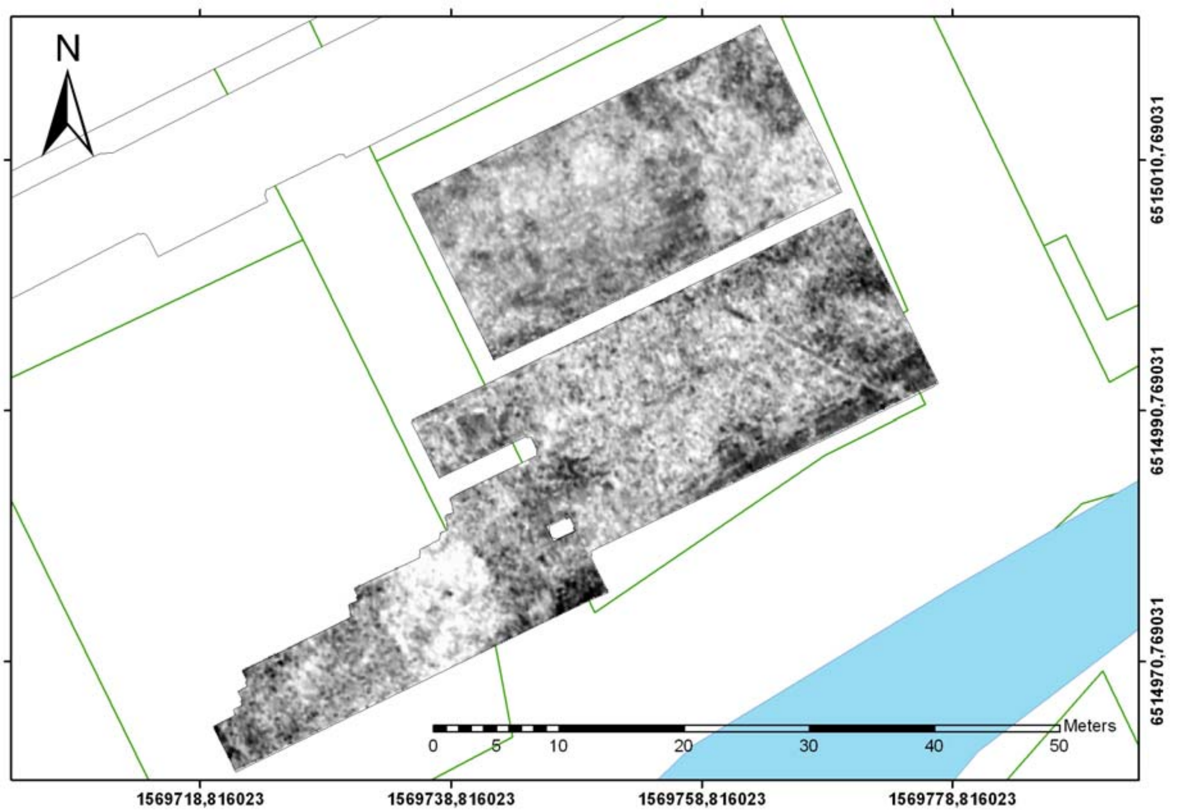

Figure 3.4.7: GPR depth-slice (30-40cm) of the survey site *Åkroken (lower part).*

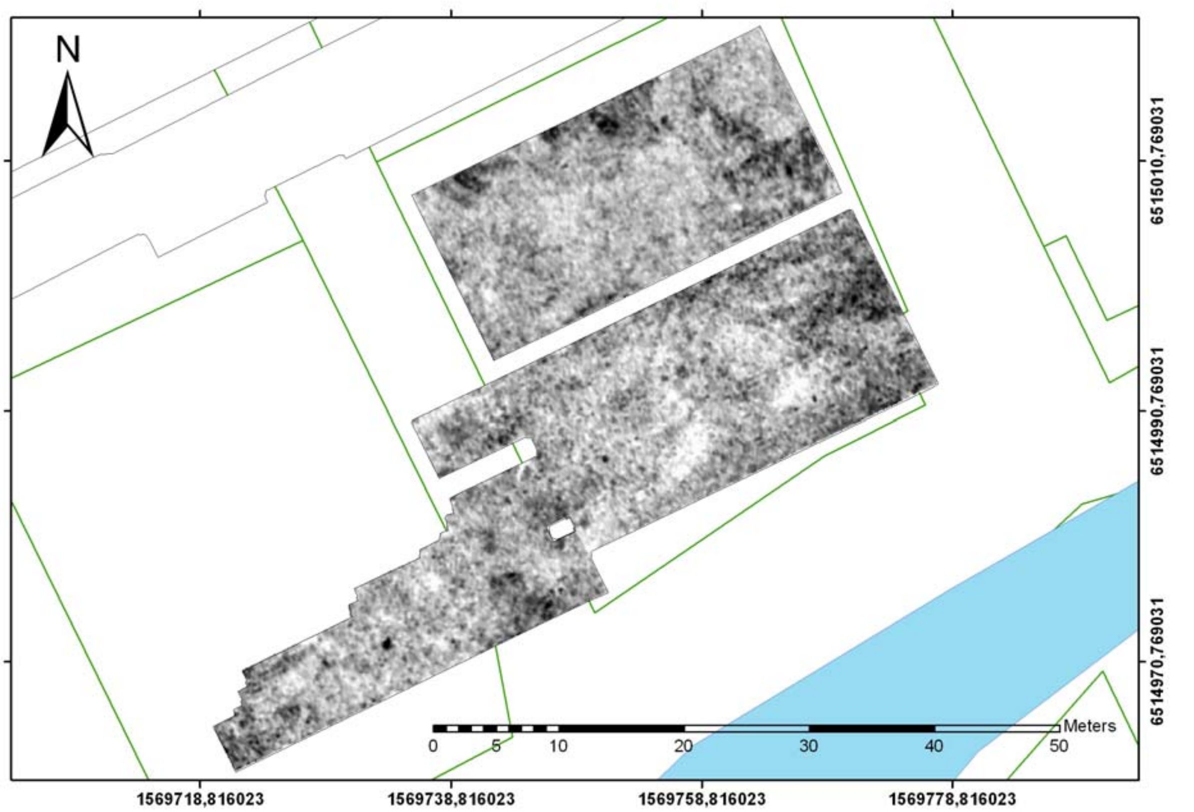

Figure 3.4.8: GPR depth-slice (50-60cm) of the survey site *Åkroken (lower part).*

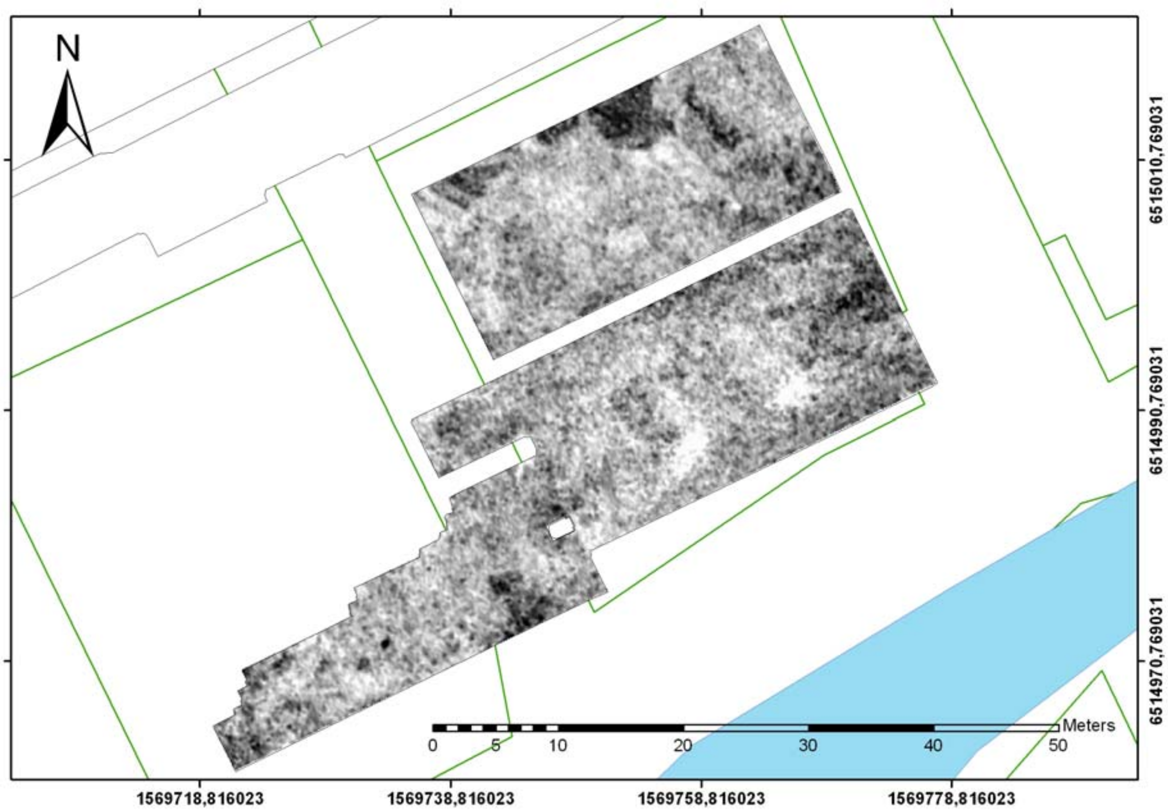

Figure 3.4.9: GPR depth-slice (60-70cm) of the survey site *Åkroken (lower part)*.

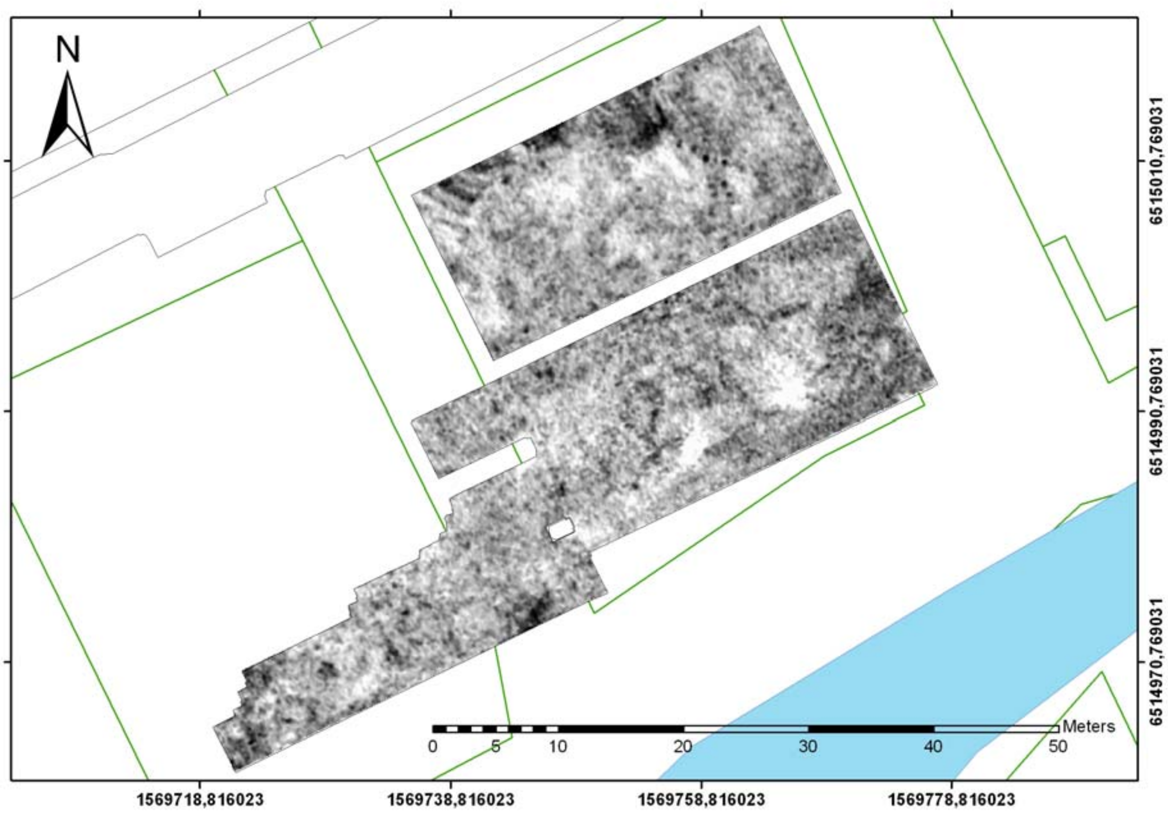

Figure 3.4.10: GPR depth-slice (80-90cm) of the survey site *Åkroken (lower part)*.

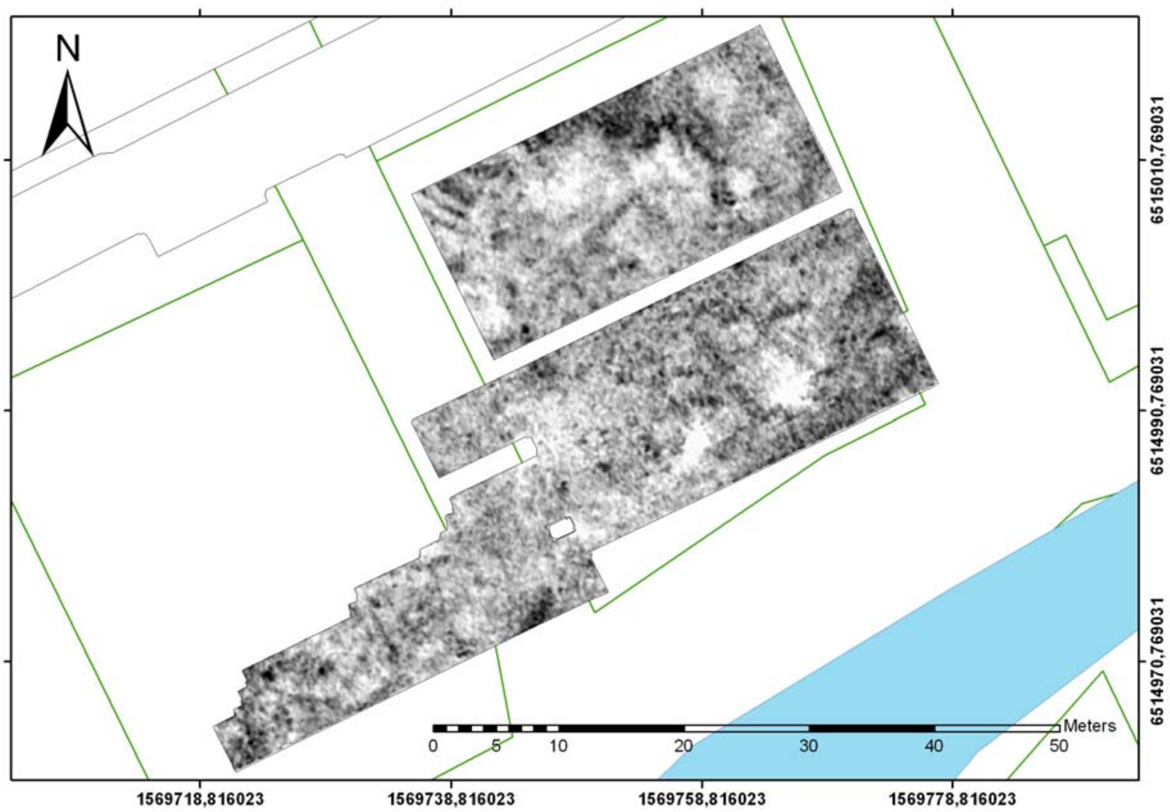

Figure 3.4.11: GPR depth-slice (90-100cm) of the survey site *Åkroken (lower part)*.

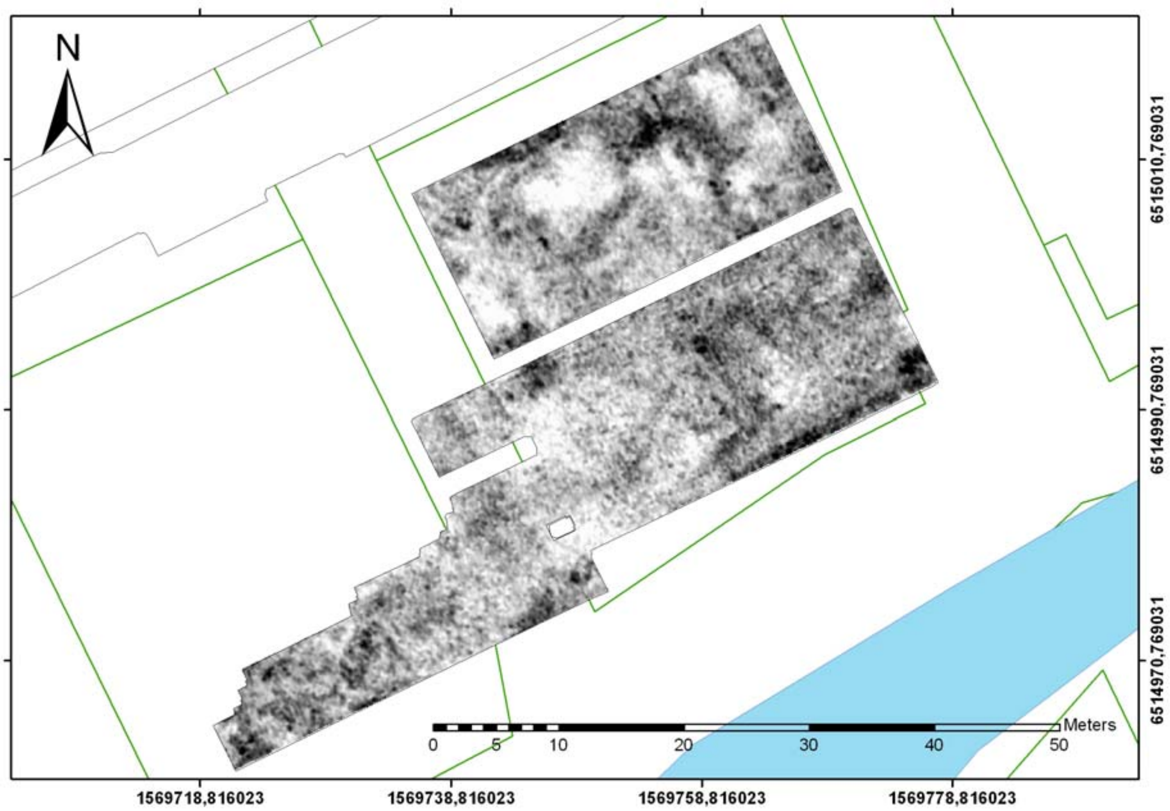

Figure 3.4.12: GPR depth-slice (120-130cm) of the survey site *Åkroken (lower part)*.

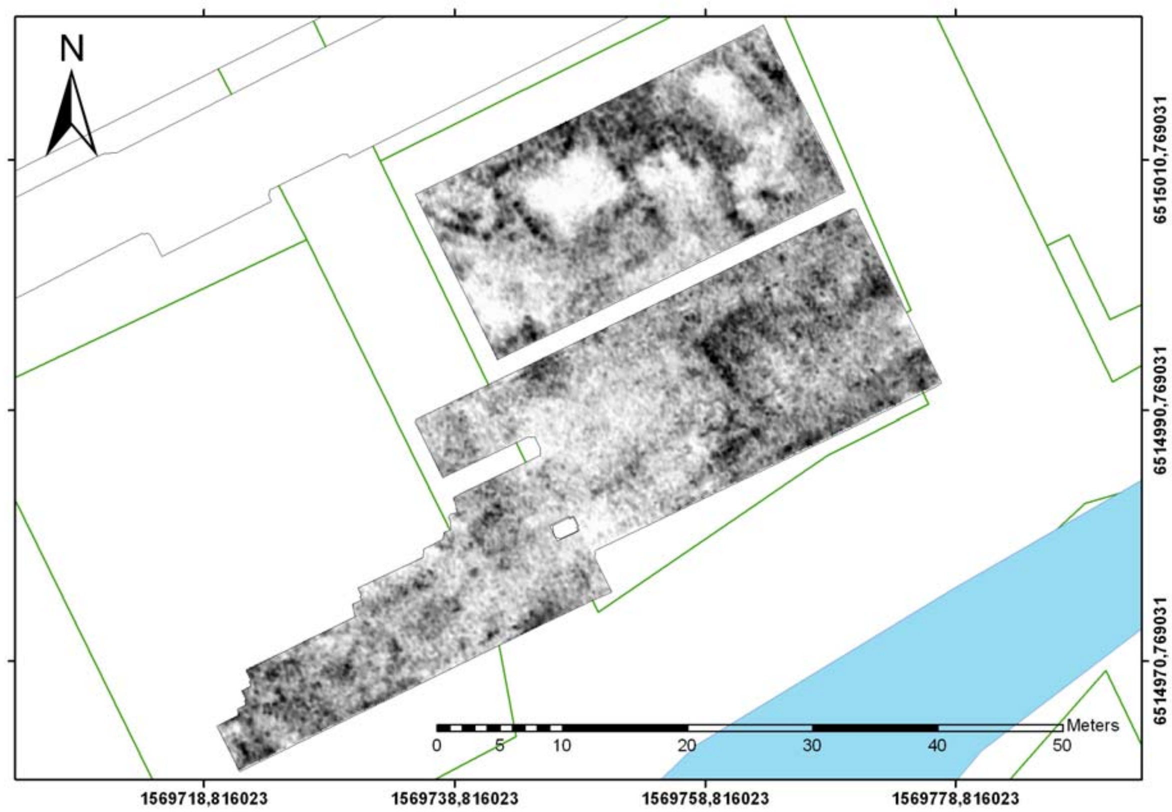

Figure 3.4.13: GPR depth-slice (140-150cm) of the survey site *Åkroken (lower part).*

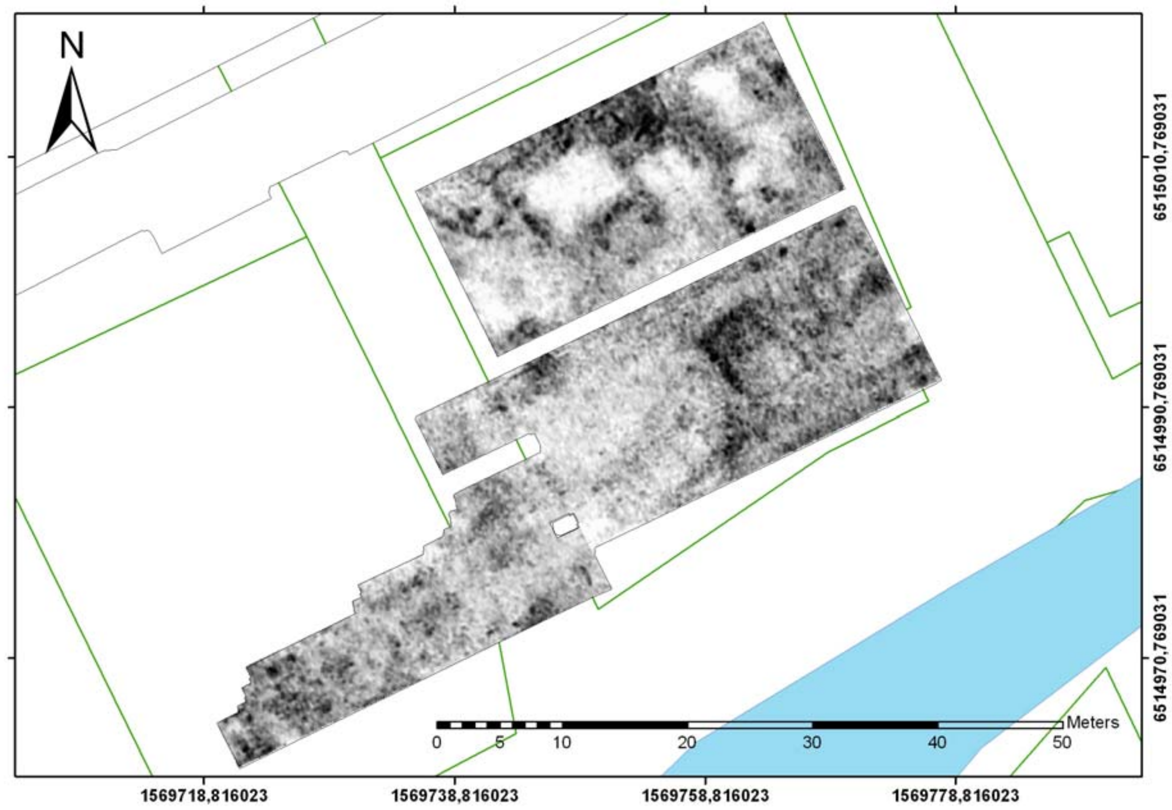

Figure 3.4.14: GPR depth-slice (150-160cm) of the survey site *Åkroken (lower part).*

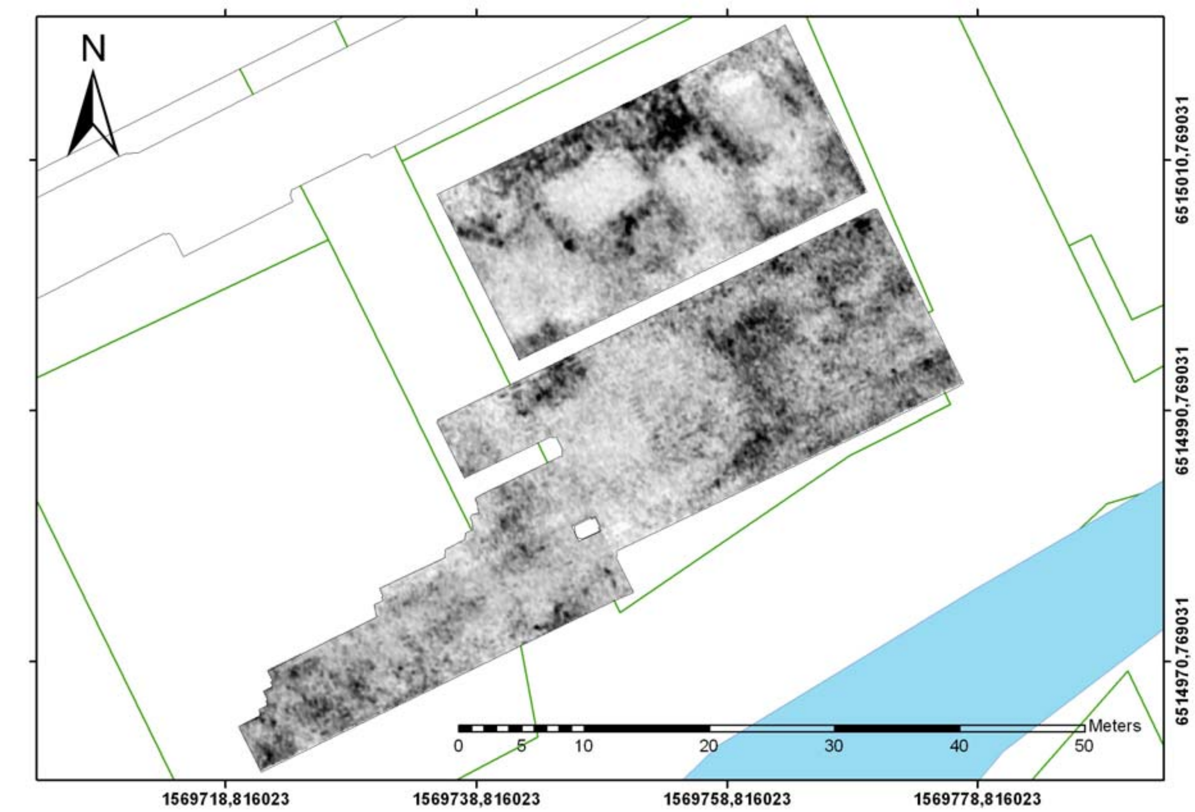

Figure 3.4.15: GPR depth-slice (170-180cm) of the survey site *Åkroken (lower part).*

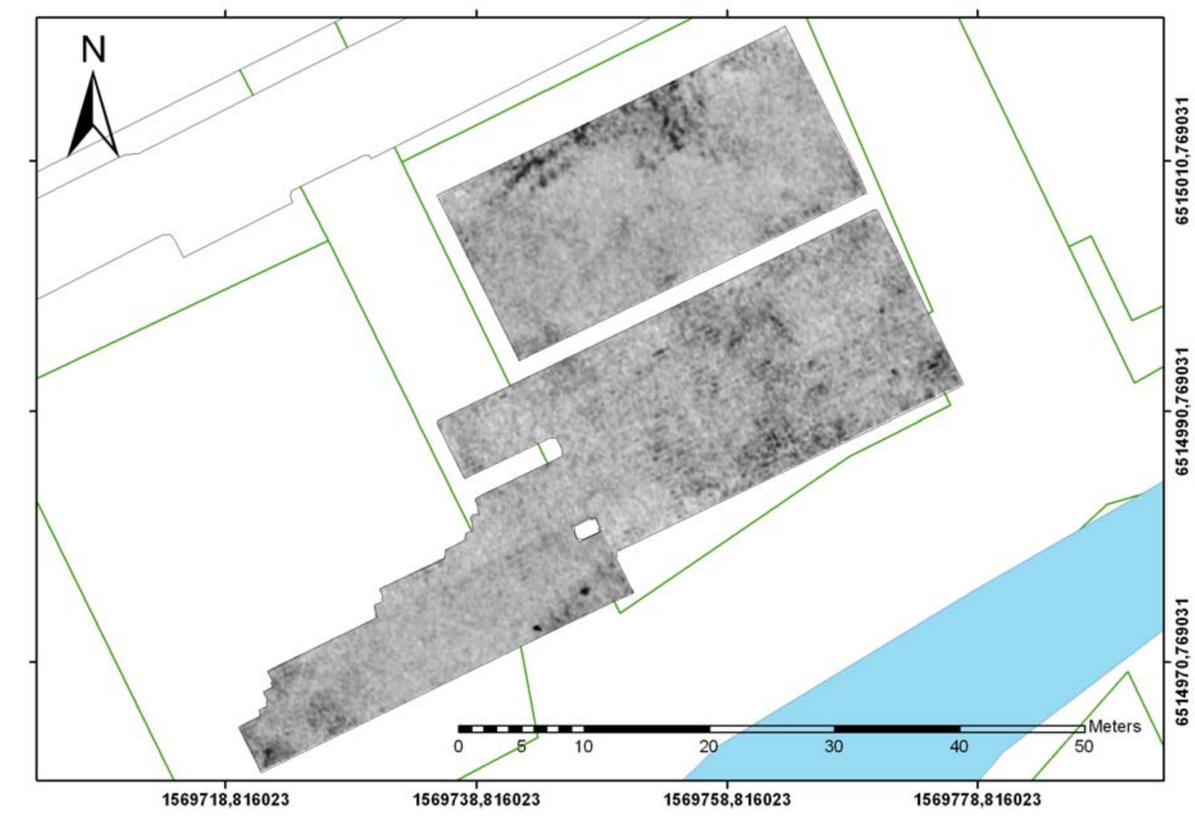

Figure 3.4.16: GPR depth-slice (230-240cm) of the survey site *Åkroken (lower part).*

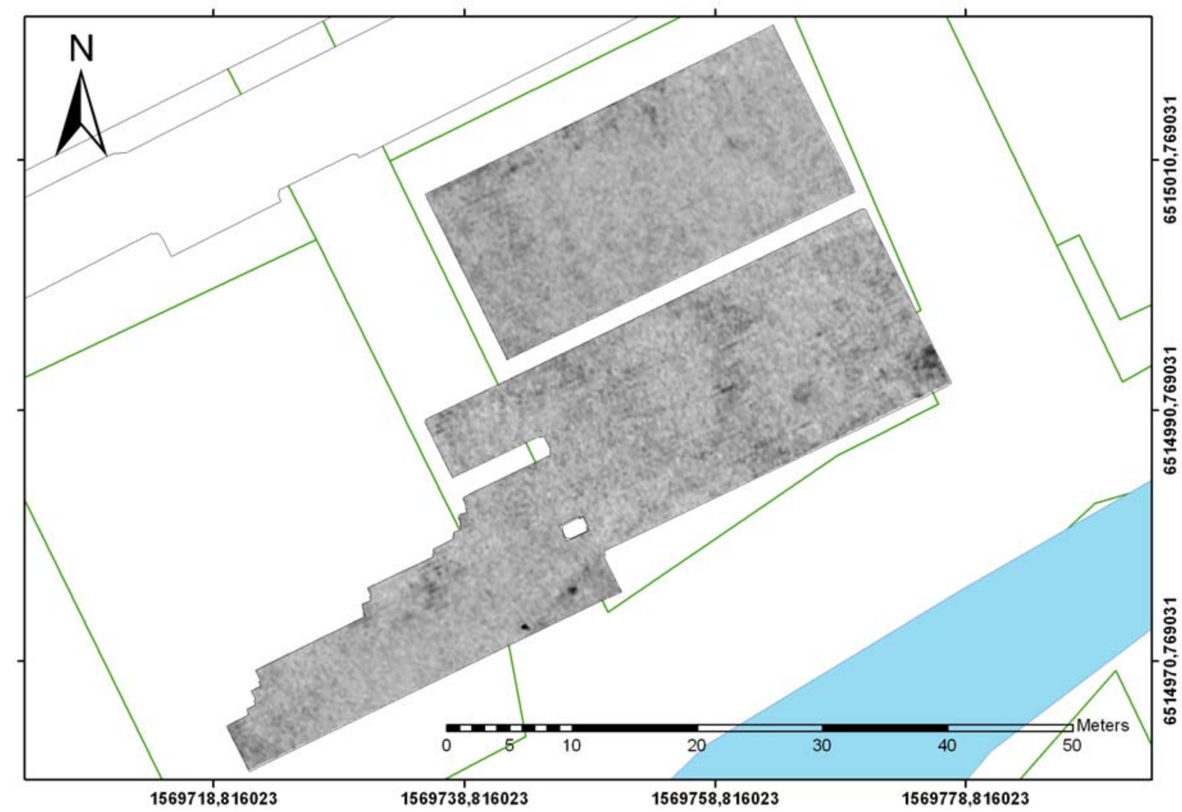

Figure 3.4.17: GPR depth-slice (290-300cm) of the survey site *Åkroken (lower part)*.

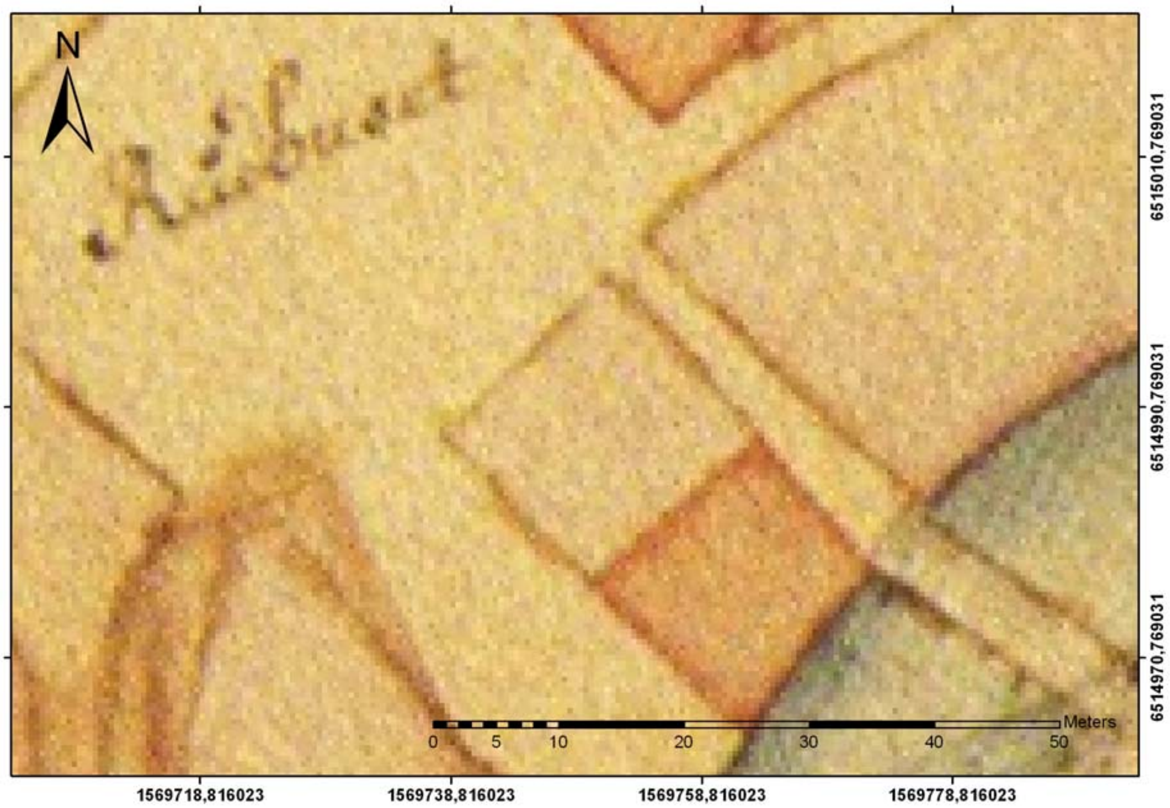

Figure 3.4.18: Section of the historical map from the year 1665 showing the older street layout in the centre of Nyköping.

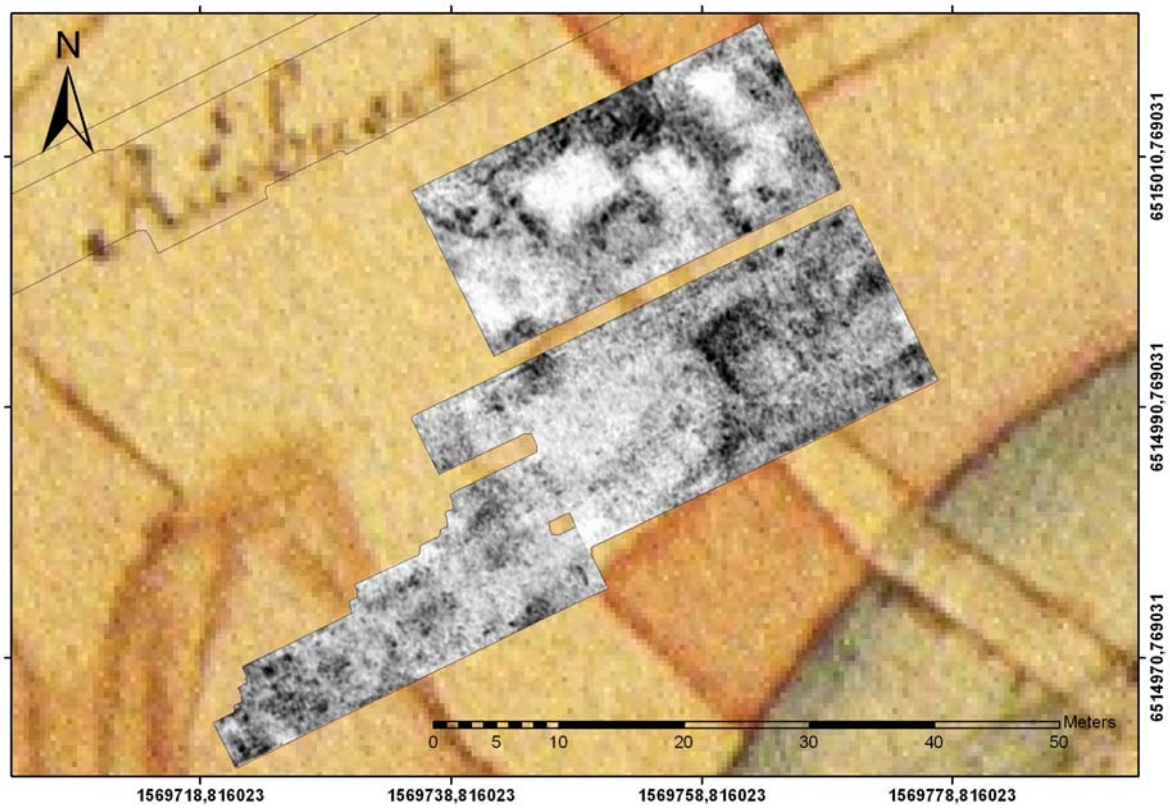

Figure 3.4.19: Section of the historical map from the year 1665 showing the older street system with superimposed GPR depth-slice (150-160cm). It can be seen that the structures visible in the GPR data have the similar orientation as the buildings depicted in the map.

4 Depth analysis

If the velocity of the GPR signal in the subsurface is know it is possible to determine the exact depth of reflections. However, this velocity distribution in the subsurface is complicated, varying laterally and vertically. Commonly, a constant velocity is approximated for the entire subsurface in GPR data processing. All depth-slices shown in this report were generated using a constant velocity of 10cm/ns for the entire subsurface at all survey sites. A detailed velocity analysis is possible for example by matching the shape of reflection hyperbolae in 2D GPR profile data, if hyperbolae are present in the data.
A velocity analysis was conducted for selected profiles from the survey areas surveyed at *Nyköping*. It can be seen that the velocity ranges from 8.5cm/ns to 12.2cm/ns. These velocity variations suggest depth variations of -15% to +22% relative to the depth-slices generated with an average velocity of 10cm/ns.
The maximum reflection depth can be approximated from the profiles shown in Figures 4.1 to 4.7. Lateral variations in the depth of the reflective layer can be seen. Metallic objects in the subsurface can give rise to a ringing signal stretching over the entire GPR profile (visible in Figure 4.3). The depth of the lower boundary of the reflective layer in the data presented here is located between 1m and 3m depth.
In dry sand the used 500MHz antenna would show a penetration depth of 5 to 6 metres. The lack of reflected signal from below a depth that is smaller than the signal penetration depth under ideal conditions suggests the presence of a layer of relatively high electrical conductivity that is absorbing the GPR energy. Layers of clay and silt can be highly conductive and therefore limiting to the penetration of GPR signal. The lack of signal does not necessarily mean the lack of reflective structures. If archaeological structures and objects are embedded in a highly conductive layer (e.g. clay) the GPR method can fail to detect them.

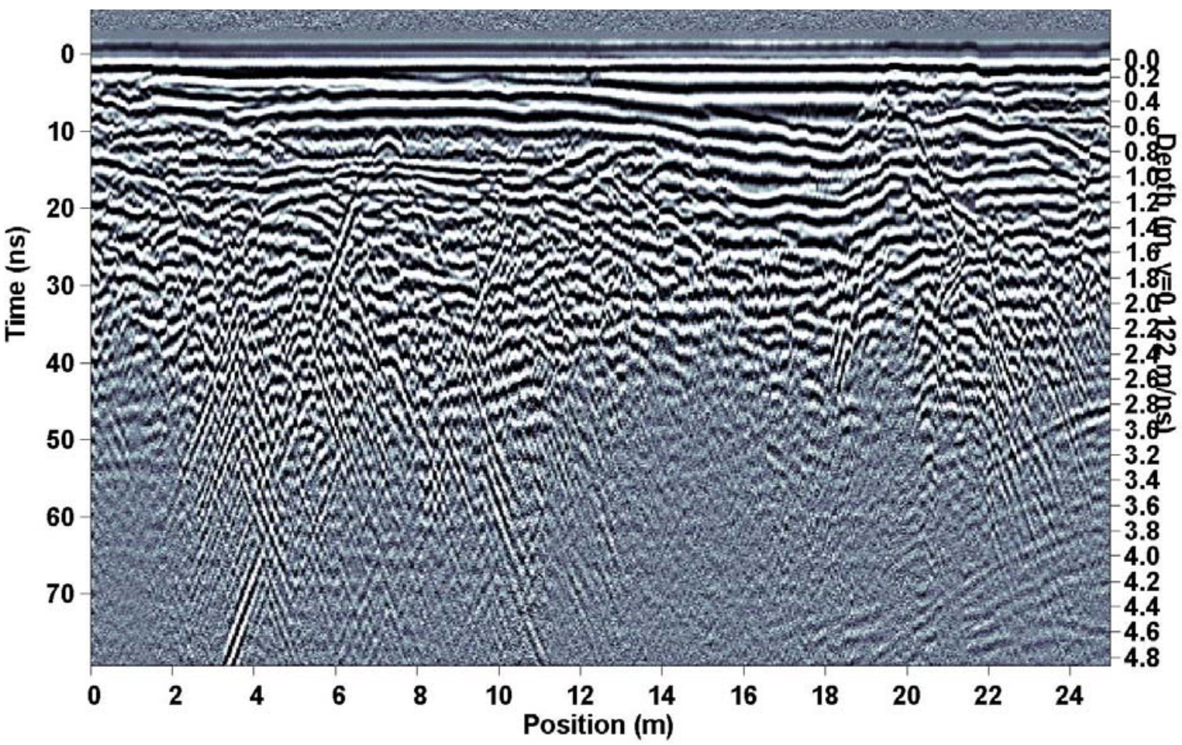

Figure 4.1: 2D GPR profile (a5) from survey site *Mejeriet (lower part)*. The velocity was determined to 12.2cm/ns. The corresponding depth-axis is shown to the right of the figure. The penetration depth of the signal can be determined from the data.

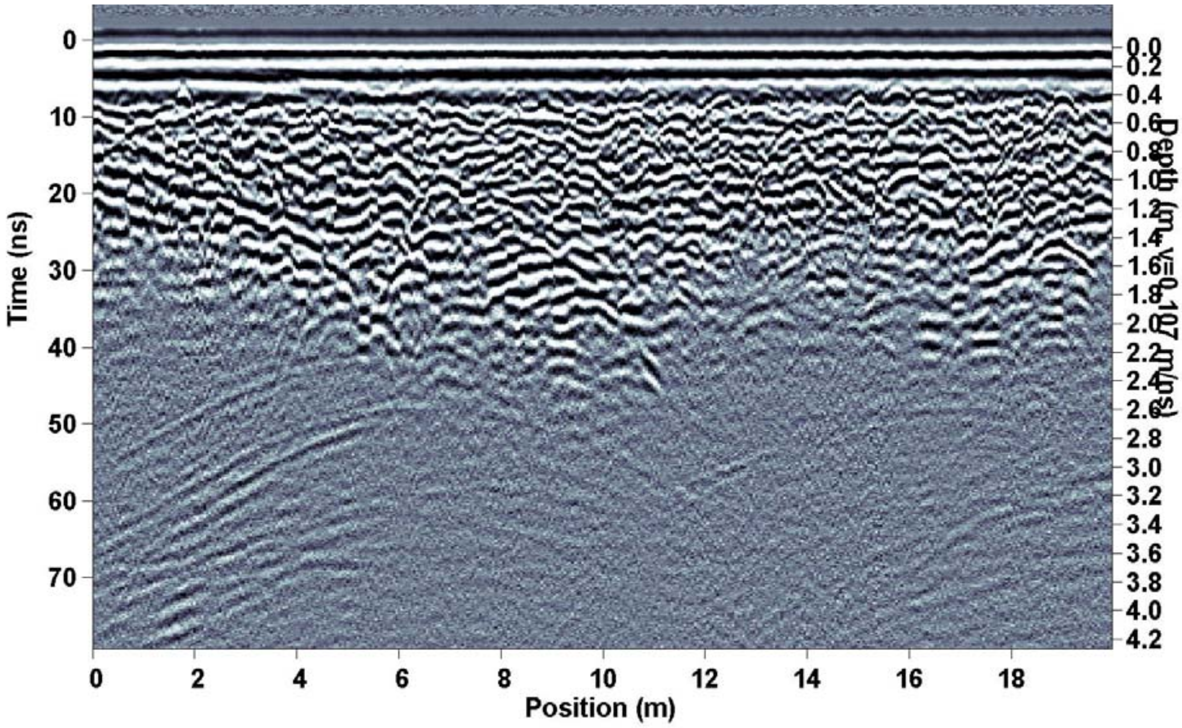

Figure 4.2: 2D GPR profile (b0) from survey site *Mejeriet (lower part)*. The velocity was determined to 10.7cm/ns. The corresponding depth-axis is shown to the right of the figure. The penetration depth of the signal can be determined from the data.

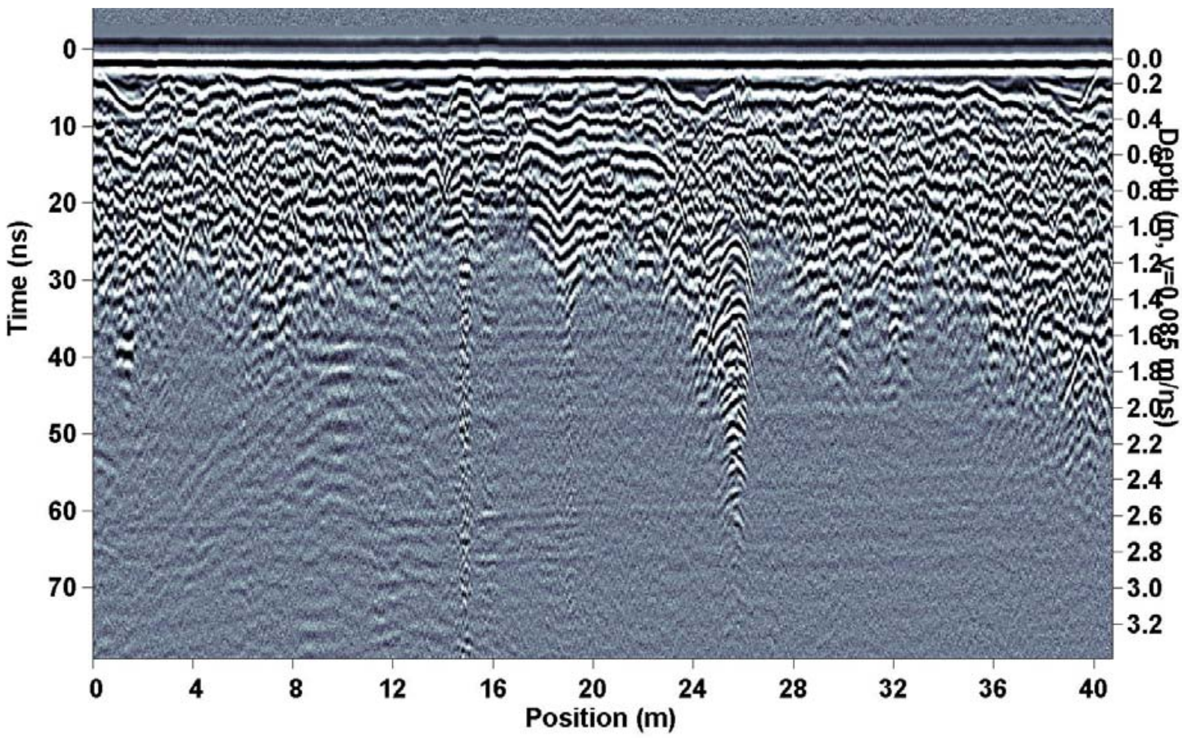

Figure 4.3: 2D GPR profile (c30) from survey site *Mejeriet (upper part)*. The velocity was determined to 8.5cm/ns. The corresponding depth-axis is shown to the right of the figure. The penetration depth of the signal can be determined from the data.

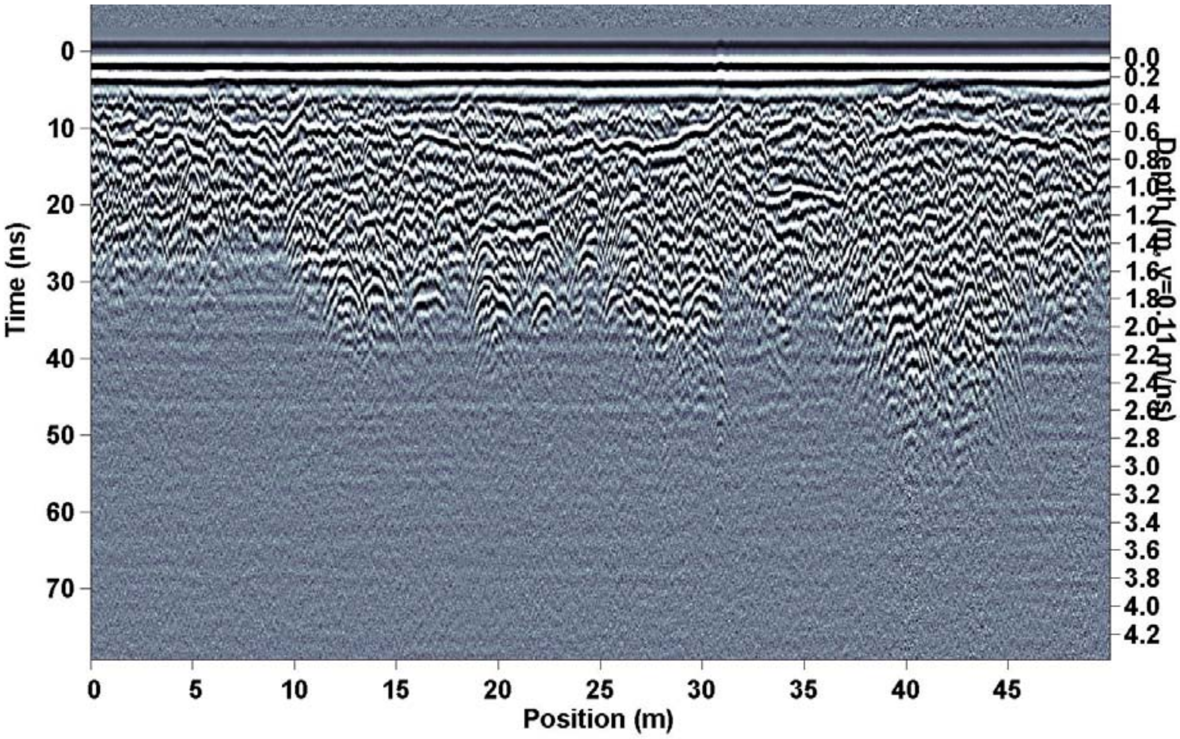

Figure 4.4: 2D GPR profile (d20) from survey site *Åkroken (upper part)*. The velocity was determined to 11cm/ns. The corresponding depth-axis is shown to the right of the figure. The penetration depth of the signal can be determined from the data.

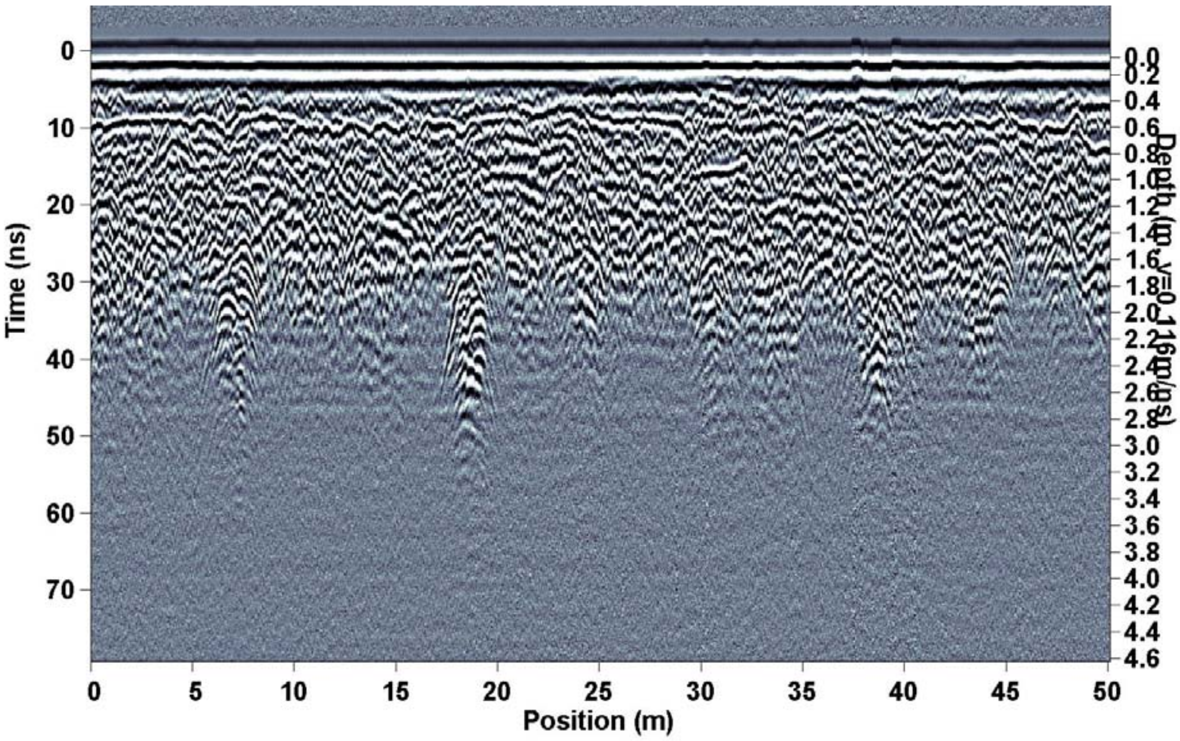

Figure 4.5: 2D GPR profile (e30) from survey site *Åkroken (upper part)*. The velocity was determined to 11.6cm/ns. The corresponding depth-axis is shown to the right of the figure. The penetration depth of the signal can be determined from the data.

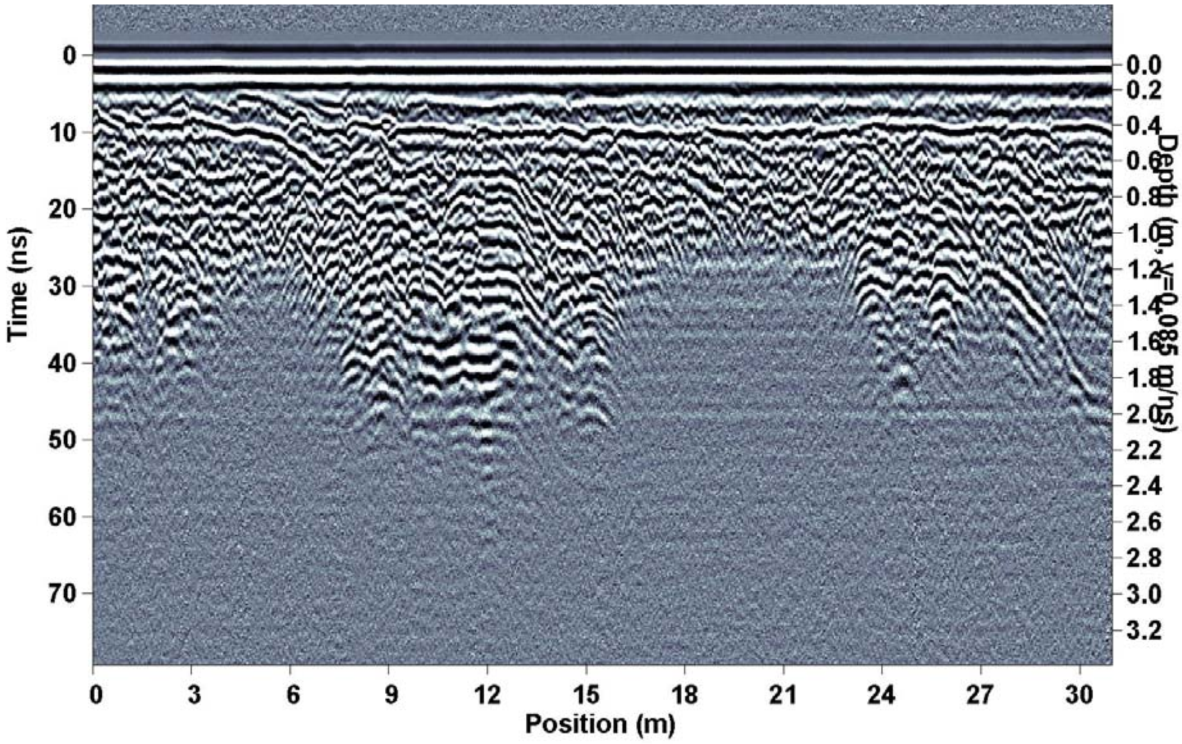

Figure 4.6: 2D GPR profile (m20) from survey site *Åkroken (lower part)*. The velocity was determined to 8.5cm/ns. The corresponding depth-axis is shown to the right of the figure. The penetration depth of the signal can be determined from the data.

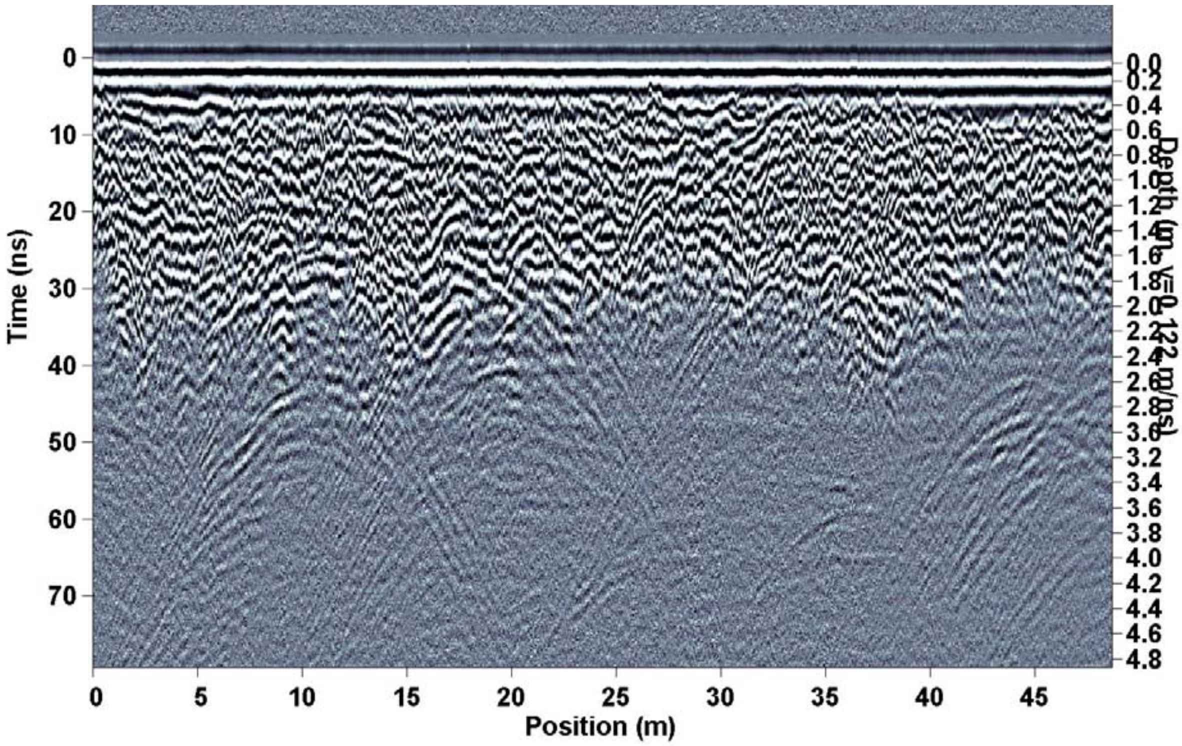

Figure 4.7: 2D GPR profile (n40) from survey site *Åkroken (lower part)*. The velocity was determined to 12.2cm/ns. The corresponding depth-axis is shown to the right of the figure. The penetration depth of the signal can be determined from the data.

5 Survey Documentation

Survey name	Nyköping 2006
Survey purpose	Detection of archaeological structures in the town centre of Nyköping, with particular interest in
Survey keywords	GPR
Administrative area	Nyköping, Sörmland, Sweden
Country	Sörmland, Sweden
Drift geology	Sandy clay, silt
Duration	Morning Monday July 3rd 2006 until afternoon Friday July 7th 2006
Weather	Warm and dry. The weeks prior to the survey have been dry.
Soil condition	Dry
Land-use	Mowed grass and sand road in case of areas *Mejeriet (lower part)*; Sand in case of area *Mejeriet (upper part);* Tarmac in case of area *Åkroken (upper part)*; Tarmac, mowed grass and sand path in case of area *Åkroken (lower part)*;
Monument type	Medieval town centre, roads, buildings, harbour constructions?
Monument period	Medieval to modern
Surveyor	Immo Trinks, Pär Karlsson, Lars-Inge Larsson Swedish National Heritage Board, UV Teknik, Box 5404, 114 84 Stockholm, Sweden E-mail: immo.trinks@raa.se
Depositor	Immo Trinks
Primary archive	Swedish National Heritage Board, UV Teknik, Box 5404, 114 84 Stockholm, Sweden
Copyright	Riksantikvarieämbetet
Geophysical coordinate system	Up to 50m long profile lines. Local coordinate system. Profile locations are described in the "GEOMETRY.1" and *.bes*-files in the folder "Original Data" on DVD.
Georeferencing	All survey areas were geo-referenced using a total station and coordinate points provided by the survey and mapping office of Nyköping council
Survey type	Ground Penetrating Radar
Instrumentation	One manually towed Sensors & Software Noggin Plus 500MHz antenna mounted in Noggin SmartCart with included odometer wheel
Area surveyed	Mejeriet (lower part) 1000 + 230 m^2 Mejeriet (upper part) 650 m^2 Åkroken (upper part) 988 + 556 m^2 Åkroken (lower part) 465 + 817 m^2 **Total area** **4706** m^2
Method of coverage	Regular grid of parallel profile lines, Zigzag
Traverse separation	25cm
Reading interval	5cm inline
Grid size	Maximum profile length: 50m

This documentation is based on the guide: *Geophysical Data in Archaeology: Guide to Good Practice* by Armin Schmidt, Arts and Humanities Data Service (http://ads.ahds.ac.uk/project/goodguides/geophys/).

6 Appendix

The Appendix contains printouts of the 10cm thick depth-slices of all measured areas between 0m and 3m depth.

6.1 Depth-slices from survey site *Mejeriet (lower part)*

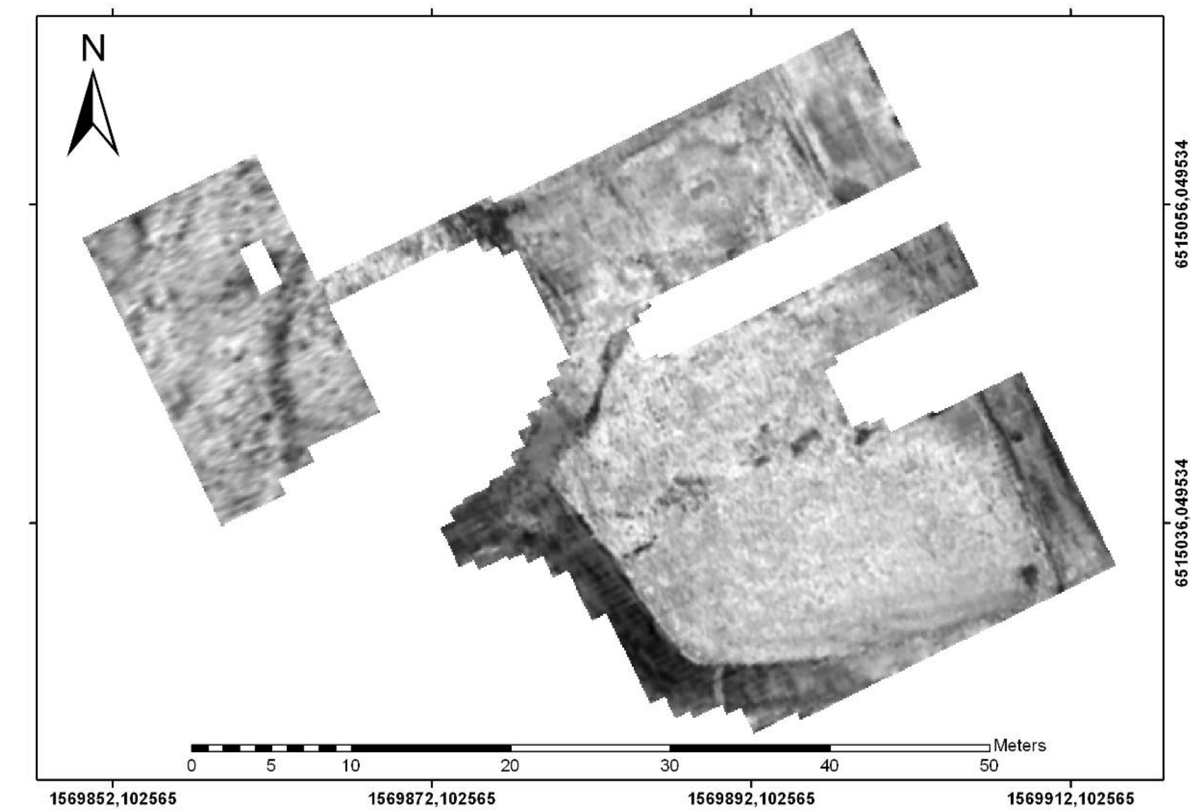

Figure 6.1.1: Depth-slice (0-10cm) survey site *Mejeriet (lower part).*

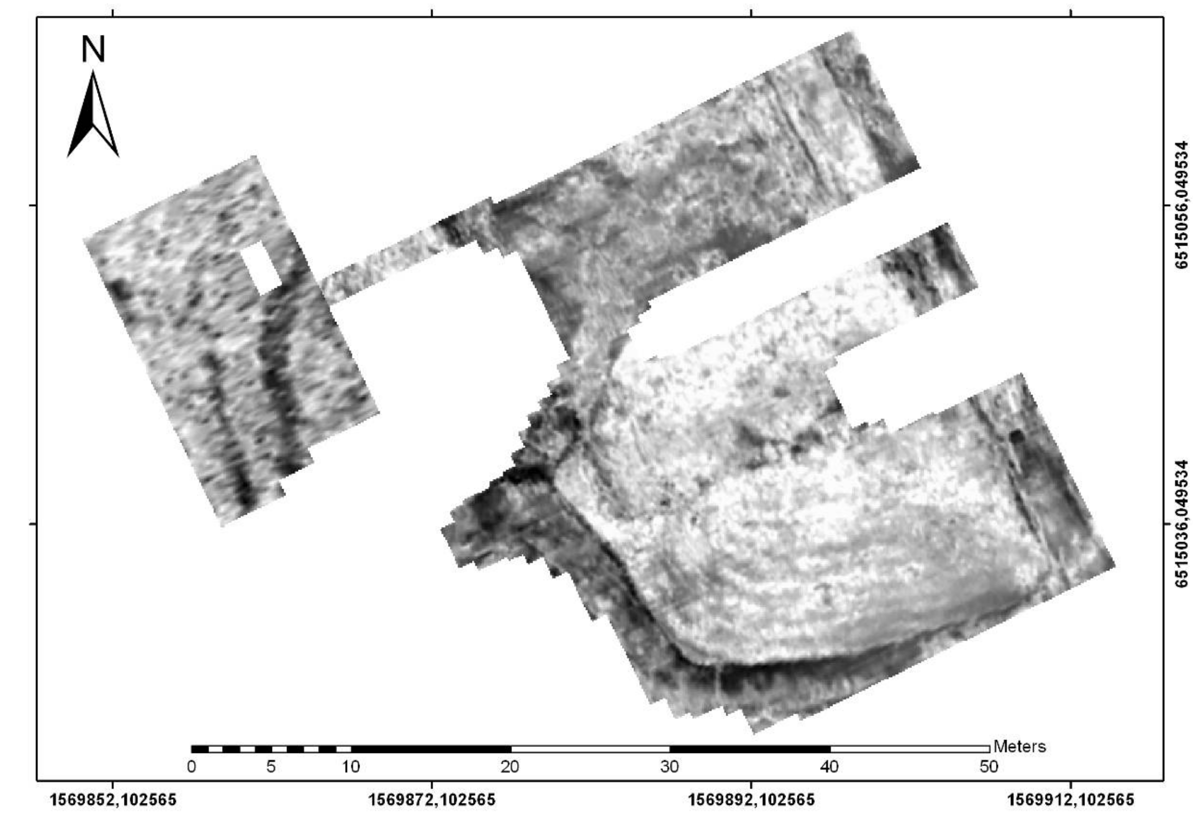

Figure 6.1.2: Depth-slice (10-20cm) survey site *Mejeriet (lower part).*

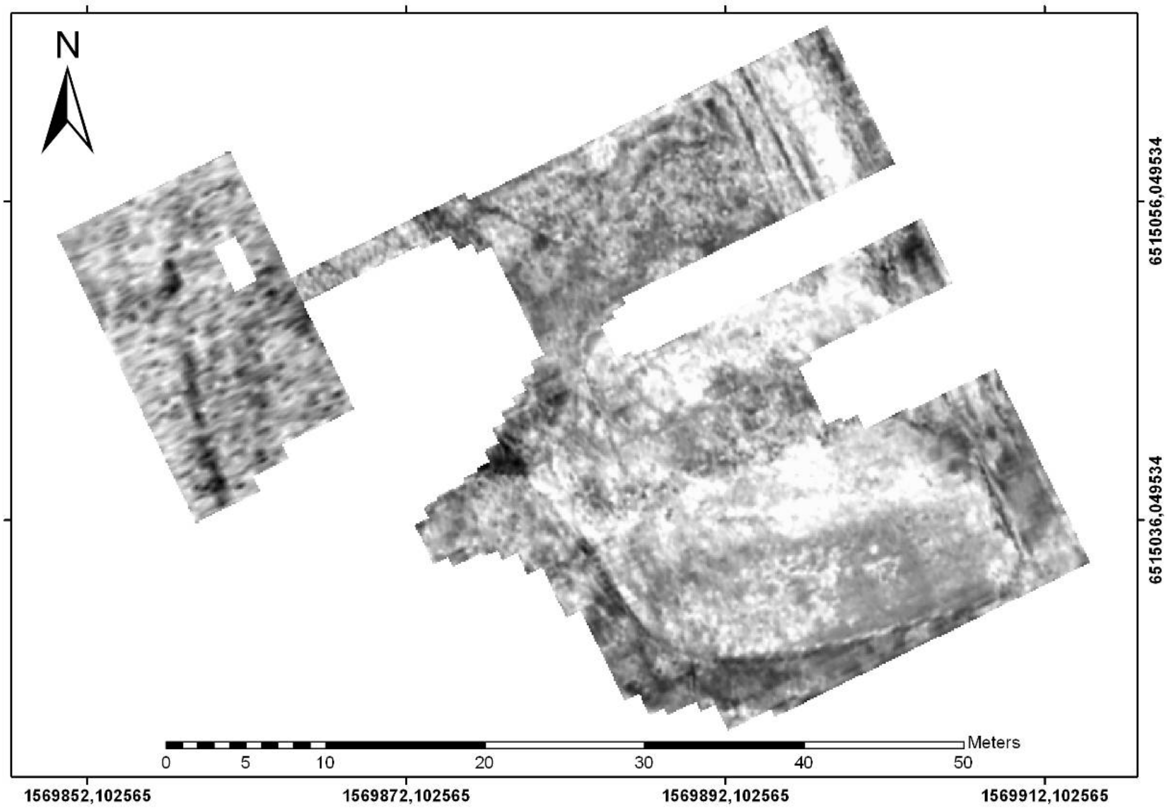

Figure 6.1.3: Depth-slice (20-30cm) survey site *Mejeriet (lower part).*

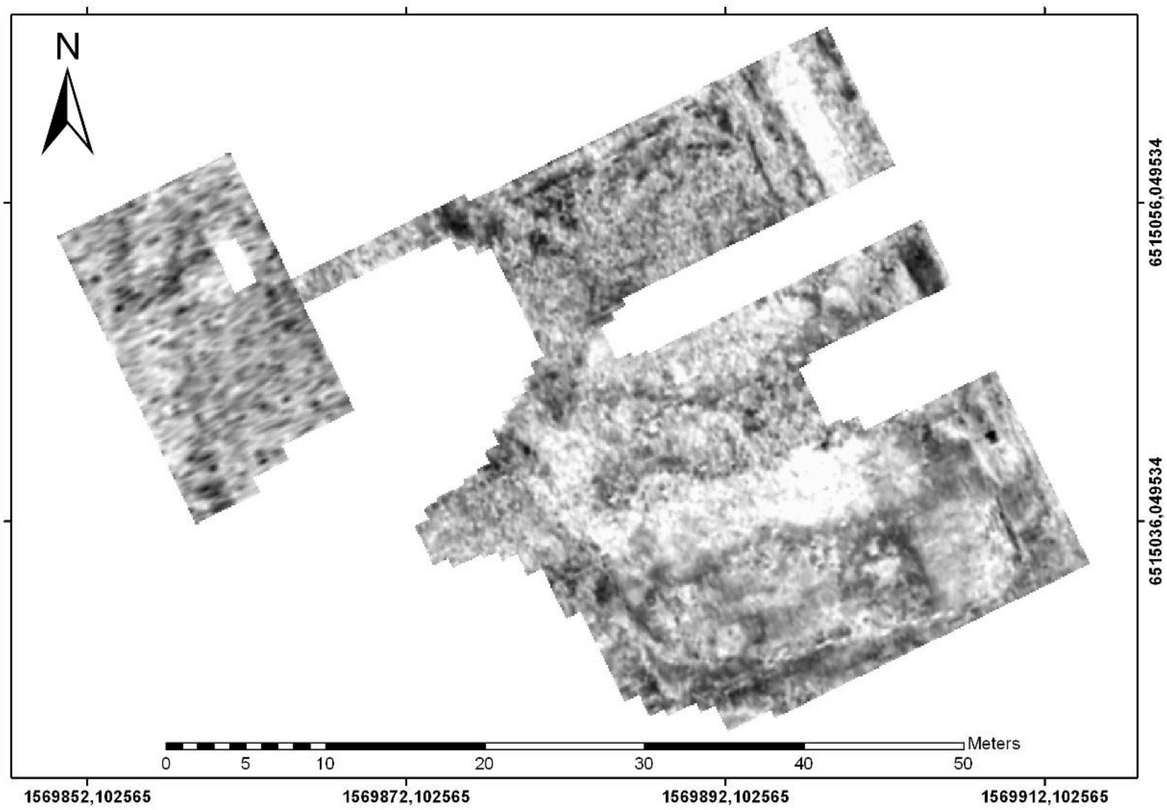

Figure 6.1.4: Depth-slice (30-40cm) survey site *Mejeriet (lower part).*

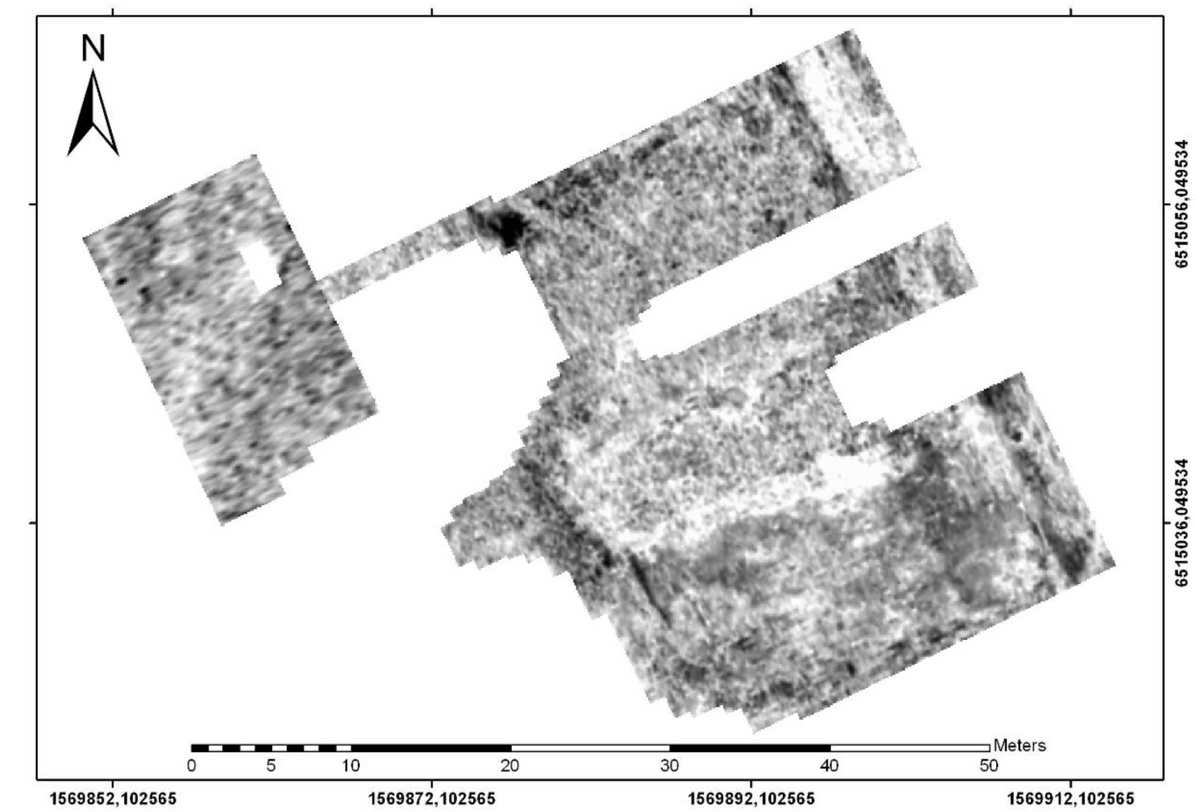

Figure 6.1.5: Depth-slice (40-50cm) survey site *Mejeriet (lower part).*

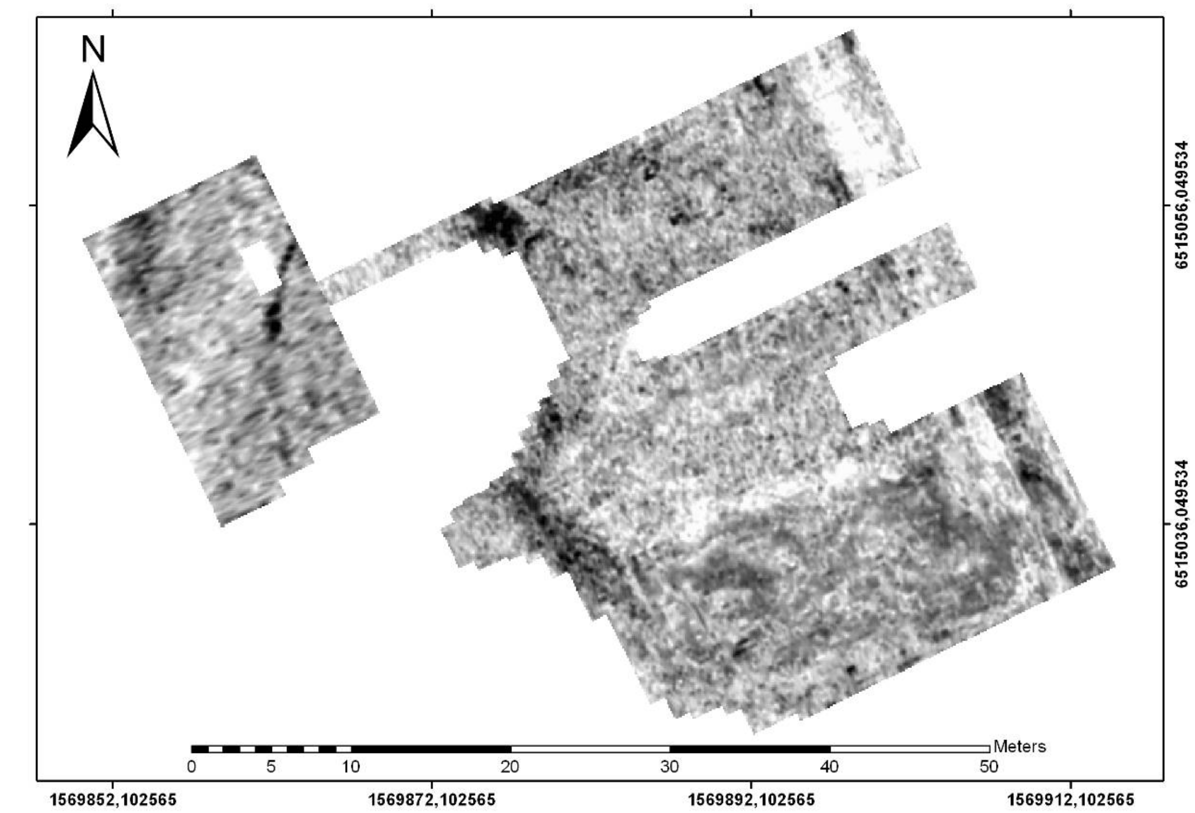

Figure 6.1.6: Depth-slice (50-60cm) survey site *Mejeriet (lower part).*

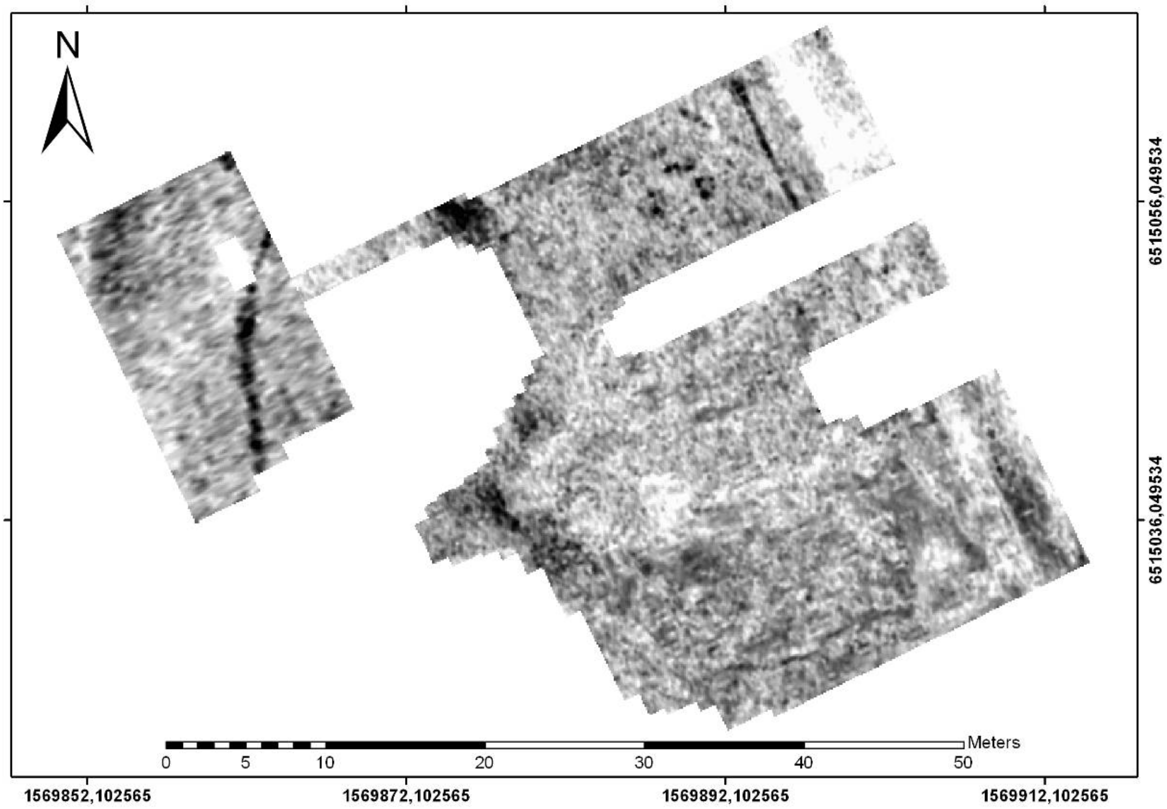

Figure 6.1.7: Depth-slice (60-70cm) survey site *Mejeriet (lower part).*

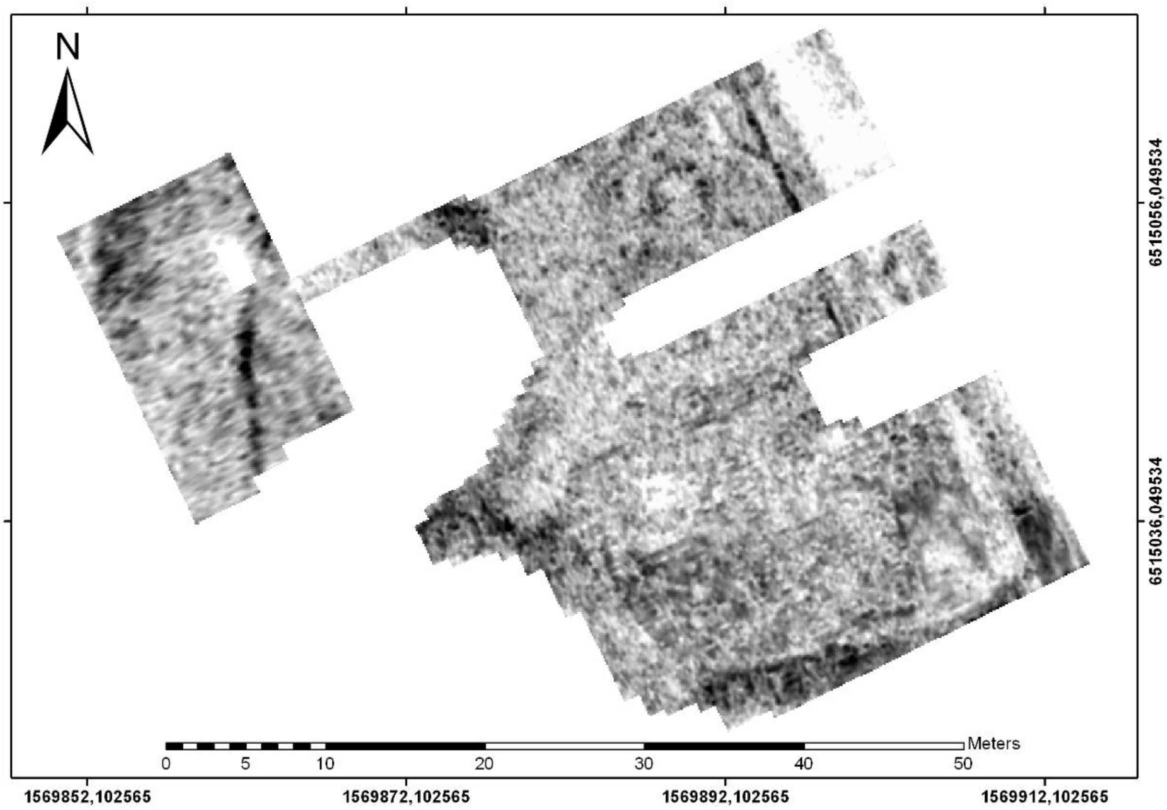

Figure 6.1.8: Depth-slice (70-80cm) survey site *Mejeriet (lower part).*

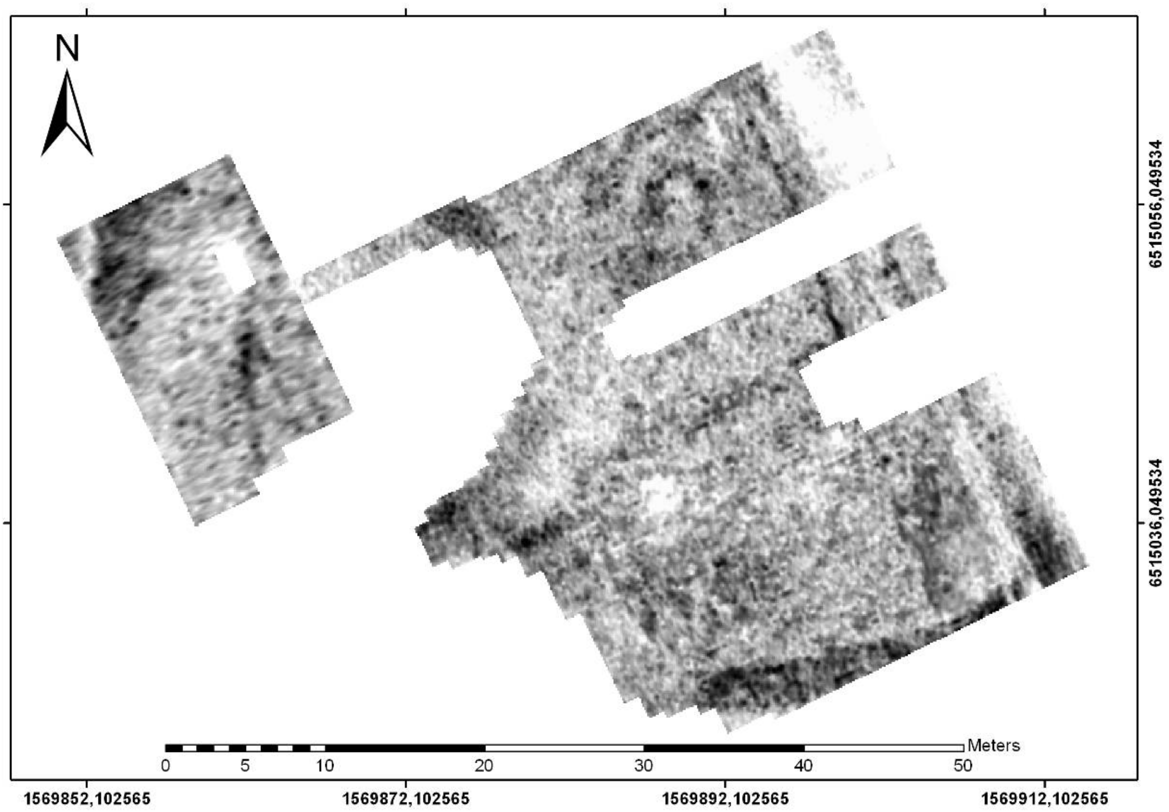

Figure 6.1.9: Depth-slice (80-90cm) survey site *Mejeriet (lower part)*.

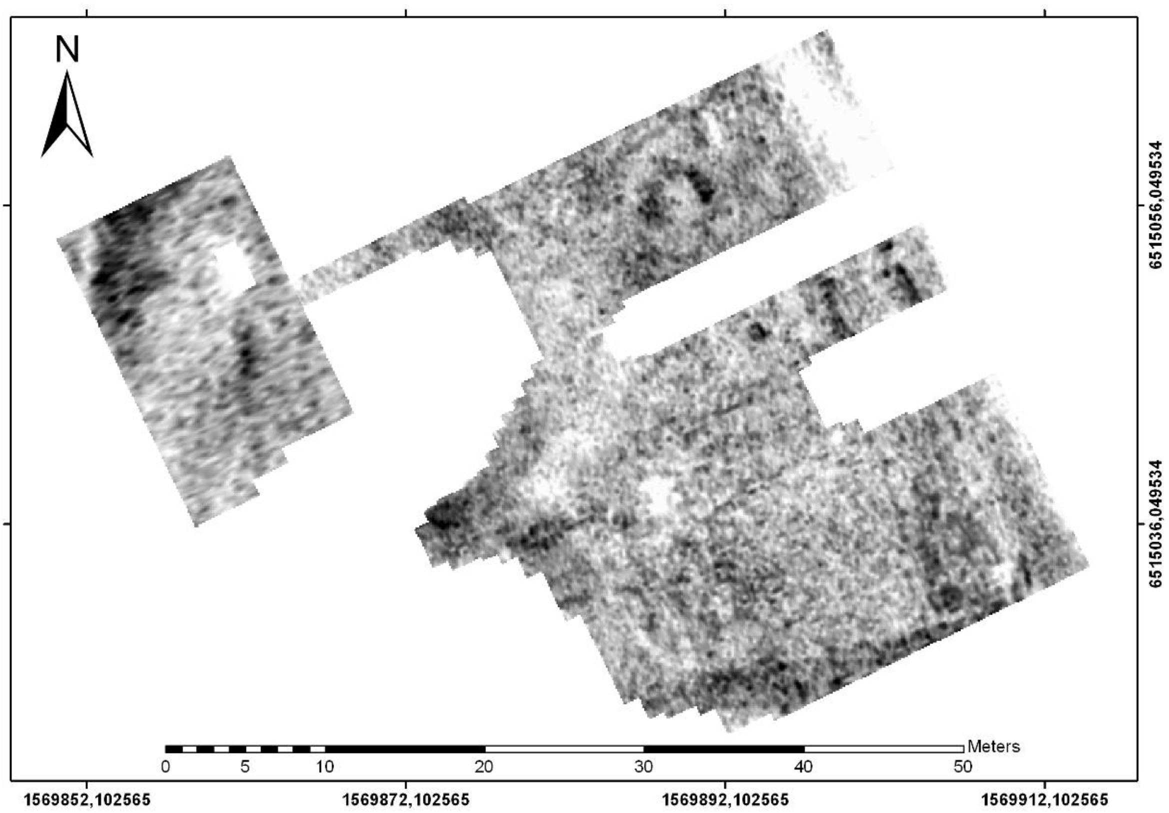

Figure 6.1.10: Depth-slice (90-100cm) survey site *Mejeriet (lower part)*.

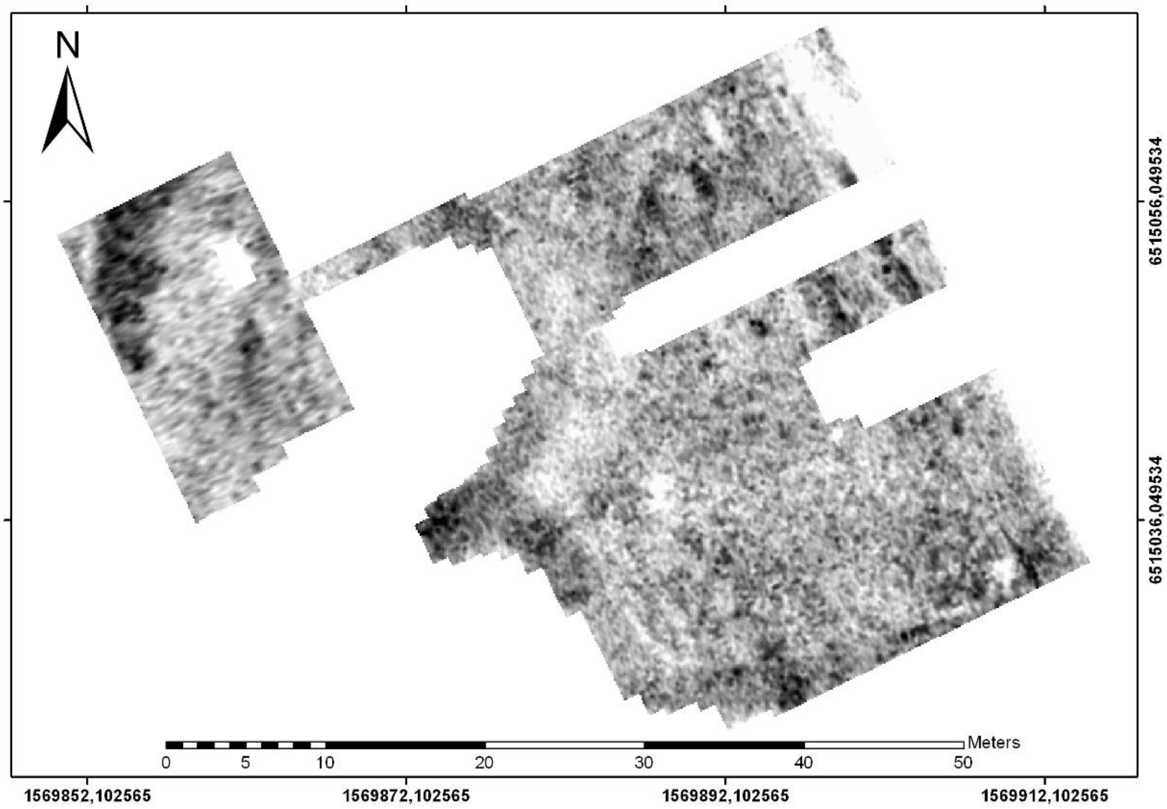

Figure 6.1.11: Depth-slice (100-110cm) survey site *Mejeriet (lower part).*

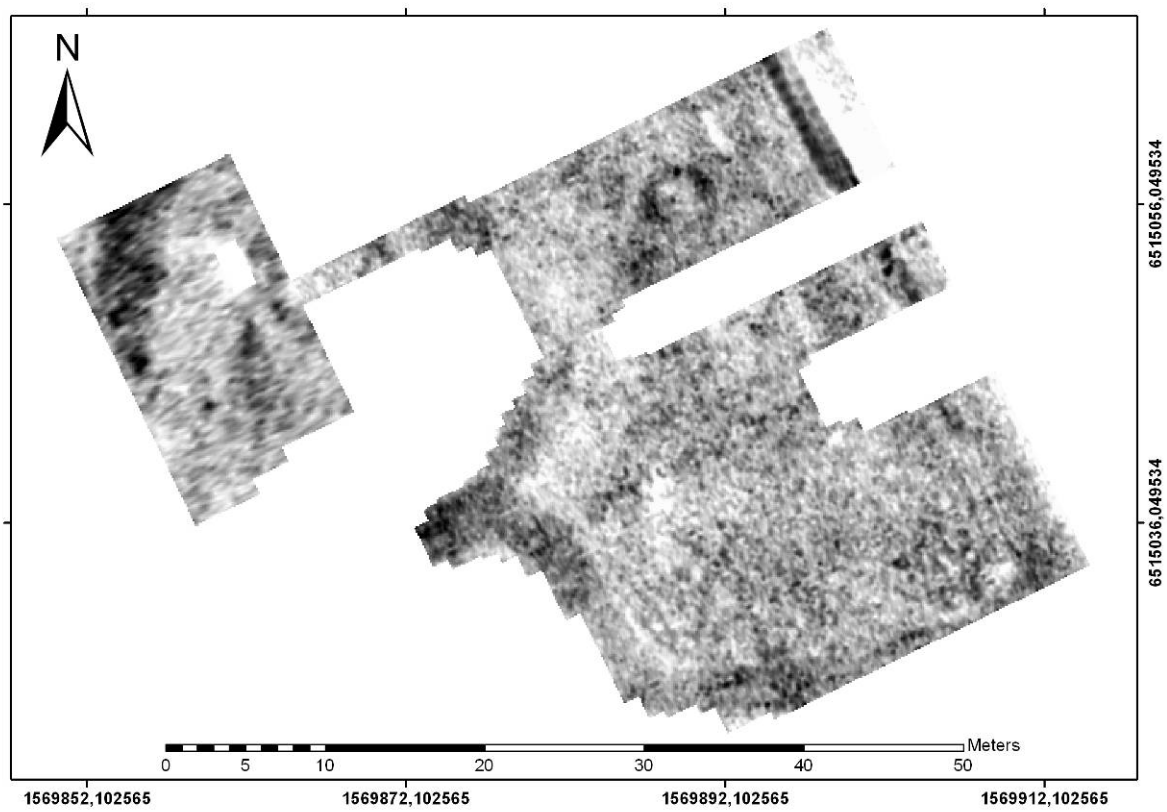

Figure 6.1.12: Depth-slice (110-120cm) survey site *Mejeriet (lower part).*

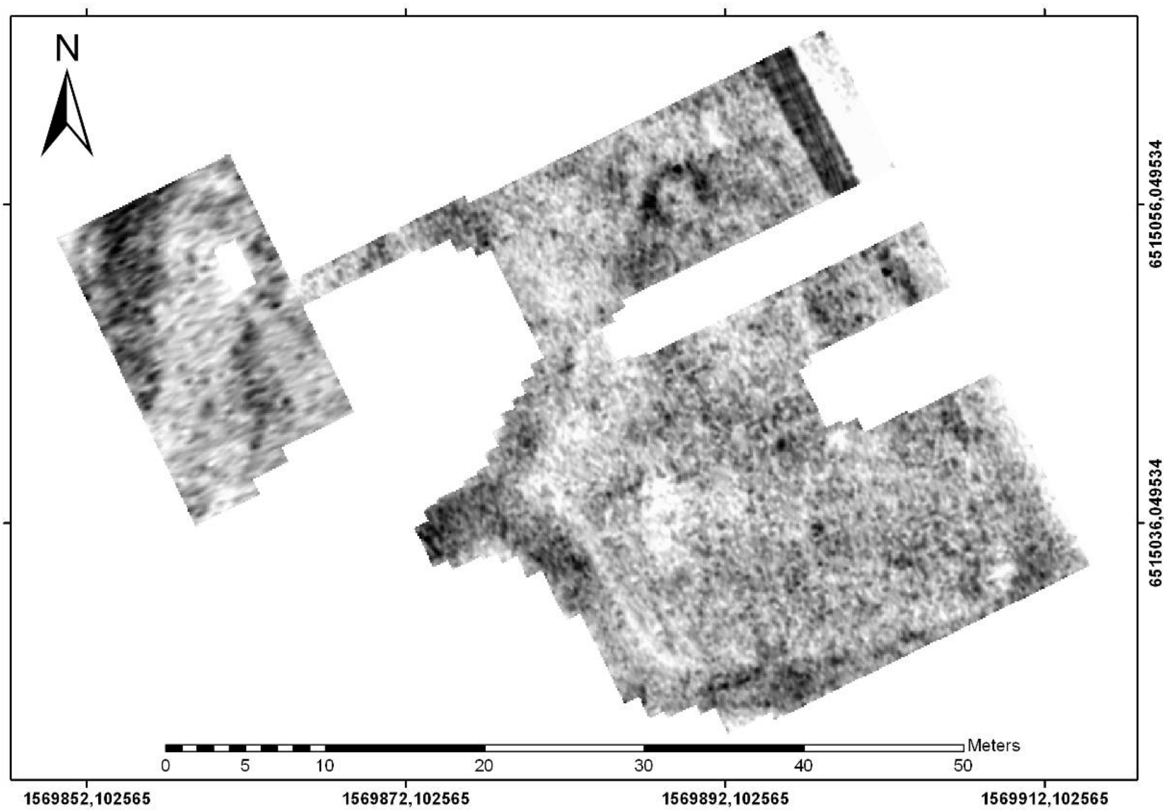

Figure 6.1.13: Depth-slice (120-130cm) survey site *Mejeriet (lower part).*

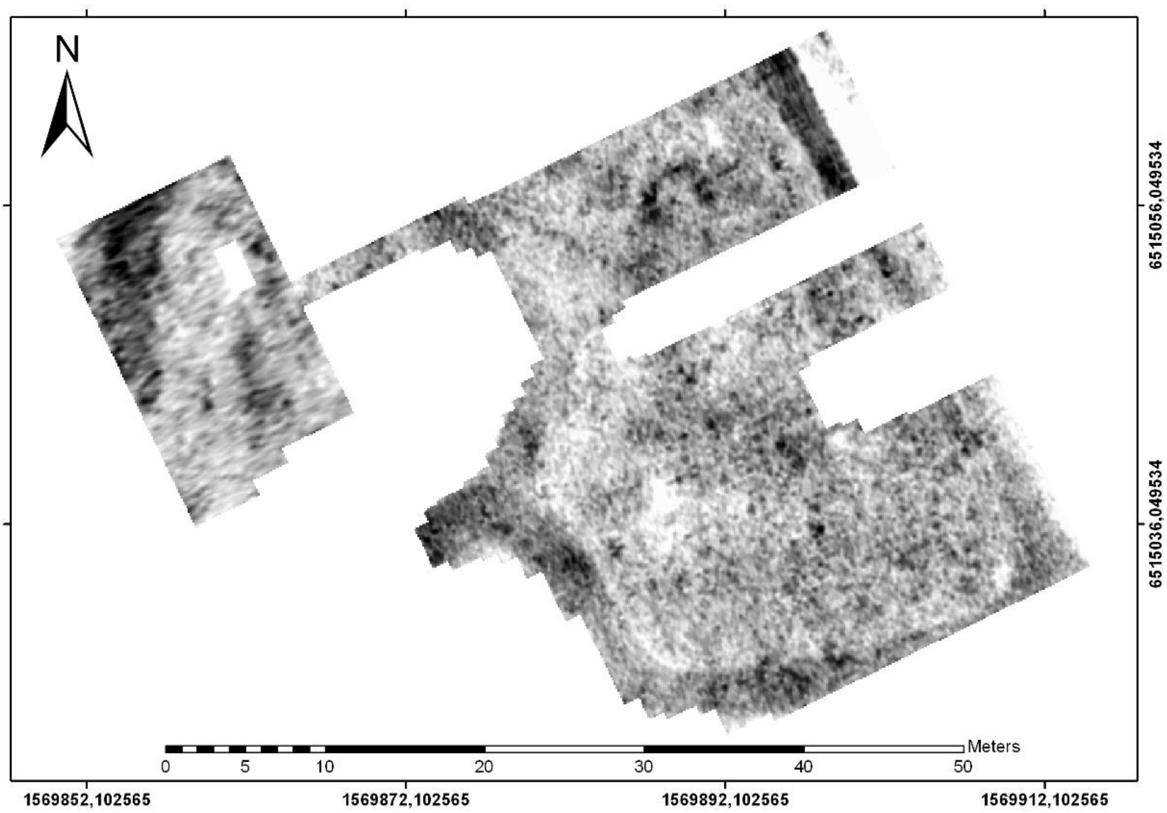

Figure 6.1.14: Depth-slice (130-140cm) survey site *Mejeriet (lower part).*

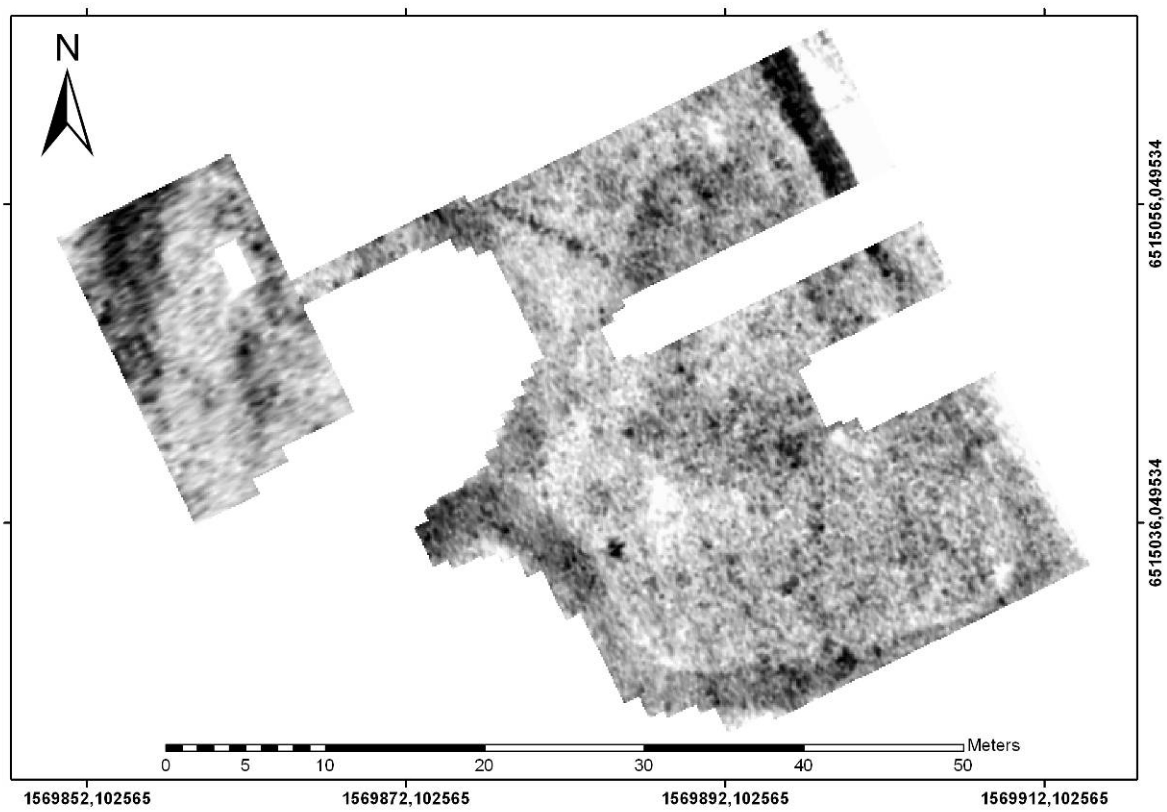

Figure 6.1.15: Depth-slice (140-150cm) survey site *Mejeriet (lower part).*

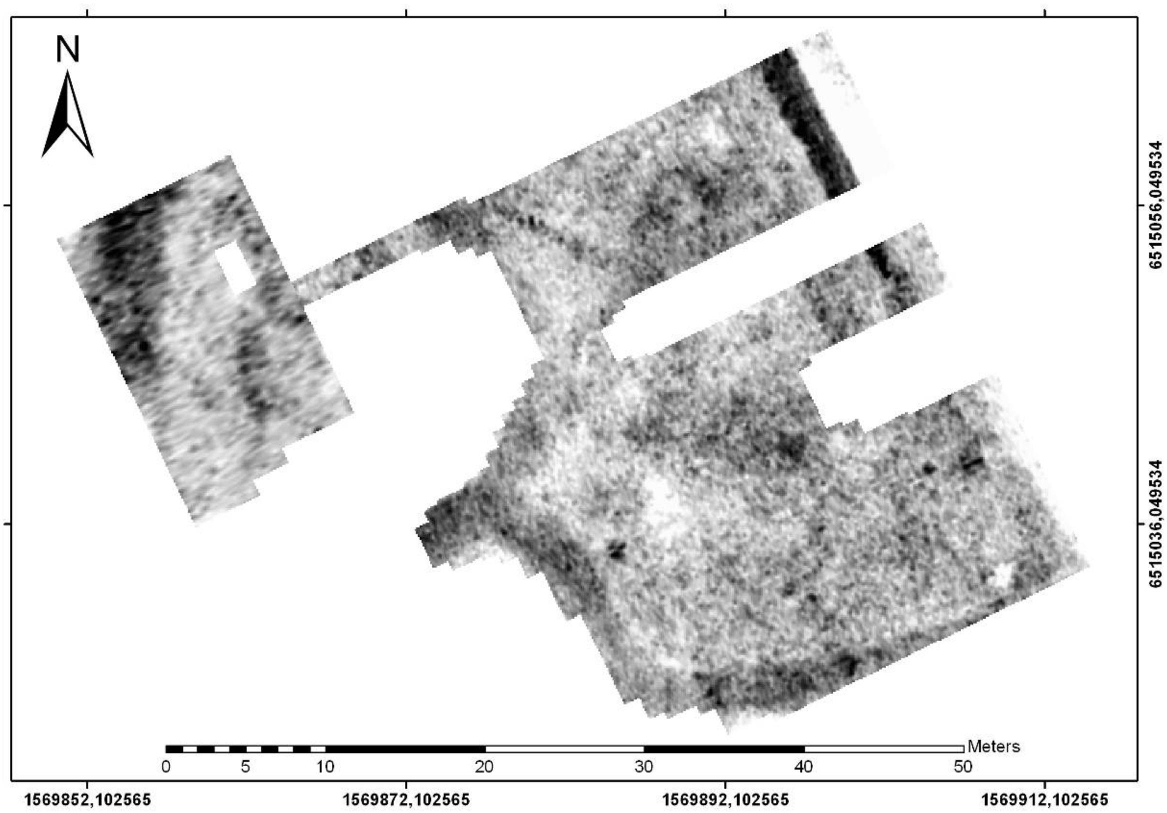

Figure 6.1.16: Depth-slice (150-160cm) survey site *Mejeriet (lower part).*

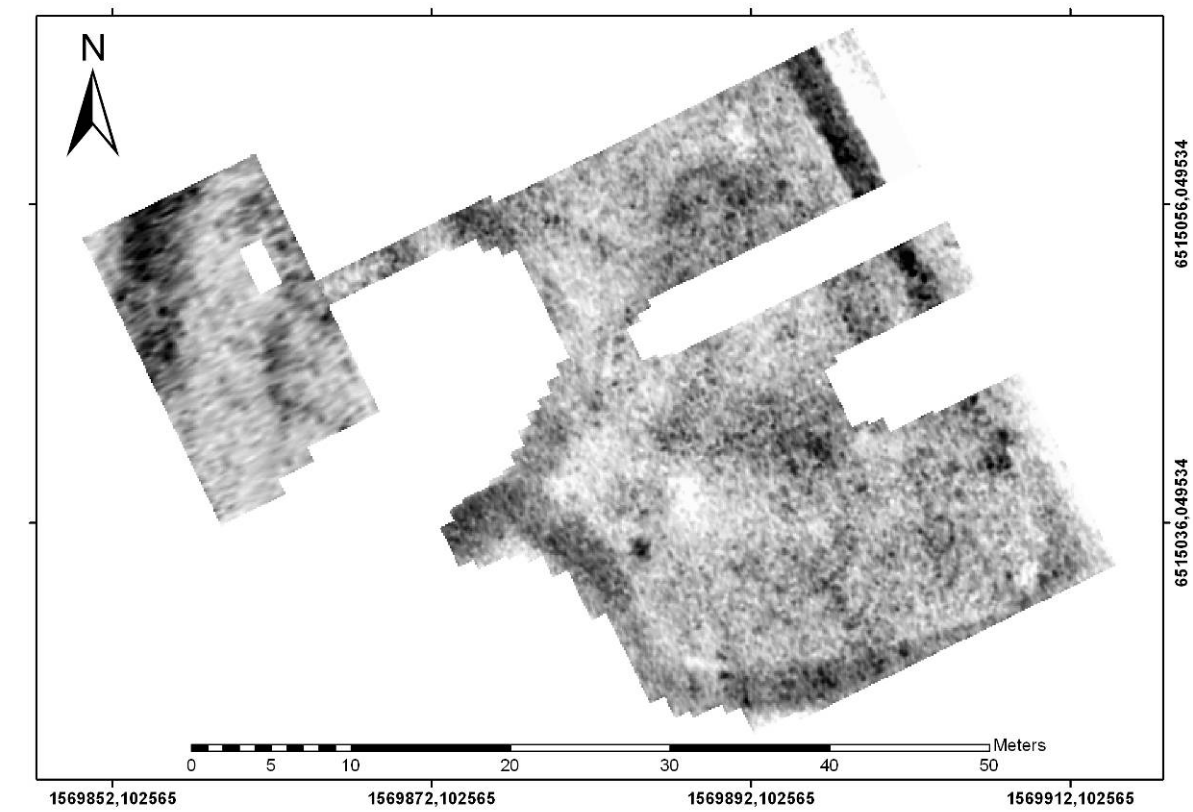

Figure 6.1.17: Depth-slice (160-170cm) survey site *Mejeriet (lower part).*

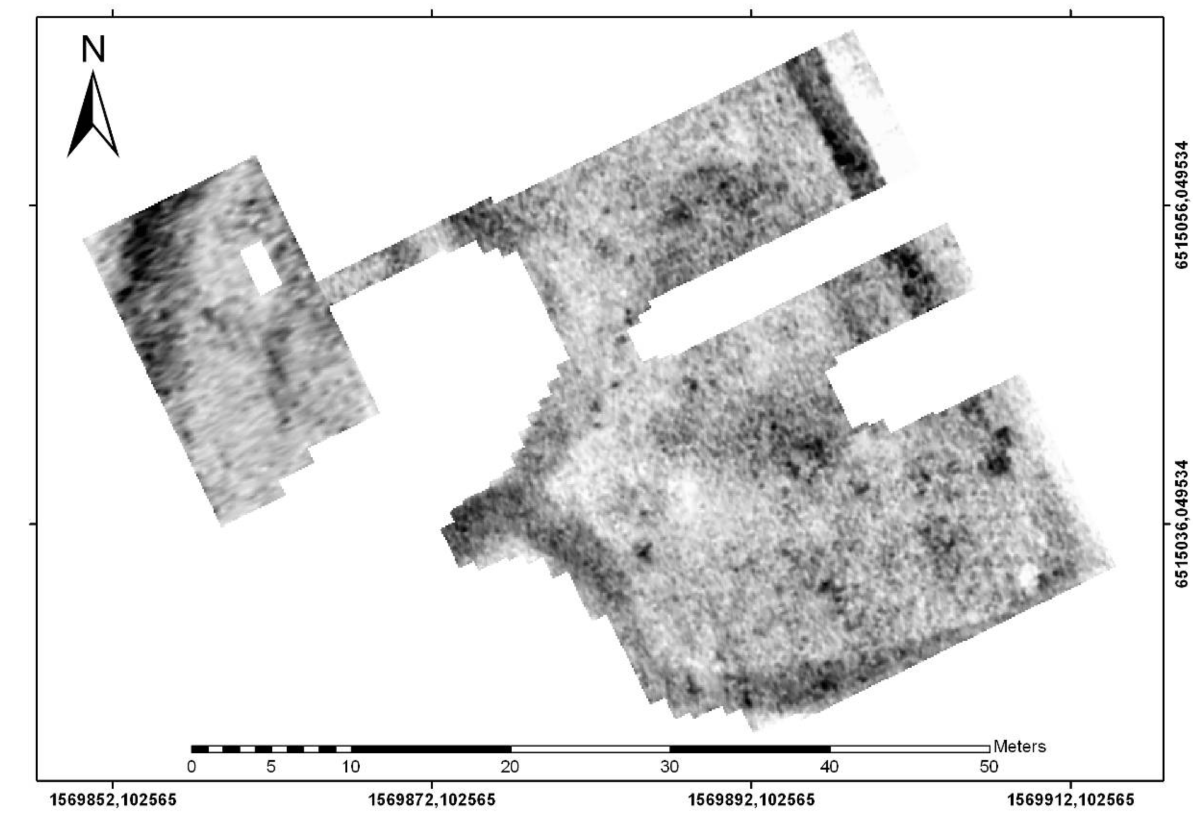

Figure 6.1.18: Depth-slice (170-180cm) survey site *Mejeriet (lower part).*

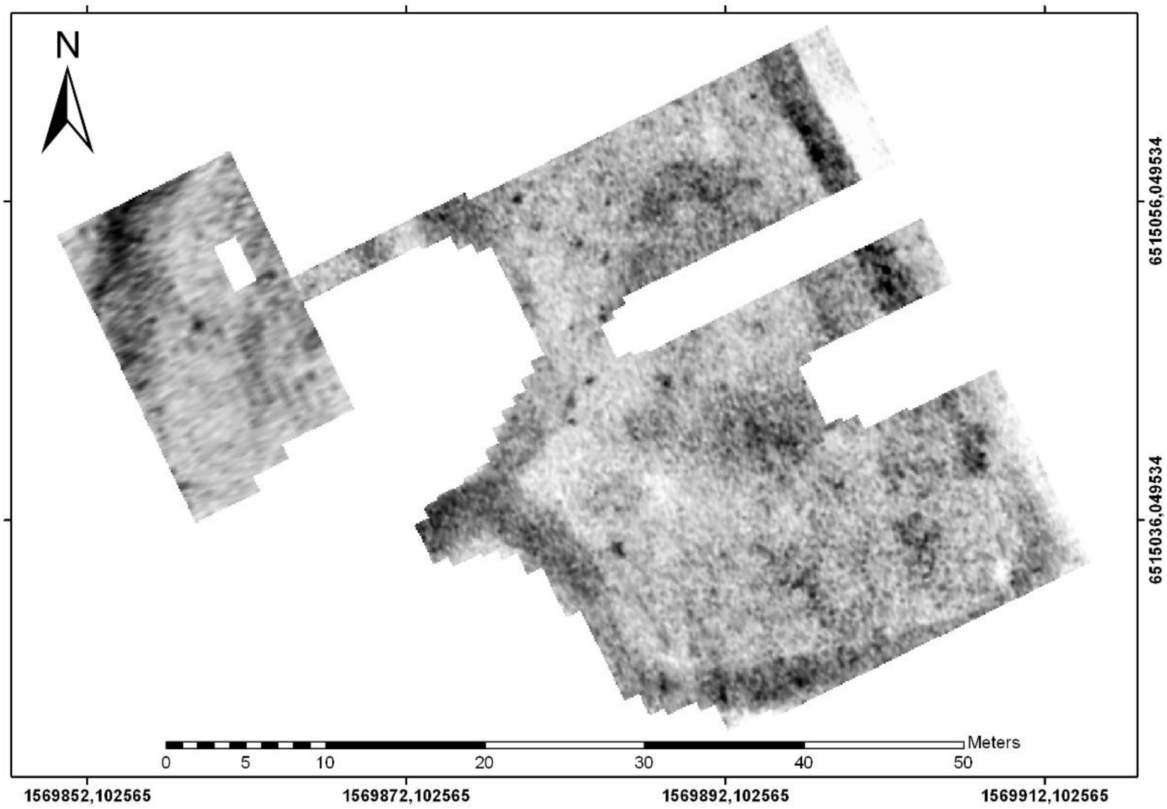

Figure 6.1.19: Depth-slice (180-190cm) survey site *Mejeriet (lower part).*

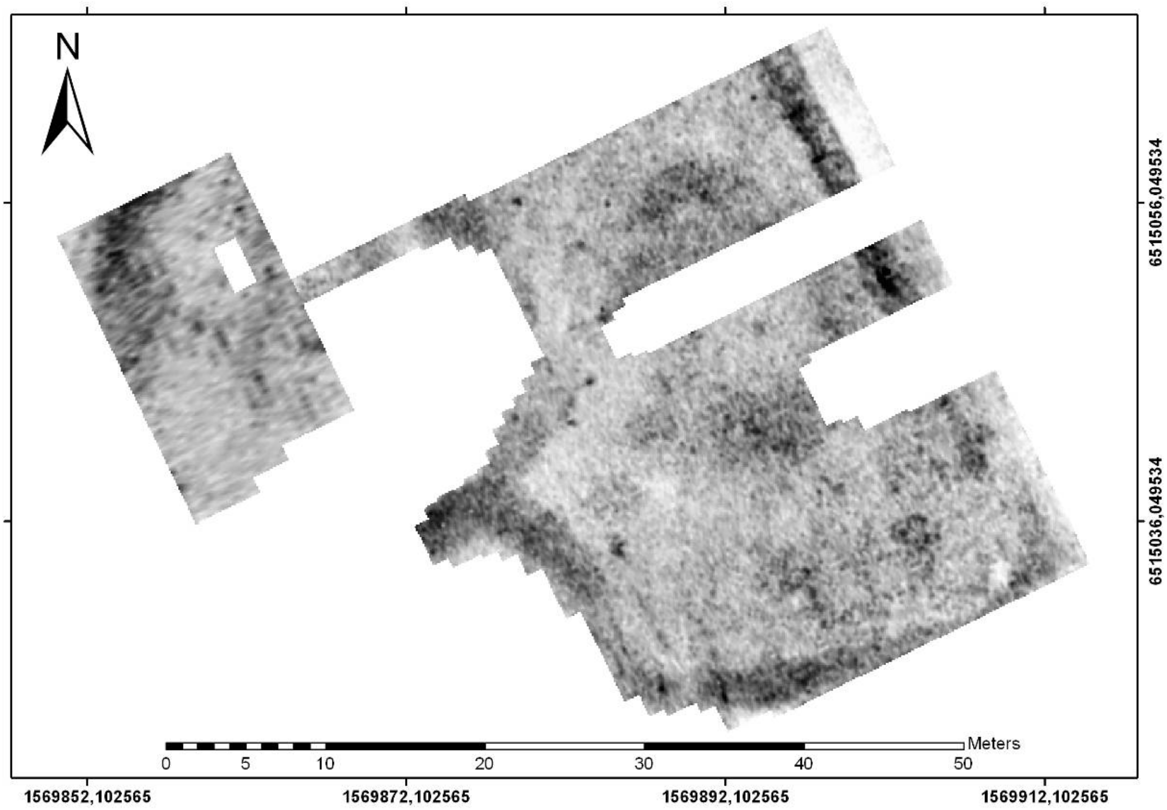

Figure 6.1.20: Depth-slice (190-200cm) survey site *Mejeriet (lower part).*

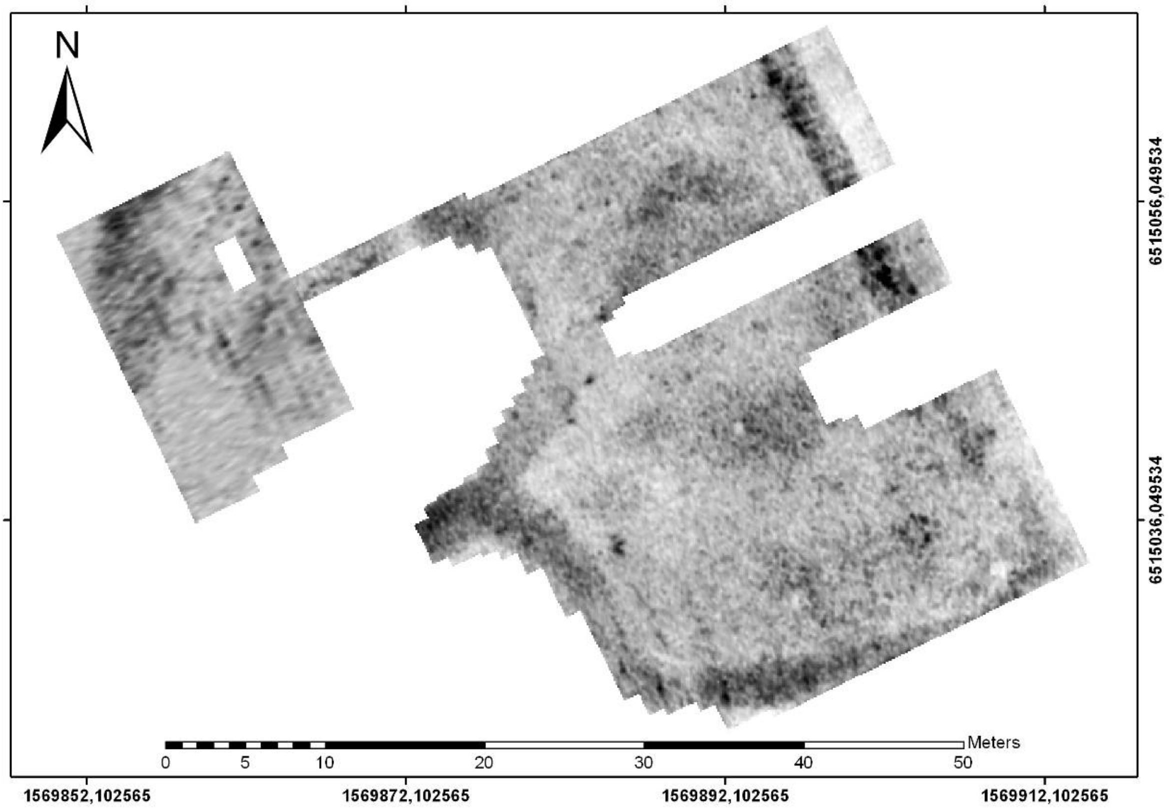

Figure 6.1.21: Depth-slice (200-210cm) survey site *Mejeriet (lower part).*

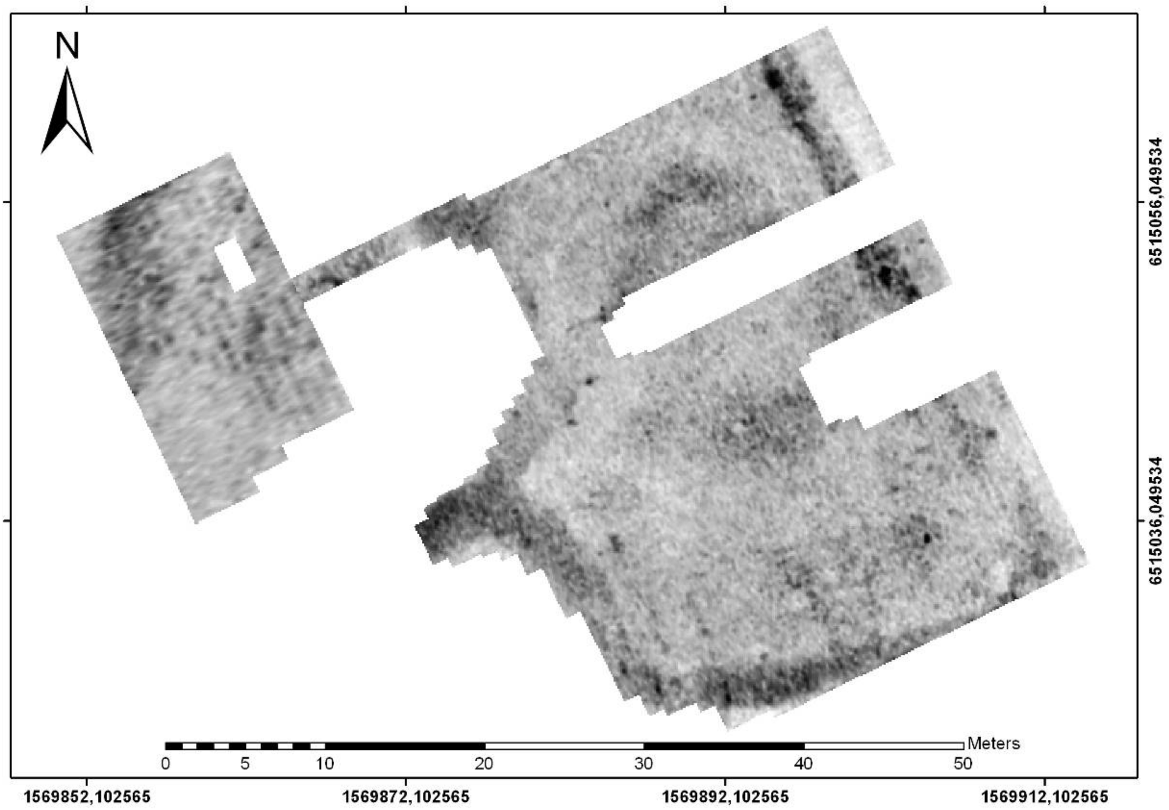

Figure 6.1.22: Depth-slice (210-220cm) survey site *Mejeriet (lower part).*

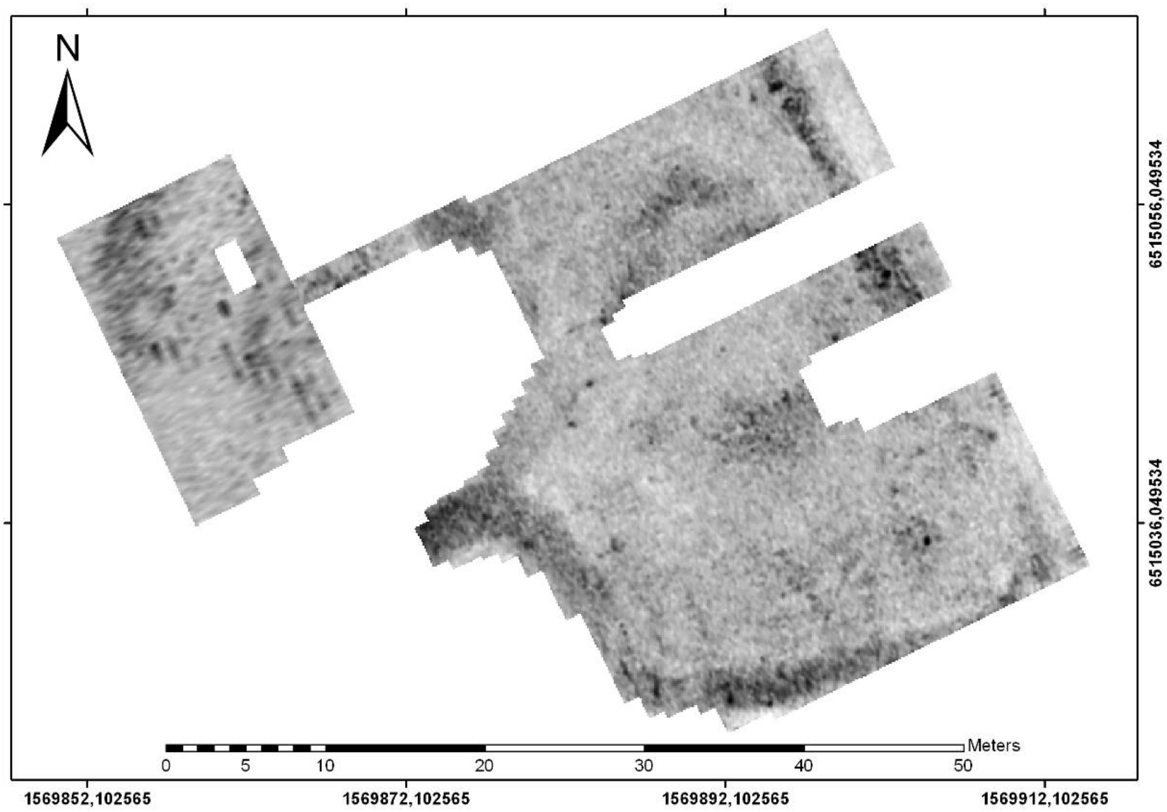

Figure 6.1.23: Depth-slice (220-230cm) survey site *Mejeriet (lower part).*

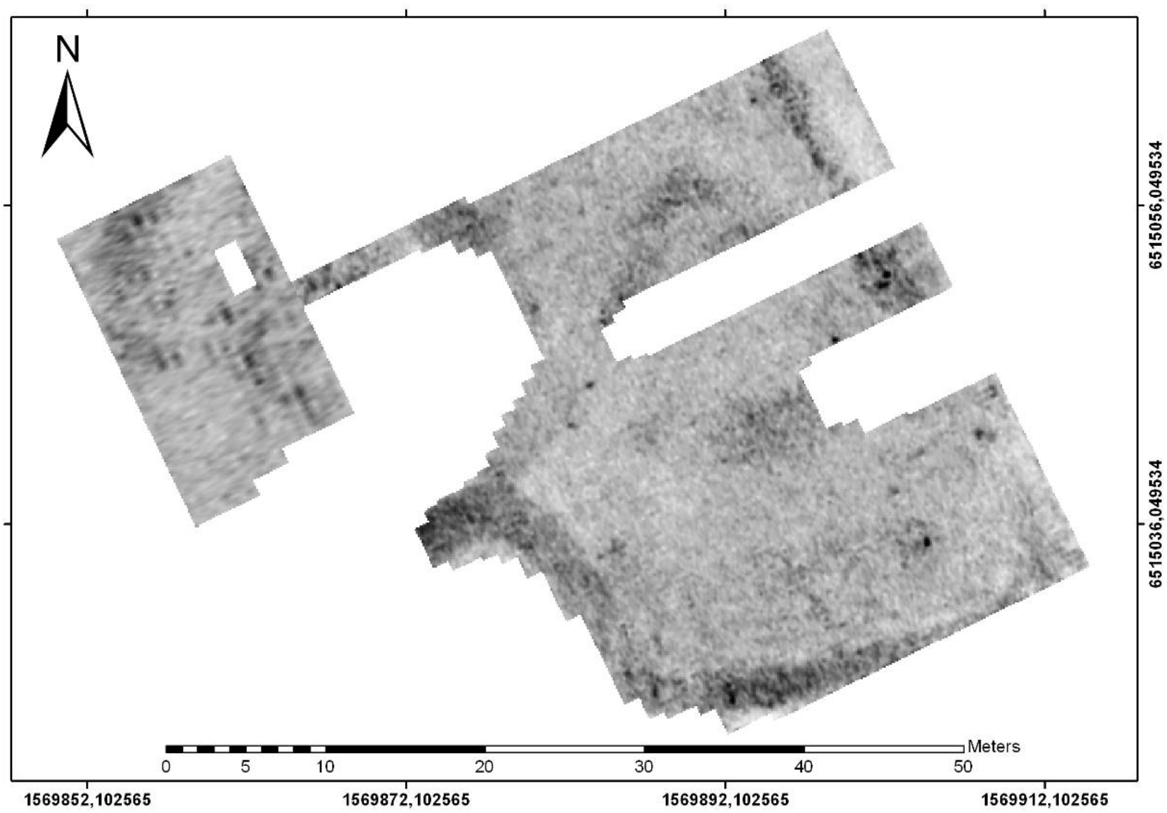

Figure 6.1.24: Depth-slice (230-240cm) survey site *Mejeriet (lower part).*

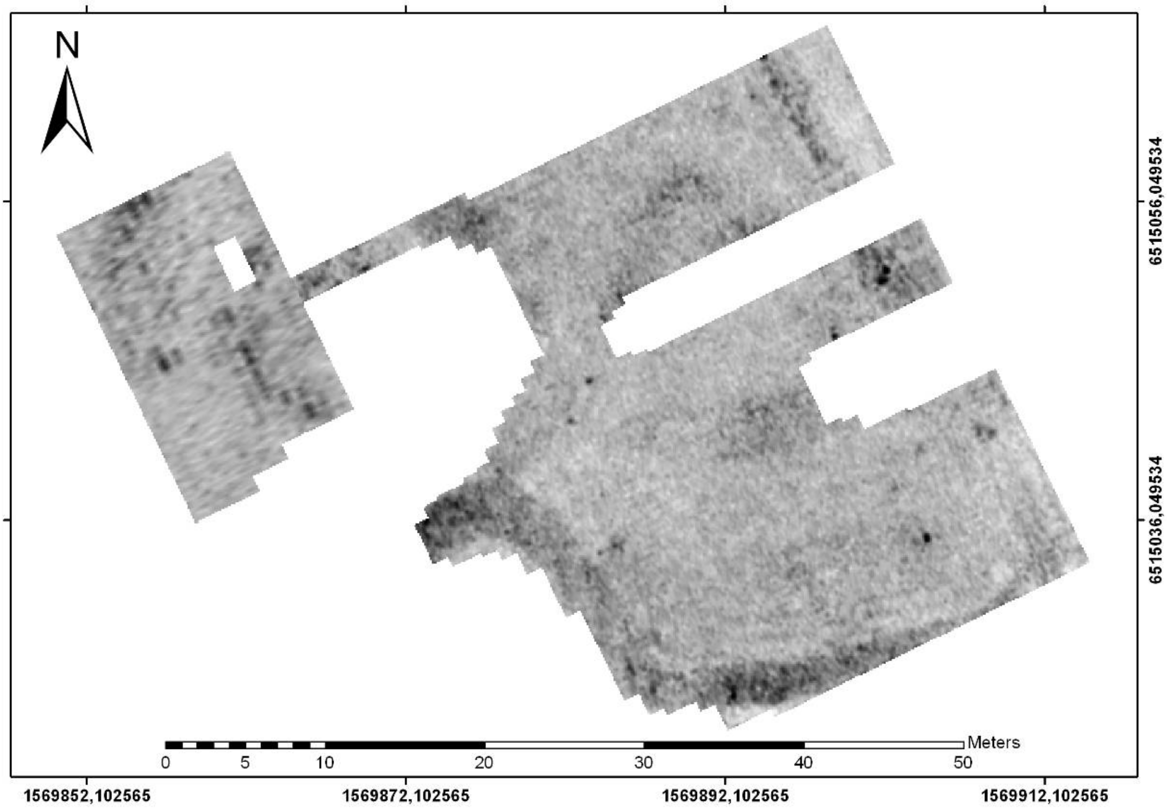

Figure 6.1.25: Depth-slice (240-250cm) survey site *Mejeriet (lower part).*

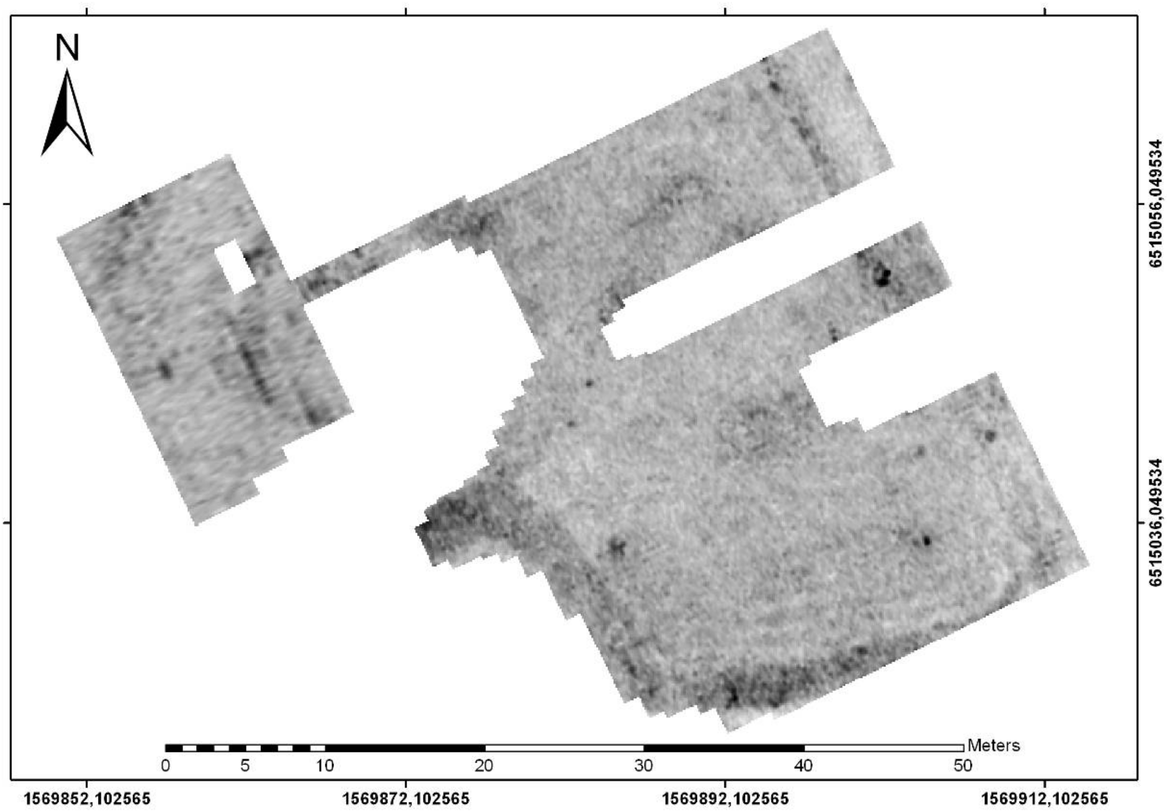

Figure 6.1.26: Depth-slice (250-260cm) survey site *Mejeriet (lower part).*

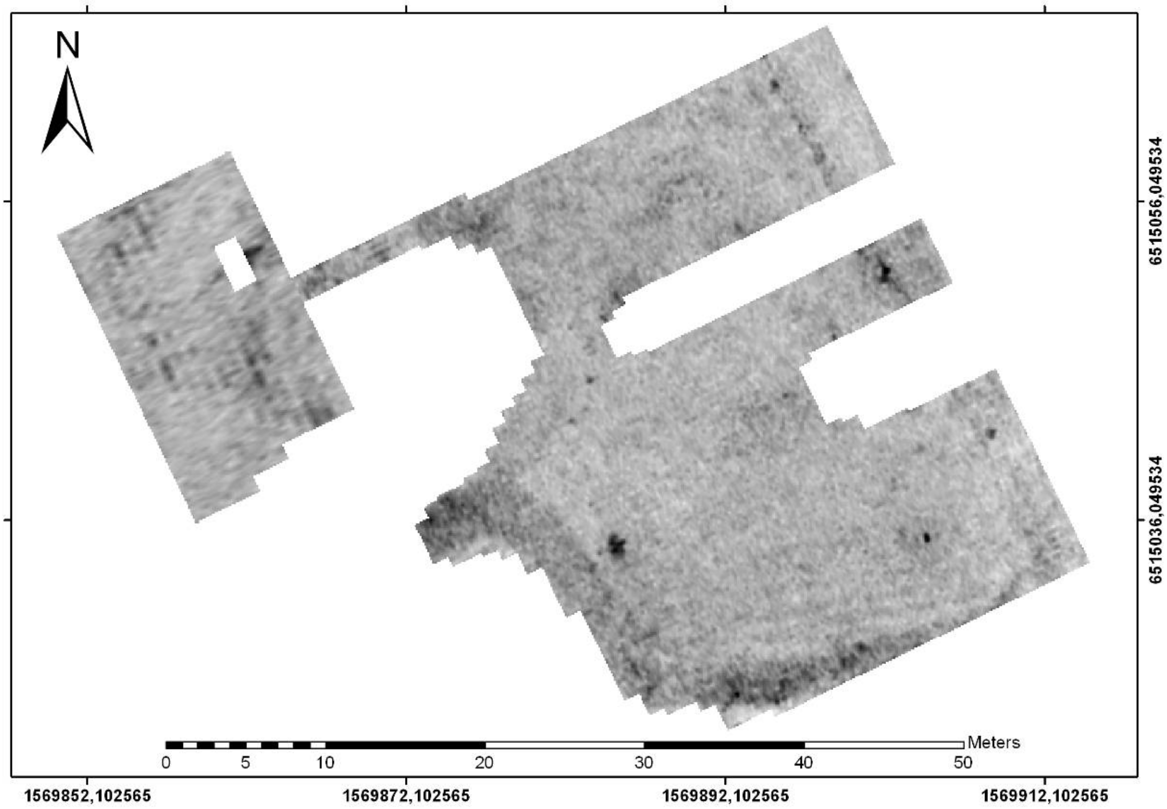

Figure 6.1.27: Depth-slice (260-270cm) survey site *Mejeriet (lower part).*

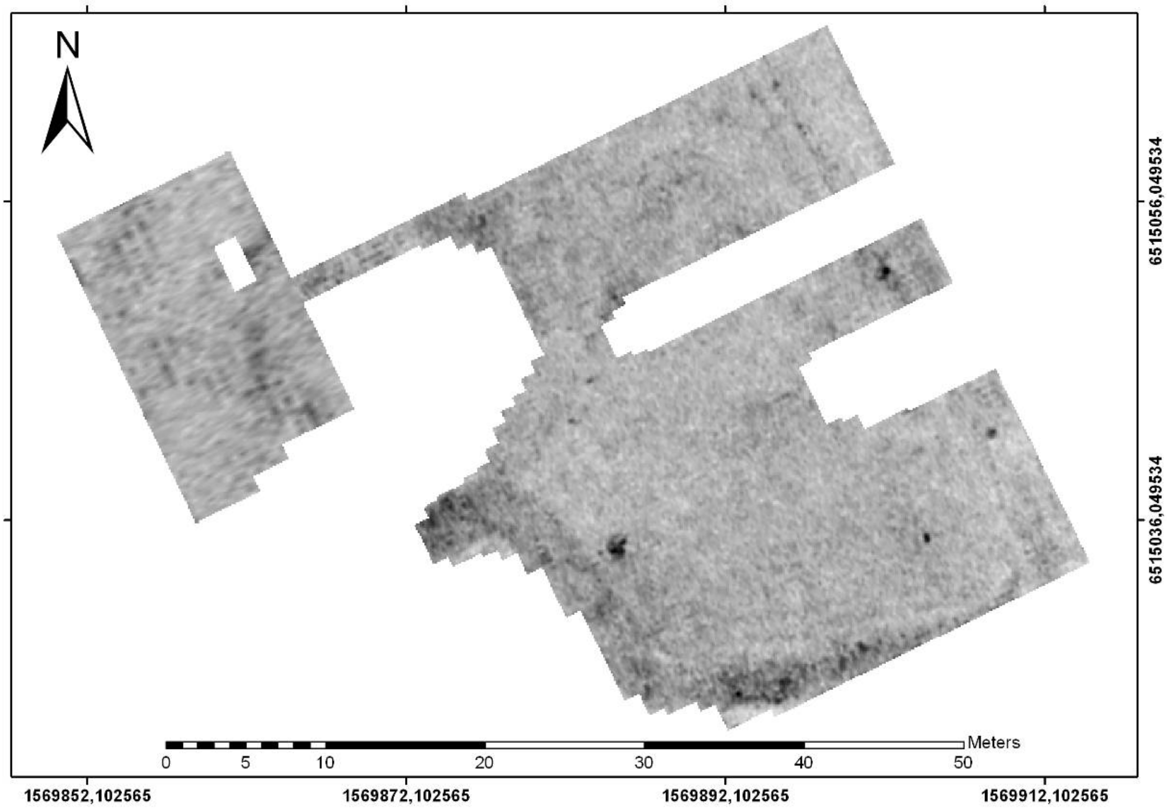

Figure 6.1.28: Depth-slice (270-280cm) survey site *Mejeriet (lower part).*

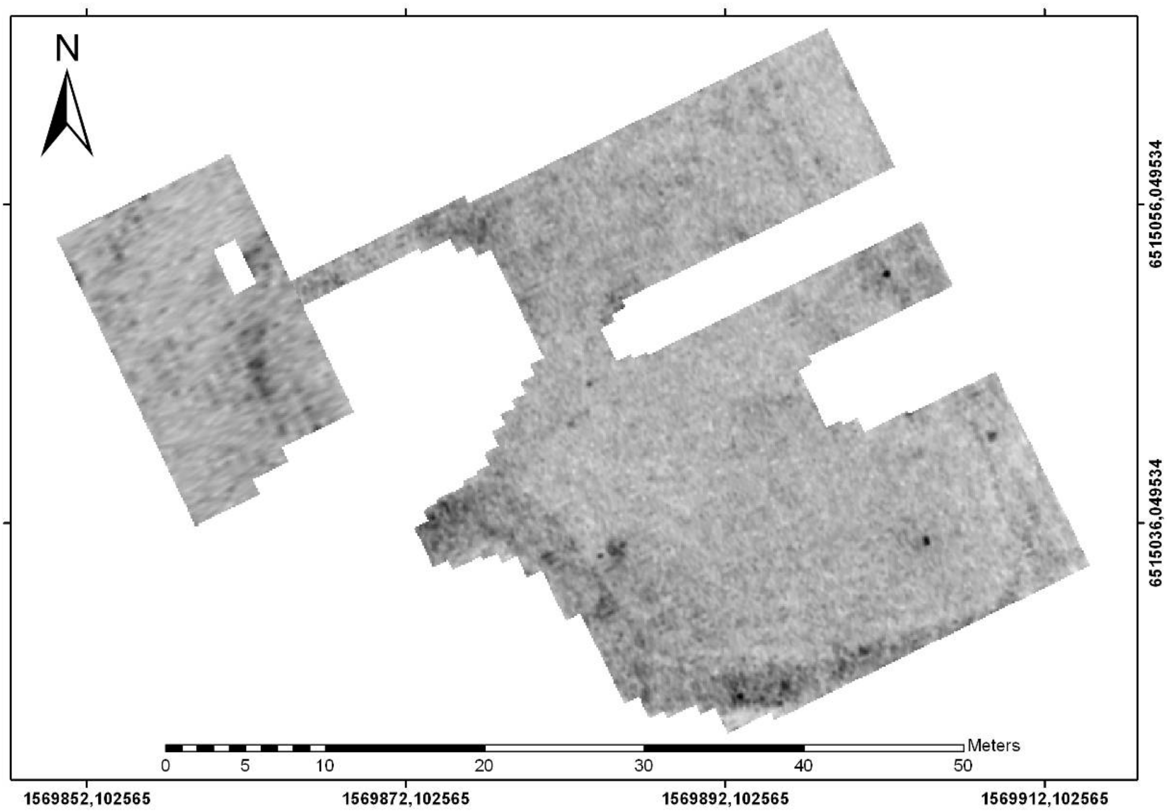

Figure 6.1.29: Depth-slice (280-290cm) survey site *Mejeriet (lower part).*

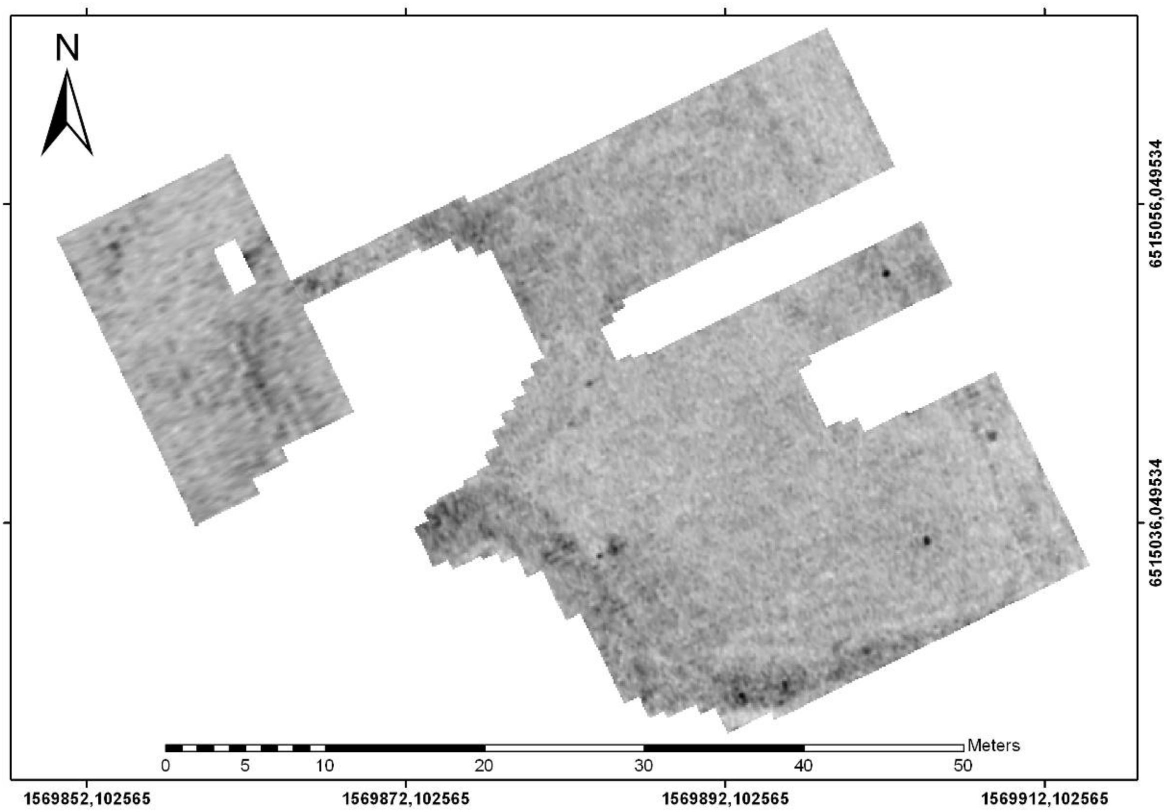

Figure 6.1.30: Depth-slice (290-300cm) survey site *Mejeriet (lower part).*

6.2 Depth-slices from survey site *Mejeriet (upper part)*

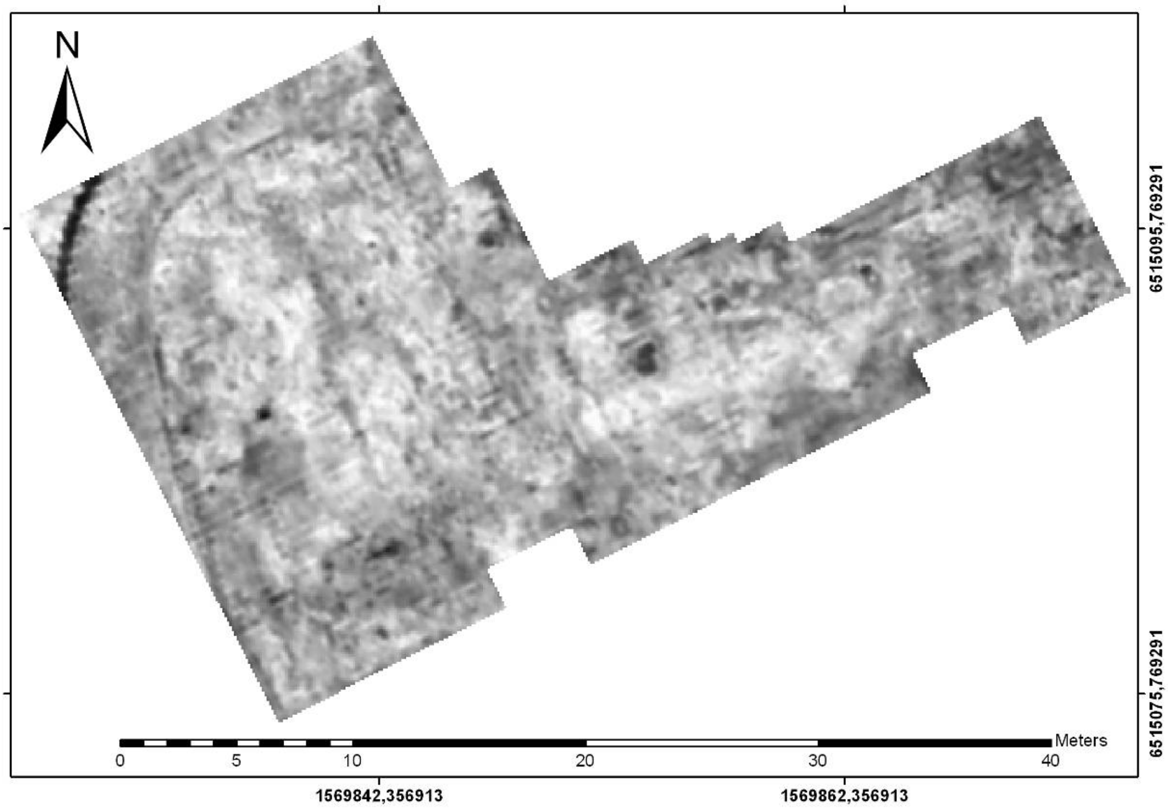

Figure 6.2.1: Depth-slice (0-10cm) survey site *Mejeriet (upper part)*.

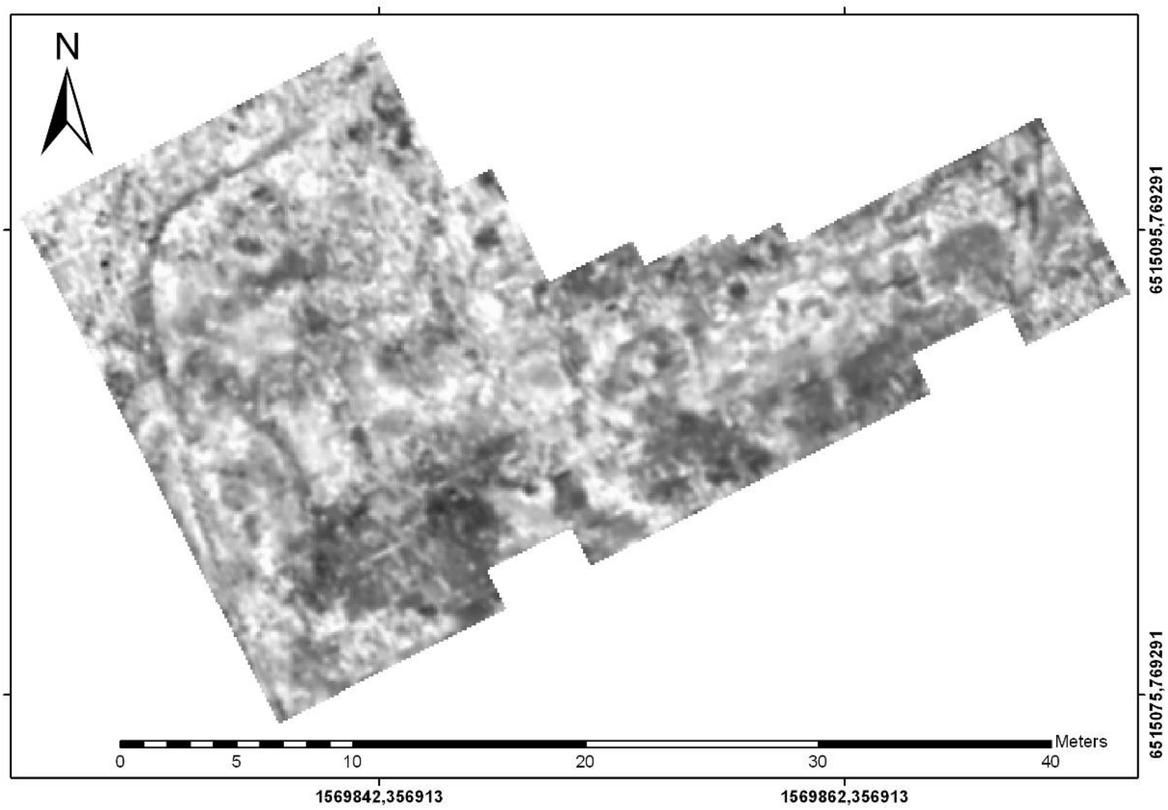

Figure 6.2.2: Depth-slice (10-20cm) survey site *Mejeriet (upper part)*.

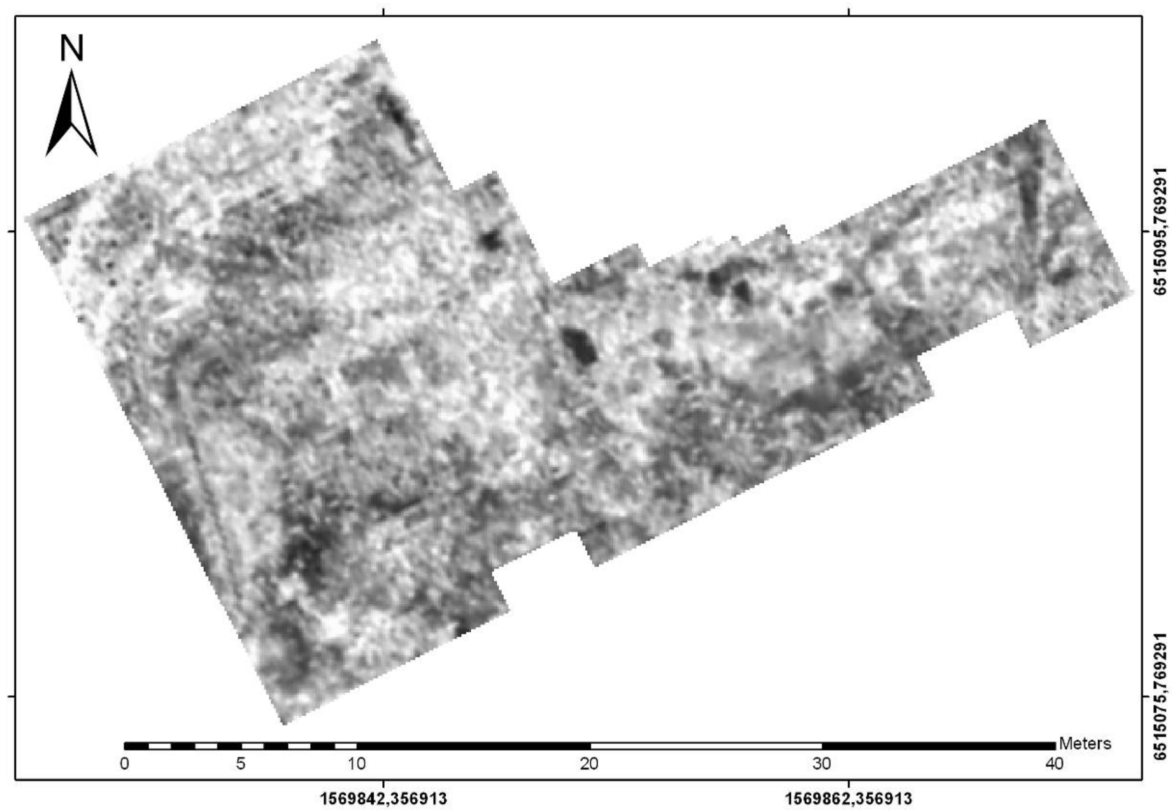

Figure 6.2.3: Depth-slice (20-30cm) survey site *Mejeriet (upper part).*

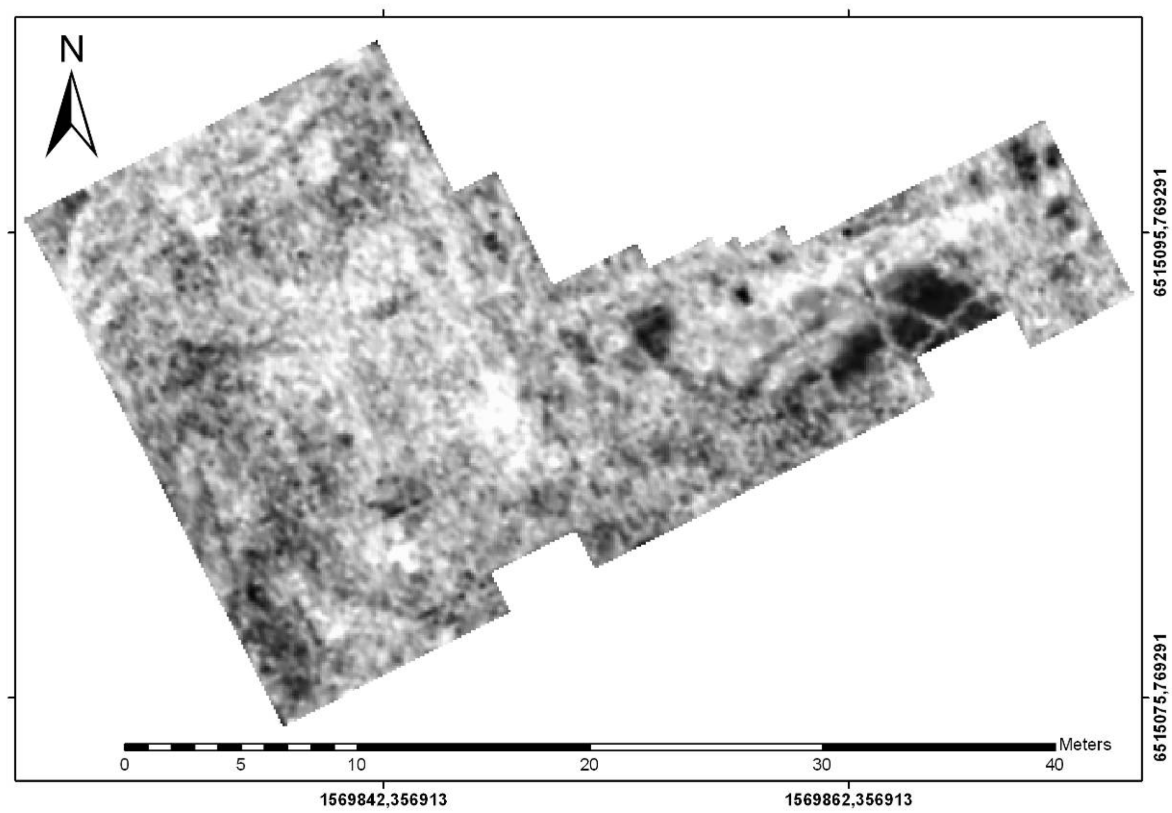

Figure 6.2.4: Depth-slice (30-40cm) survey site *Mejeriet (upper part).*

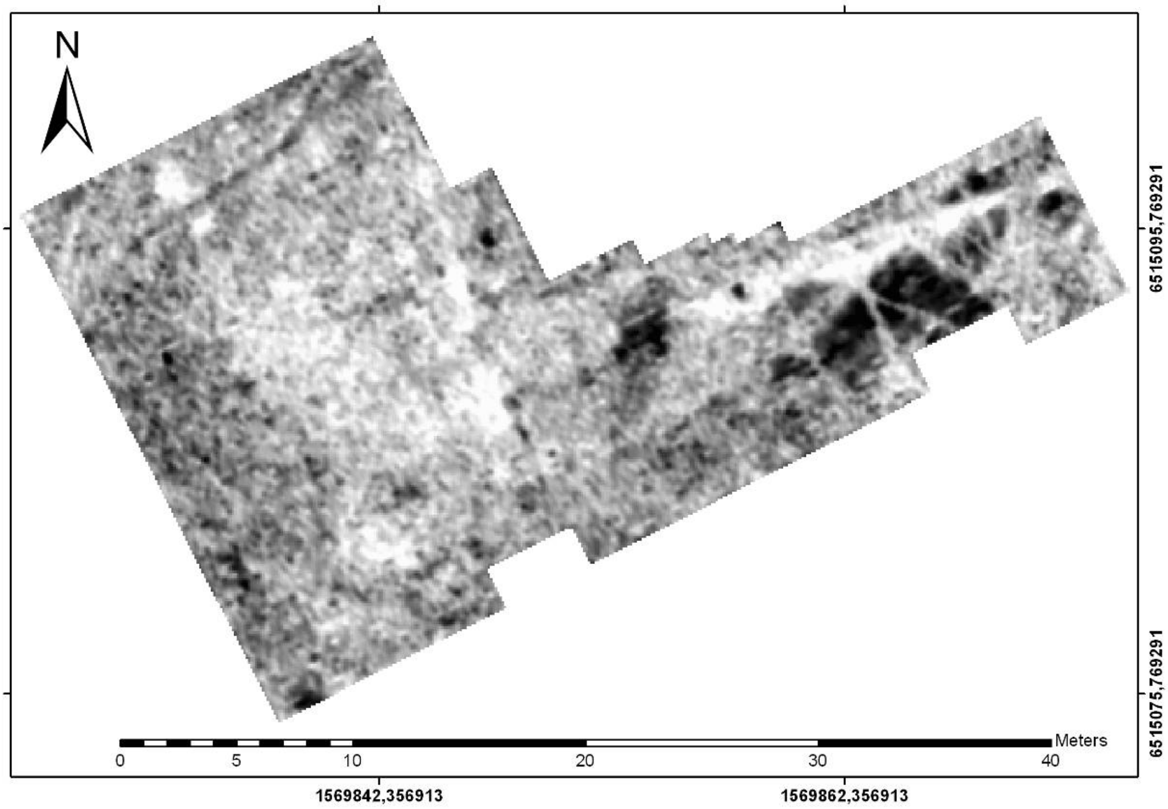

Figure 6.2.5: Depth-slice (40-50cm) survey site *Mejeriet (upper part).*

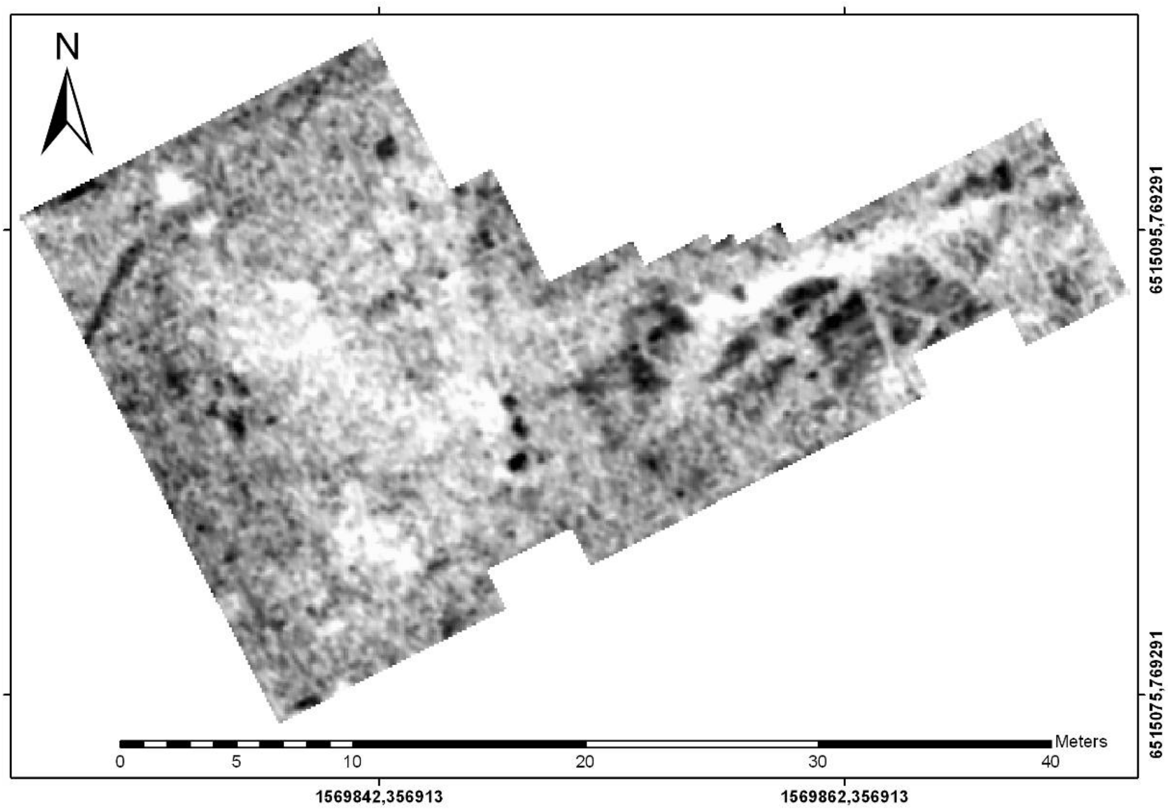

Figure 6.2.6: Depth-slice (50-60cm) survey site *Mejeriet (upper part).*

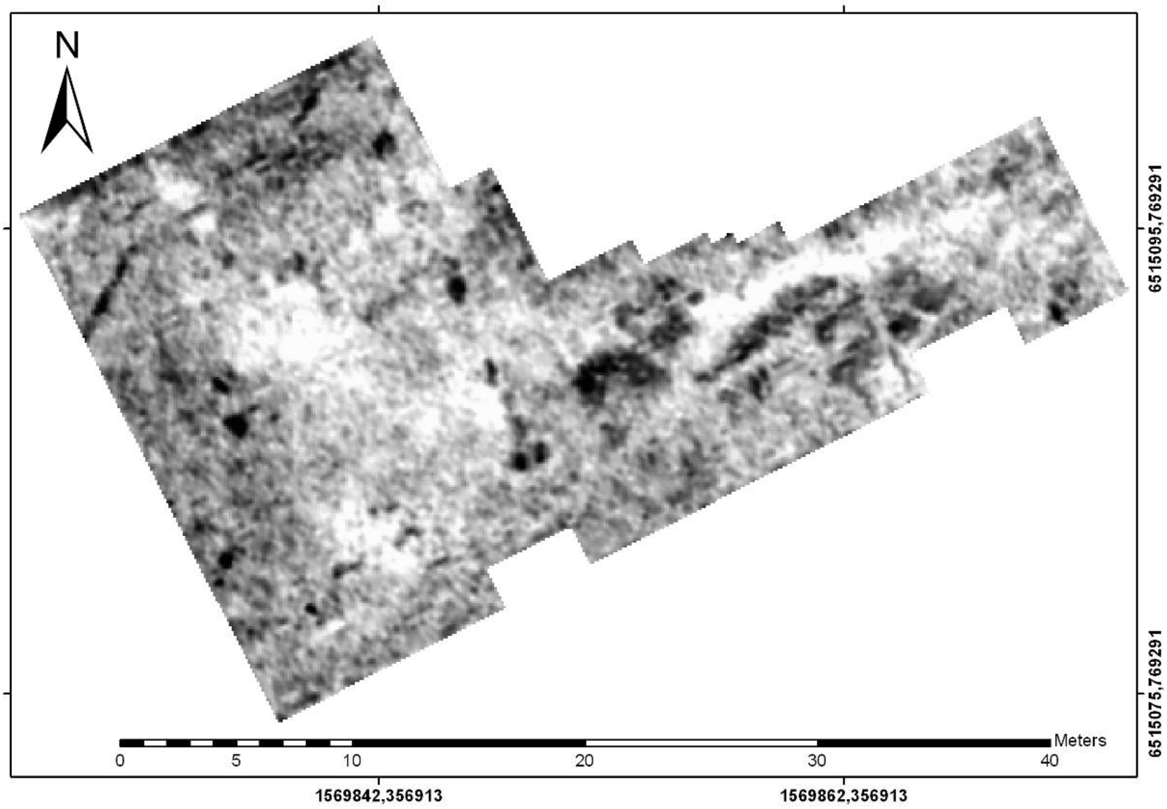

Figure 6.2.7: Depth-slice (60-70cm) survey site *Mejeriet (upper part).*

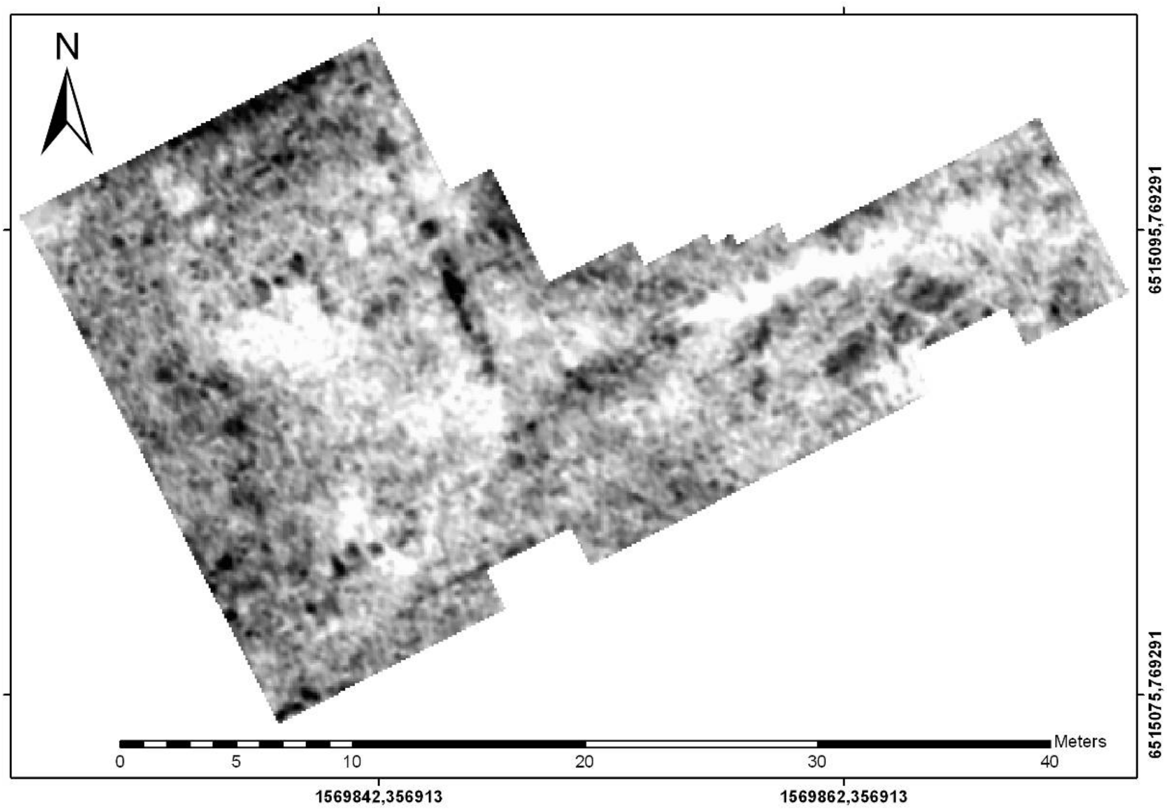

Figure 6.2.8: Depth-slice (70-80cm) survey site *Mejeriet (upper part).*

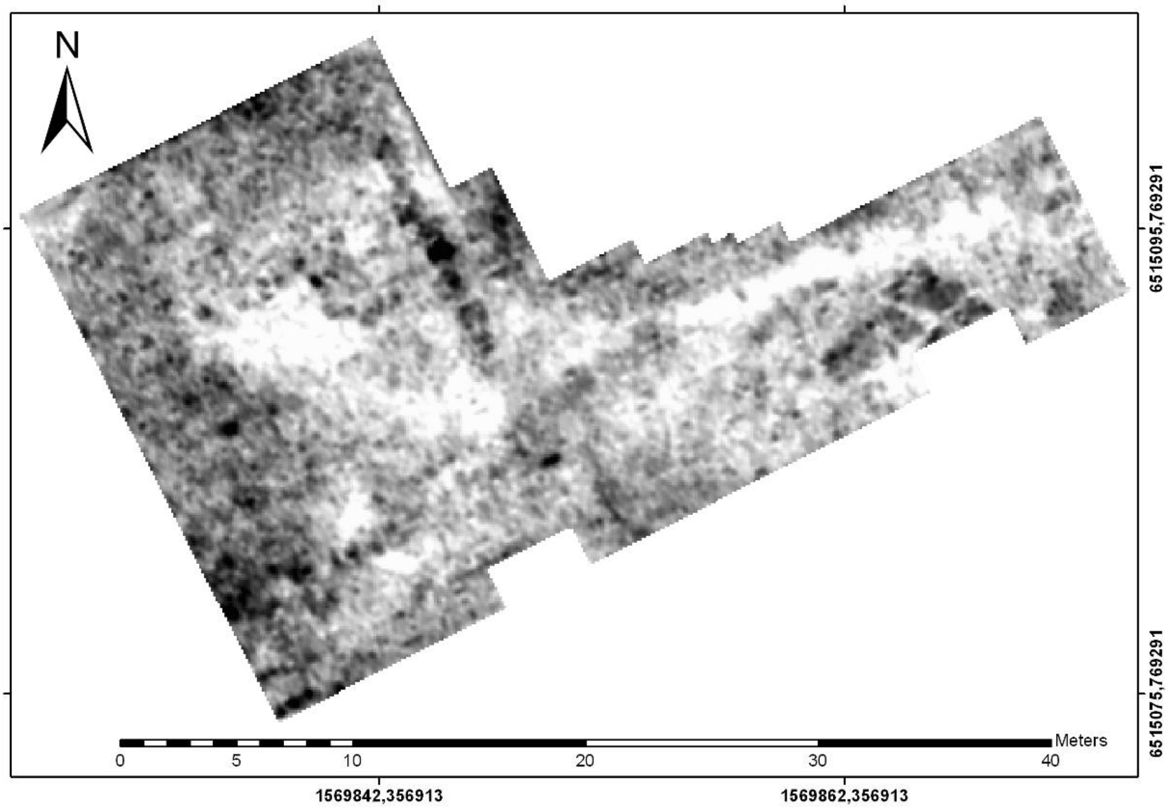

Figure 6.2.9: Depth-slice (80-90cm) survey site *Mejeriet (upper part)*.

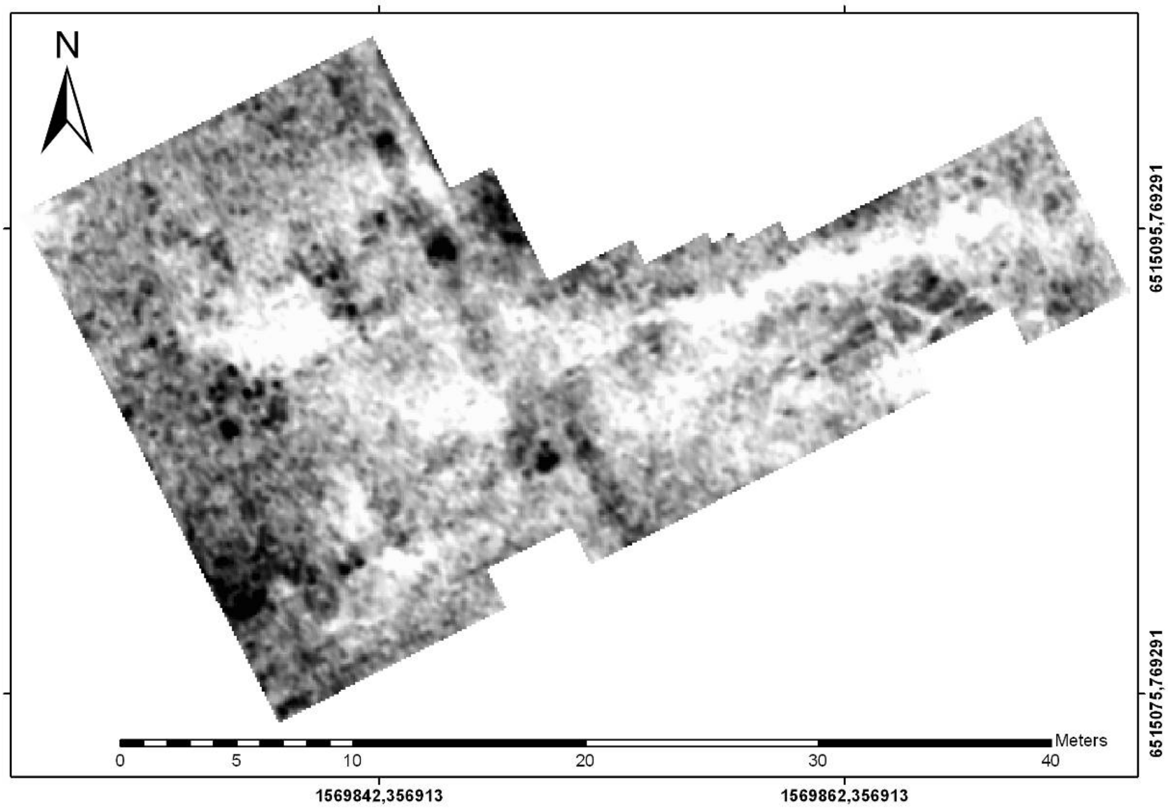

Figure 6.2.10: Depth-slice (90-100cm) survey site *Mejeriet (upper part)*.

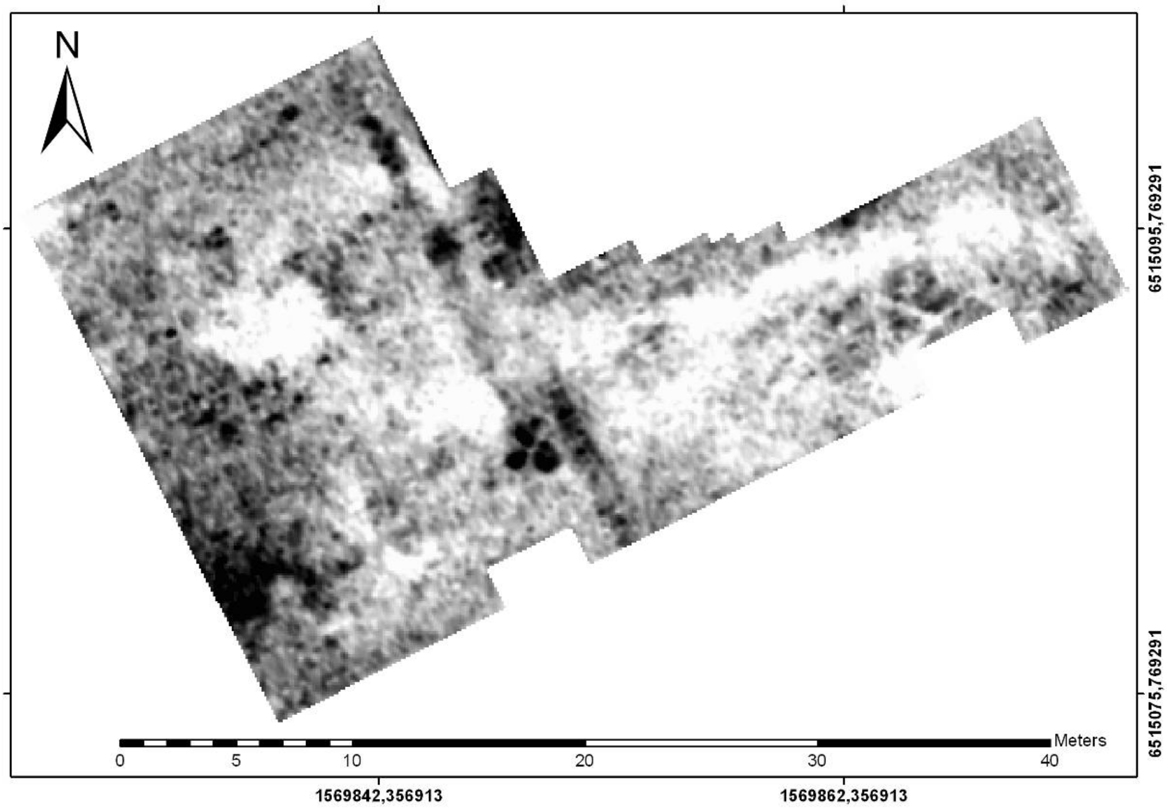

Figure 6.2.11: Depth-slice (100-110cm) survey site *Mejeriet (upper part)*.

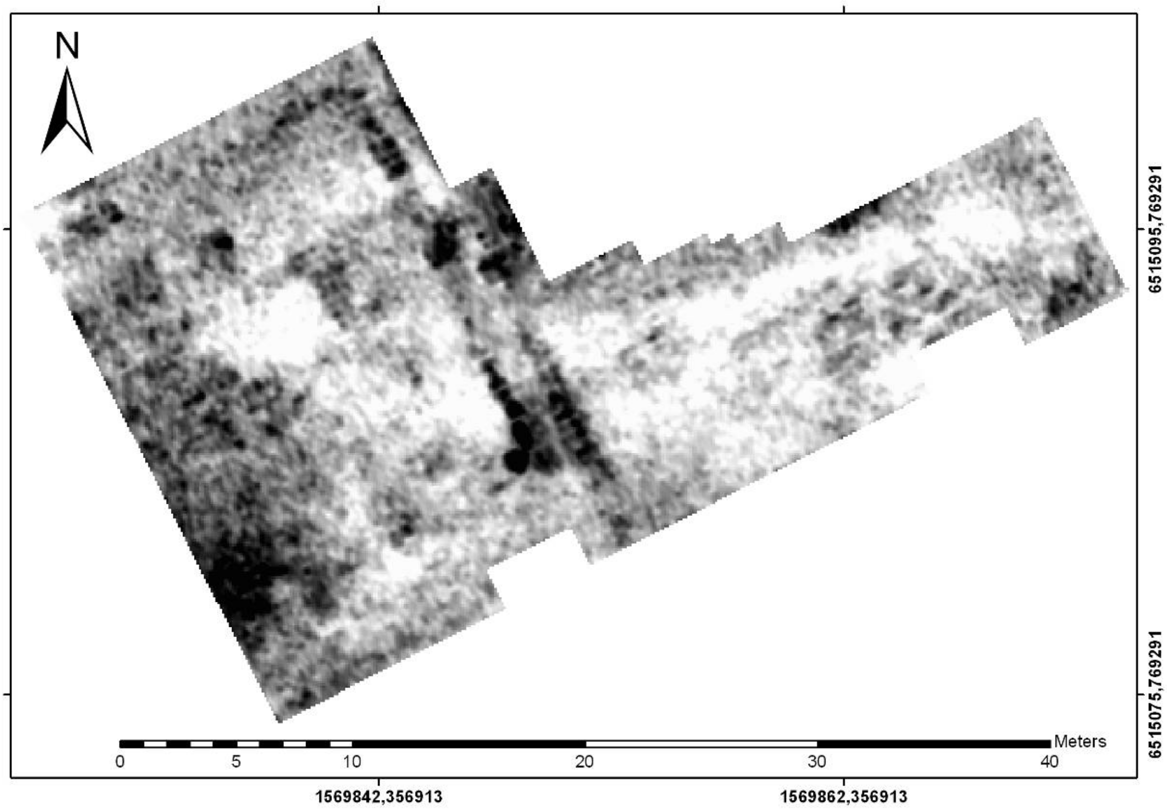

Figure 6.2.12: Depth-slice (110-120cm) survey site *Mejeriet (upper part)*.

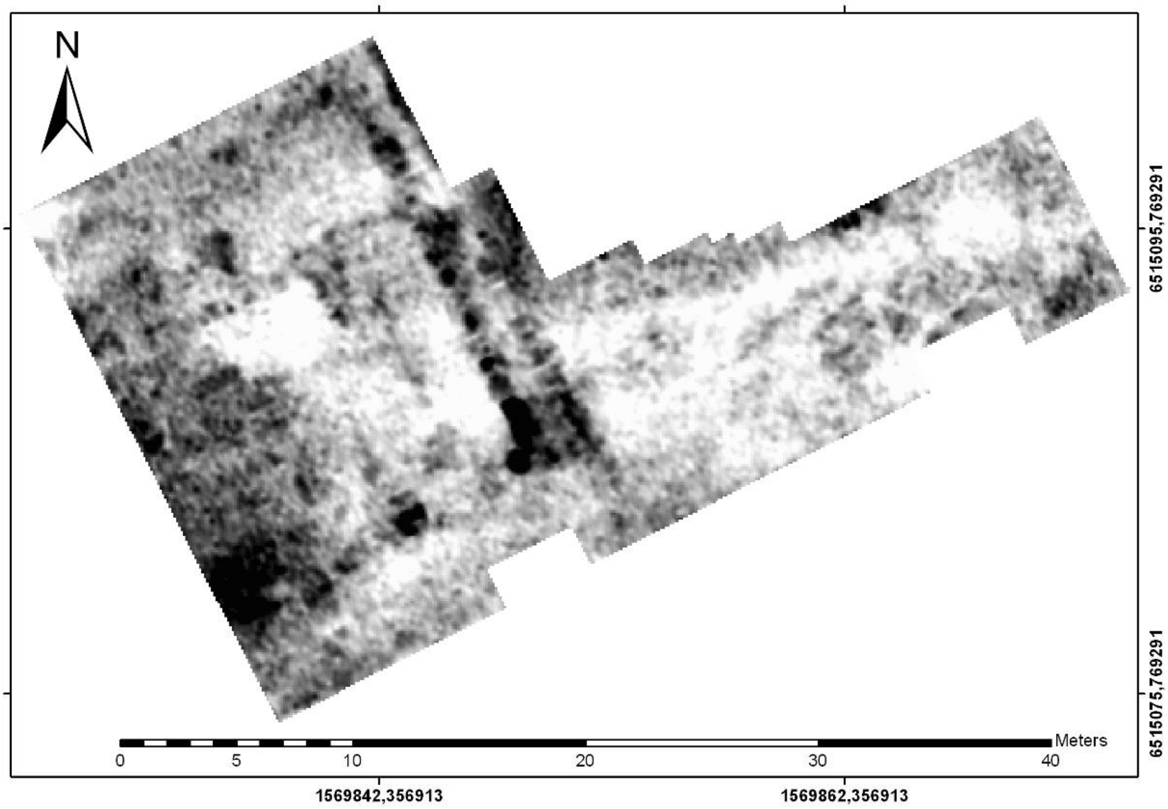

Figure 6.2.13: Depth-slice (120-130cm) survey site *Mejeriet (upper part)*.

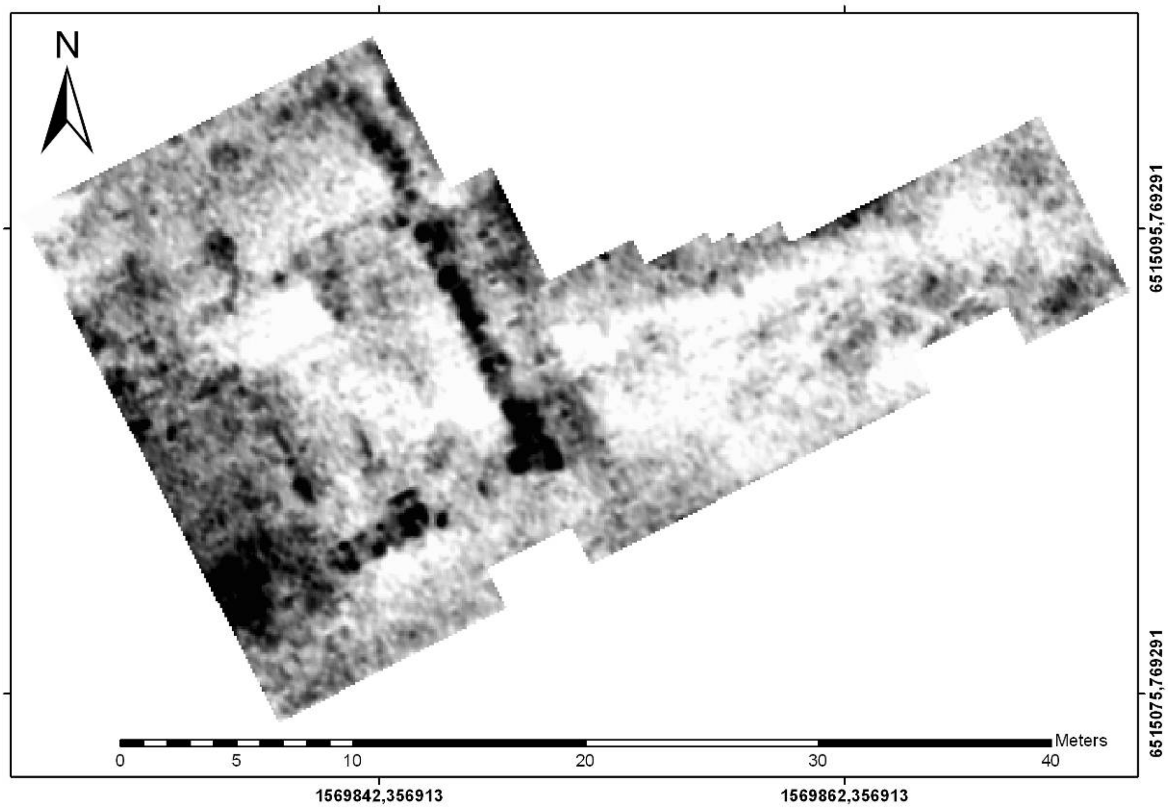

Figure 6.2.14: Depth-slice (130-140cm) survey site *Mejeriet (upper part)*.

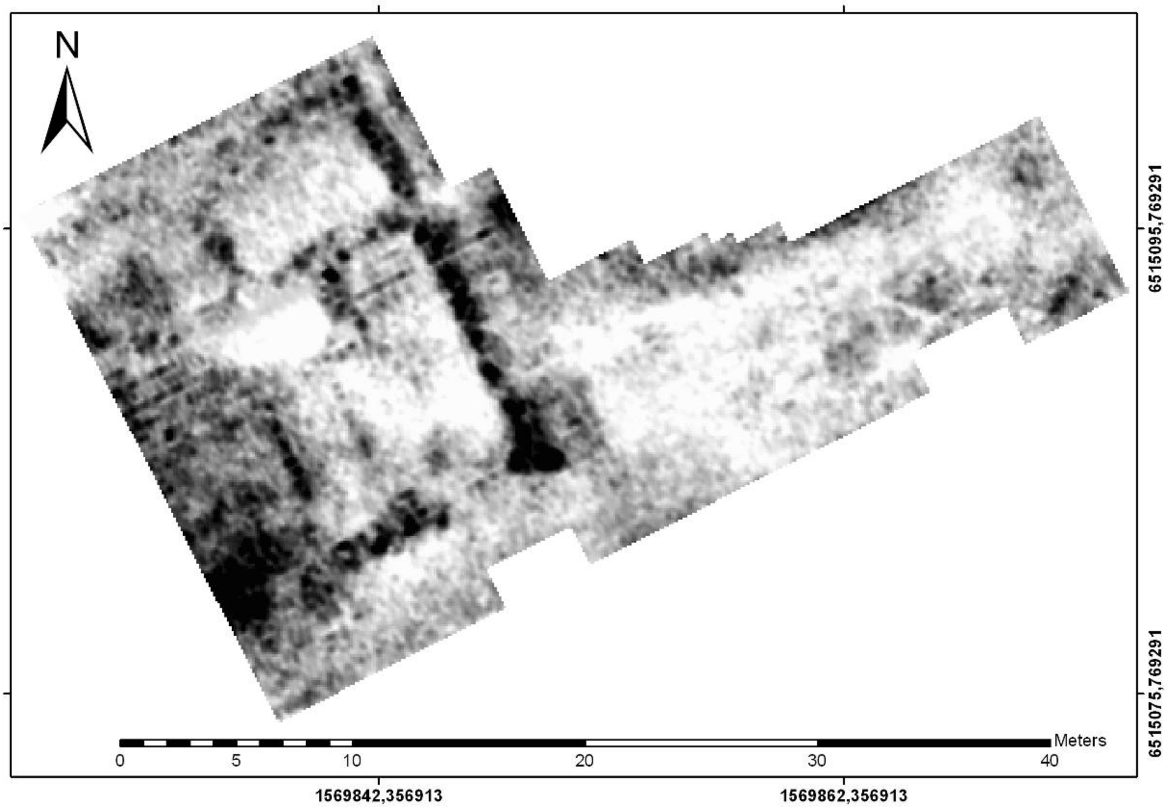

Figure 6.2.15: Depth-slice (140-150cm) survey site *Mejeriet (upper part).*

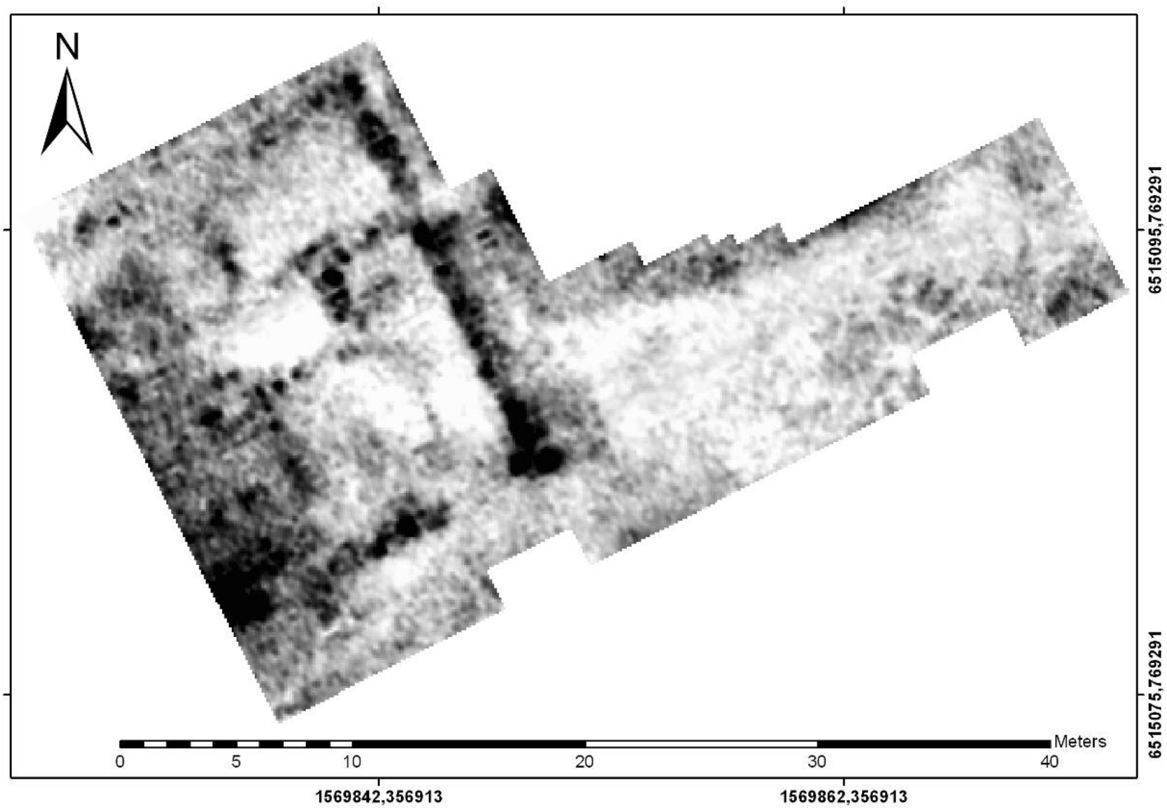

Figure 6.2.16: Depth-slice (150-160cm) survey site *Mejeriet (upper part).*

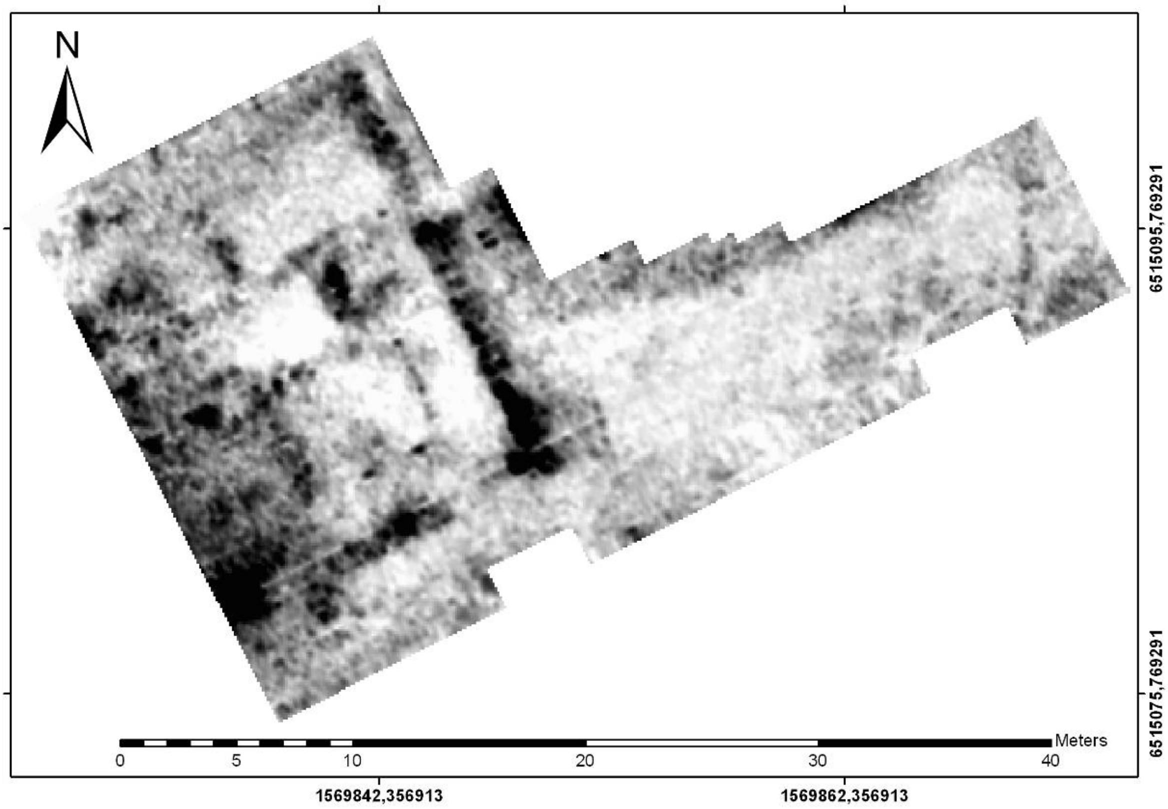

Figure 6.2.17: Depth-slice (160-170cm) survey site *Mejeriet (upper part)*.

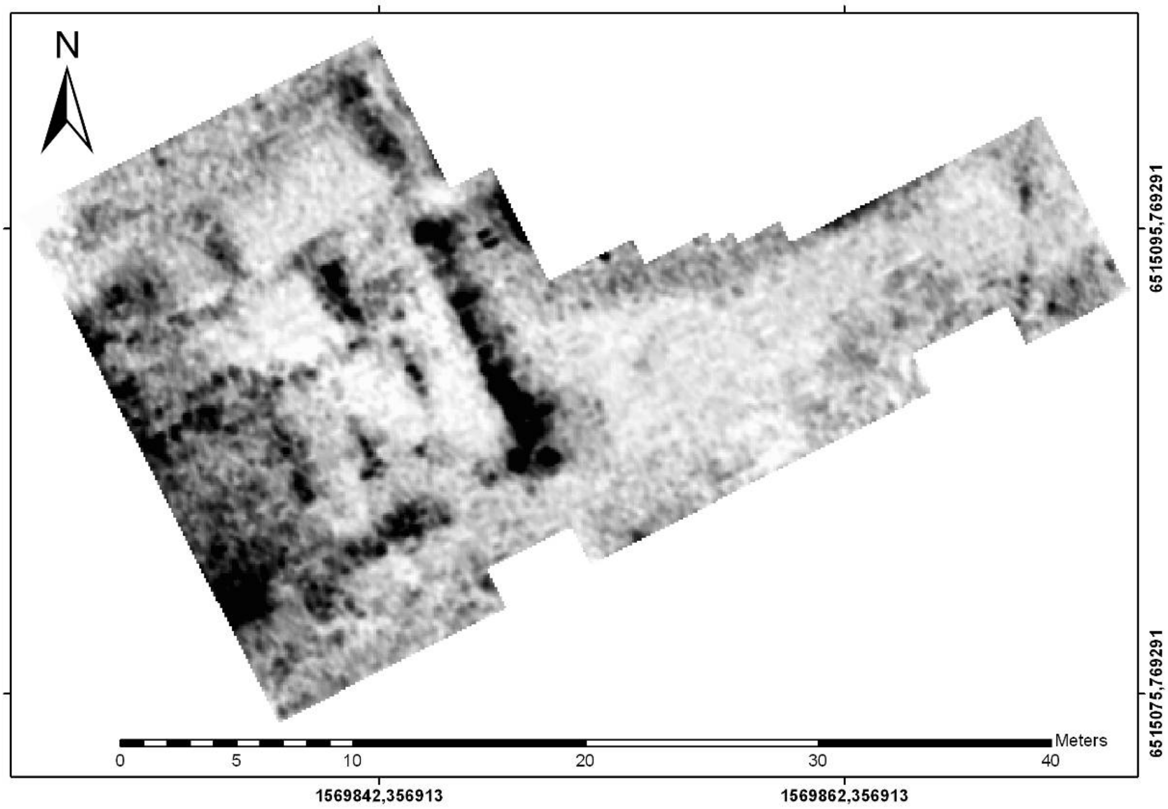

Figure 6.2.18: Depth-slice (170-180cm) survey site *Mejeriet (upper part)*.

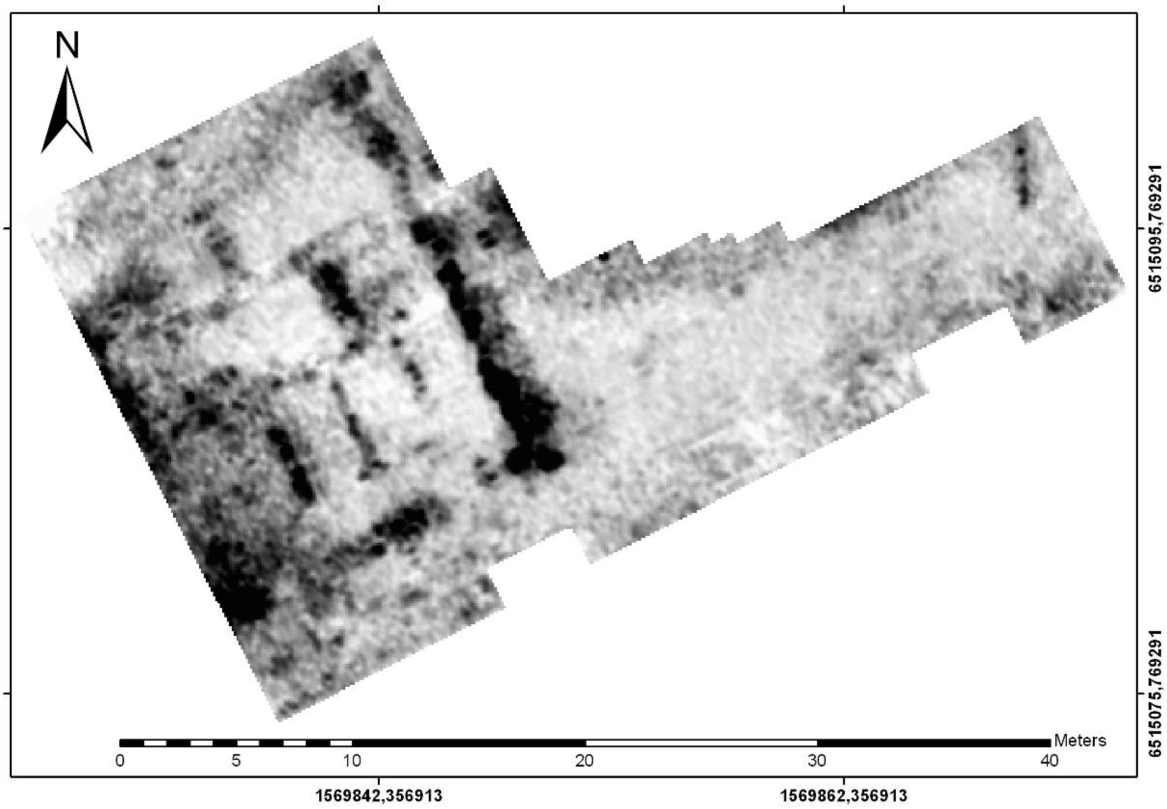

Figure 6.2.19: Depth-slice (180-190cm) survey site *Mejeriet (upper part)*.

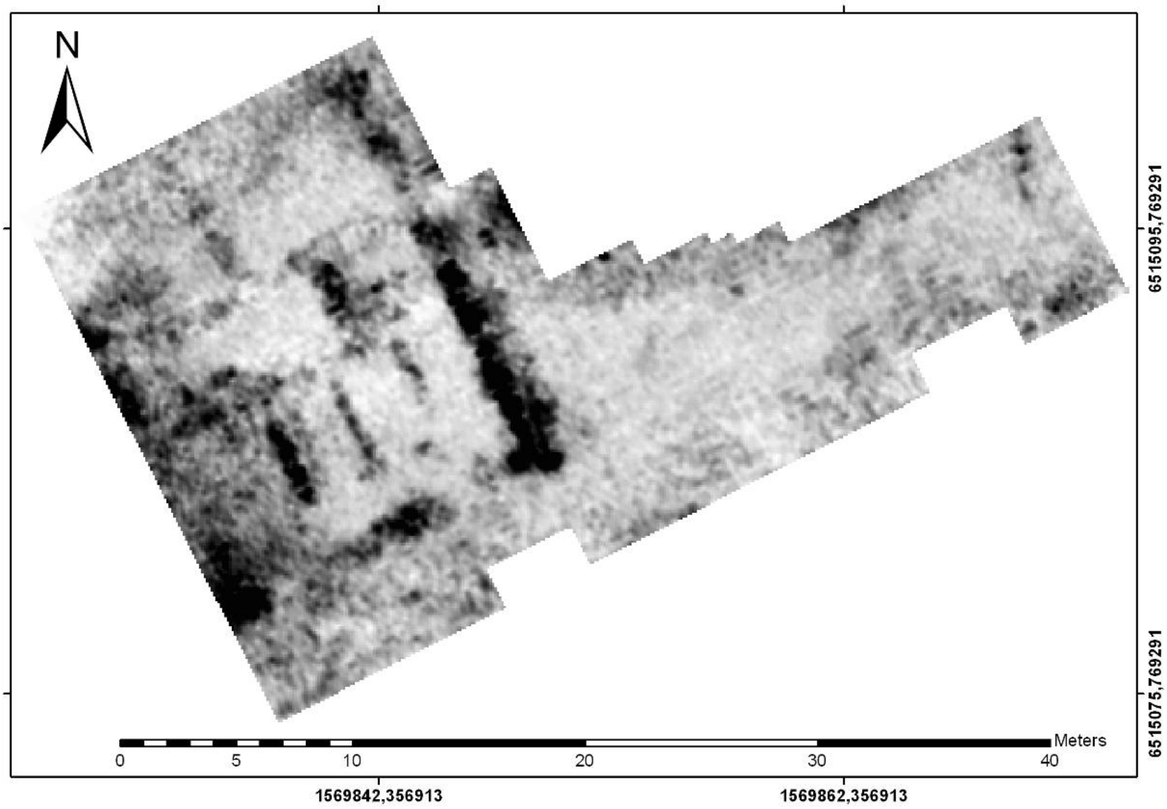

Figure 6.2.20: Depth-slice (190-200cm) survey site *Mejeriet (upper part)*.

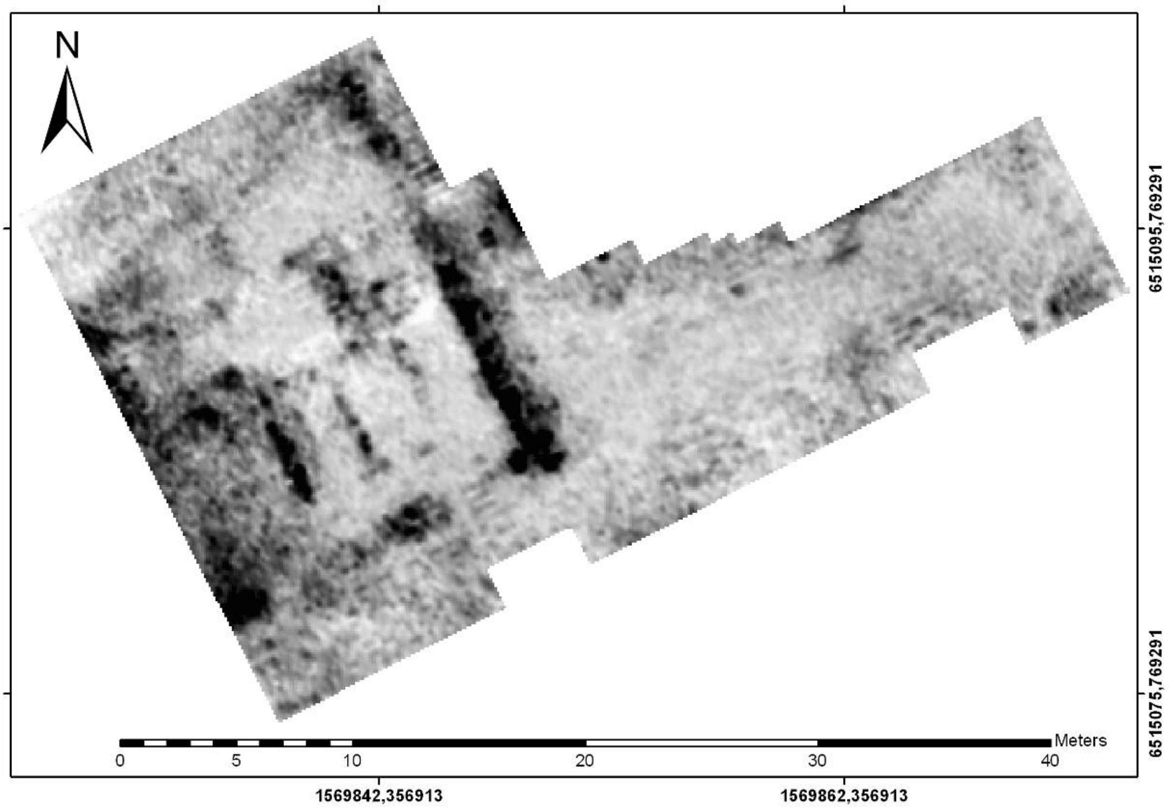

Figure 6.2.21: Depth-slice (200-210cm) survey site *Mejeriet (upper part)*.

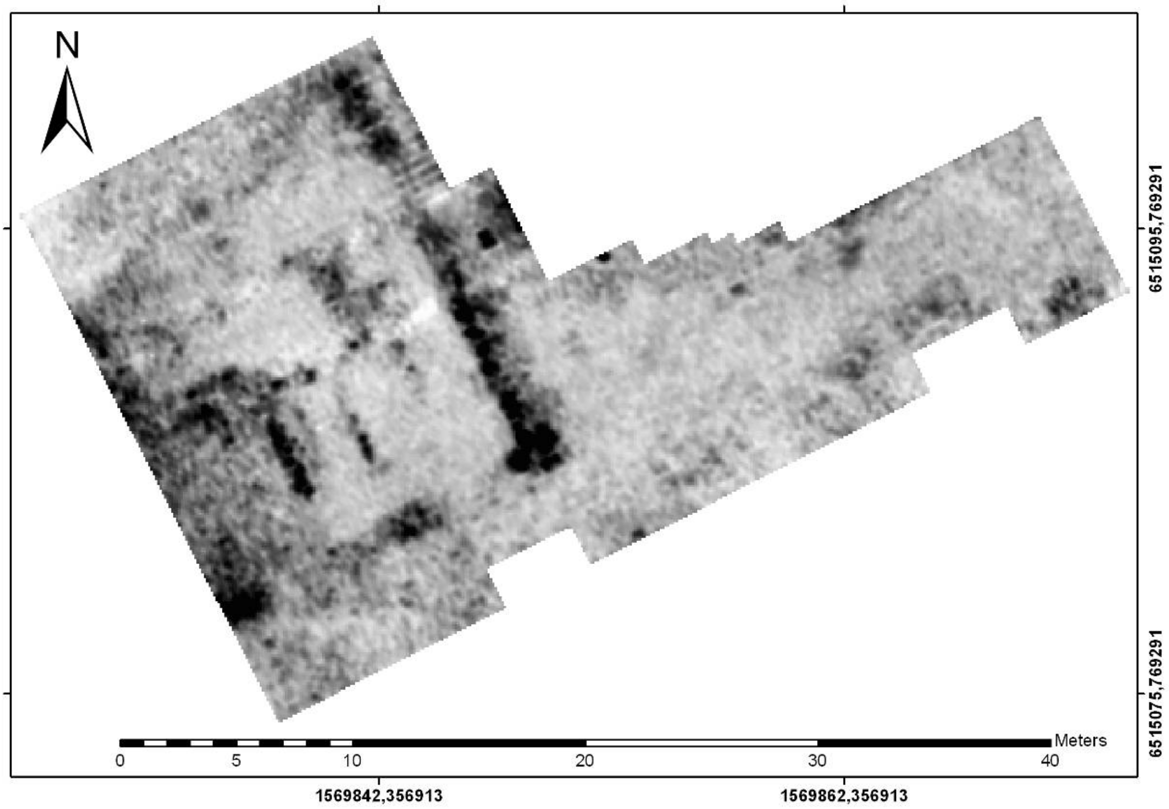

Figure 6.2.22: Depth-slice (210-220cm) survey site *Mejeriet (upper part)*.

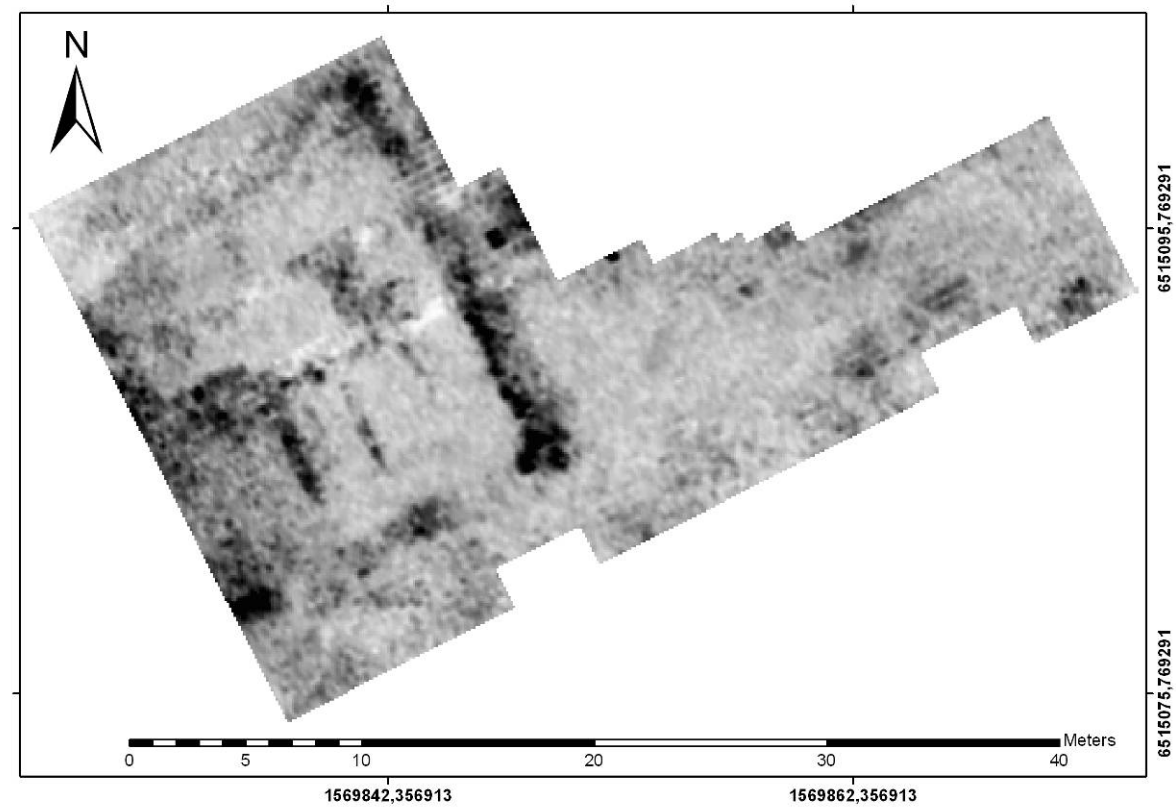

Figure 6.2.23: Depth-slice (220-230cm) survey site *Mejeriet (upper part)*.

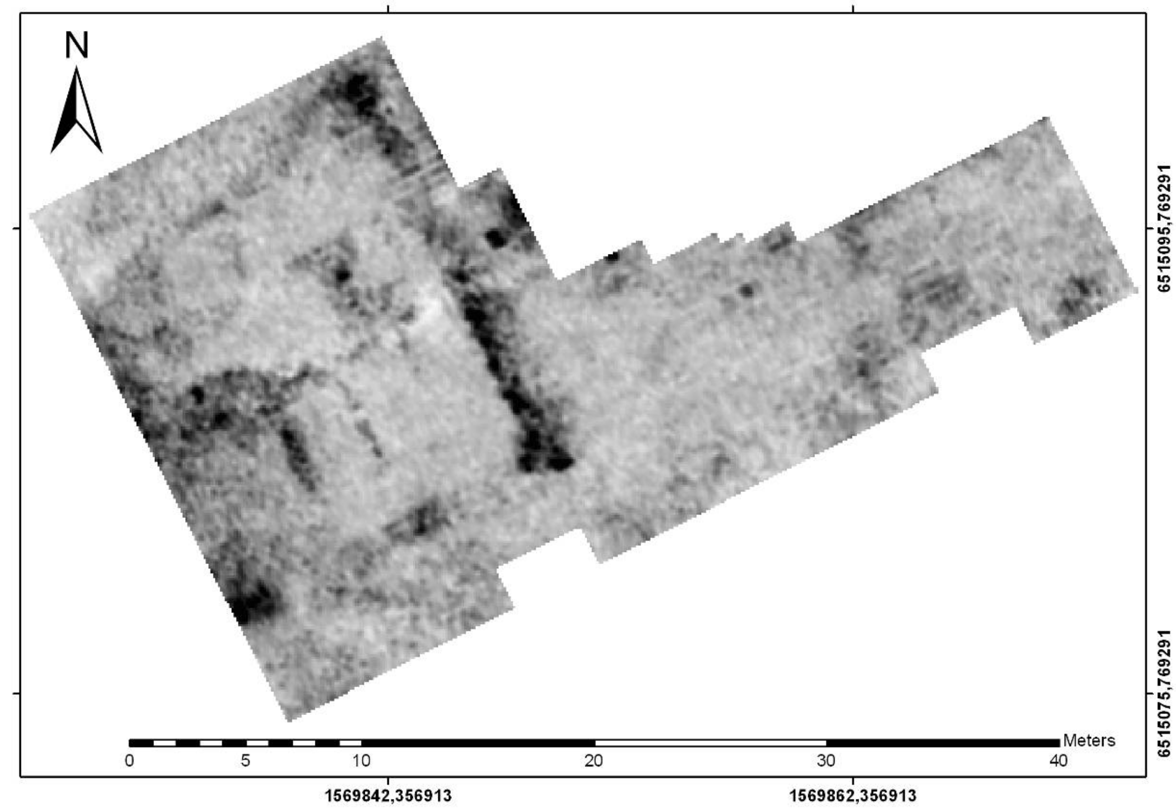

Figure 6.2.24: Depth-slice (230-240cm) survey site *Mejeriet (upper part)*.

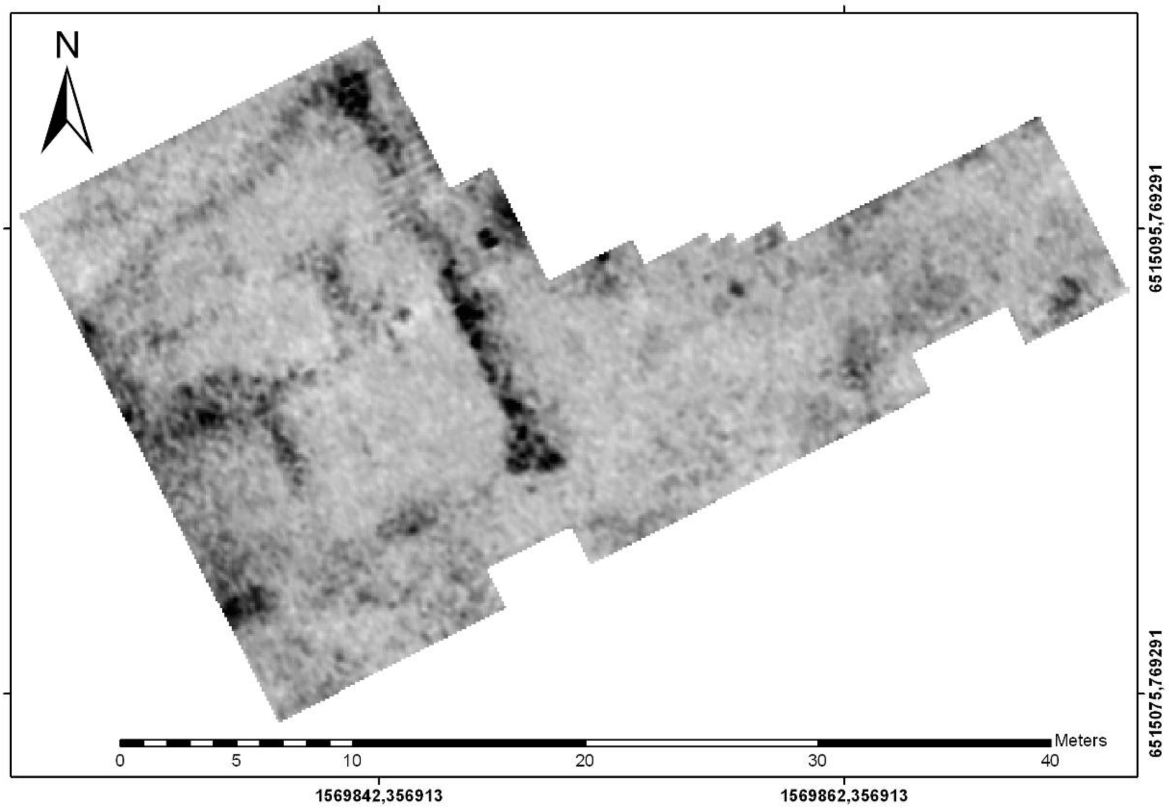

Figure 6.2.25: Depth-slice (240-250cm) survey site *Mejeriet (upper part)*.

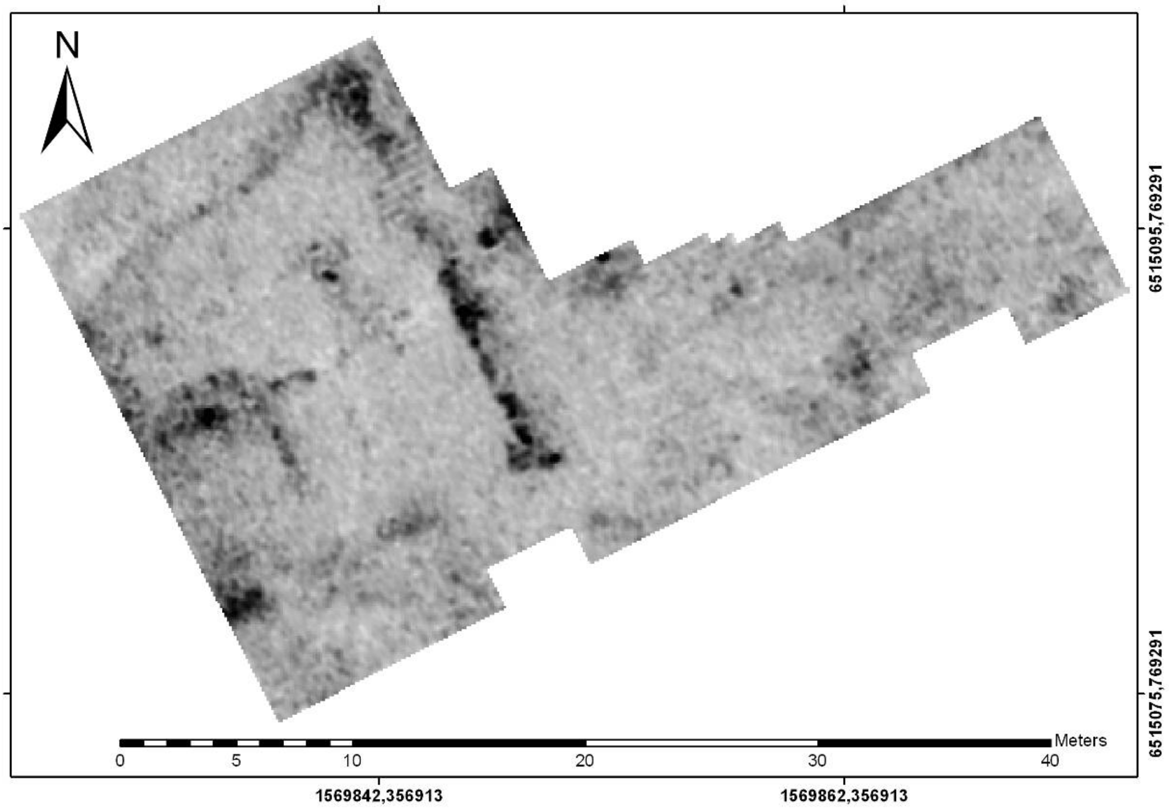

Figure 6.2.26: Depth-slice (250-260cm) survey site *Mejeriet (upper part)*.

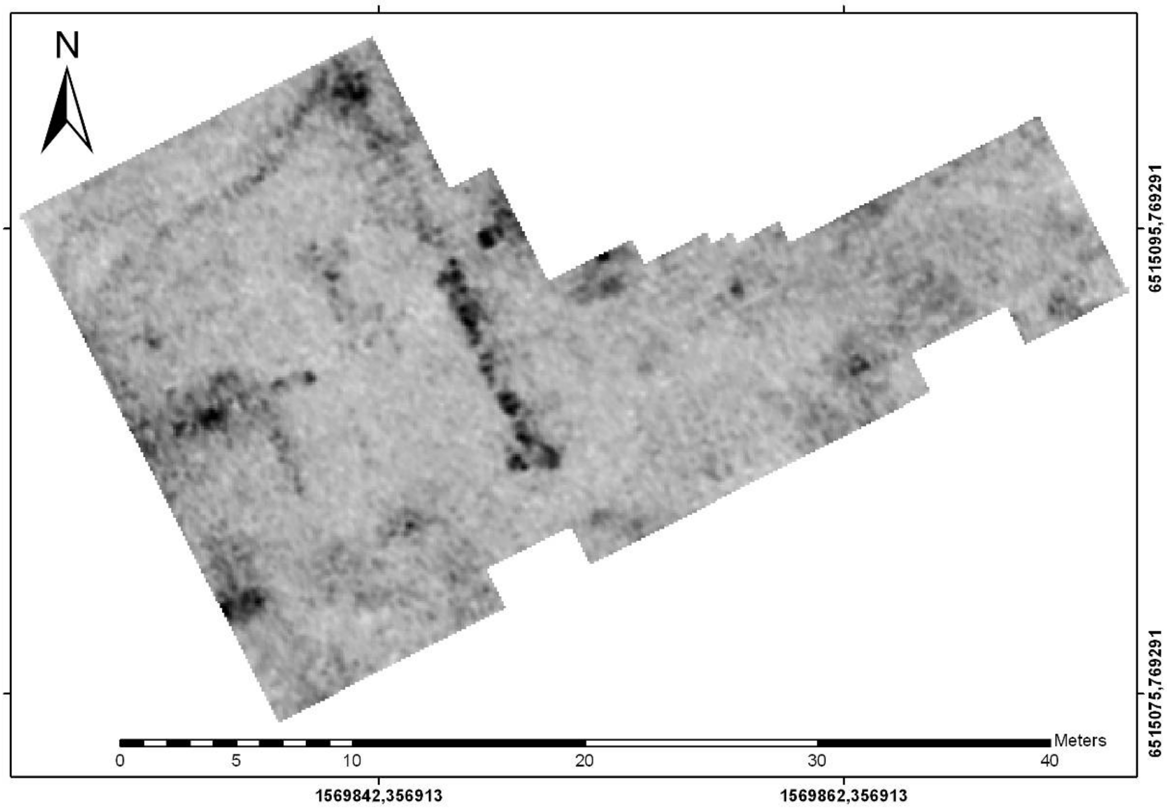

Figure 6.2.27: Depth-slice (260-270cm) survey site *Mejeriet (upper part)*.

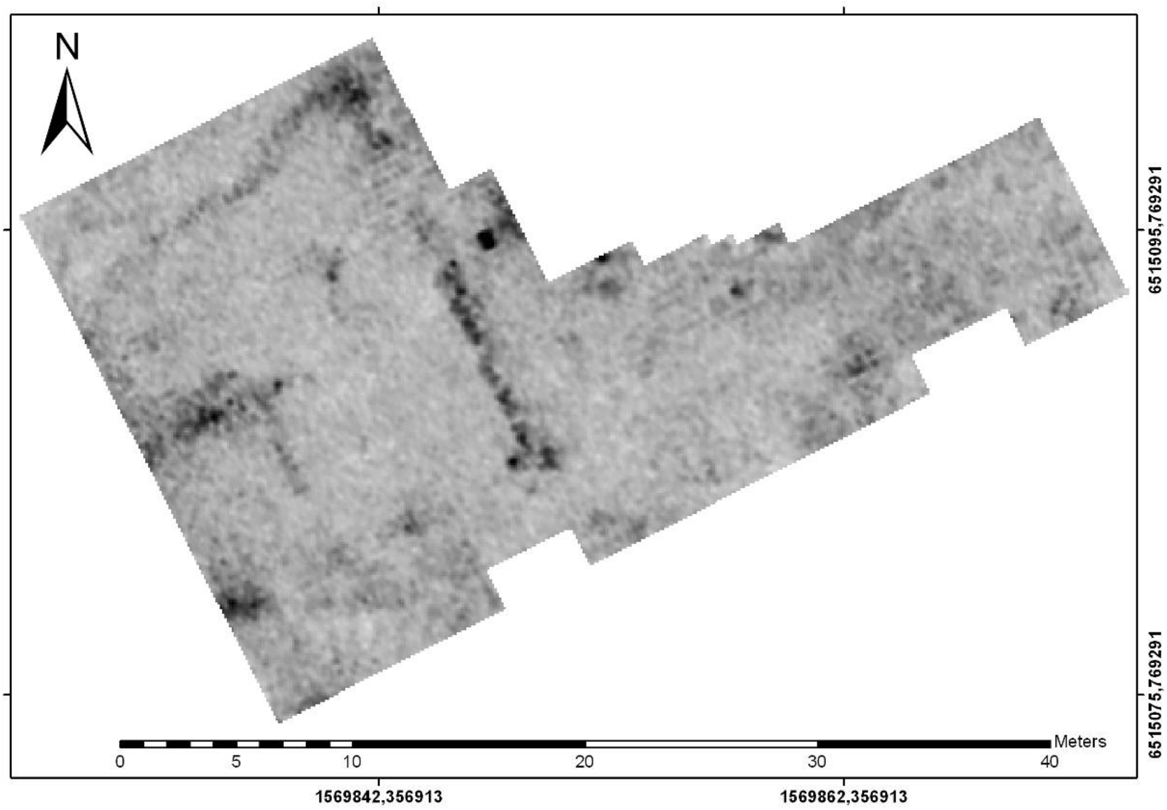

Figure 6.2.28: Depth-slice (270-280cm) survey site *Mejeriet (upper part)*.

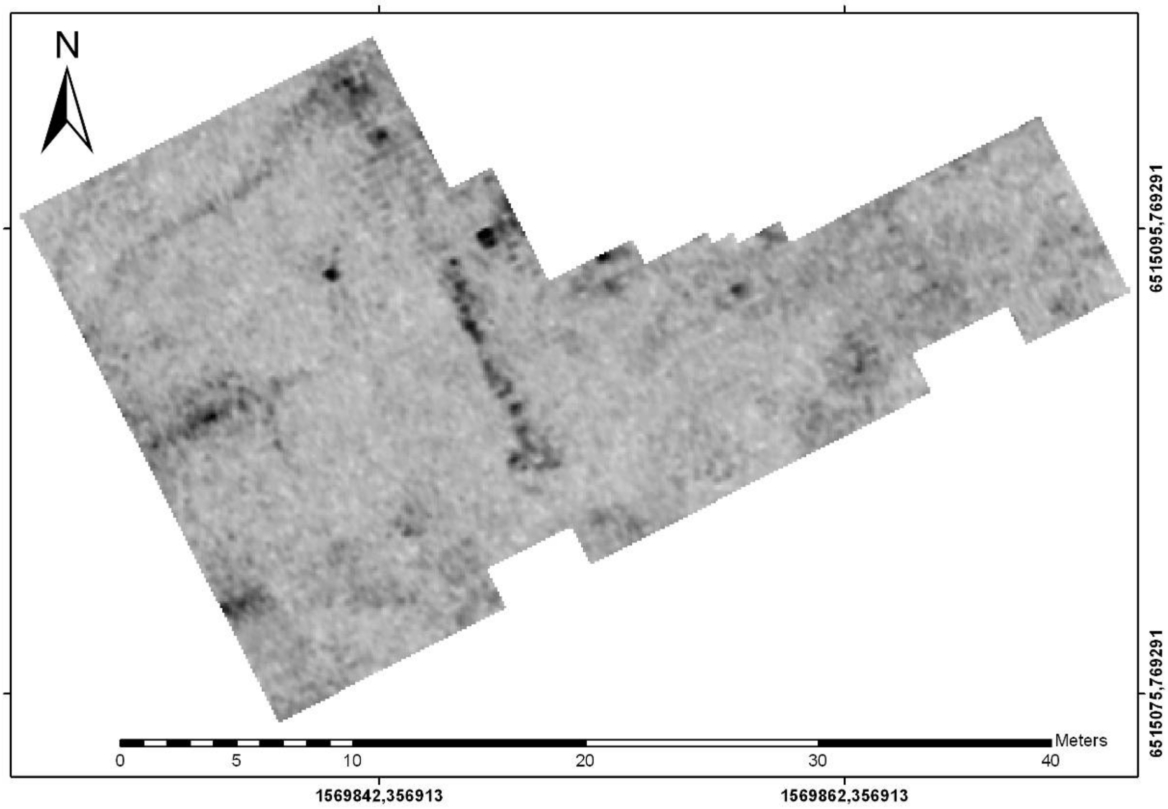

Figure 6.2.29: Depth-slice (280-290cm) survey site *Mejeriet (upper part)*.

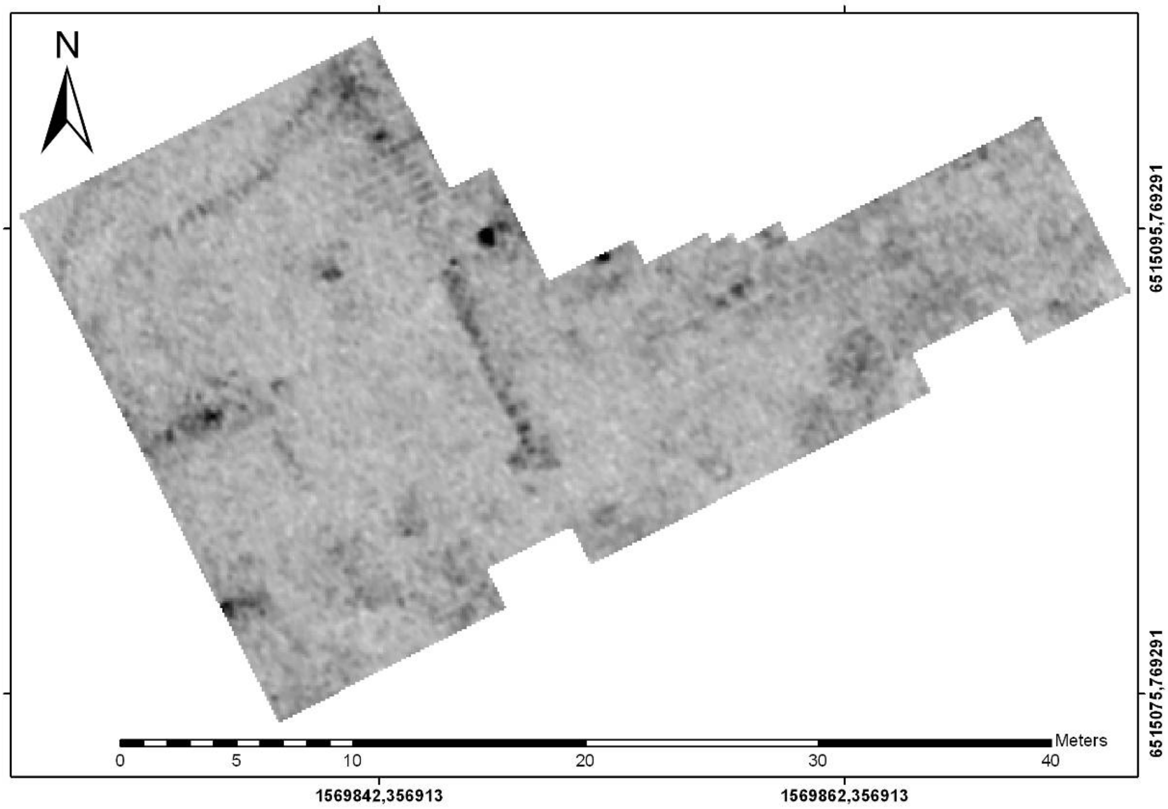

Figure 6.2.30: Depth-slice (290-300cm) survey site *Mejeriet (upper part)*.

6.3 Depth-slices from survey site *Åkroken (upper part)*

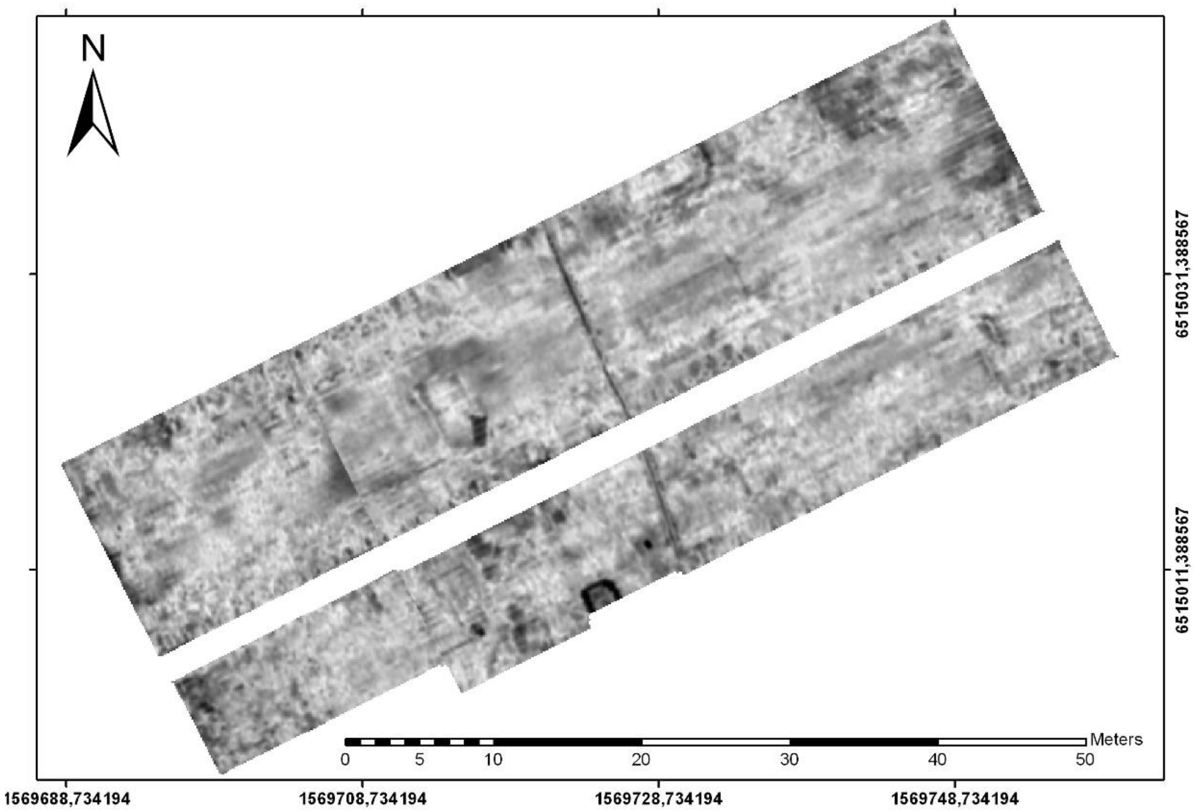

Figure 6.3.1: Depth-slice (0-10cm) survey site *Åkroken (upper part).*

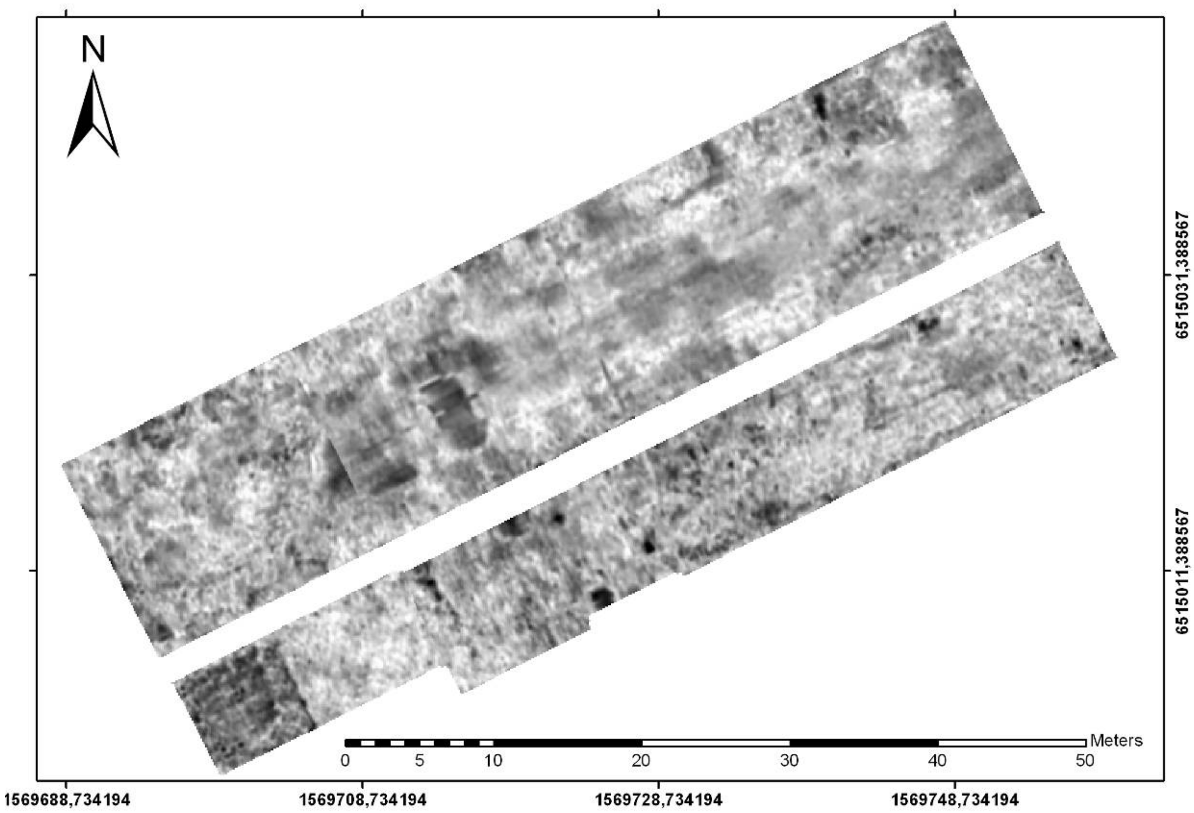

Figure 6.3.2: Depth-slice (10-20cm) survey site *Åkroken (upper part).*

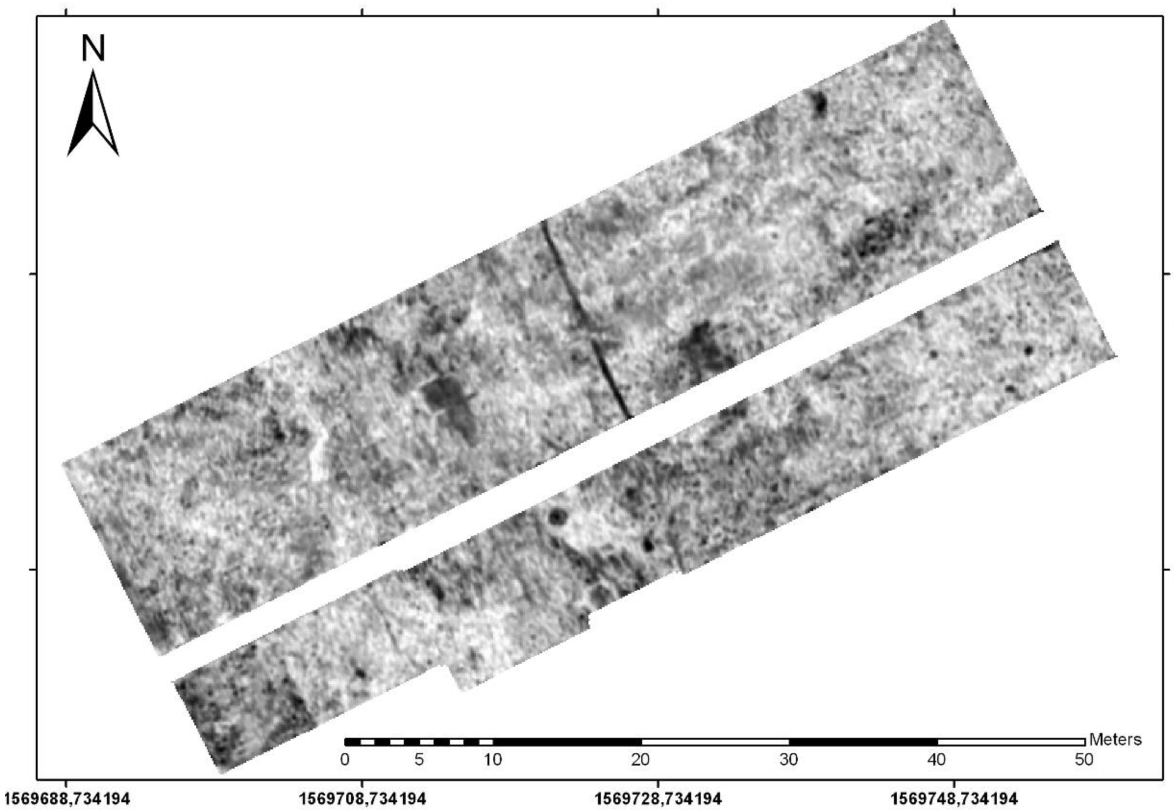

Figure 6.3.3: Depth-slice (20-30cm) survey site *Åkroken (upper part).*

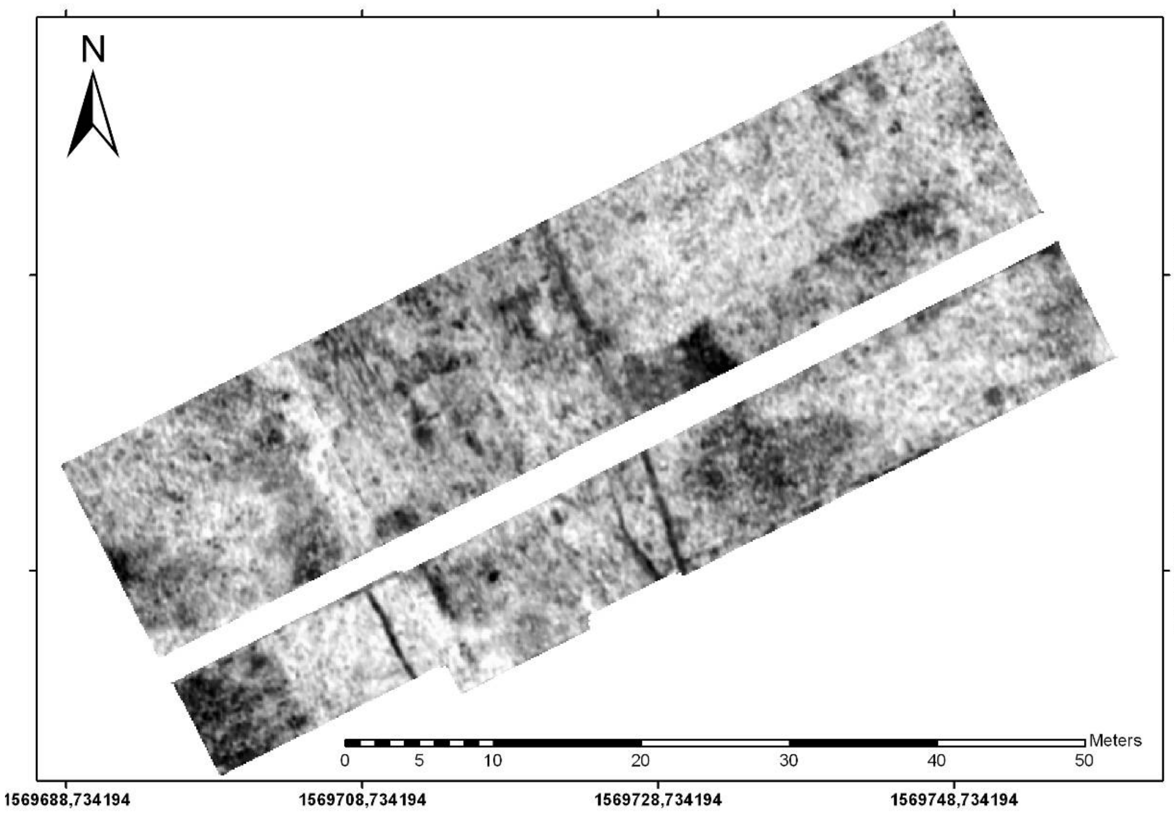

Figure 6.3.4: Depth-slice (30-40cm) survey site *Åkroken (upper part).*

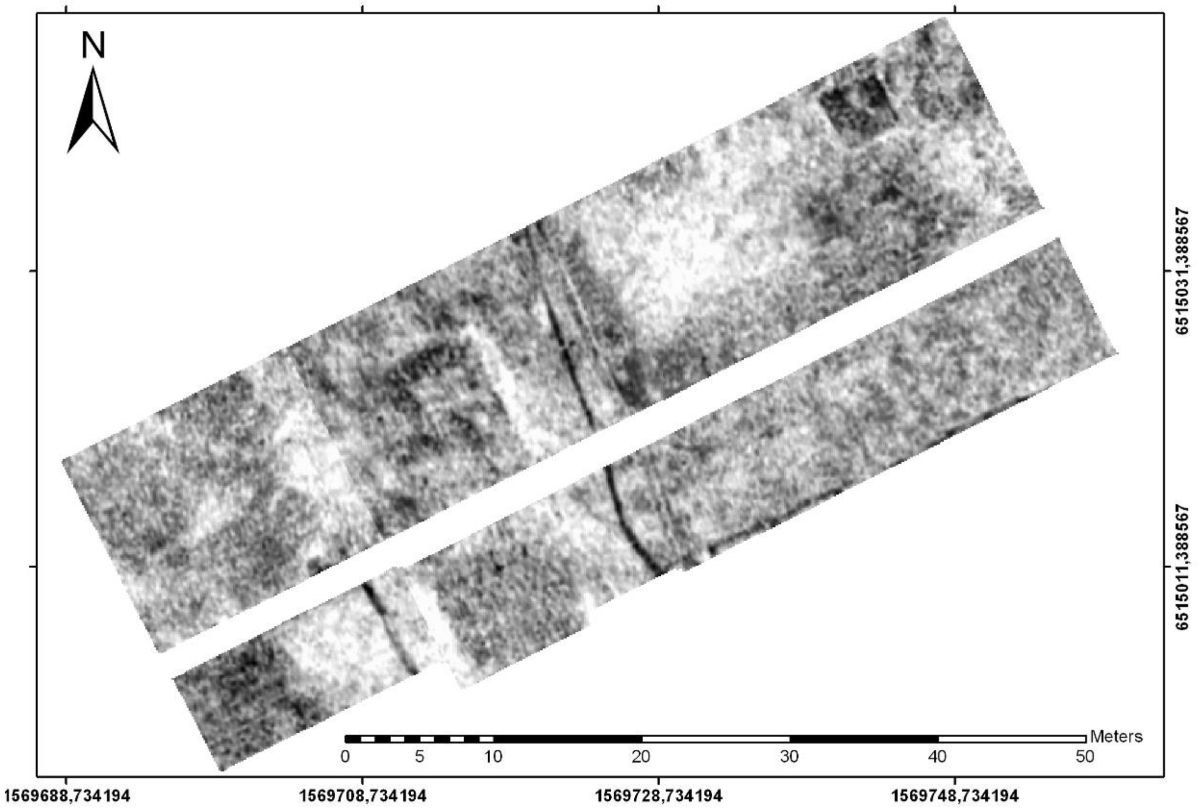

Figure 6.3.5: Depth-slice (40-50cm) survey site *Åkroken (upper part).*

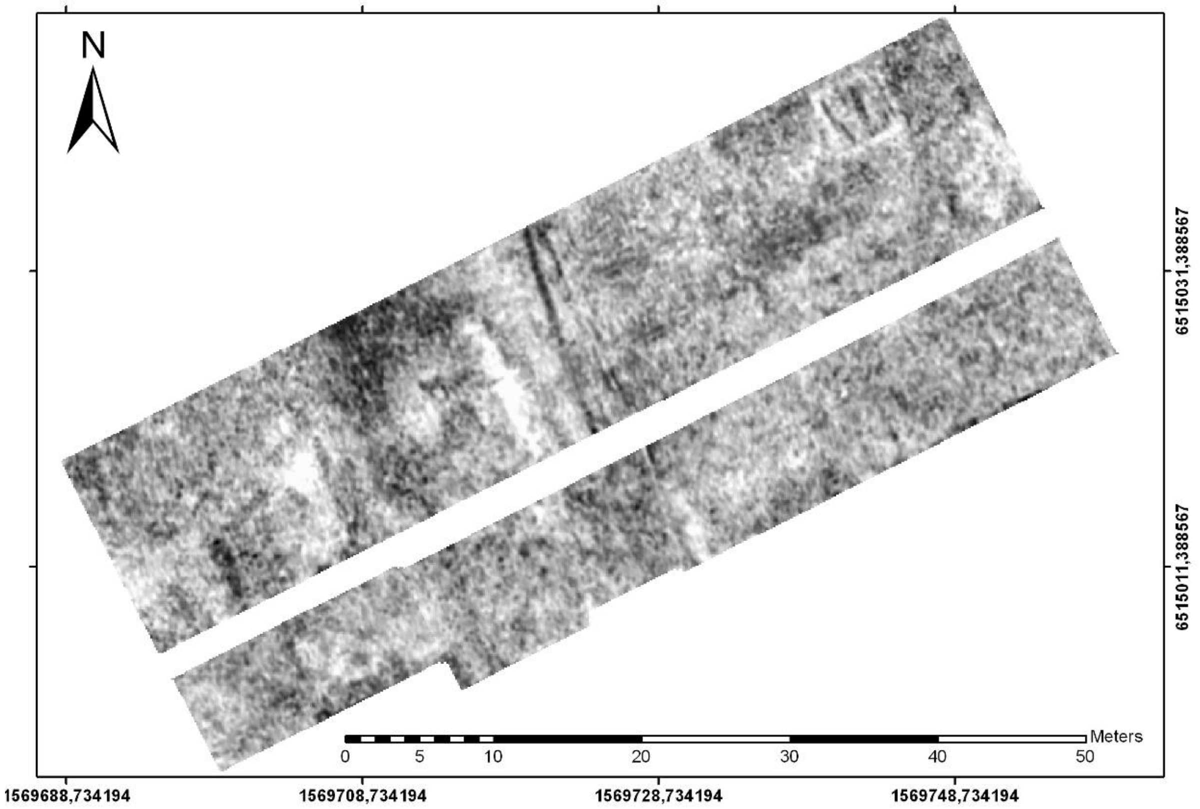

Figure 6.3.6: Depth-slice (50-60cm) survey site *Åkroken (upper part).*

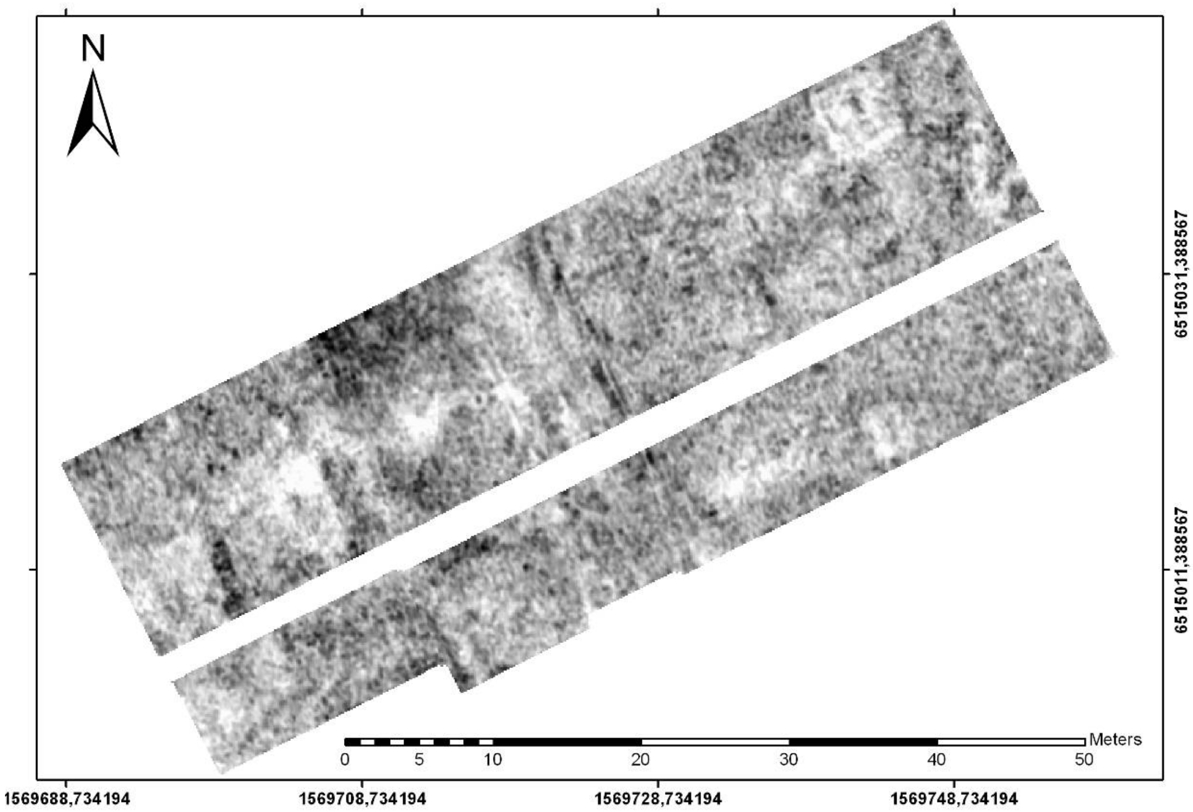

Figure 6.3.7: Depth-slice (60-70cm) survey site *Åkroken (upper part).*

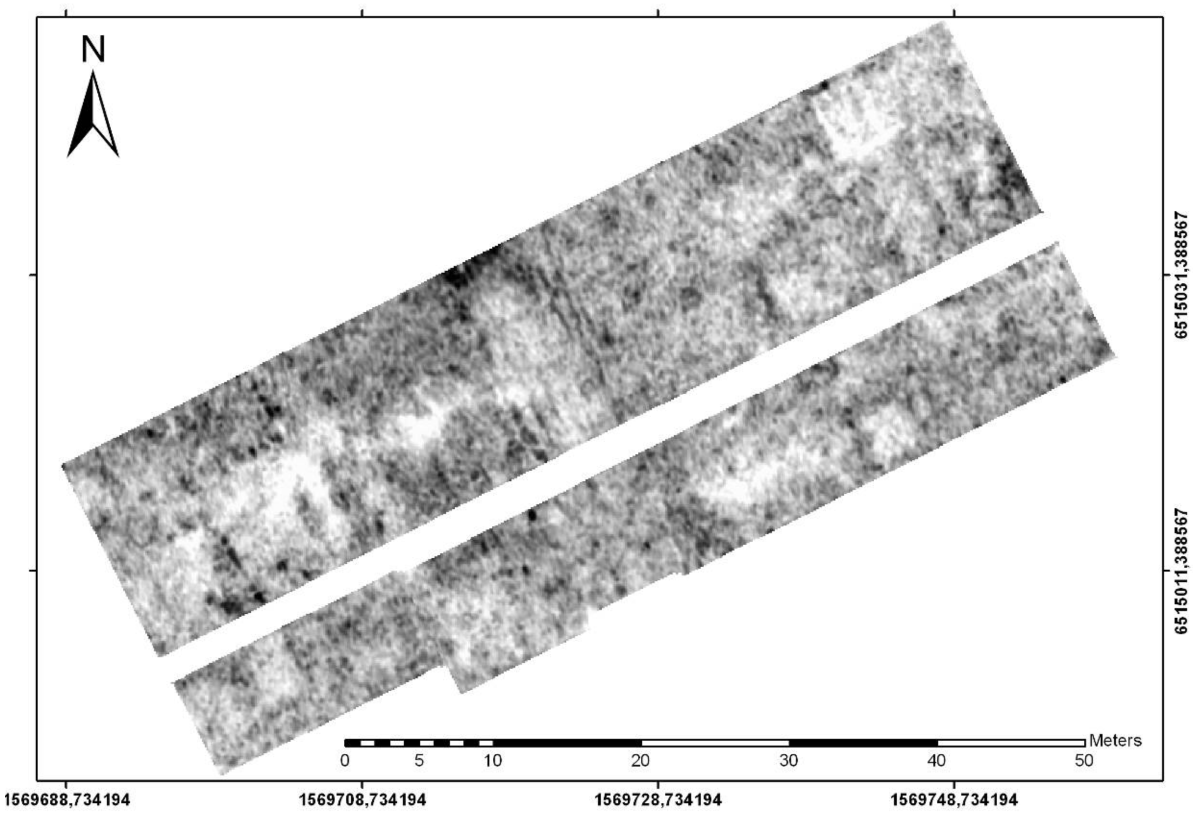

Figure 6.3.8: Depth-slice (70-80cm) survey site *Åkroken (upper part).*

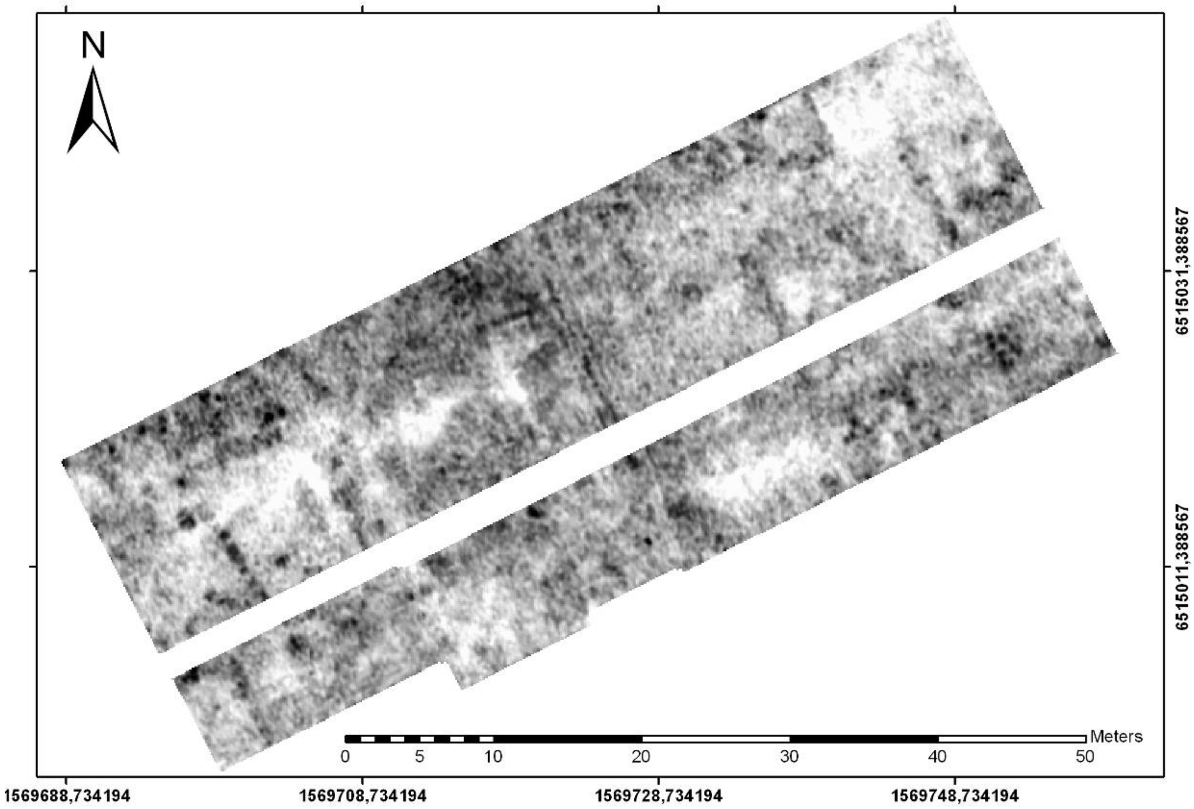

Figure 6.3.9: Depth-slice (80-90cm) survey site *Åkroken (upper part).*

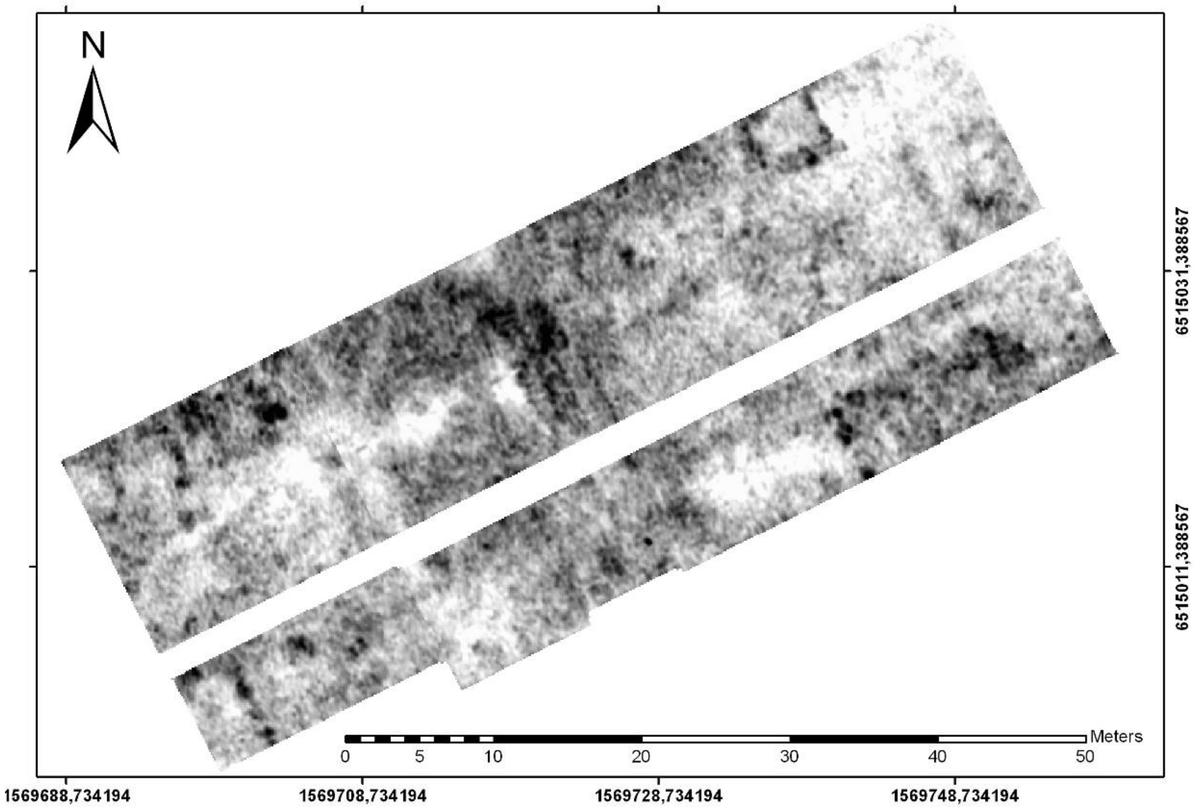

Figure 6.3.10: Depth-slice (90-100cm) survey site *Åkroken (upper part).*

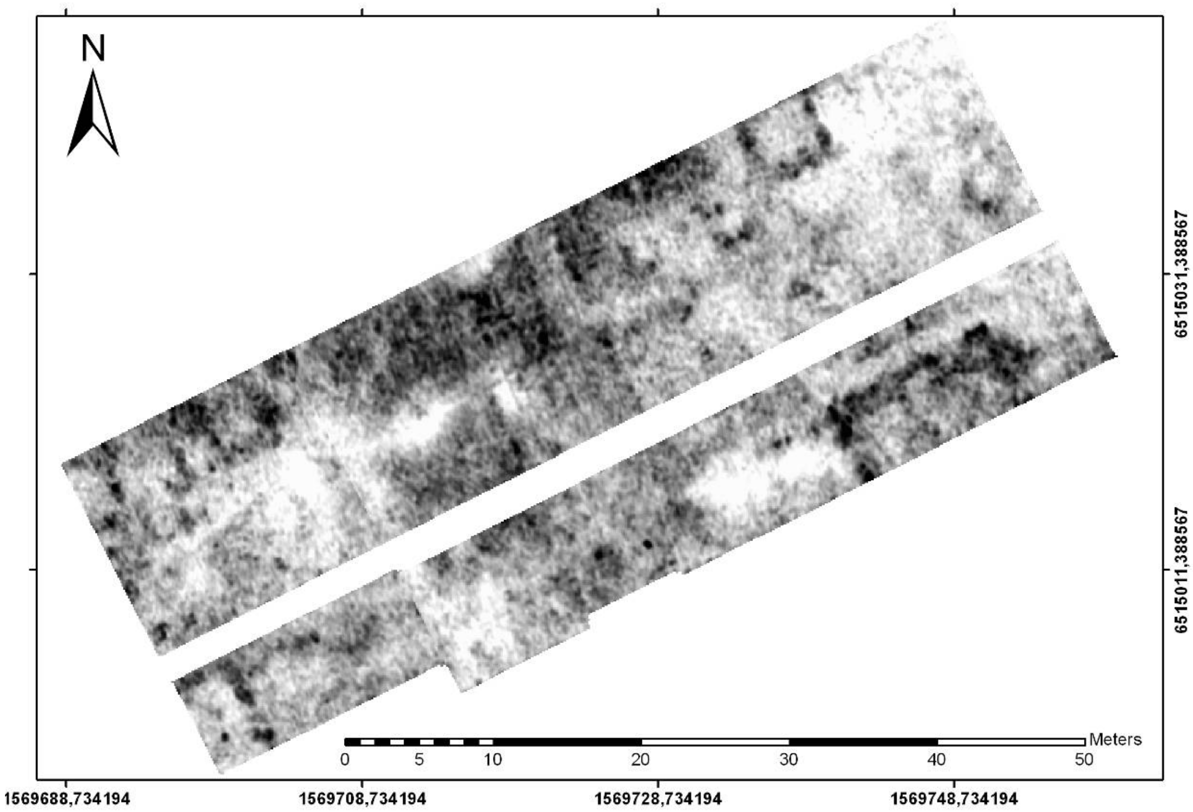

Figure 6.3.11: Depth-slice (100-110cm) survey site *Åkroken (upper part).*

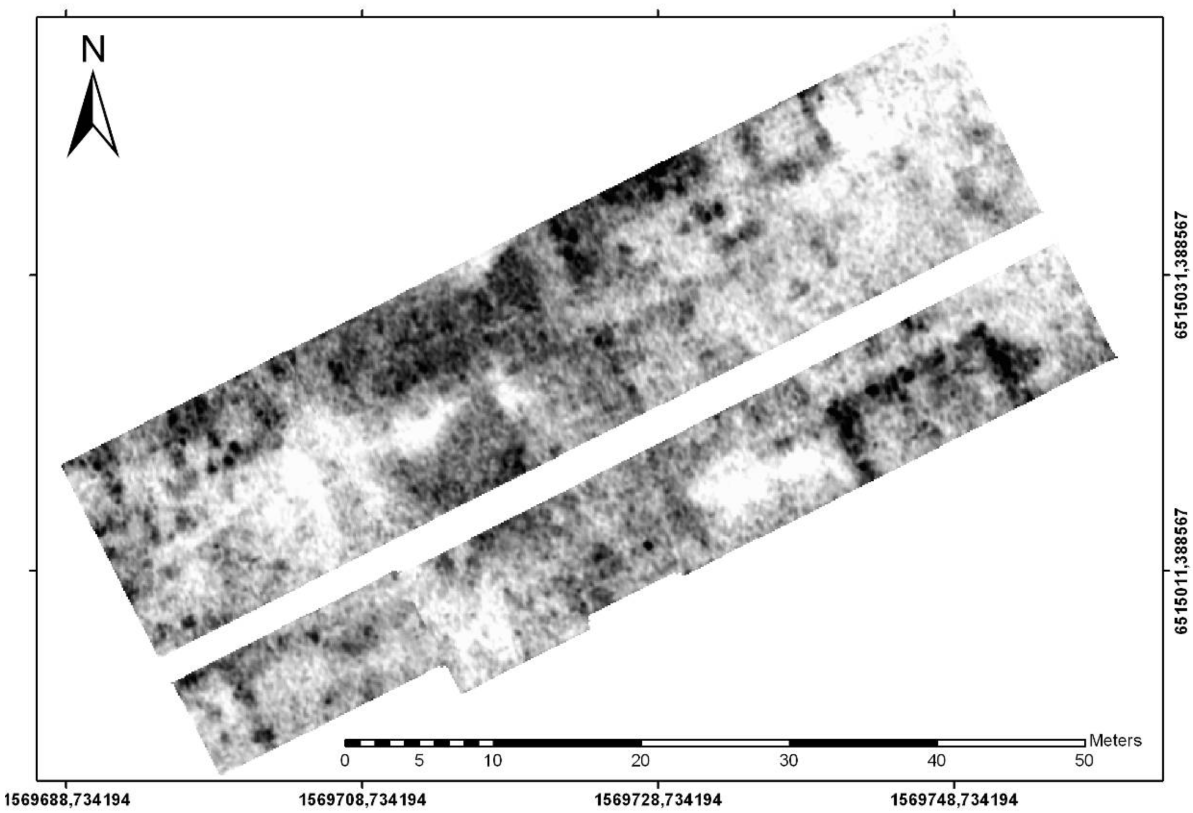

Figure 6.3.12: Depth-slice (110-120cm) survey site *Åkroken (upper part).*

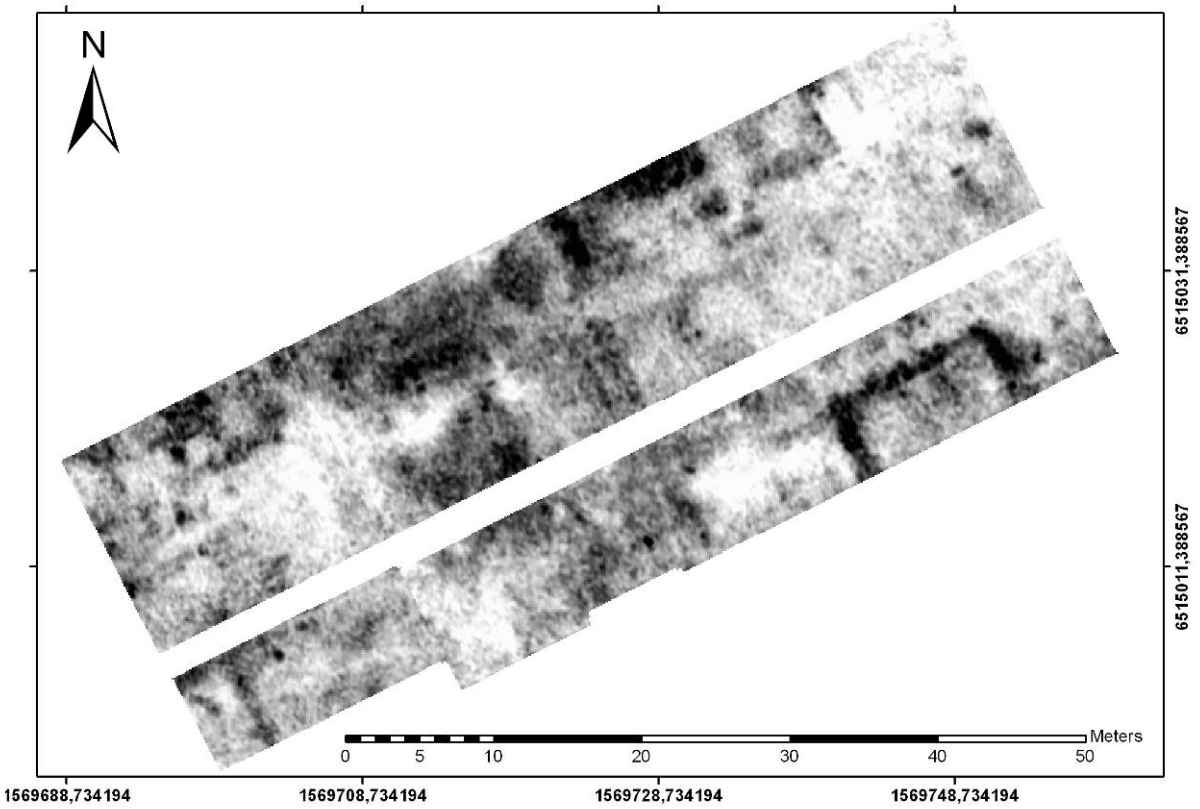

Figure 6.3.13: Depth-slice (120-130cm) survey site *Åkroken (upper part).*

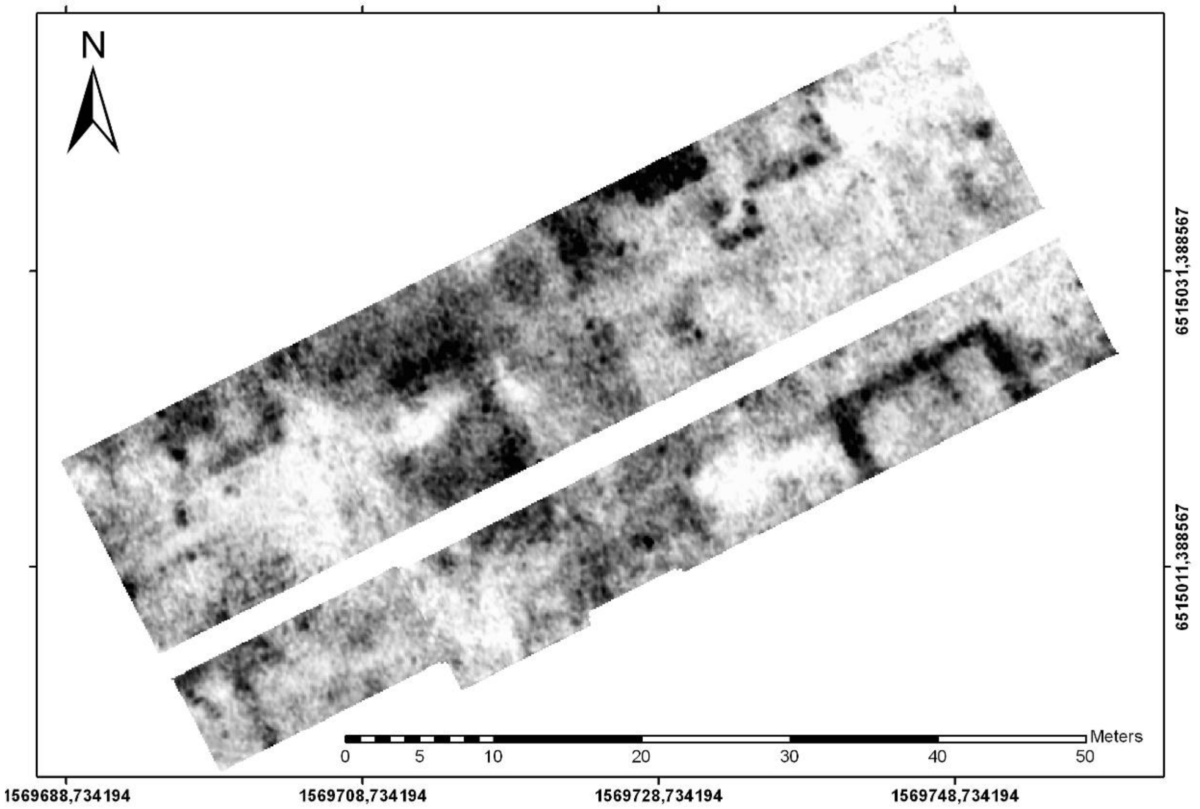

Figure 6.3.14: Depth-slice (130-140cm) survey site *Åkroken (upper part).*

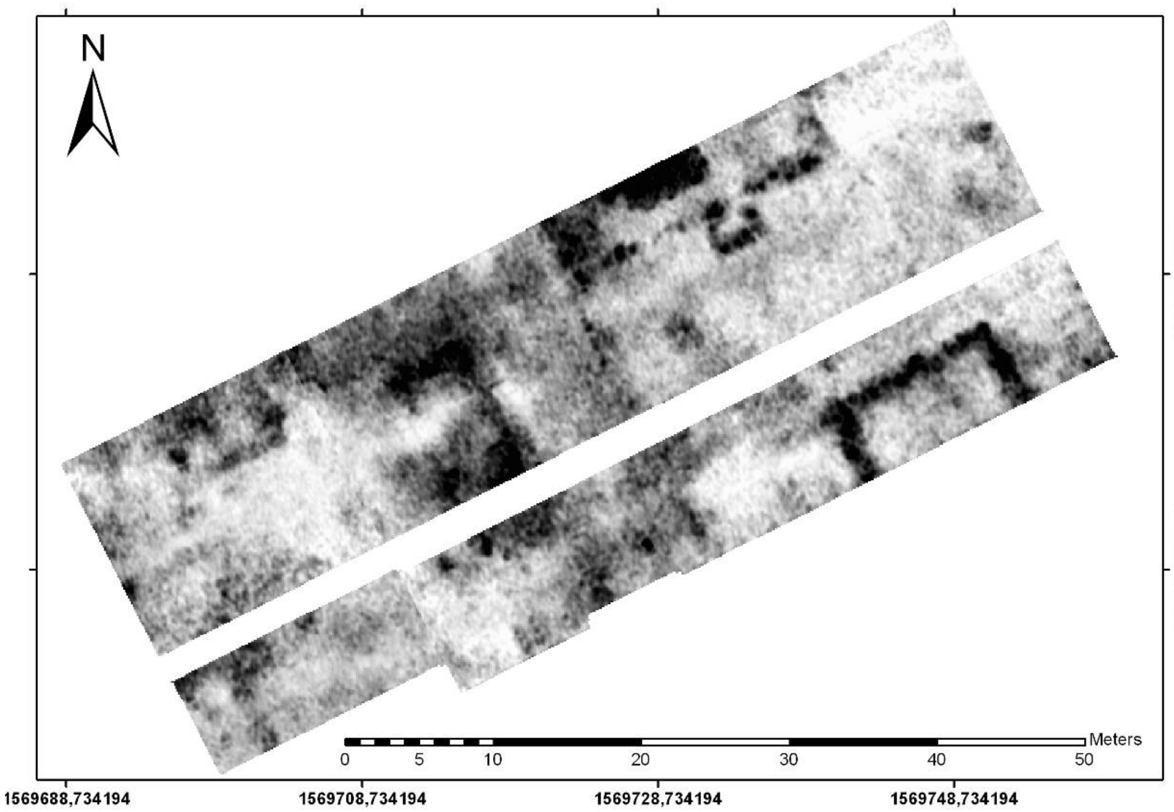

Figure 6.3.15: Depth-slice (140-150cm) survey site *Åkroken (upper part).*

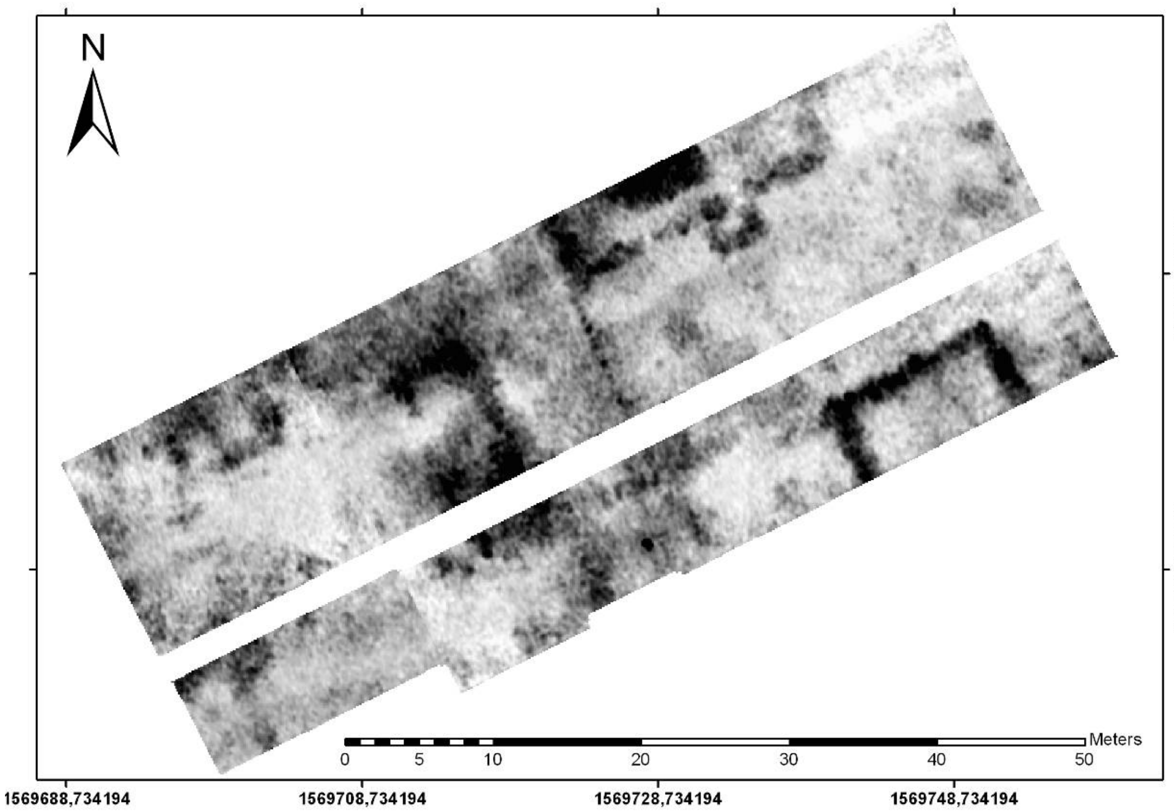

Figure 6.3.16: Depth-slice (150-160cm) survey site *Åkroken (upper part).*

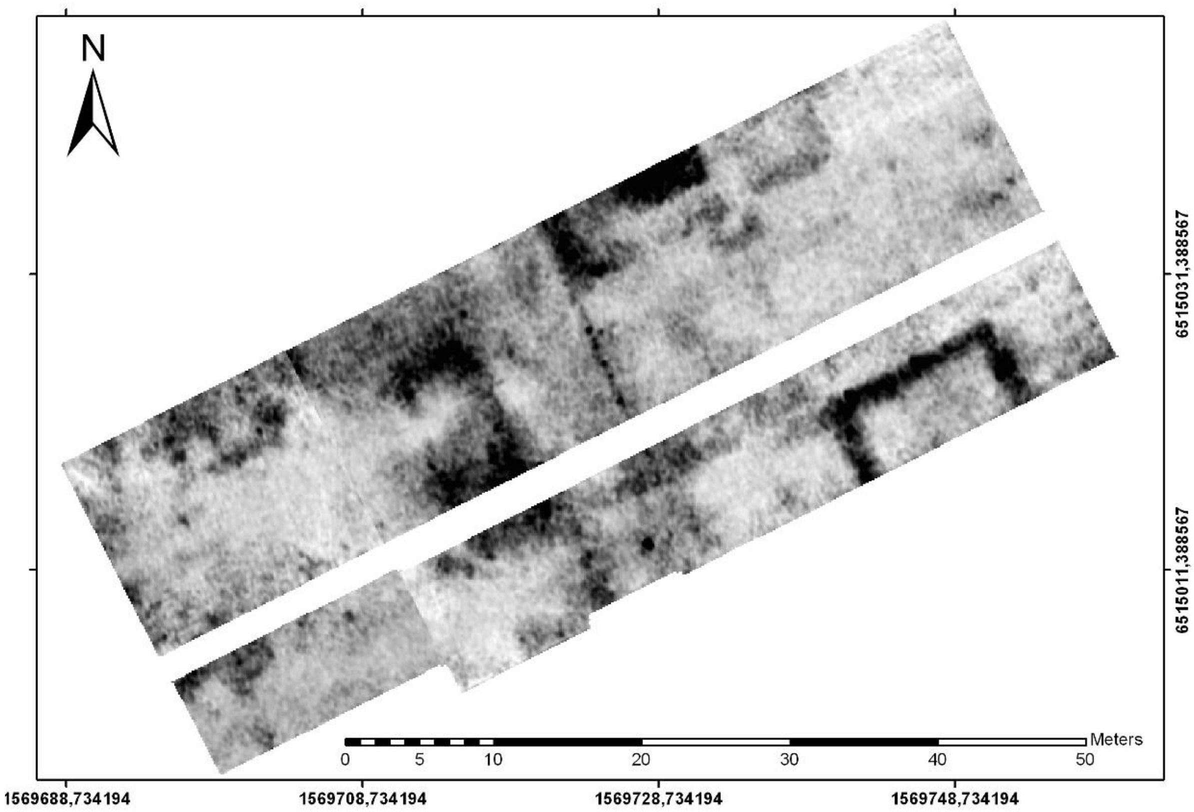

Figure 6.3.17: Depth-slice (160-170cm) survey site *Åkroken (upper part).*

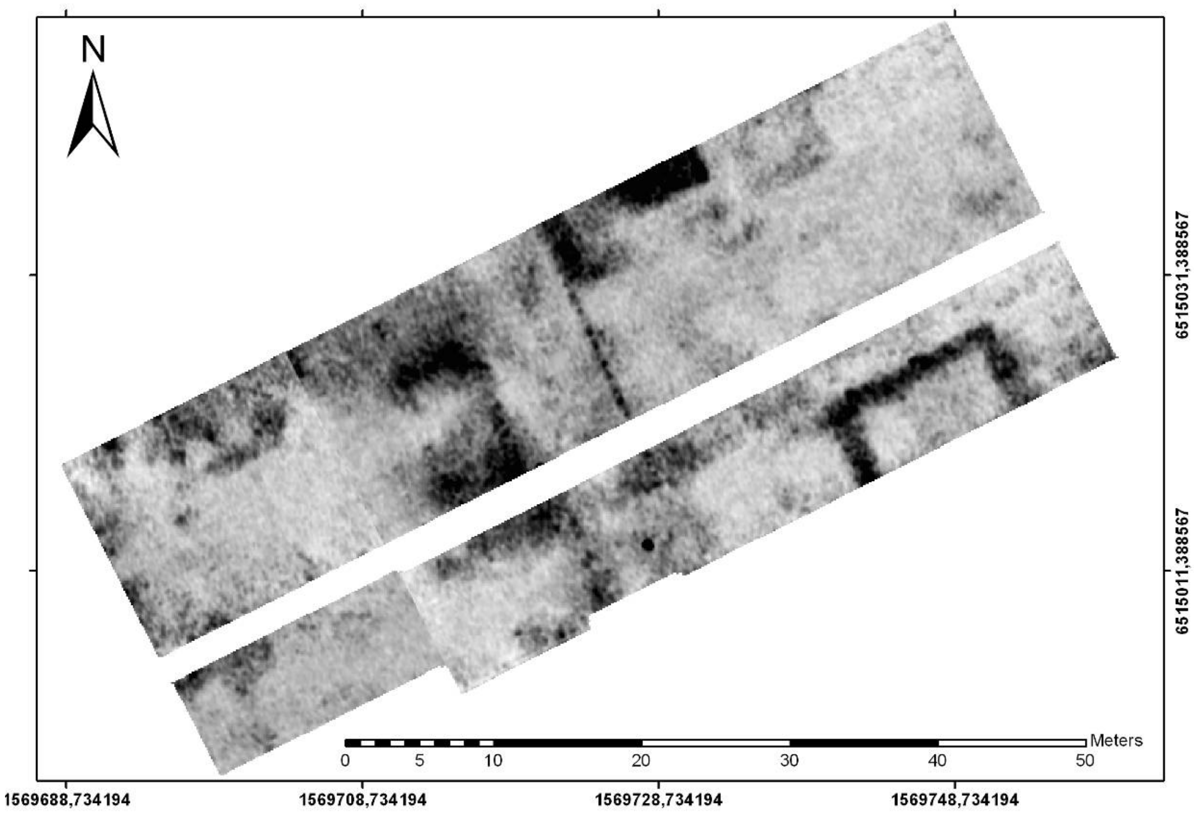

Figure 6.3.18: Depth-slice (170-180cm) survey site *Åkroken (upper part).*

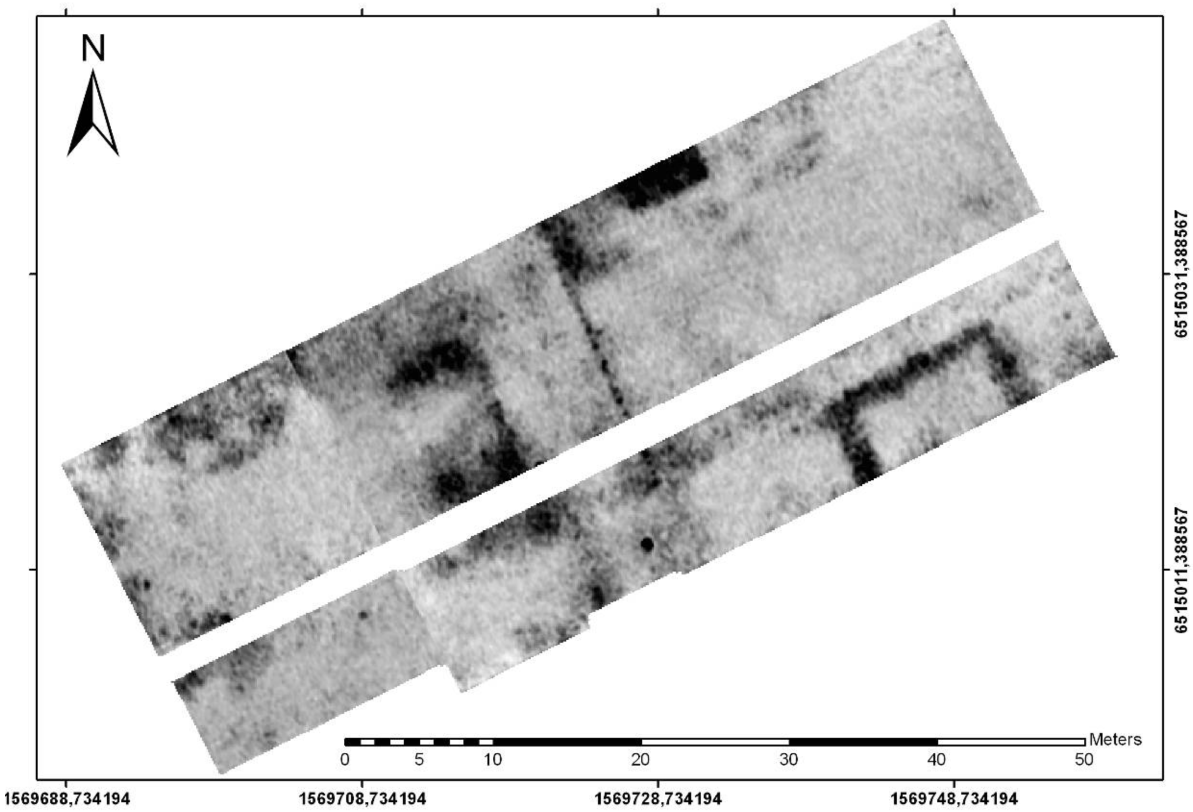

Figure 6.3.19: Depth-slice (180-190cm) survey site *Åkroken (upper part).*

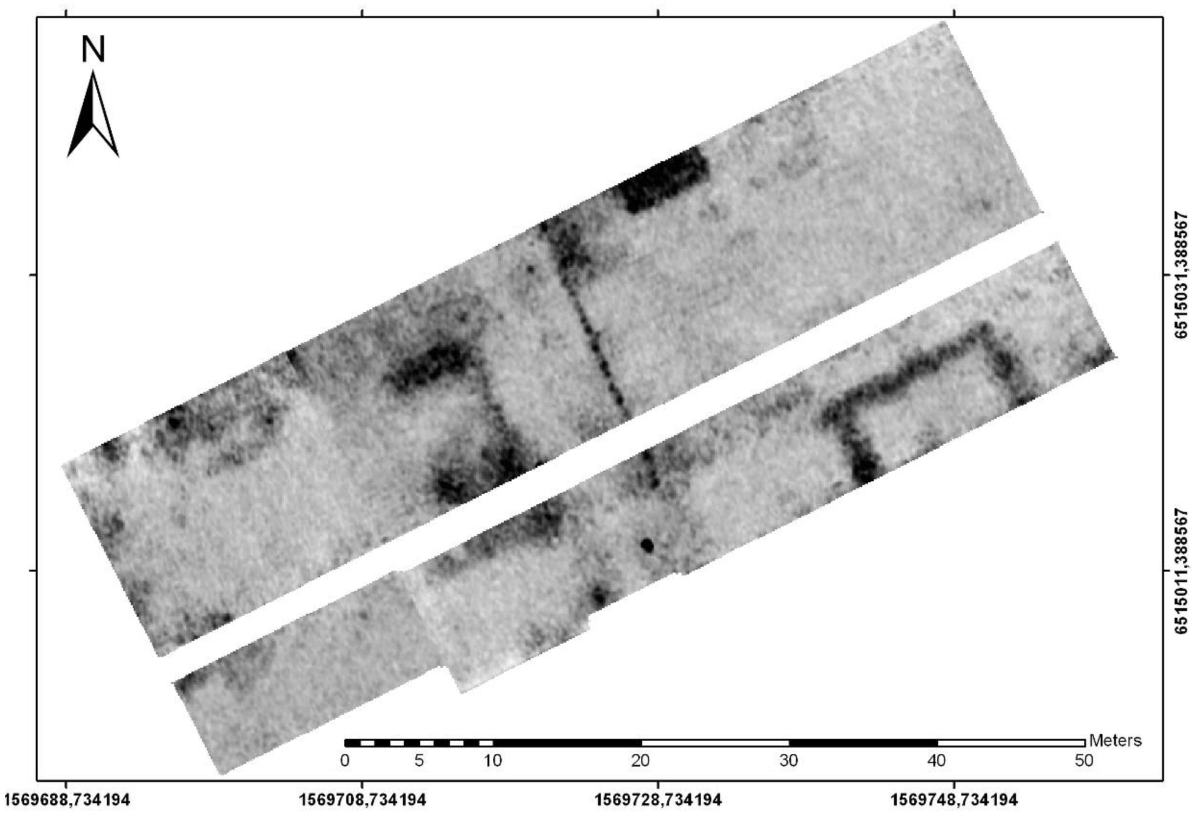

Figure 6.3.20: Depth-slice (190-200cm) survey site *Åkroken (upper part).*

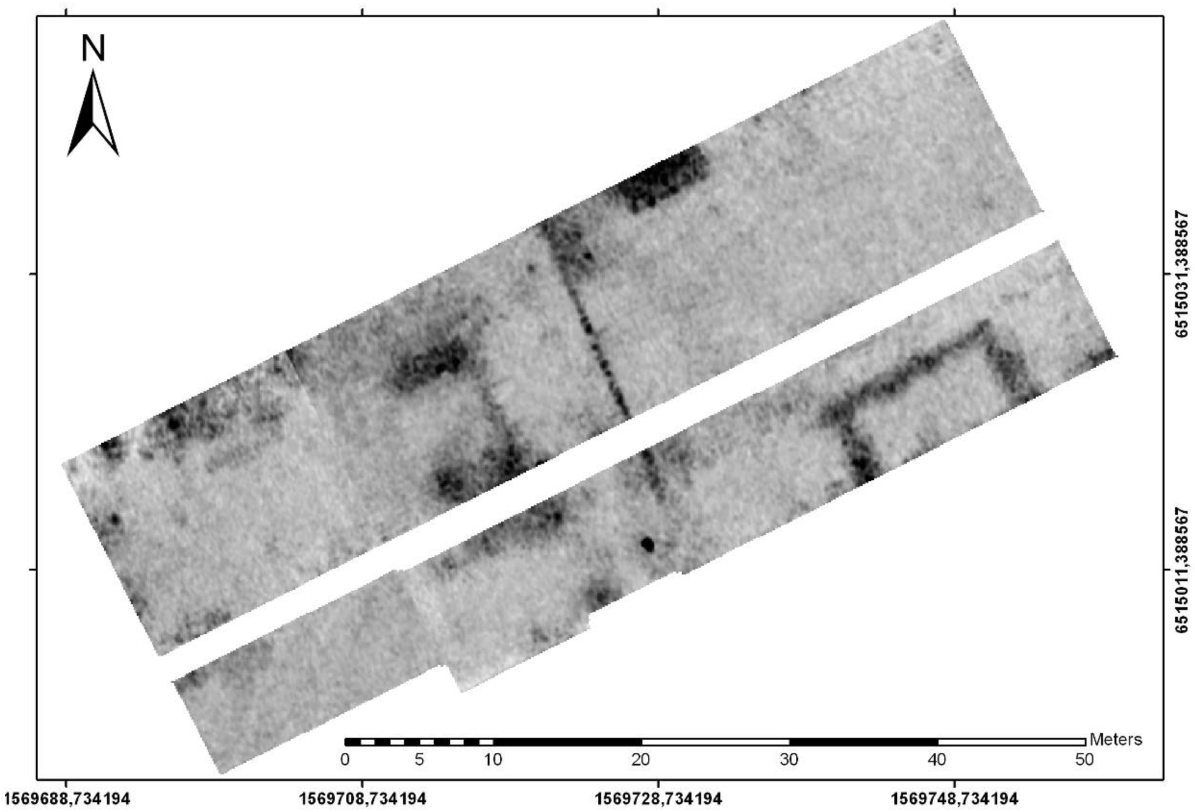

Figure 6.3.21: Depth-slice (200-210cm) survey site *Åkroken (upper part).*

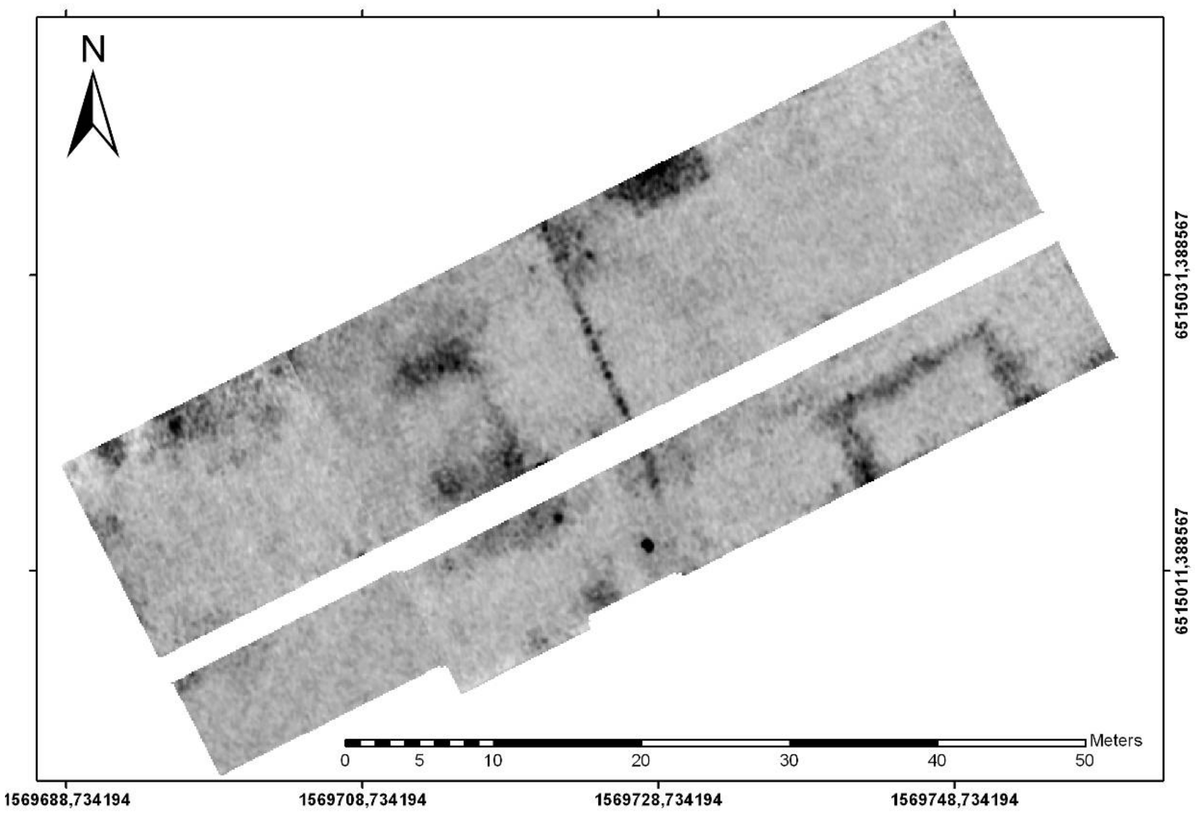

Figure 6.3.22: Depth-slice (210-220cm) survey site *Åkroken (upper part).*

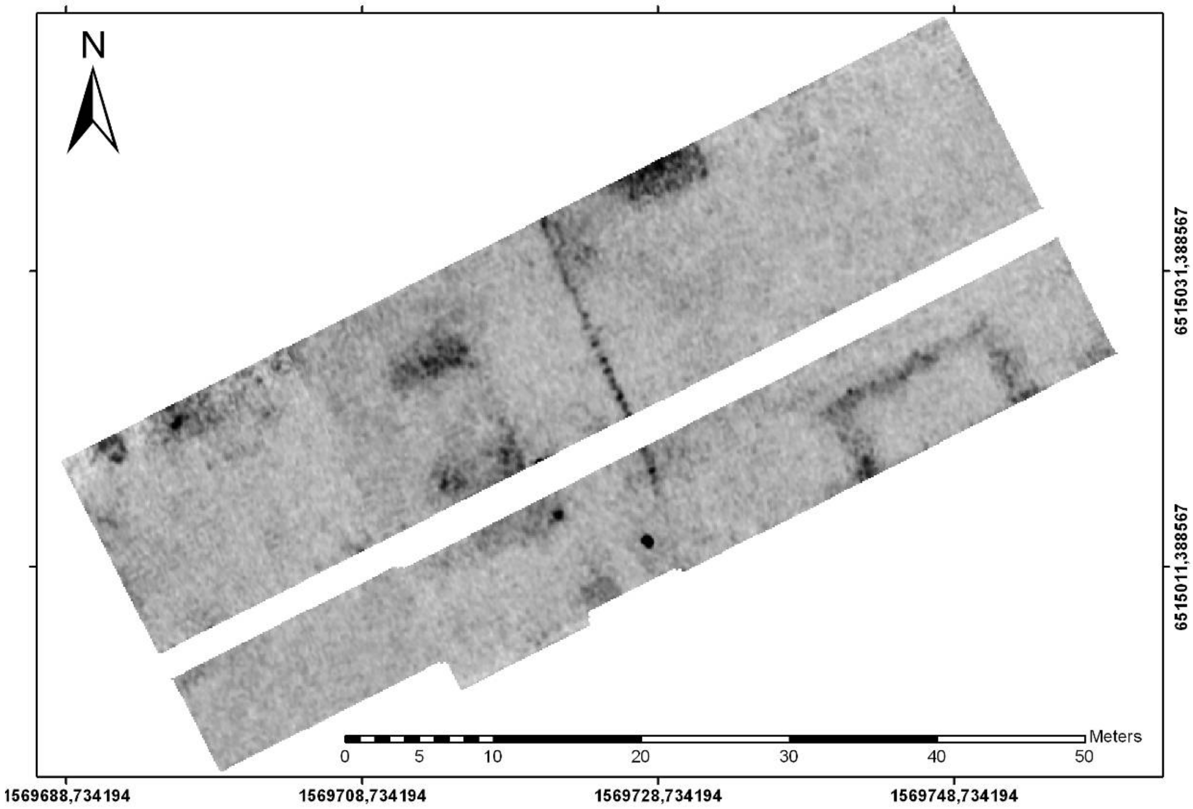

Figure 6.3.23: Depth-slice (220-230cm) survey site *Åkroken (upper part).*

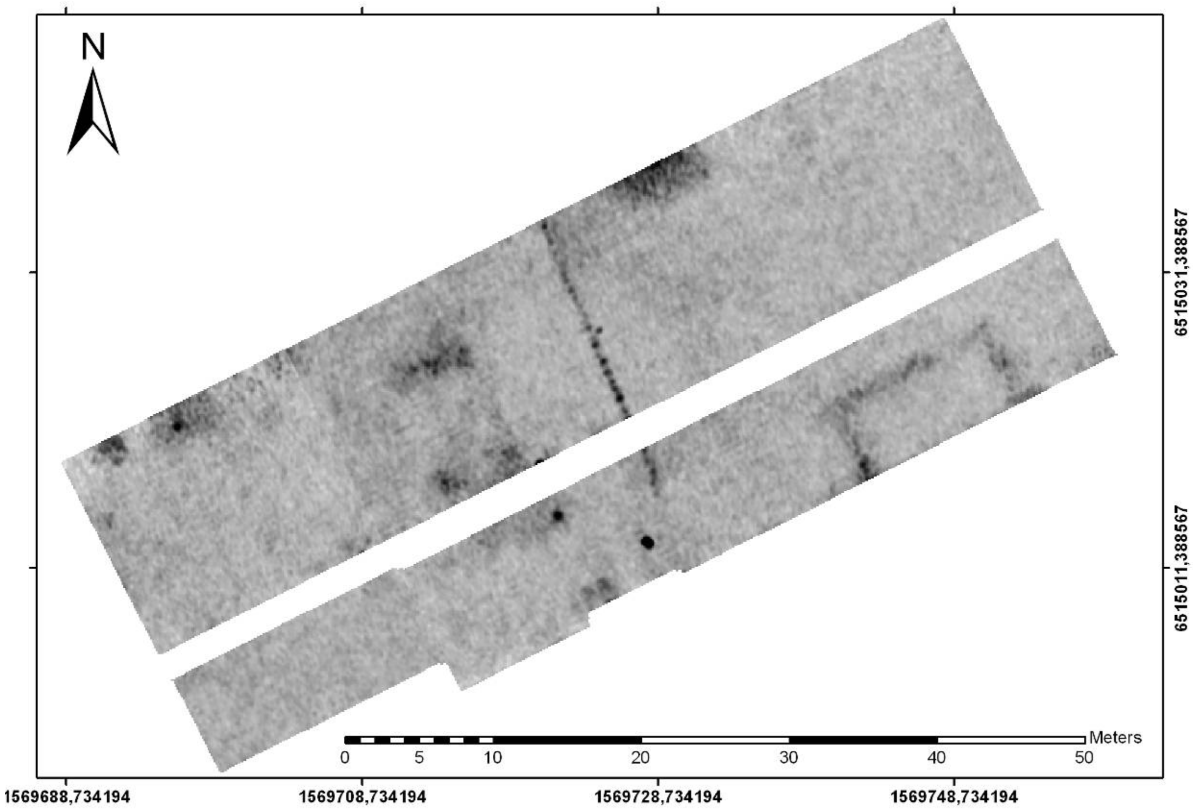

Figure 6.3.24: Depth-slice (230-240cm) survey site *Åkroken (upper part).*

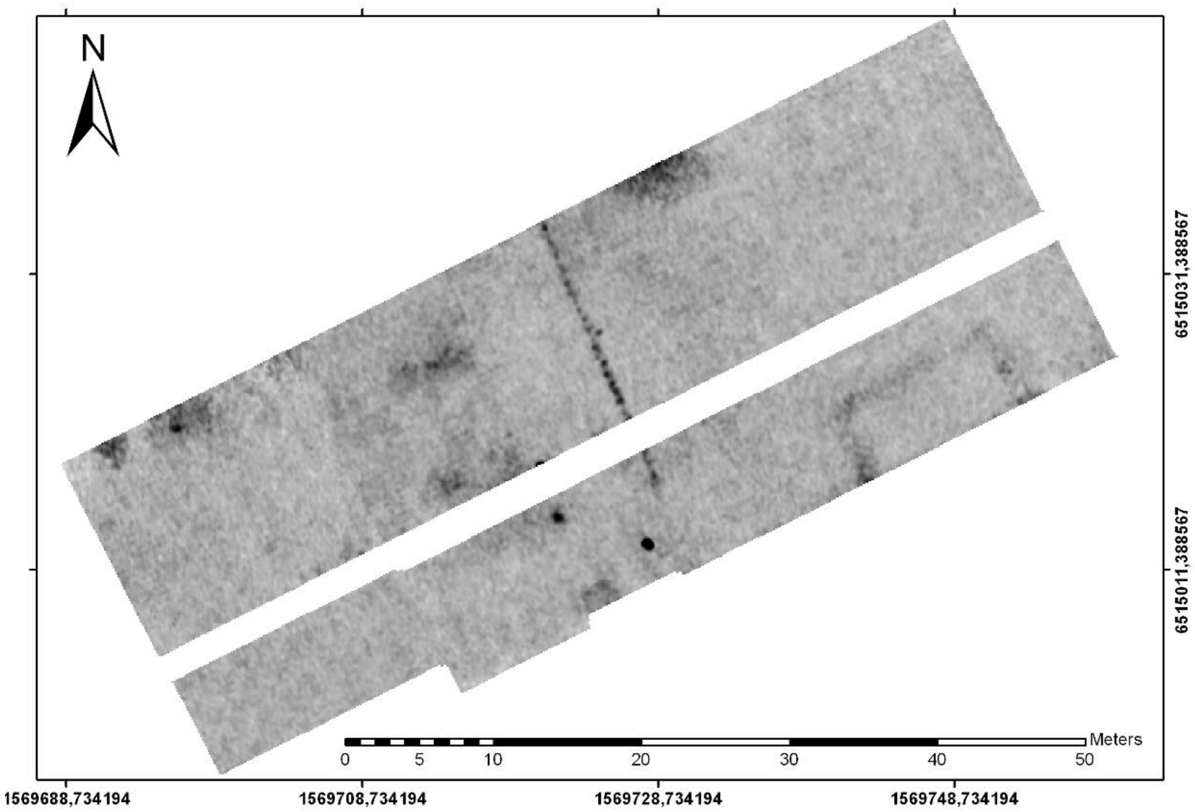

Figure 6.3.25: Depth-slice (240-250cm) survey site *Åkroken (upper part).*

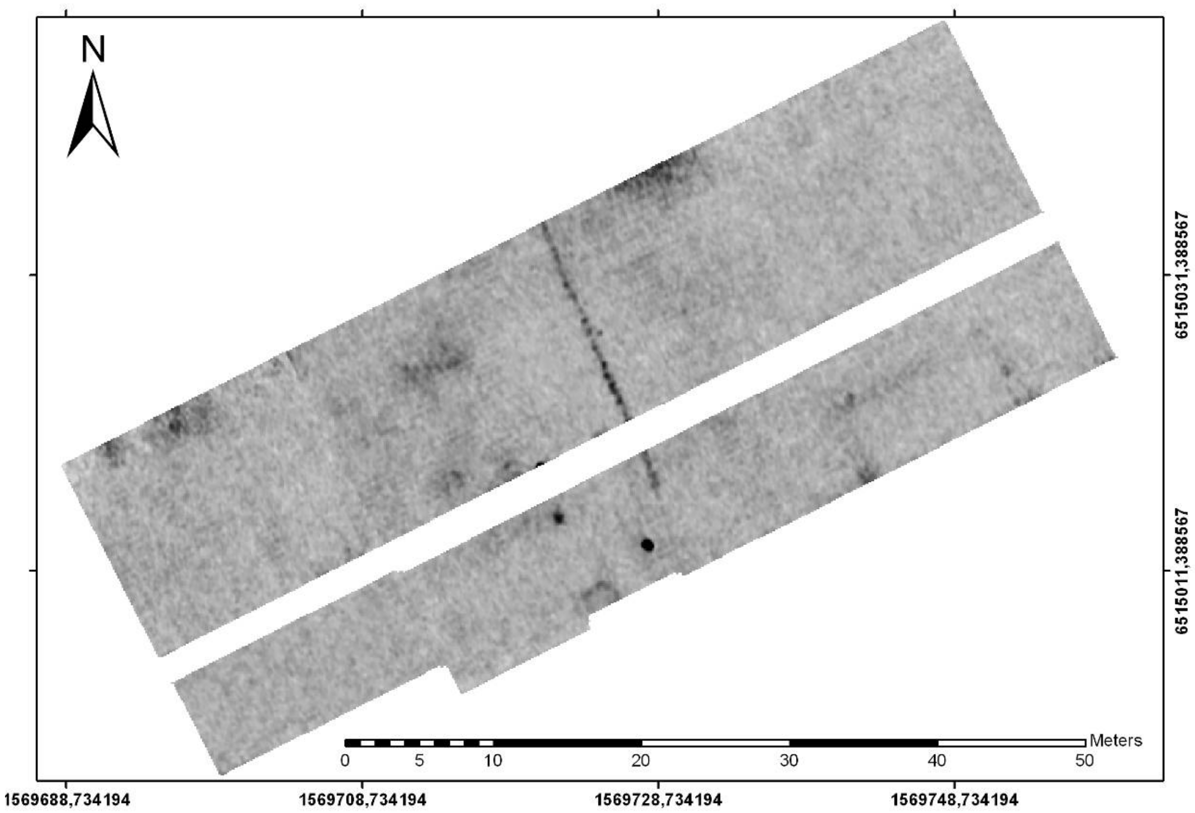

Figure 6.3.26: Depth-slice (250-260cm) survey site *Åkroken (upper part).*

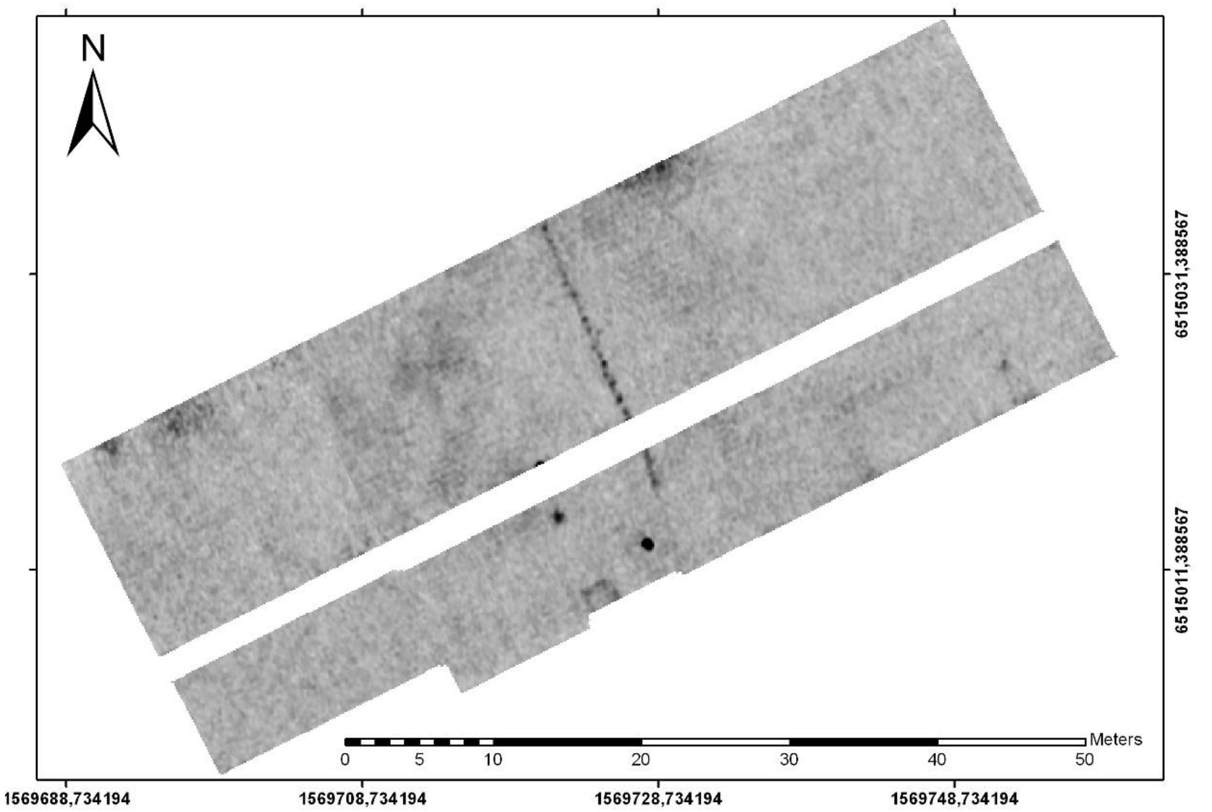

Figure 6.3.27: Depth-slice (260-270cm) survey site *Åkroken (upper part).*

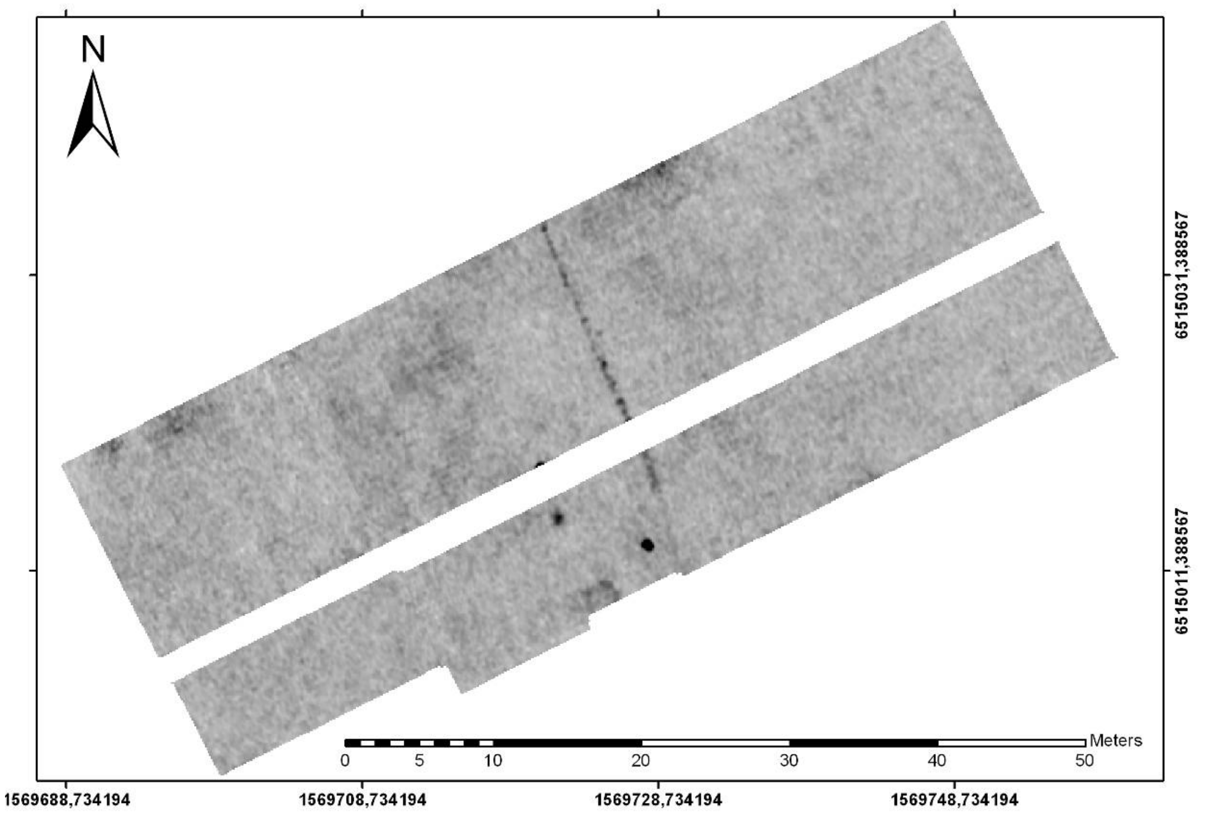

Figure 6.3.28: Depth-slice (270-280cm) survey site *Åkroken (upper part).*

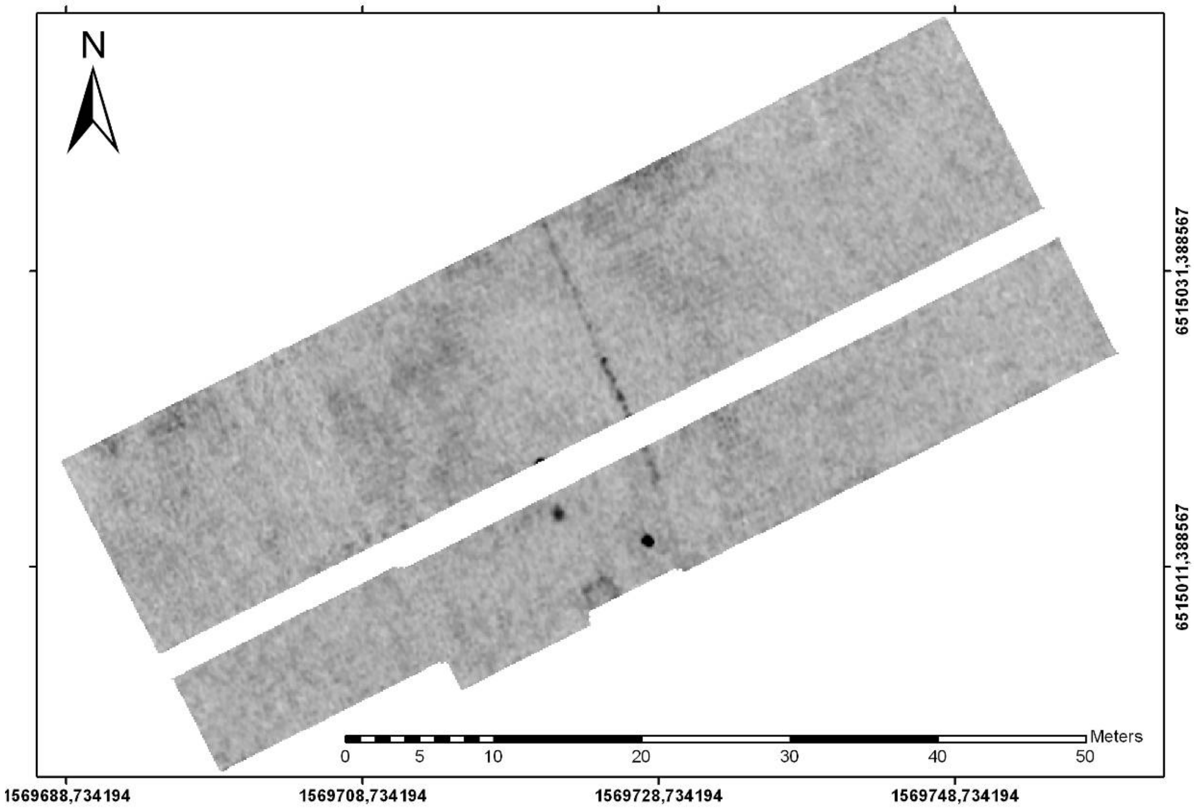

Figure 6.3.29: Depth-slice (280-290cm) survey site *Åkroken (upper part).*

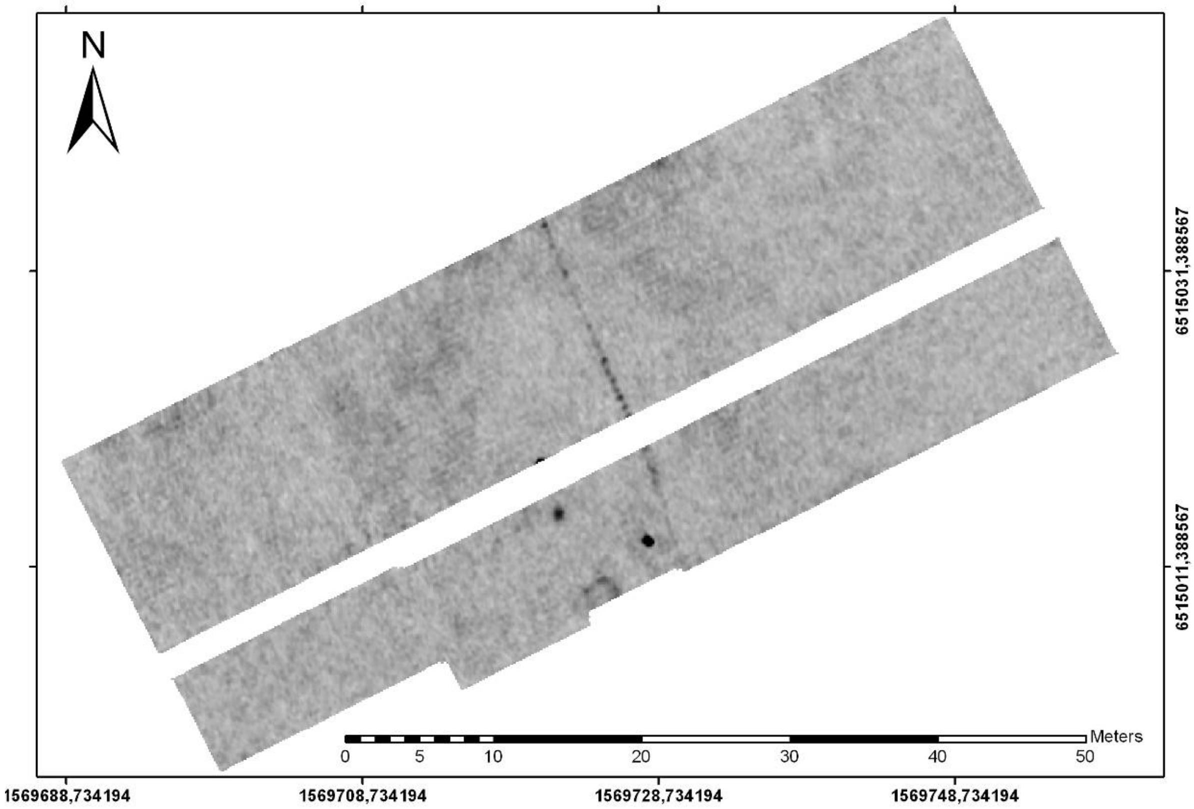

Figure 6.3.30: Depth-slice (290-300cm) survey site *Åkroken (upper part).*

6.4 Depth-slices from survey site *Åkroken (lower part)*

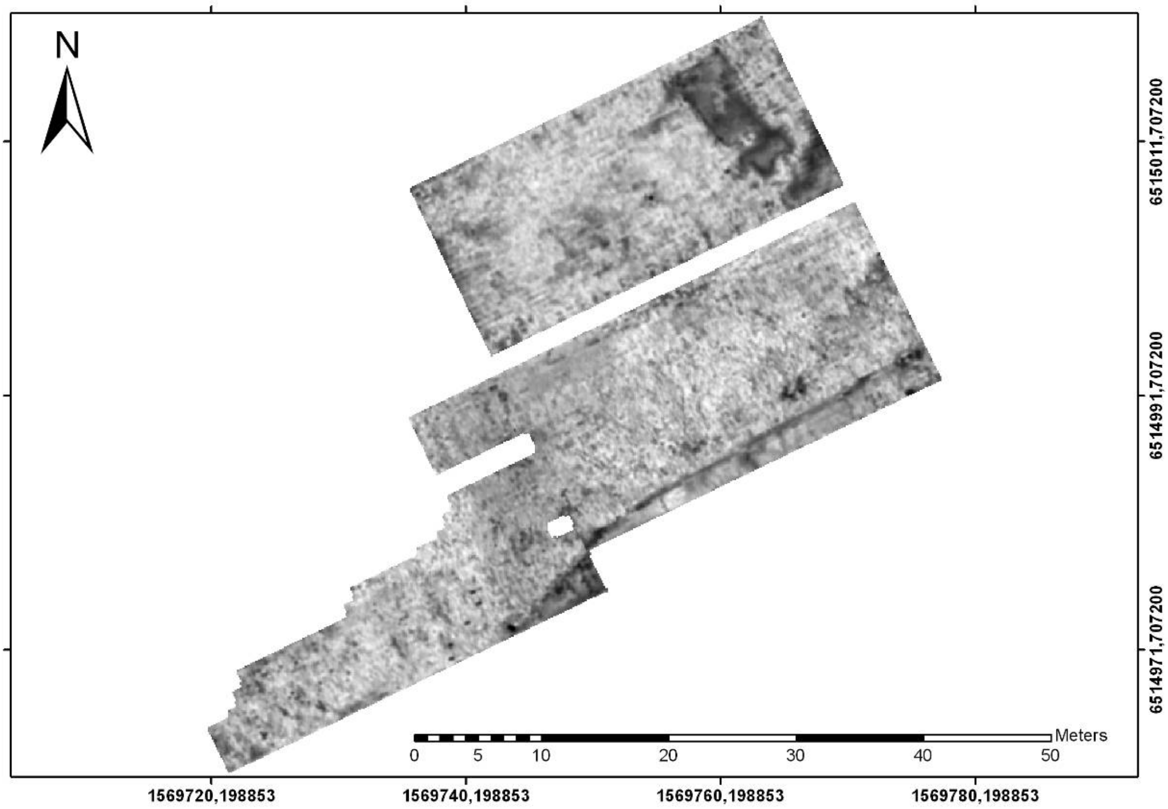

Figure 6.4.1: Depth-slice (0-10cm) survey site *Åkroken (lower part).*

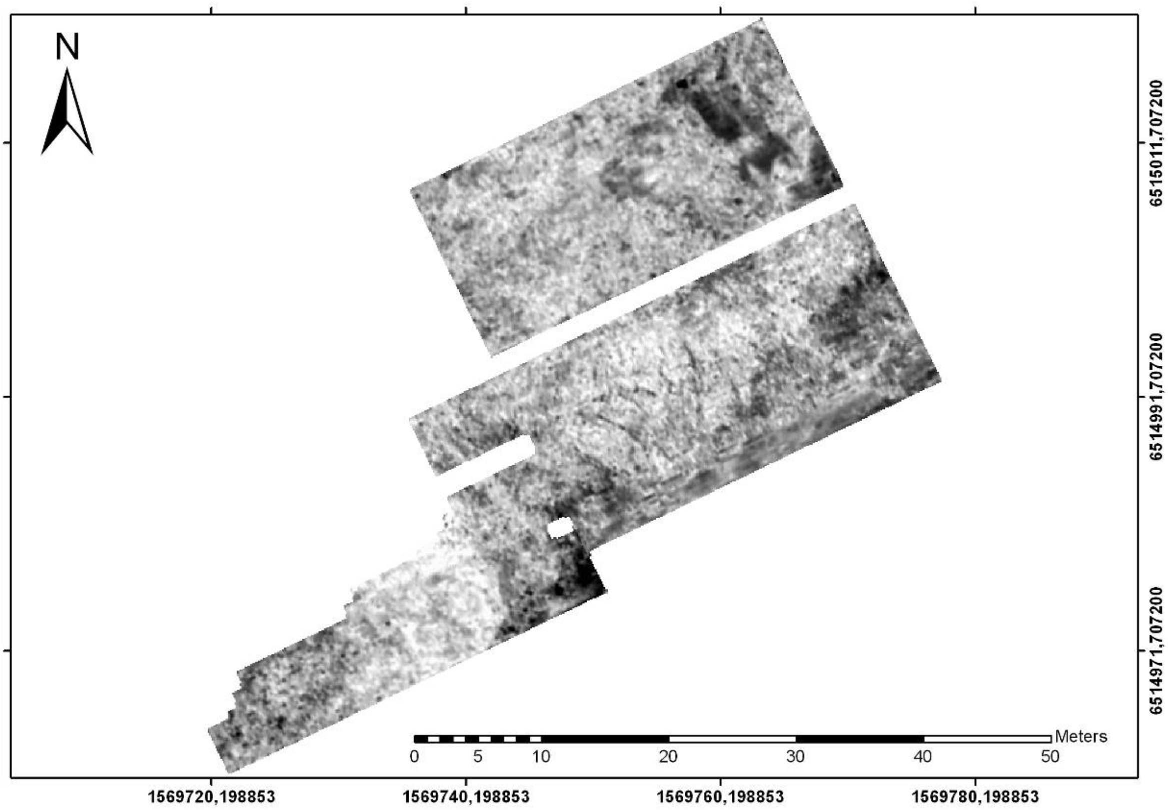

Figure 6.4.2: Depth-slice (10-20cm) survey site *Åkroken (lower part).*

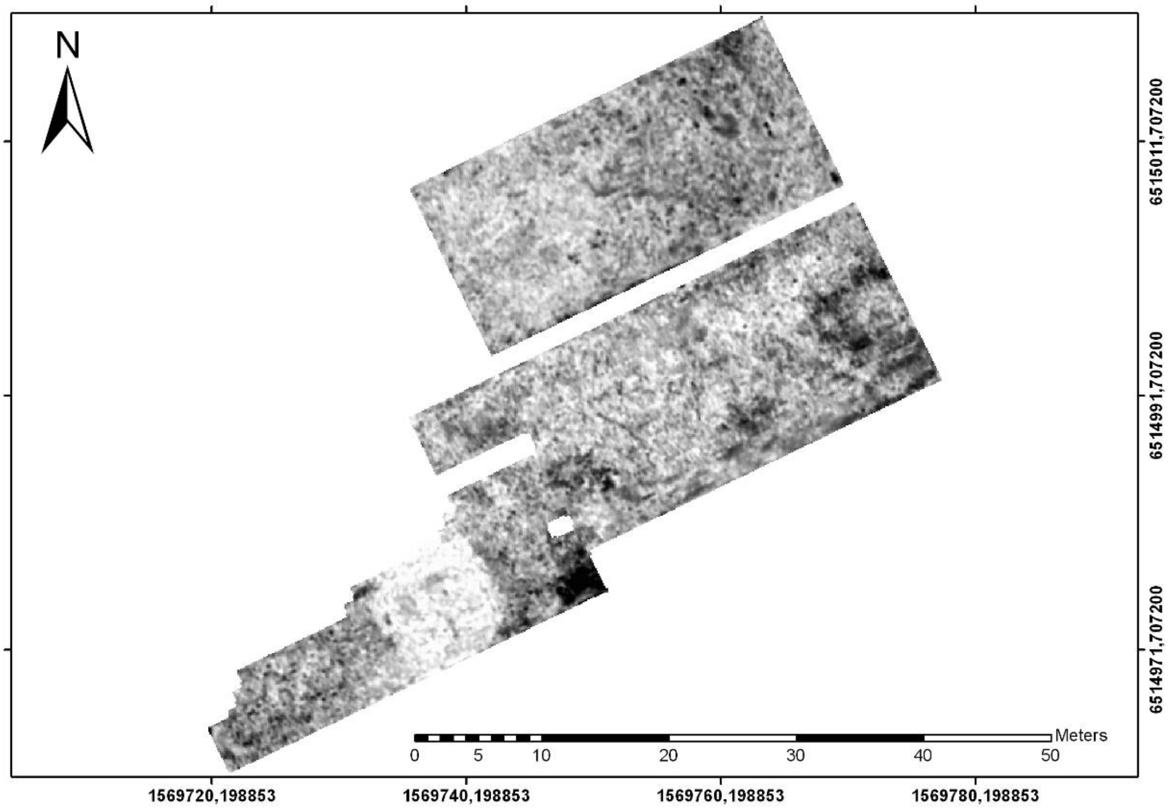

Figure 6.4.3: Depth-slice (20-30cm) survey site *Åkroken (lower part)*.

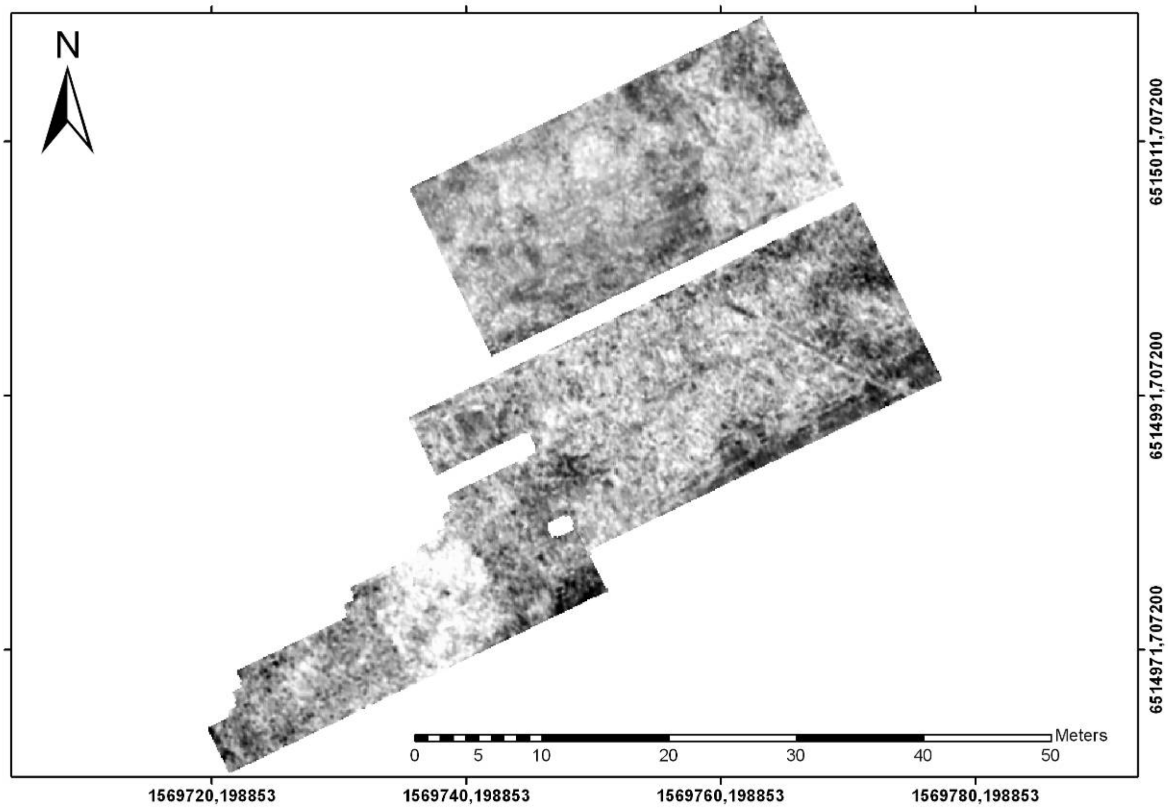

Figure 6.4.4: Depth-slice (30-40cm) survey site *Åkroken (lower part)*.

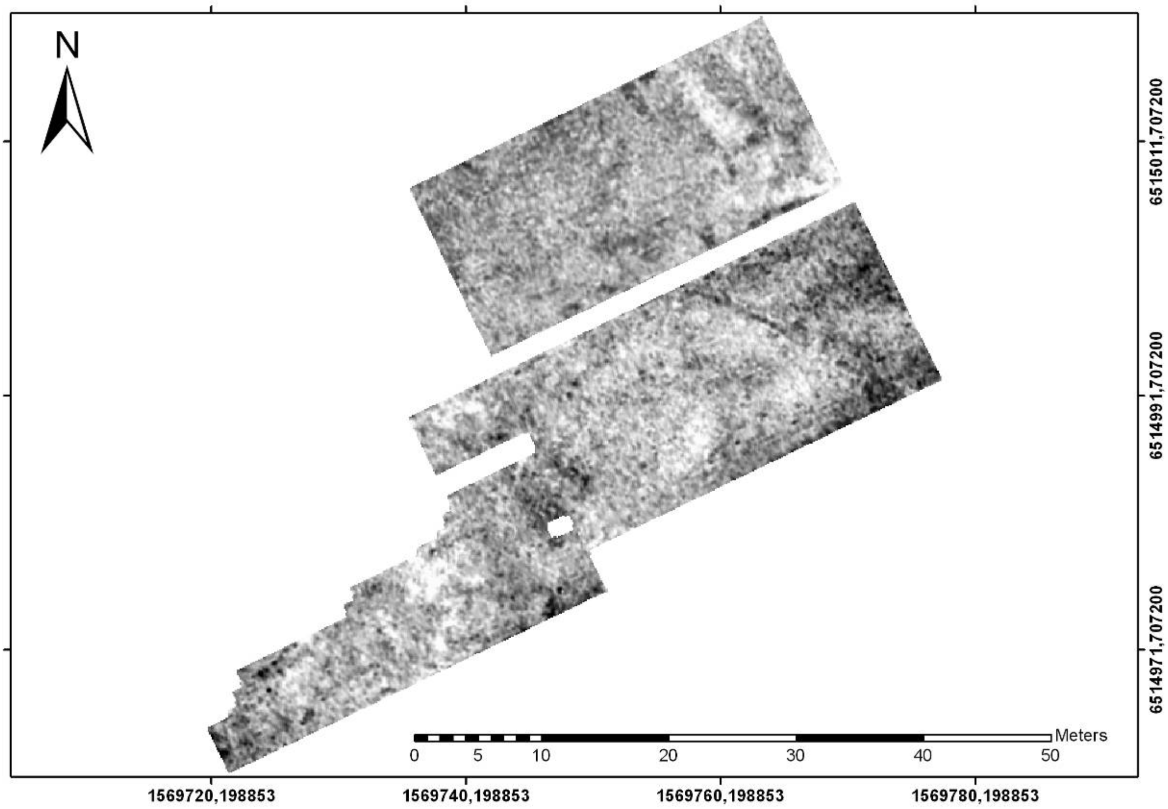

Figure 6.4.5: Depth-slice (40-50cm) survey site *Åkroken (lower part).*

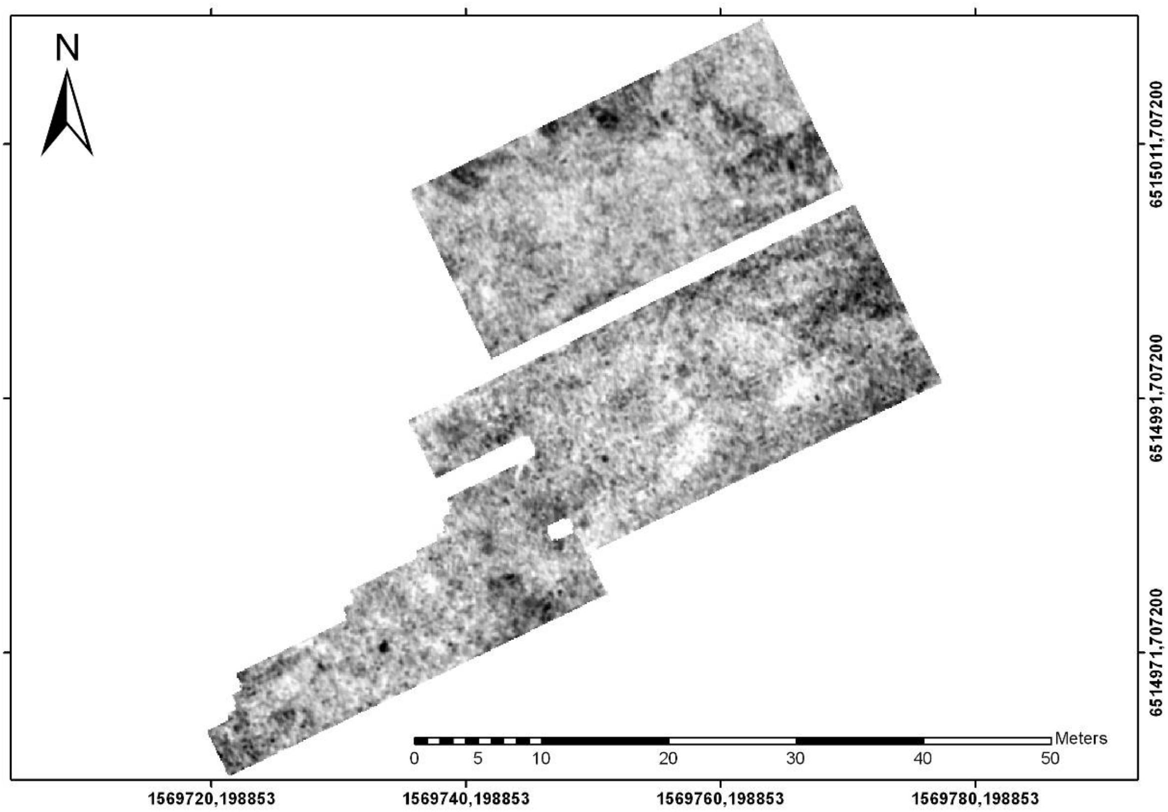

Figure 6.4.6: Depth-slice (50-60cm) survey site *Åkroken (lower part).*

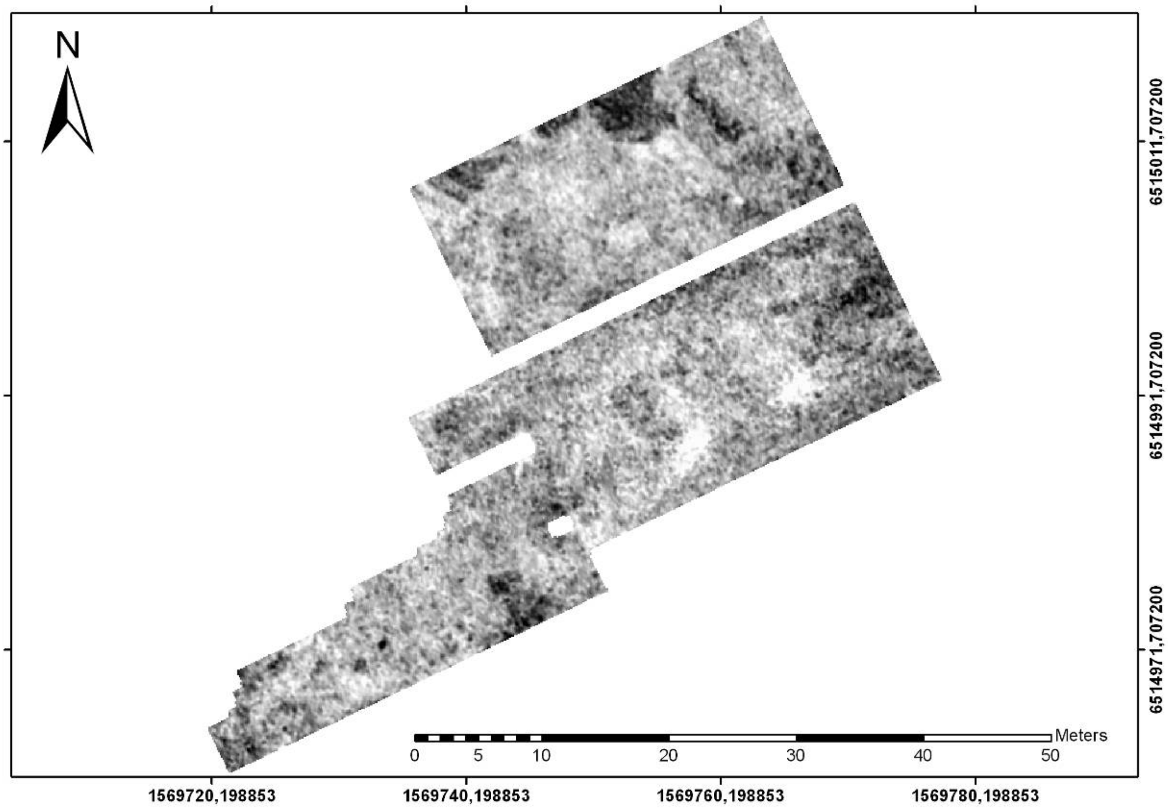

Figure 6.4.7: Depth-slice (60-70cm) survey site *Åkroken (lower part)*.

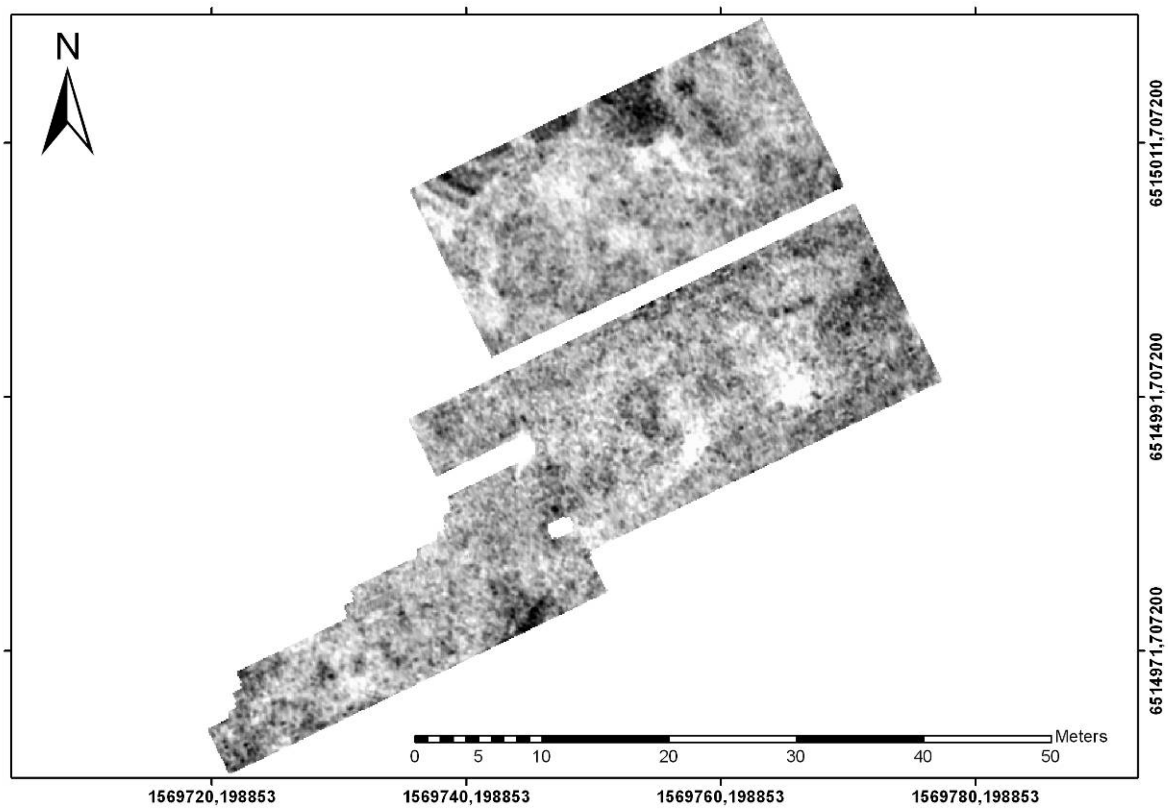

Figure 6.4.8: Depth-slice (70-80cm) survey site *Åkroken (lower part)*.

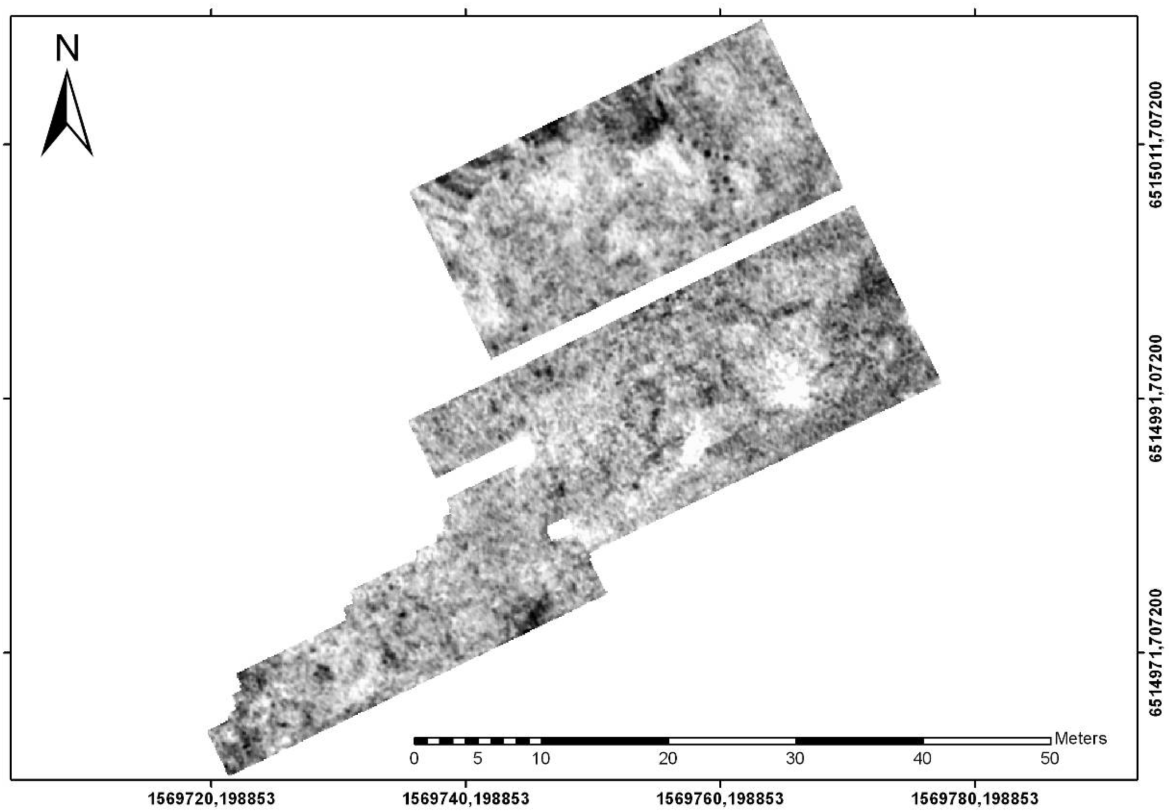

Figure 6.4.9: Depth-slice (80-90cm) survey site *Åkroken (lower part)*.

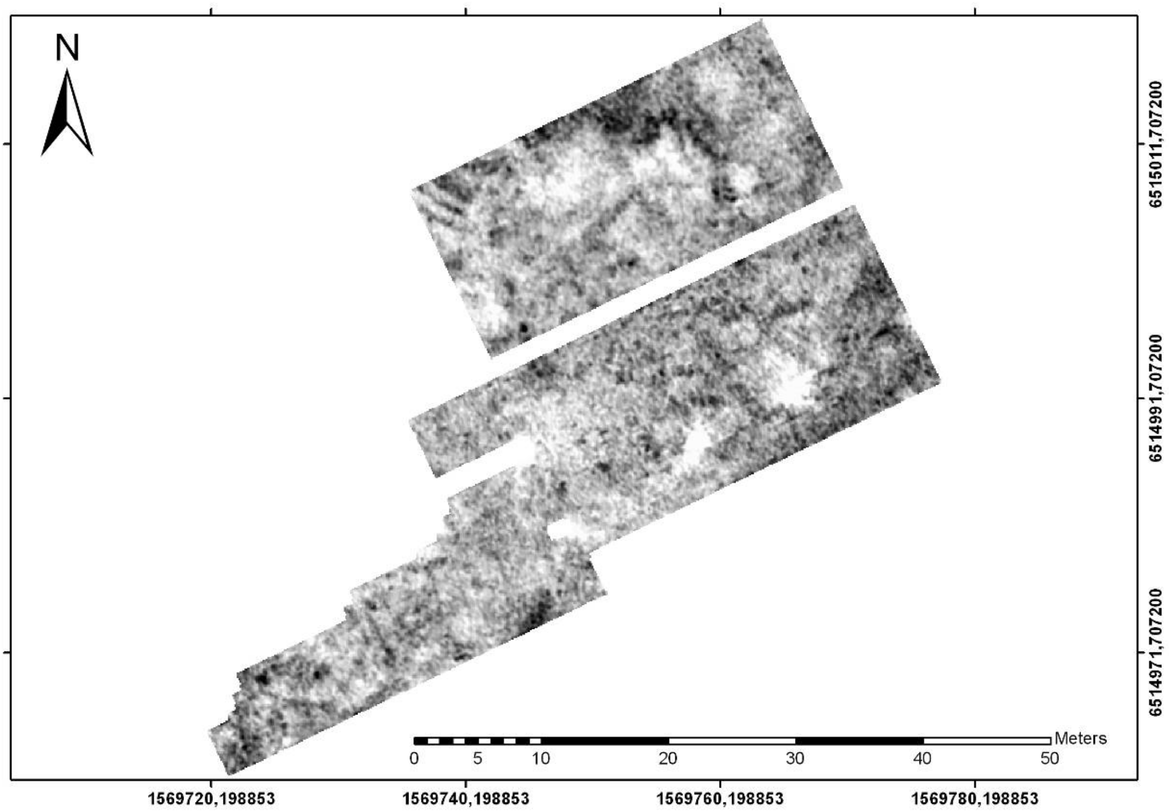

Figure 6.4.10: Depth-slice (90-100cm) survey site *Åkroken (lower part)*.

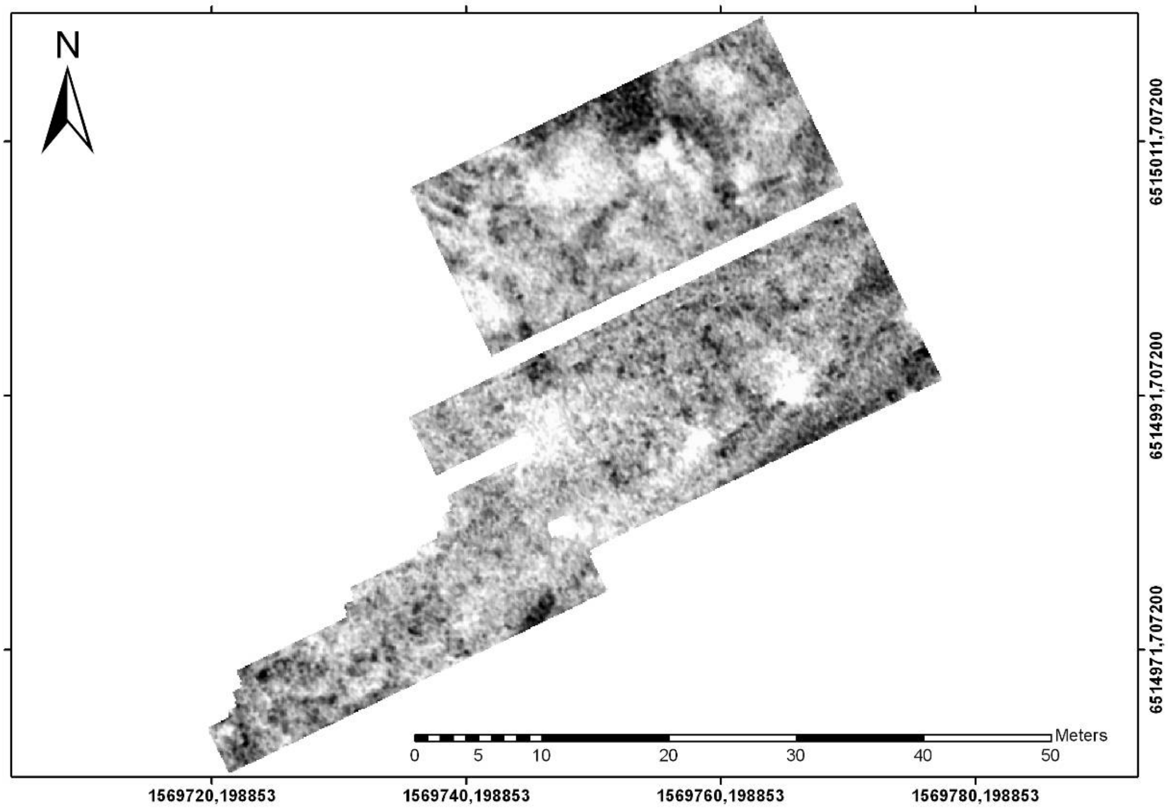

Figure 6.4.11: Depth-slice (100-110cm) survey site *Åkroken (lower part).*

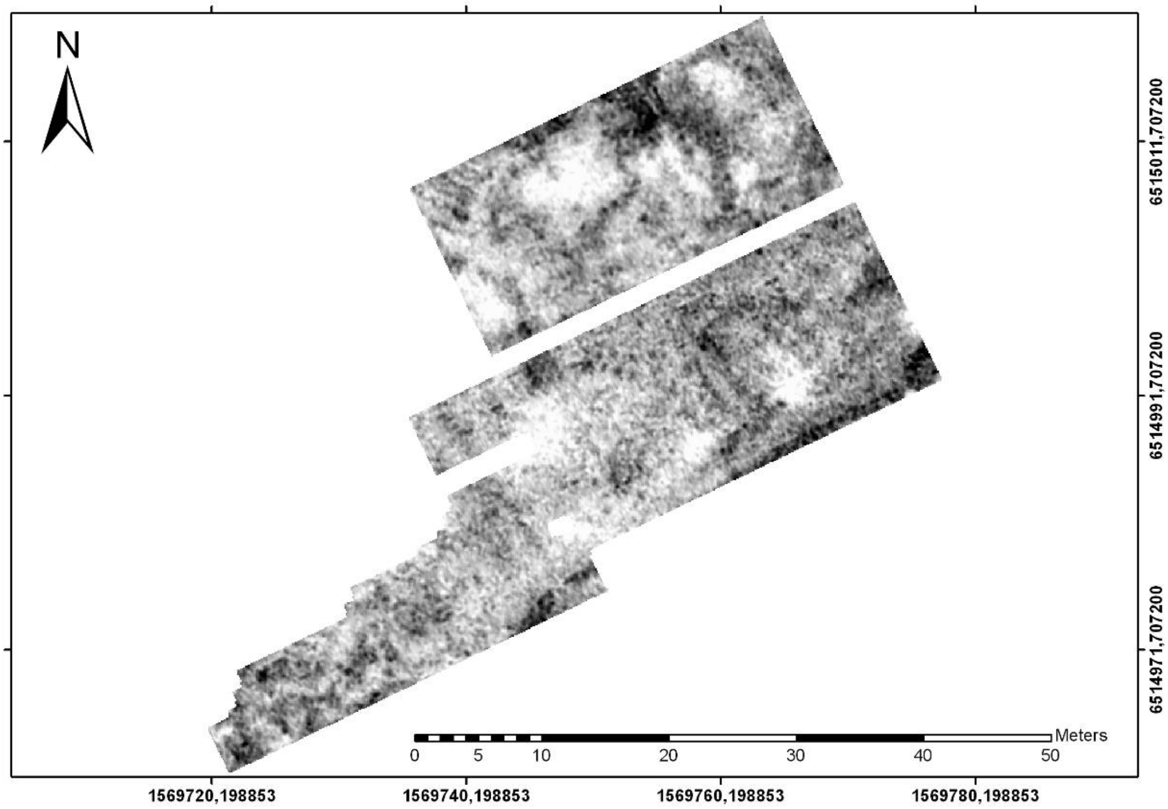

Figure 6.4.12: Depth-slice (110-120cm) survey site *Åkroken (lower part).*

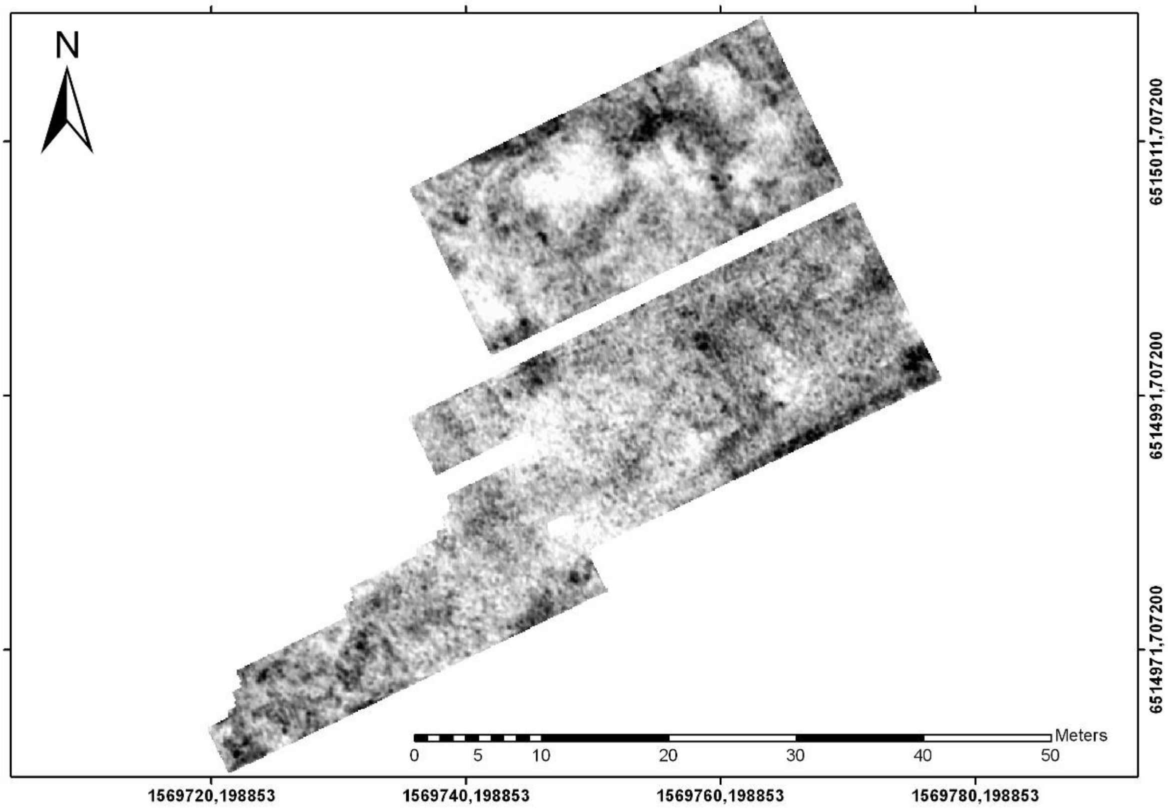

Figure 6.4.13: Depth-slice (120-130cm) survey site *Åkroken (lower part).*

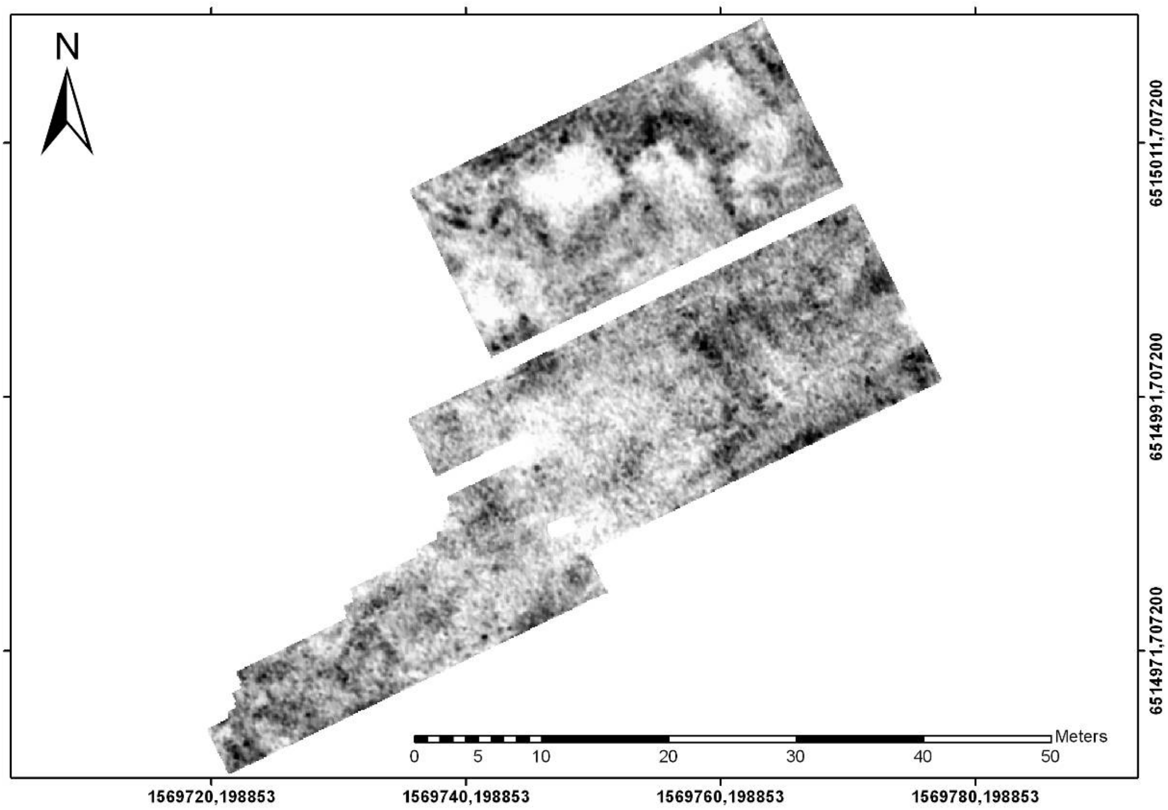

Figure 6.4.14: Depth-slice (130-140cm) survey site *Åkroken (lower part).*

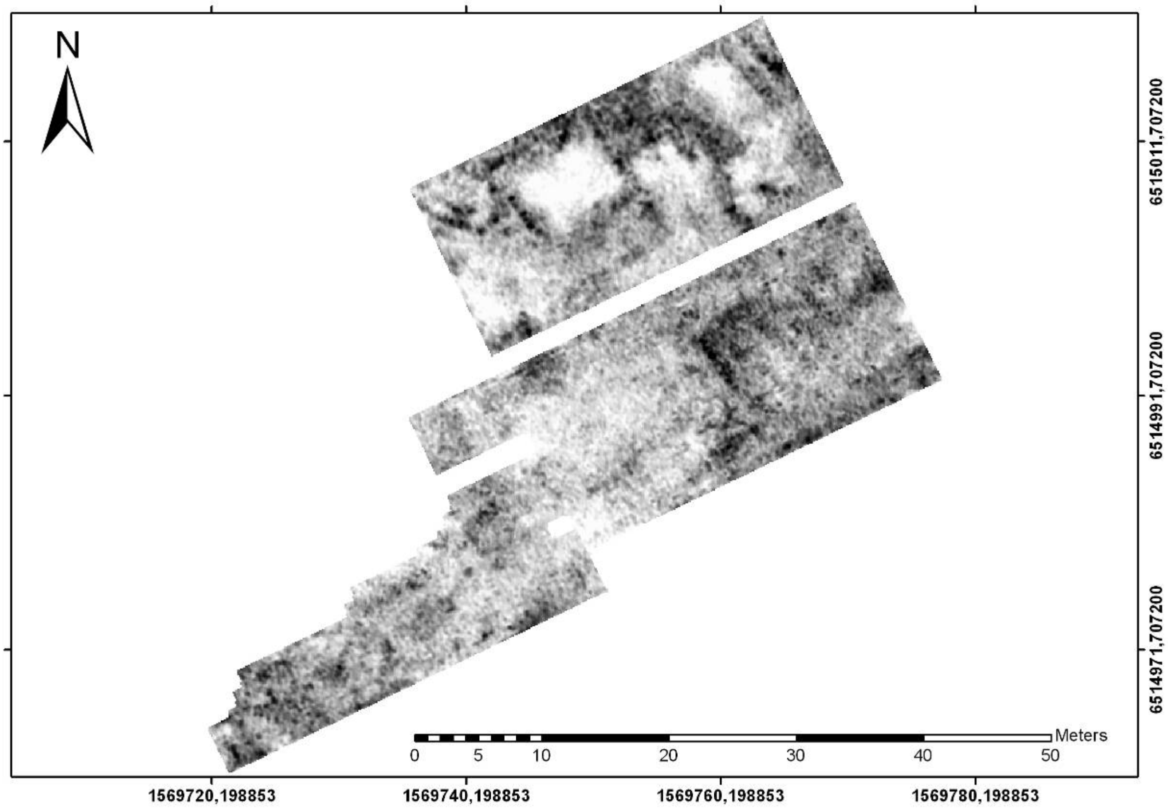

Figure 6.4.15: Depth-slice (140-150cm) survey site *Åkroken (lower part).*

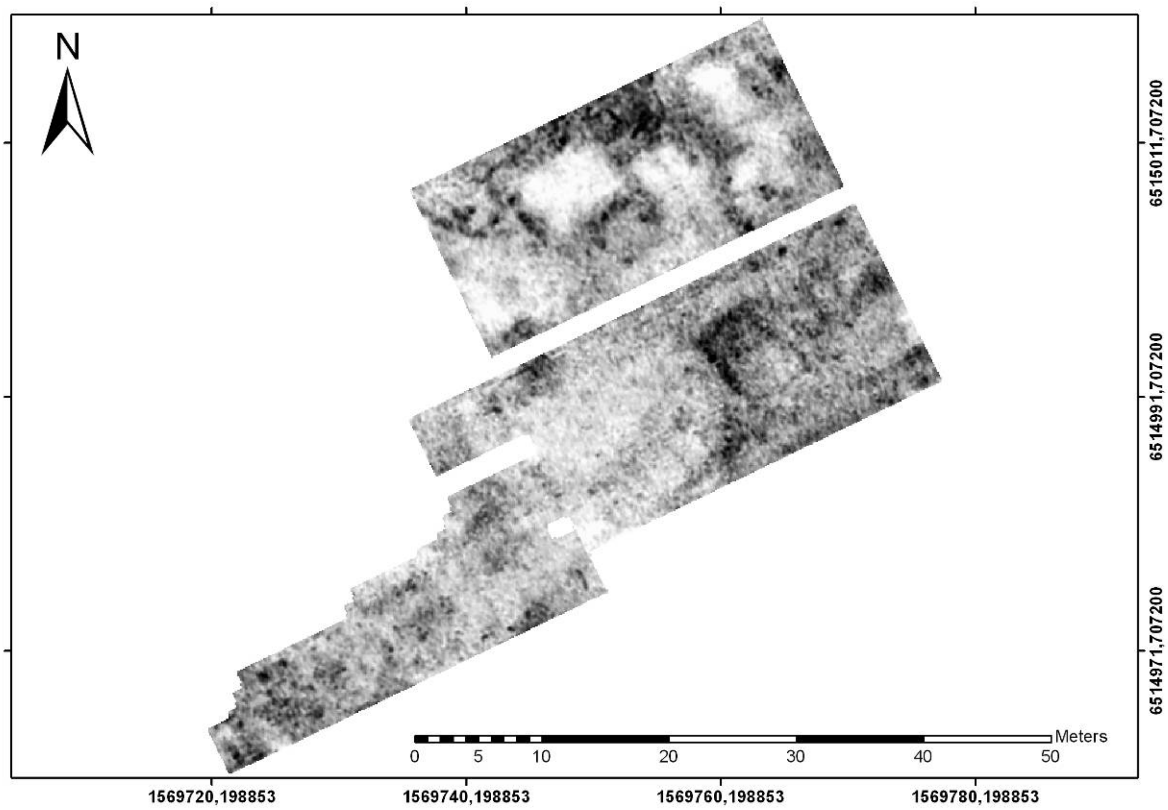

Figure 6.4.16: Depth-slice (150-160cm) survey site *Åkroken (lower part).*

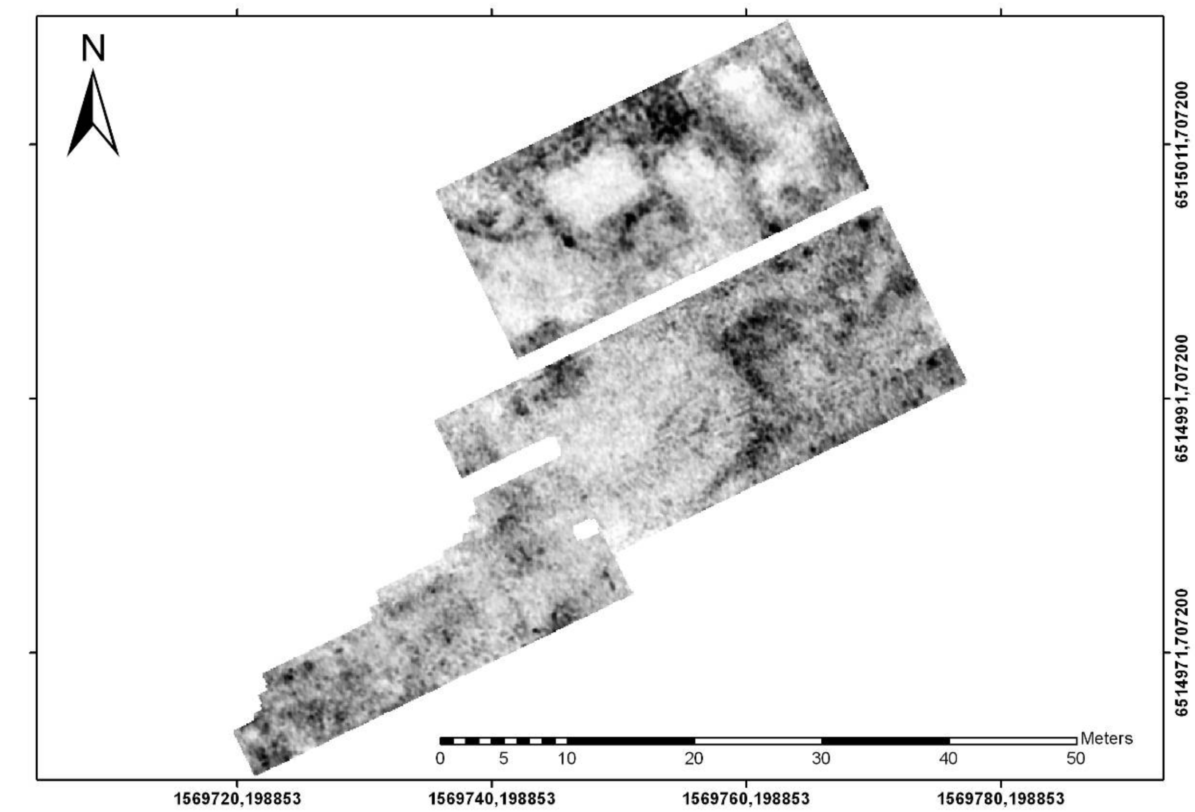

Figure 6.4.17: Depth-slice (160-170cm) survey site *Åkroken (lower part).*

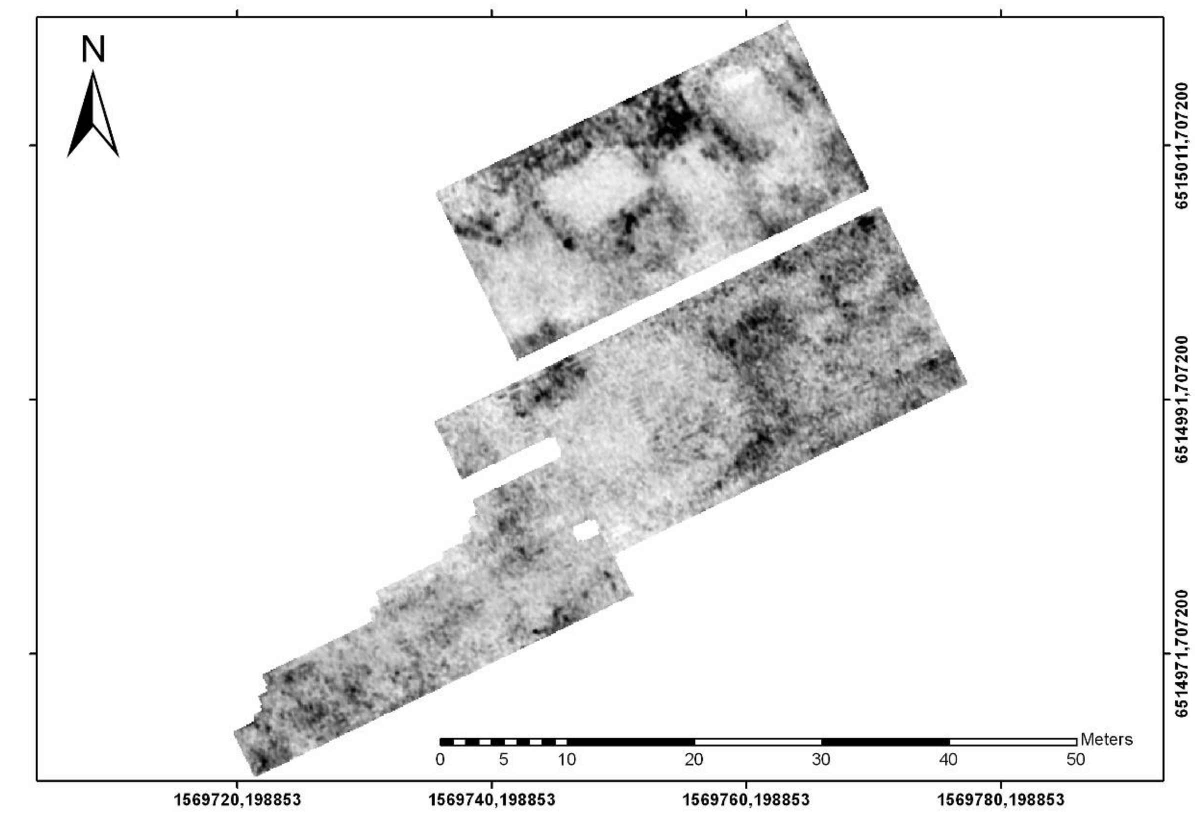

Figure 6.4.18: Depth-slice (170-180cm) survey site *Åkroken (lower part).*

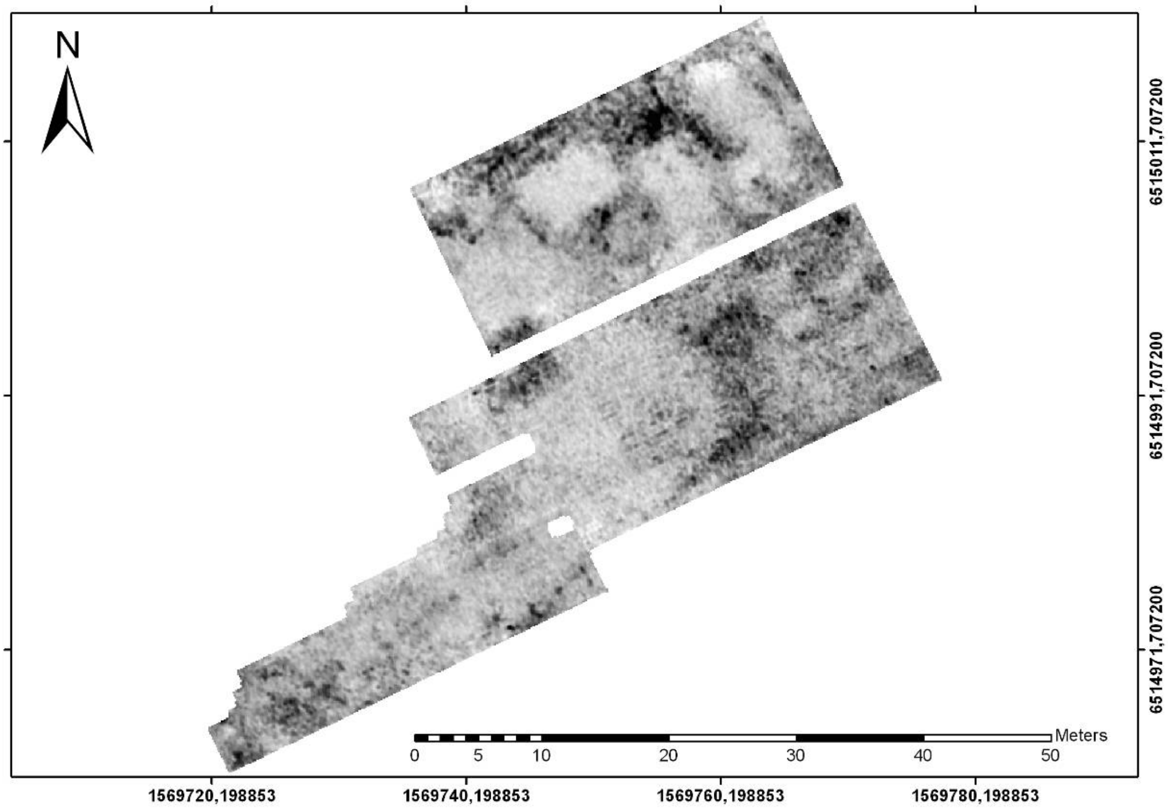

Figure 6.4.19: Depth-slice (180-190cm) survey site *Åkroken (lower part).*

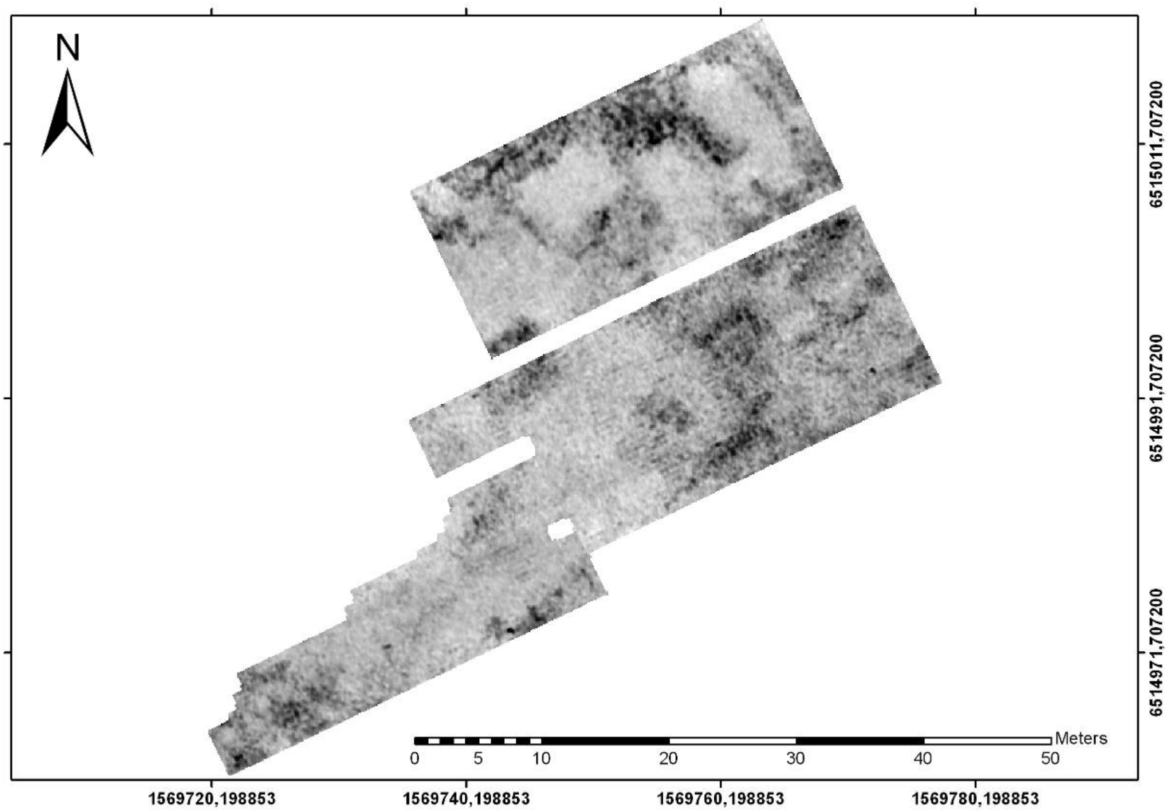

Figure 6.4.20: Depth-slice (190-200cm) survey site *Åkroken (lower part).*

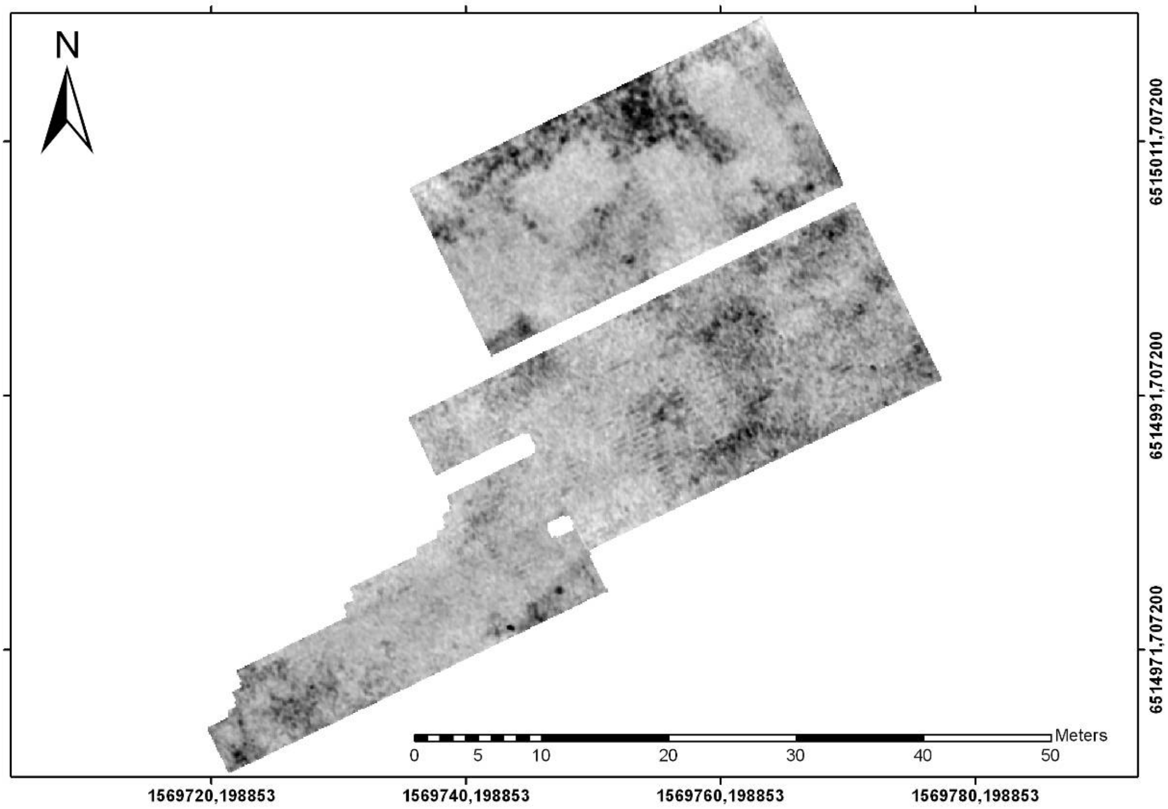

Figure 6.4.21: Depth-slice (200-210cm) survey site *Åkroken (lower part).*

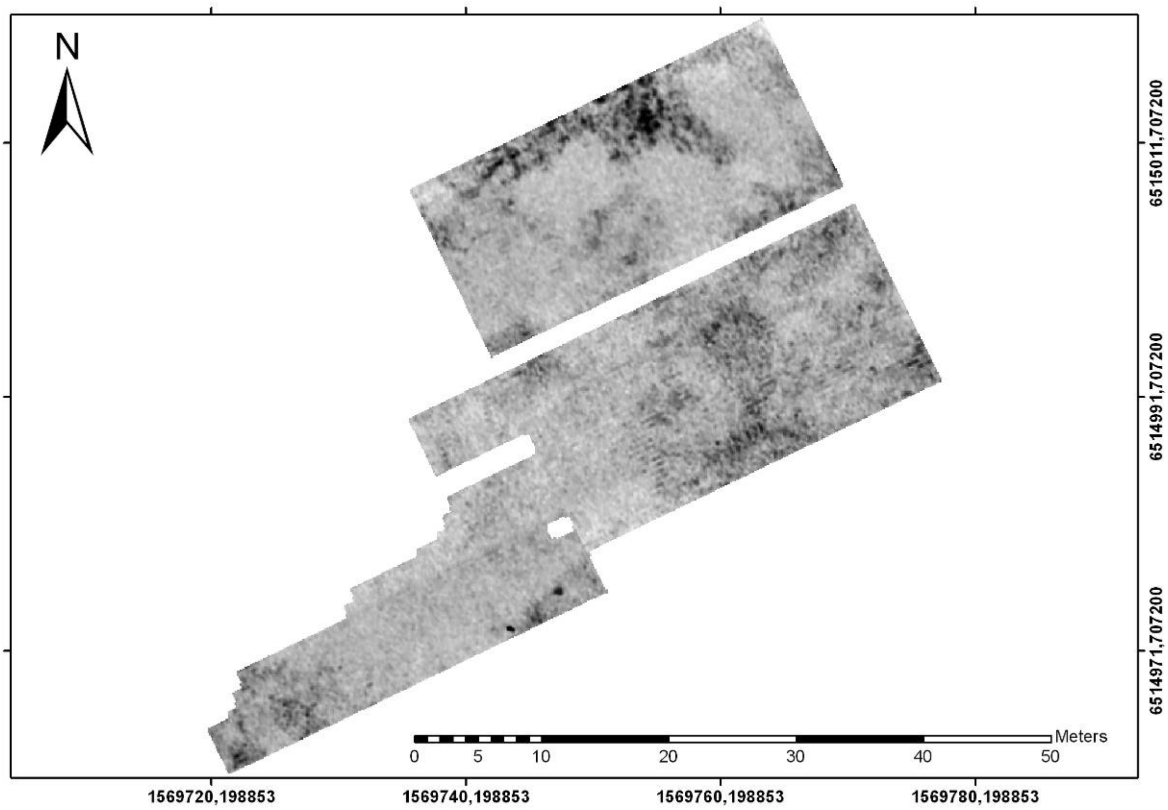

Figure 6.4.22: Depth-slice (210-220cm) survey site *Åkroken (lower part).*

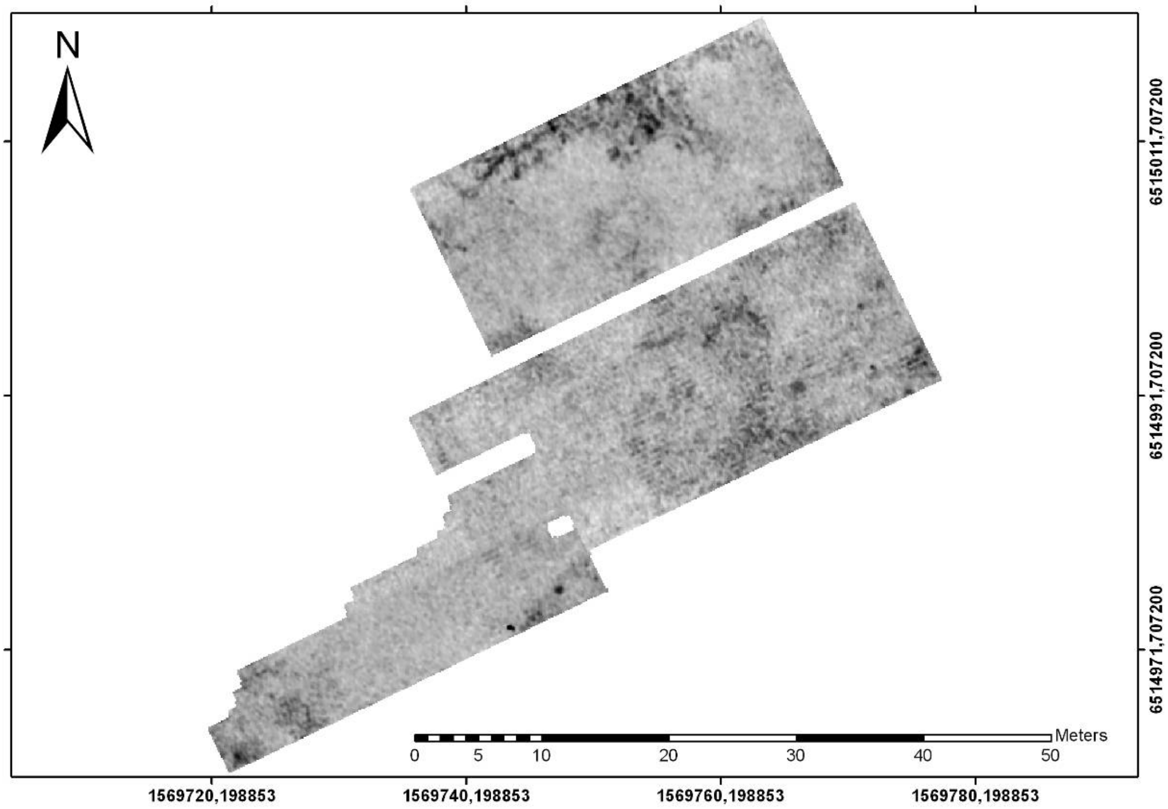

Figure 6.4.23: Depth-slice (220-230cm) survey site *Åkroken (lower part).*

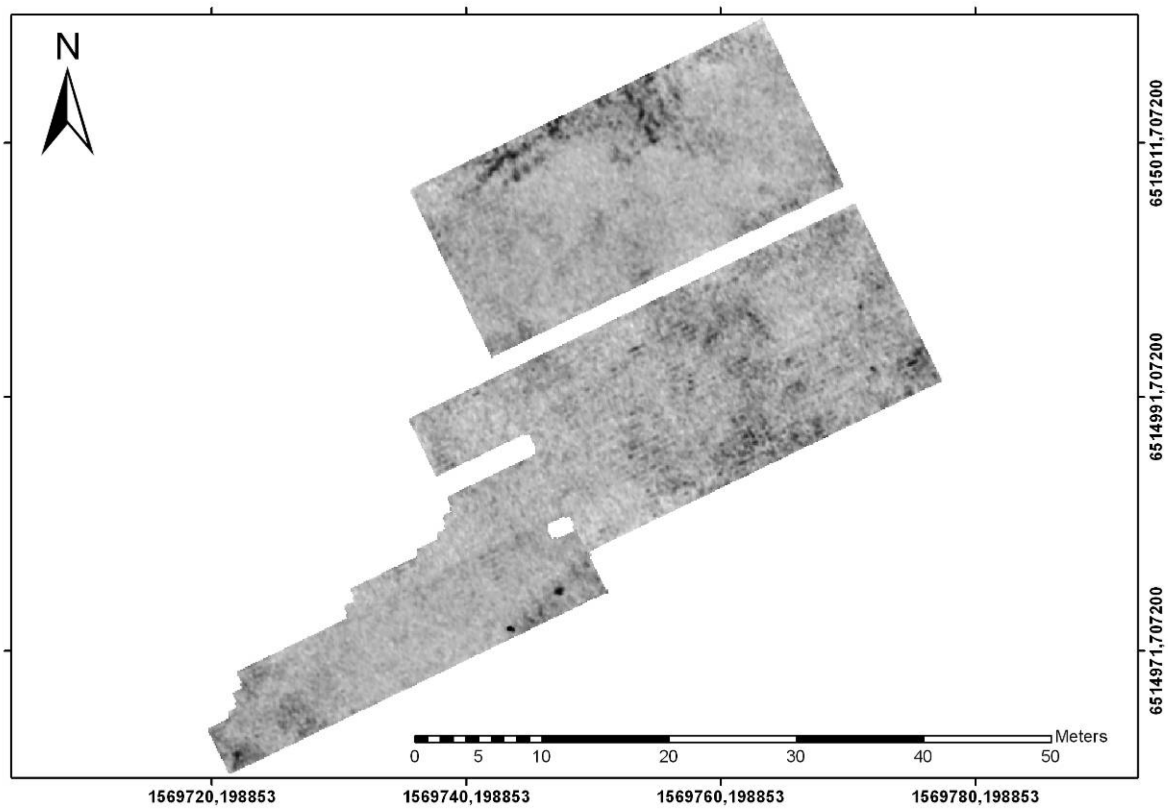

Figure 6.4.24: Depth-slice (230-240cm) survey site *Åkroken (lower part).*

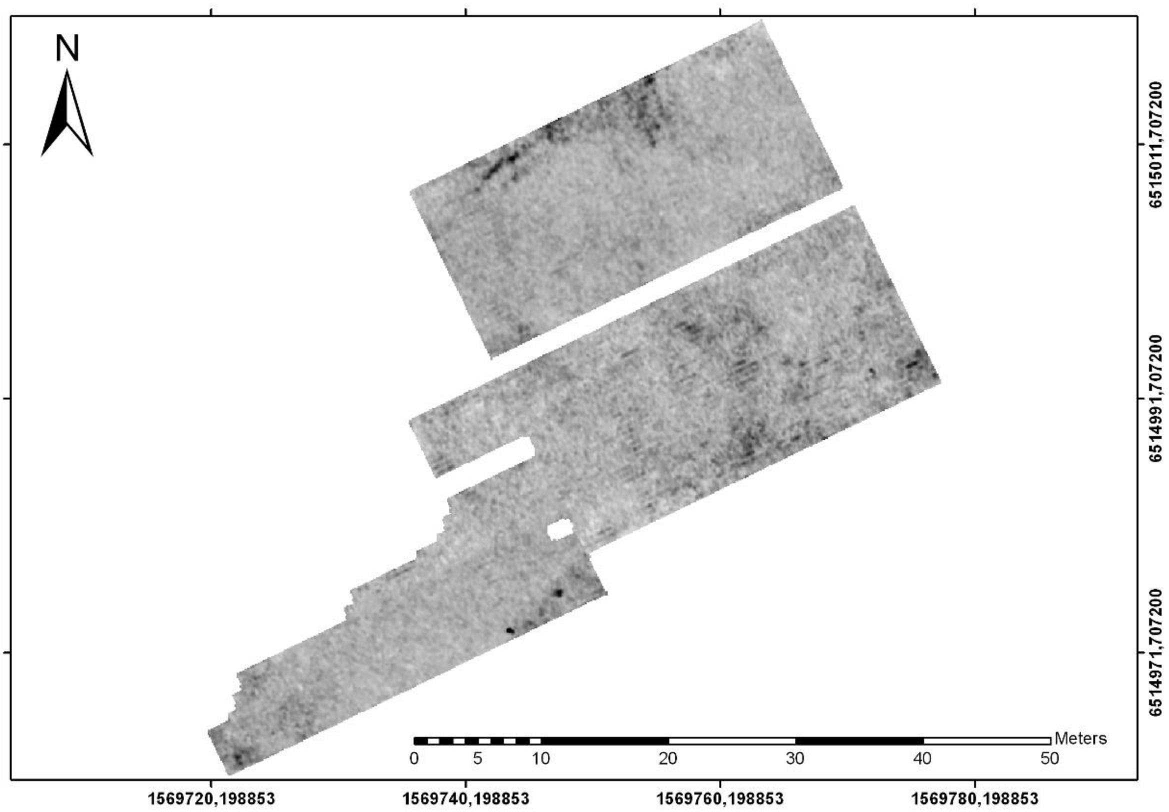

Figure 6.4.25: Depth-slice (240-250cm) survey site *Åkroken (lower part).*

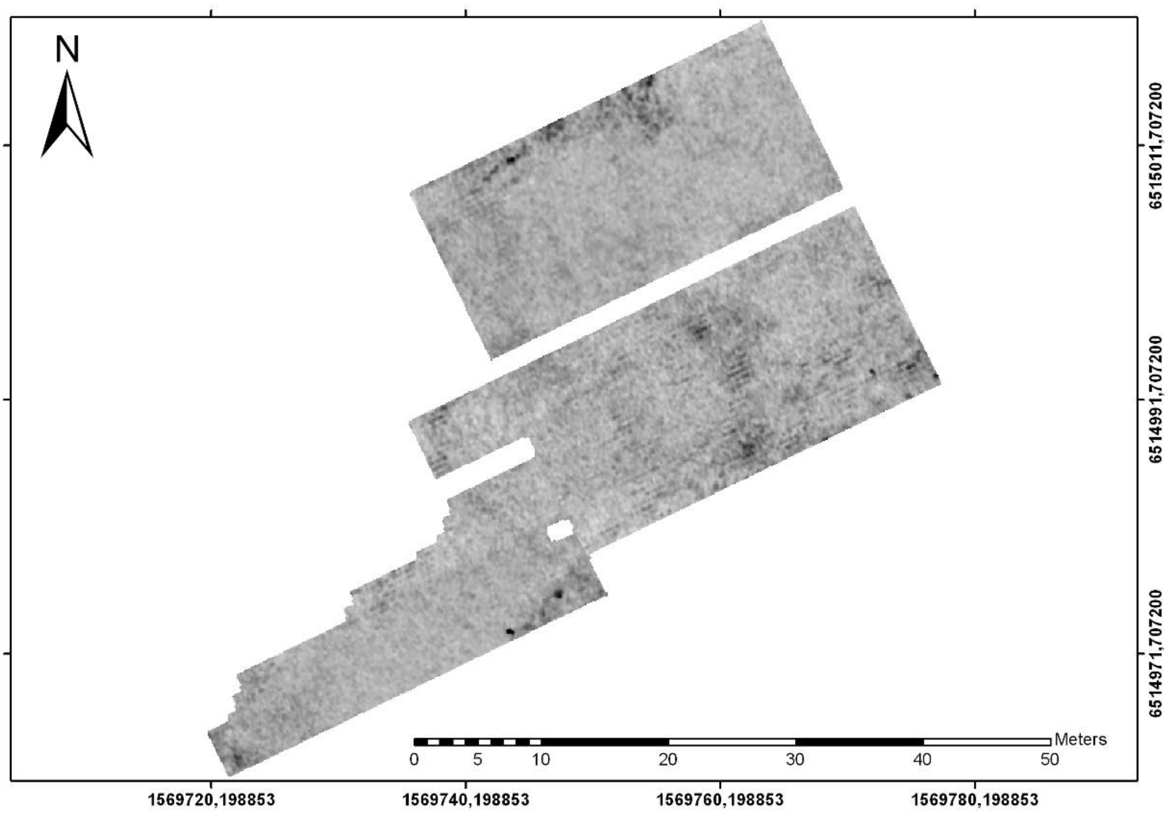

Figure 6.4.26: Depth-slice (250-260cm) survey site *Åkroken (lower part).*

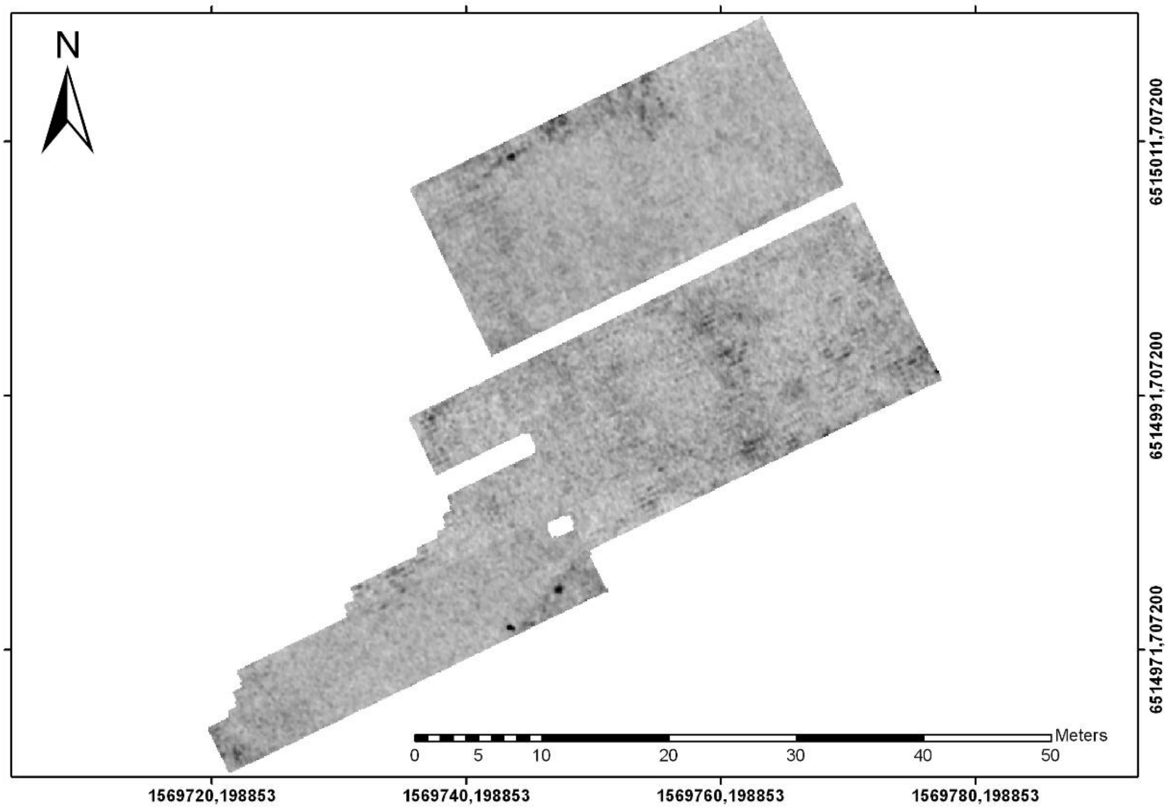

Figure 6.4.27: Depth-slice (260-270cm) survey site *Åkroken (lower part).*

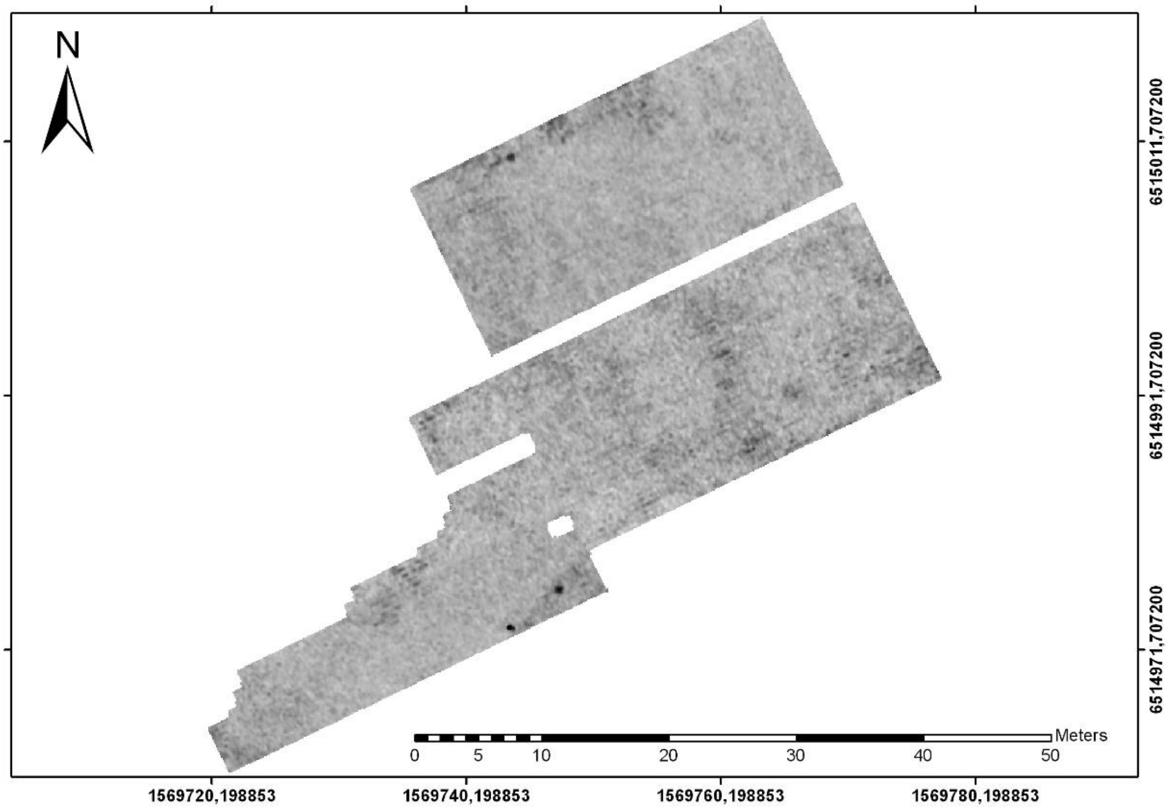

Figure 6.4.28: Depth-slice (270-280cm) survey site *Åkroken (lower part).*

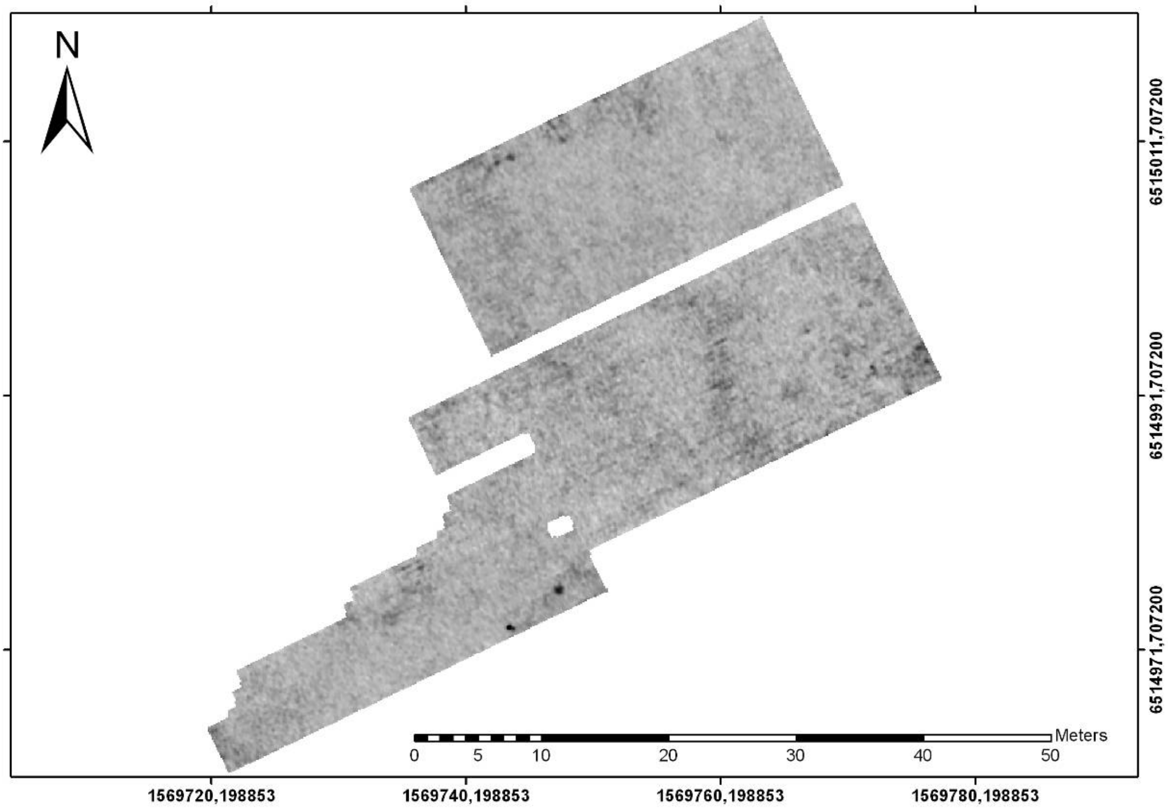

Figure 6.4.29: Depth-slice (280-290cm) survey site *Åkroken (lower part)*.

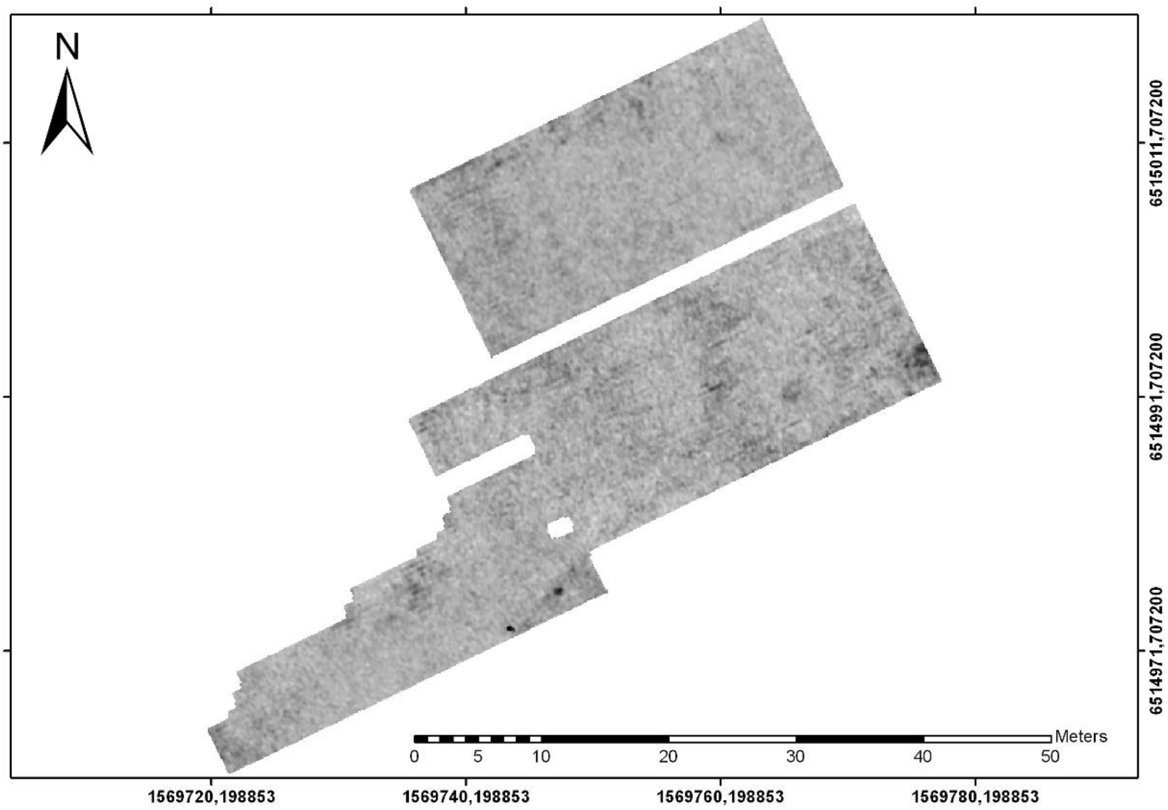

Figure 6.4.30: Depth-slice (290-300cm) survey site *Åkroken (lower part)*.