Krzysztof Kiersnowski and Arne Anderson Stamnes

Geophysical investigations of the copper smelting site of Feragen Smeltehytte, Røros Municipality

NTNU Vitenskapsmuseet arkeologisk rapport 2023-8

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GPR system in the GPR 1 Area. Photo: Krzysztof Kiersnowski, the NTNU University Musem

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Sammendrag

K. Kiersnowski and A. A.Stamnes 2023: NTNU Vitenskapsmuseet arkeologisk rapport 2023:8. Geophysical investigations of the copper smelting site of Feragen Smeltehytte, Røros Municipality

I November 2020 foretok NTNU Vitenskapsmuseet en geofysisk undersøkelse av Feragen Smeltehytte på vegne av Museene i Sør-Trøndelag i samarbeid med Røros kommune. Dette er et kobbersmelteverk plassert på et relativt flatt område langs vannfaret Elva. Målet med undersøkelsen var å påvise eventuelle kontruksjonsspor og aktivitetsområder relatert til den metallurgiske aktiviteten ved hjelp av en rekke ulike geofysiske teknikker, inkludert; magnetisk susceptibilitet (MS), magnetometer og georadar.

Resultatene fra susceptibilitetsundersøkelsene påviste flere områder med markante og høye målinger, hvor måleverdiene var tilsvarende høye som på den bevarte slagghaugen. Disse undersøkele viste klart avgrensningen av smelteaktiviteten på den sørlige siden av elva. Magnetometer- og georadarundersøkelsene påviste flere hesteskoformede avvik, som viste høye magnetiske målinger og sterk magnetisk polarisering, og ble tolket som smelteinstallasjoner – altså mulige ovner. Disse ble påvist innenfor en 30 meters radious nordvest for slagghaugen, og hadde en klar sammenheng med topografiske formasjoner som forsekninger og konsentrasjoner av steiner synlig på overflaten. Undersøkelsene påviste også områder som kan ha blitt brukt til kaldrøstin i form av magnetiske band med relativt homogene, men høye, verdier. Disse båndene var påvist enda lenger mot nordvest.

Alt i alt viste undersøkelsene omfattende informasjon fra flere ulike geofysiske metoder, og gir verdifull innsikt i organiseringen av aktiviteten på smeltehytta, samt indikerer nedgravde strukturer og aktivitetsområder fra koppersmeltingen her ved Feragen Smeltehytte.

Stikkord: georadar – koppersmelting – magnetisk susceptibilitet – gradiometerundersøkelser – metallurgisk industri – 1600-tallet

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Summary

K. Kiersnowski and A. A.Stamnes 2023: NTNU Vitenskapsmuseet arkeologisk rapport 2023:8. Geophysical investigations of the copper smelting site of Feragen Smeltehytte, Røros Municipality

In November 2022, a geophysical survey was conducted to study the Feragen Smeltehytte copper smelting site located in Røros Municipality, Norway. The site is characterized by a large slag mound and a relatively flat area located along the Elva stream. The survey aimed to assess the presence of remnants related to the smelting hut activity using various geophysical survey methods including magnetic susceptibility (MS), magnetometer, and ground-penetrating radar surveys.

The MS results pinpointed several spots with values equal to those of the measurements from the slag mound and also showed clear limits of smelting activity at the southern bank of the river. Magnetometer and GPR surveys revealed several horseshoe-shaped features displaying high levels of magnetic polarization, which were interpreted as smelting installations. These were found within a 30-meter radius to the northwest of the slag mound and were clearly connected to topographic features such as wooden trough or concentrations of rocks. The survey also identified areas that could have been used for cold roasting in the form of magnetic swaths of homogeneous values. These were located further to the northwest.

Overall, the survey delivered comprehensive information from various geophysical methods and provides valuable insights into the buried cultural materials and remaining structures of the copper smelting site at Feragen Smeltehytte.

Keywords: ground penetrating radar – copper smelting – magnetic susceptibility – magnetic gradiometry – metallurgic process – 17th century

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Archival references

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Fylke	Trøndelag
Kommune	Røros
Gårdsnavn	Feragshage
Gårdsnummer	140/1
Lokalitet	Kobbersmeltingsanlegg
Kulturminnetype	Metallurgisk produksjon
Datering	16-1800-tallet

Content

List of figures

1. Background

The survey was undertaken on behalf of Rørosmuseene, a part of the consolidated museums of Sør Trøndelag (MIST). The project is done in collaboration with Røros Municipality. The investigations were initiated to get a better overview of the size, extent and possible layout of the copper smelting hut of Feragen (Feragen smeltehytte) and its associated area for metallurgic activity.

1.1 Area Description

Feragen Smeltehytte is located close to the stream "Elva", connecting the small lake of Røragen with the much larger Feragen lake. The site is located about a kilometre northwest of the northern end of the Feragen lake and about 50 meters southeast of the farm Jonasgården. The current preserved part of the site is the remains of a large slag mound on the northern side of Elva and some possible stone-built walls seemingly present on the southern side of the river.
The area dedicated to comprehensive magnetometer and GPR surveys is located between the stream, more or less at a similar elevation, and a slope stretching in the same direction as the stream. Over the slope are the farm buildings. Down from the road crossing the river, there is a tractor road going down to the site area and further by the foot of the slope. The area is wooded with medium-sized trees, and the terrain is rocky, uneven, and slightly sloping towards the stream.

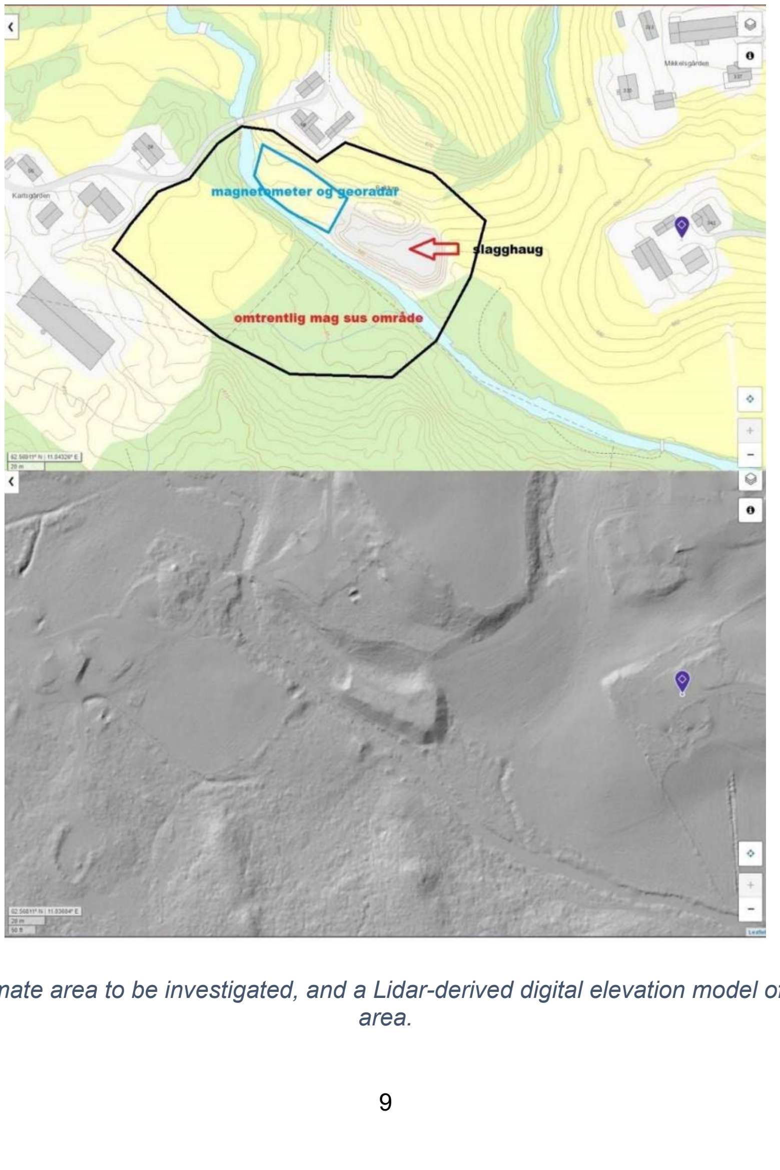


Figure 1: Approximate area to be investigated, and a Lidar-derived digital elevation model of the investigation area.

Figure 2: View at the investigated area from the top of the tractor road.

1.2 Cultural-Historical Background

The Feragen Smeltehytte was used from 1661 to 1692, making it one of the older copper smelting huts associated with the UNESCO world heritage area of Røros and its copper manufacture. Copper ore was discovered in Røros in 1644, and the earliest mining started in 1646. According to written sources from 1678, there have been as many as four smelting huts at Feragenhytta. In 1678, the smelting hut was burnt in a Swedish attack on Røros.
The smelting huts were the centre of a larger complex, usually consisting of a range of buildings with specialized functions. These could be workshops, storage facilities, buildings for drying wood ("badstue"), administration buildings, smithy, and areas used for roasting the ore in different stages and a weight. Most of the roasting was done close by the mines at the earliest times of ore mining. From 1730, most of the roasting was done by the smelting huts. It is, therefore, uncertain if it is expected to find traces of the roasting at Feragen smeltehytte, although it is generally assumed that this had been done here (Austnes, n.d.).

2. Survey framework

2.1 Time and collaborators

Planning and execution the fieldwork and data collection was done by Krzysztof Kiersnowski, who also authored the report. The fieldwork was greatly supported by the local partners from the Røros Museum - Jenny Fjellheim and Erik Roll. The work was supervised by Arne Anderson Stamnes from the Terrestrial, Marine and Aerial Remote Sensing for Archaeology Research Group at the Department of Archaeology and Cultural History, The Norwegian University of Science and Technology (NTNU) in Trondheim, Norway.
The survey at Feragen Smeltehytte was carried out on the days 22-25 of November 2022 in temperatures of -3 to -8 Celsius degrees with a bit of snow cover laying on the surface and with episodes of freezing wind.

2.2 Aims and objectives

The purpose of the survey was to delineate the high-temperature metal working at Feragen smeltehytte, and to assess if there are remnants of the smelting huts in the area just west of the preserved slag heap.

2.3 Dissemination

Social media platforms have become an increasingly popular way to promote and share information about various projects. In this context, it is noteworthy that an Instagram post by @rorosmuseet was made about the survey conducted at Feragen Smeltehytte.
The creation of the Instagram post has several advantages that can contribute to the survey's success, helping to build support and interest in the project. This can also help attract additional resources and support for the project, as well as serve as a historical record of the survey.

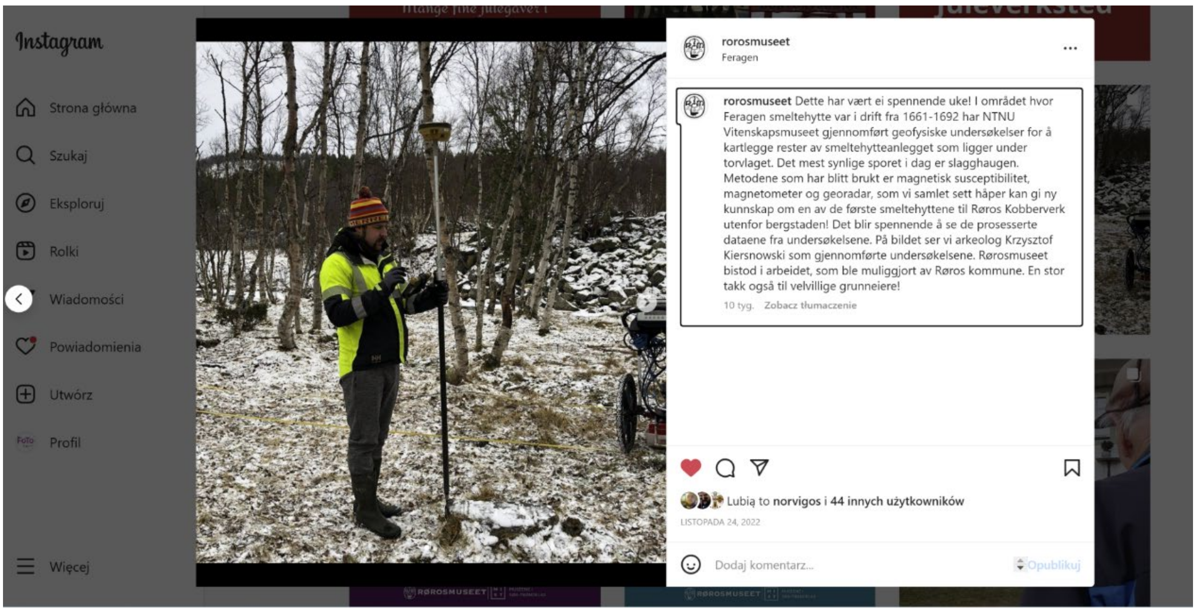


Figure 3: Screenshot of the Instagram post about the survey.

2.4 Method

2.4.1 Data Collection – methodological approach

The investigations were undertaken using several geophysical survey methods to gain a comprehensive understanding of the site's subsurface. This involved the use of magnetic susceptibility (MS) and topographic survey for the delineation of the metal working area, as well as combining a magnetometer survey with a single channel ground penetrating radar (GPR) survey in an effort to get a more detailed impression of any construction details that might have survived.

2.4.2 Magnetic susceptibility (MS)

The Feragen Smeltehytte archaeological site was investigated using a magnetic susceptibility survey to determine the presence and limits of buried cultural materials, especially remains of copper smelting activity. Magnetic susceptibility is a measure of the responsiveness of a material to a magnetic field. It is commonly used in archaeological surveys to detect and highlight areas of increased human impac, and has previously proven valuable for delimiting metallurgic activity areas in Norway and abroad (Powell, McDonnell, Batt, & Vernon, 2002; Schmidt et al., 2016; Stamnes & Rødsrud, 2020; Stamnes, Stenvik, & Gaffney, 2019; Vernon, 2004)
The survey was carried out using a hand-held magnetic susceptibility meter Bartington MS2 with a field coil, which measures the magnetic properties of the soil. The survey covered an area of approximately 5725 square meters, with measurements taken at regular intervals along grid lines - 1610 sq. m at the NE bank of the river, 1280 sq. m at the SE bank of the river, and 2835 sq. m at the SW bank on the river (Fig. 4).
Measurements interval was 2,5 to max 5 meters distance. Some chosen areas were investigated with even higher resolution with few measurements taken close to each other within a 1.5 by 1.5 meter chosen areas. Such resolution is good enough to determine limits of the human activity on the site and to roughly estimate the location of the areas with high potential of activity related to copper smelting.

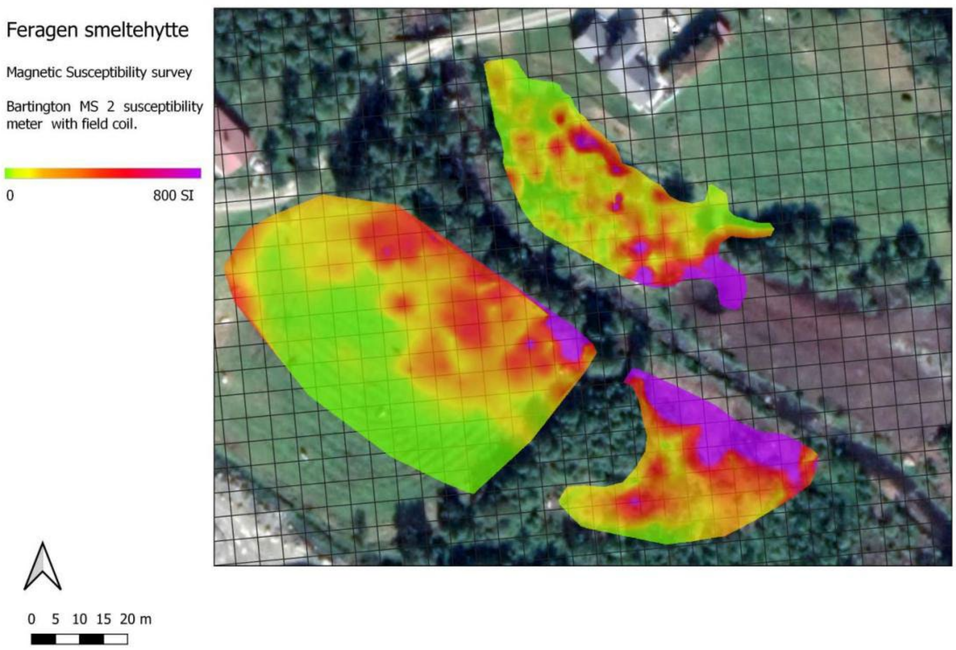


Figure 4: The results of the magnetic susceptibility survey.

2.4.3 Magnetometer survey

Magnetometer surveys are an important tool for archaeological investigation, providing information about the presence and distribution of buried structures, features, and artifacts, based on their magnetic properties. The Bartington Grad-601 Fluxgate Gradiometer, which was used for this survey, is a high-precision instrument that measures the magnetic field in the soil, providing detailed information about what lies beneath the surface (Aspinall, Gaffney, & Schmidt, 2009).
A 5 by 5 meter grid pattern was established over the area of interest. The measurements were taken at regular intervals of 0.5 m along parallel lines with in-line measurements spacing of 0.125 m within 10 by 10 m grids, and walking direction to the West. The instrument was operated in two gradient range modes, 100 nT and 1000 nT providing different range of detail.
Due to the vegetation on the site - many small trees, rocks and uneven terrain, the instrument was used in the configuration with one probe. The area covered with the 100 nT gradient range was 870 sq. m, and with the 1000 nT gradient range was 600 sq. m, overlapping each other (Fig. 5).
The acquired data was first assembled and interpolated in Terra Surveyor software. Obtained results were transferred into Q-gis software where contour-line maps were created. After the *EAC Guidelines for the Use of Geophysics in Archaeology...* the contour maps "can also be deployed advantageously to highlight very high magnitude thermoremanent anomalies in magnetometer surveys" which in Feragen Smeltehytte case found a successful application.

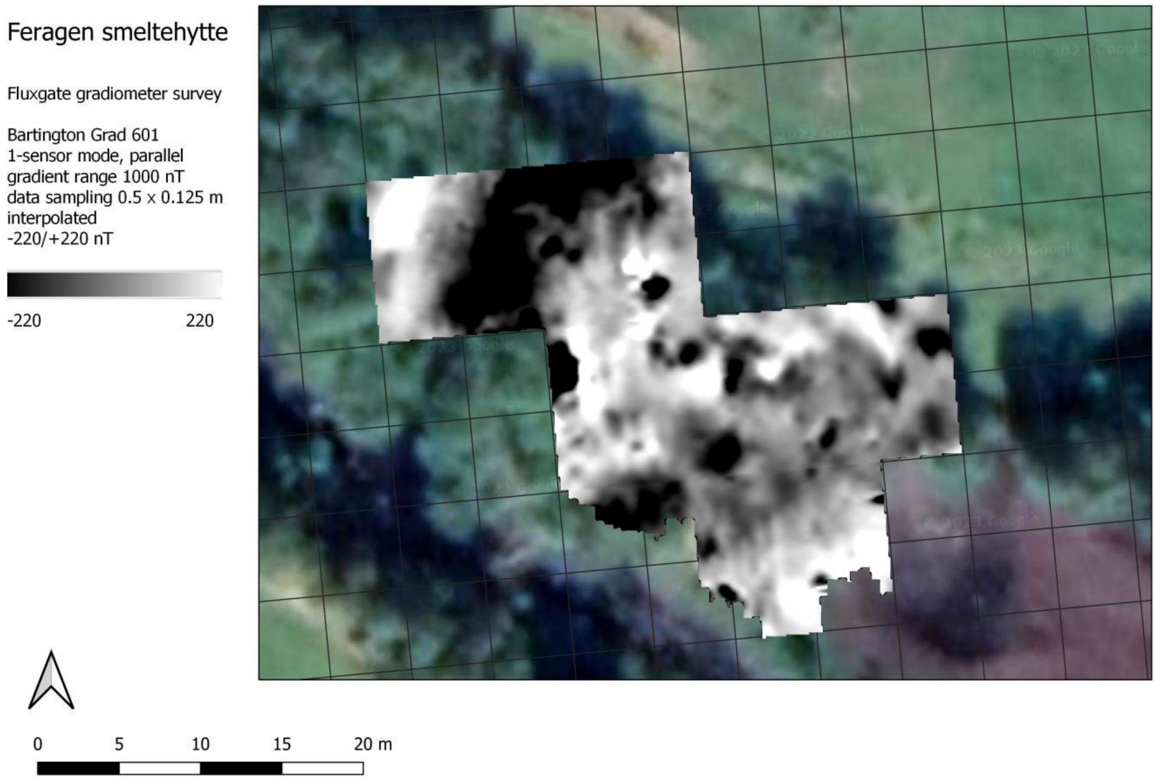


Figure 5: The results of the magnetic gradiometer survey in 1000 nT gradient range.

2.4.4 GPR Survey

Ground-penetrating radar (GPR) is a geophysical method that uses electromagnetic waves to penetrate the subsurface and image the structure of the ground, based on received waves' reflections. The GSSI SIR 3000 system paired with a 400 MHz antenna is a common setup for GPR surveys. The antenna frequency determines the depth of penetration and resolution of the image while the system processes and records the data. Such a ground-penetrating radar survey was conducted at Feragen Smeltehytte (Lawrence B. Conyers, 2012; Larry B. Conyers, 2013). This survey aimed to gather subsurface information and identify any potential archaeological features.

The survey was carried out by walking the antenna over the survey area in a systematic grid pattern in a parallel mode with 0.25 m spacing between the profiles. The GPR system was set to record data continuously as the antenna was moved, and the data was saved for later analysis. The GPR system was set to a time window of 50 ns which can penetrate the ground to the depth of approximately 2 meters.

The survey was carried out over two relatively flat and open areas among the trees and rocks. The area called GPR 1 covers approximately 54 sq. m and the area called GPR 2 covers approximately 64 sq. m, which gives 118 sq. meters of GPR area surveyed (Fig. 6).

The collected data has been processed in GPR-Slice software, utilizing various techniques to enhance the results. The processing steps included the application of a bandpass filter (approximately 100-700 MHz), removal of background noise, migration, and the use of a Hilbert transform. The images presented showcase different depth slices and different processing stages.

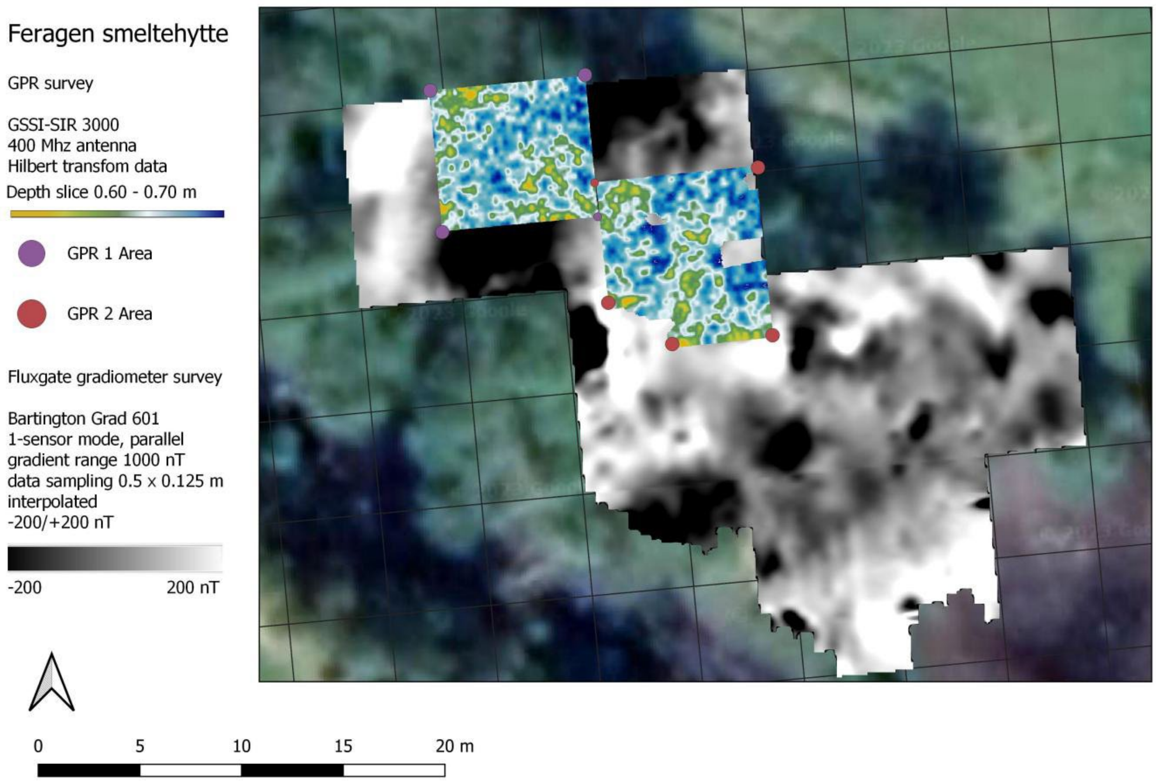


Figure 6: The results of the GPR survey visible at the 0.60 - 0.70 m depth slice.

2.4.5 Geographical Information System (GIS) and documentation

Magnar Mojaren Gran provided the GIS support and GNSS equipment from NTNU Vitenskapsmuseet. The data collection for the survey was carried out utilizing the Topcon HiperV GNSS receiver and the Topcon FC6000 data logger. Real-time correction was performed through the CPOS positioning service reference network to ensure the accuracy and precision of the collected data.
All the results of the surveys were assembled and processed into figures in Q-gis 3.22 software.

3. Observations, interpretations and discussion

The general orientation of features on the site is northwest-southeast and northeast-southwest, which is parallel and perpendicular to the Elva stream - the necessary for the smelting process source of water. The investigation of the site provides valuable insight into its boundaries and spatial organization, as well as to identify specific locations of possible installations. Each survey method employed reveals a unique spectrum of information. The observation and interpretation task aims to compute and consolidate all of these spectra into a coherent view.

3.1 Magnetic Susceptibility

The magnetic susceptibility values at the Feragen Smeltehytte archaeological site reveal a good frame for further interpretation. First of all, the MS values from the slag mound are significantly higher, responding to a high concentration of slag. Values from 800 SI to over 1000 SI were recorded on the mound, indicating the range that could be recorded on similar archaeological features and activity areas.
On the southern bank of the river, the MS values clearly show the limits of human activity on the site, which corresponds with the beginning of a swampy area in the southwestern end of the investigated area (Fig. 7). Additionally, the MS survey reveals high values, again up to 1000 SI and higher, in the southeastern part of the southern bank of the river, indicating a concentration of activity in that area. Surface observations of slag pieces further support this conclusion. It is worth noticing that the exact limits of the site the most to the southeast were not revealed.
Several spots with magnetic susceptibility values reaching 800 SI were recorded outside the slag mound on both sides of Elva. Such high readings point out the presence of magnetic materials, such as slag. Tracing these locations may provide insight into potential areas for furnaces, hearths, or roasting places (Fig. 7). These observations could tentatively be interpreted as a confirmation of the roasting of slags also occurred south of the river.
It is important to note that these high magnetic susceptibility readings could also be due to any other of multiple possible (read. random) reasons for slag presence, which is not unexpected in a copper smelting area.
One area involving high MS measurement values is located on the southwestern bank of the river, on the field with the swampy part. The area of interest is located just by the stream slope and is cutting off from the area with slag in the southeastern part, by both lower MS values and a stone wall in the surface. That part of the site also has less vegetation on the river slope and slightly builds up toward the opposite bank. This could be an indication of a former existence of a bridge or other construction connecting both sides of the stream. The other end of that bridge would end just by the foot of the slag mound (Fig. 7).
It's possible that other regions with elevated MS values on the site could signal the locations of different activities related to copper smelting. However, the available information only offers

suggestions about the site's layout and boundaries. Conducting a magnetic gradiometer survey in the southwestern area could shed additional light on past activities on that river bank.

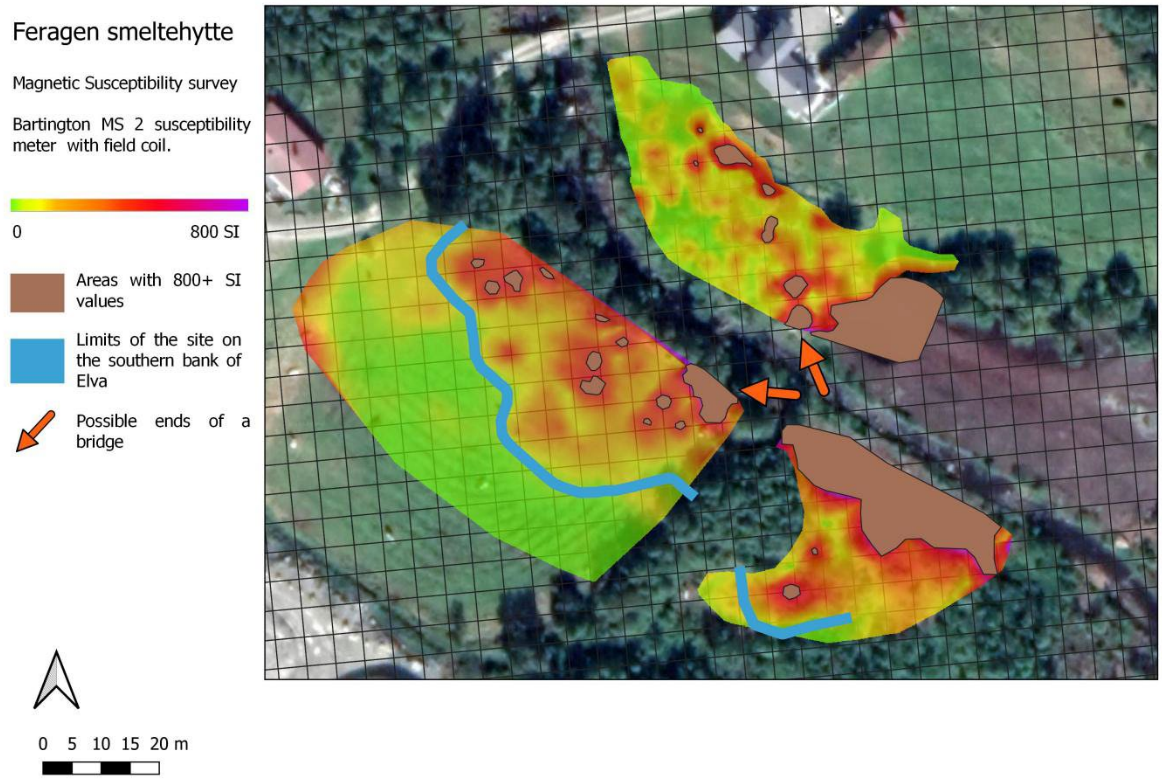


Figure 7: Interpretation of the magnetic susceptibility results.

3.2 Magnetometer survey

The magnetometer survey using a fluxgate gradiometer at Feragen Smeltehytte suggests that the majority of human activity, such as buildings or installations, can be located within a 30-meter radius to the northwest of the slag mound.
In the direction of the bridge, further to the northwest, the survey results show high uniform magnetic values and high gradient differences within three areas, which are roughly 5 by 10 meters in size. These areas are oriented in a northeast-southwest direction, and the middle area is characterized by high positive homogeneous magnetic values, while the two neighbouring areas are characterized by high negative homogeneous magnetic values, distributed quite evenly. Their representation on the magnetic map are high- and low- values swaths (Fig. 8, represented by black and white swaths).
The size and equal distribution of the magnetic values suggest that the area may have been used for cold roasting, as described by Alexander Austnes*, who states that roasting furnaces were approximately 2.5 meters high and 5 meters wide, with varying lengths. This interpretation, as one of the first steps in processing copper ore, could be supported by the location's proximity to the road, which was possibly present during the operation of the Smeltehytte.
It should be noted that this interpretation is based on the available information cited from the website *Verdensarven Røros bergstad og Circumferensen (*https://verdensarvenroros.no/den-gamle-smelteprosessen*). However, this interpretation also contradicts the authors' statement that such cold roasting places were not located by the smelting huts, but by the mines, until 1730,

while the operating time of Feragen Smeltehytte is stated for years 1661-1692. It is also possible that only the middle one of these areas - the white 'swath' (high positive magnetic values), represents a roasting place, while the two black 'swaths' on the sides (negative magnetic values) are influenced by the activity in the central part. These information can contribute to the further investigation of the site and discussion on smelting huts.

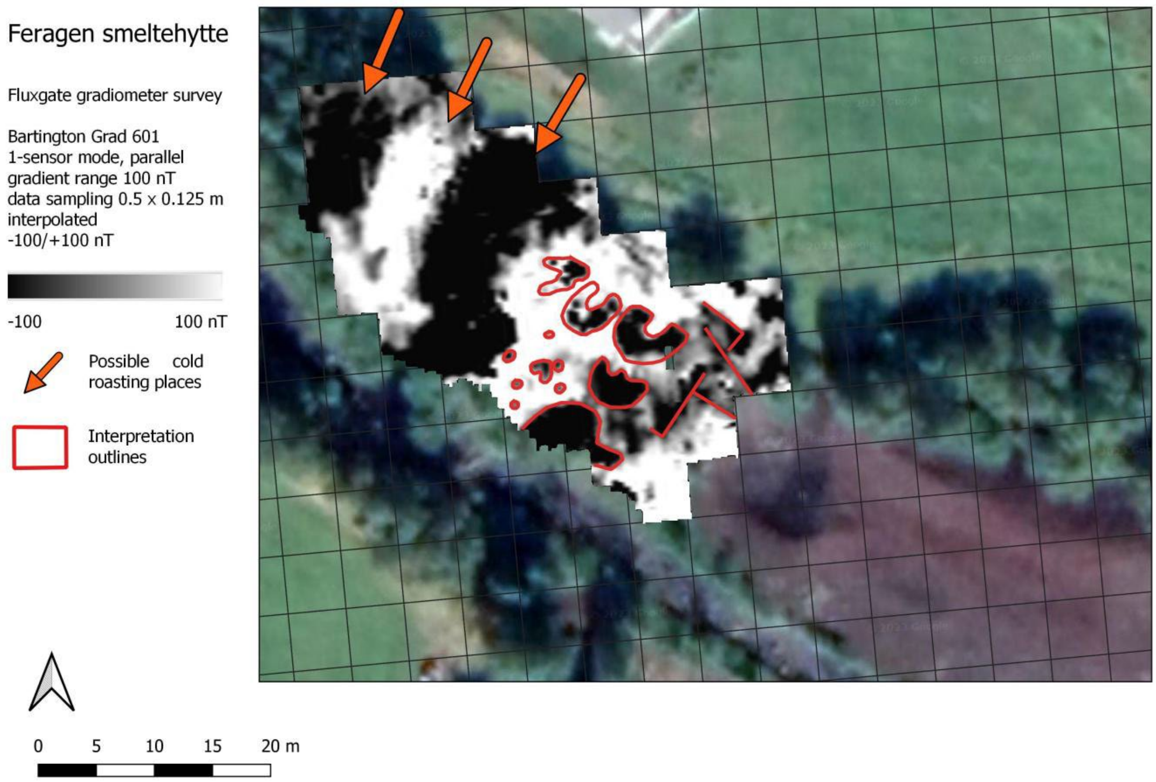


Figure 8: Interpretation of the magnetic gradiometer survey results.

In the area closer to the slag mound, two horseshoe-shaped features were observed, positioned side by side with the open end facing northeast (Fig. 8). The ring parts of these features display high levels of magnetic polarization, which is typical for objects affected by high temperatures such as furnaces or hearths (after *Vernon, R. W. (2004). Application of archaeological geophysical techniques to the investigation of British smelting sites (Vol. 1 of 2). University of Bradford*). The one of these two features located further to the northwest was also identified as a highly reflective structure in the GPR 2 area. Possible interpretations of these objects are furnaces, hearths, or other places involving high temperatures.
The area near the slag mound displays numerous magnetic anomalies, characterized by only positive or negative values, or slightly polarized. These anomalies could be different types and purposes pits, or remnants of various structures and installations, possibly more furnaces or hearths. Although their exact interpretation is difficult, they indicate a highly active area (Fig. 8). Also, something reminding of a pathway leading from the possible furnaces to the slag mound from the northwest direction could be possibly observed in the magnetic map, however, this is just a free interpretation based on observed tendencies in the results and relations between the anomalies. A view presented at the magnetic map with 50 nT contour interval can provide a good

insight to these relations and tendencies, and also to levels of magnetic values. Contours map can as well give an overview and a sense of spatial organization of the place (Fig. 9).

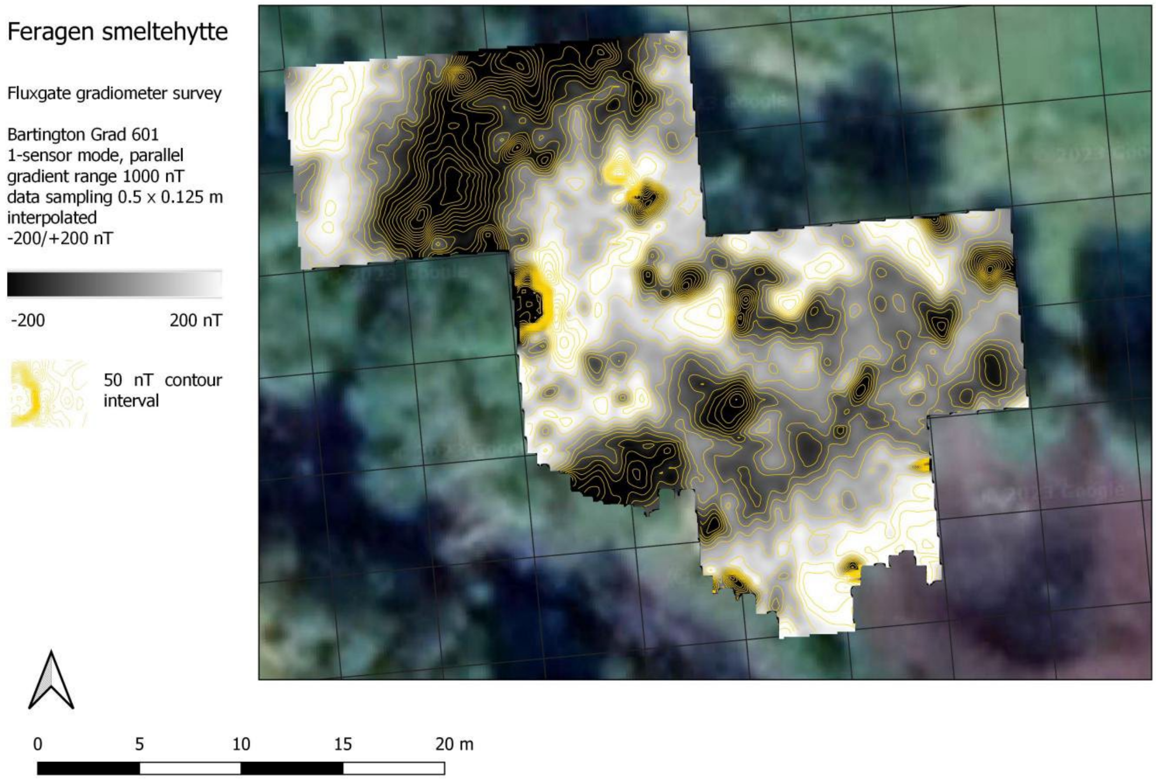


Figure 9: Contour map interpretation of the magnetic gradiometer survey results.

3.3 GPR Area 1

The GPR 1 Area reveals some exciting insights. A rectangular feature has been detected beneath the surface at a depth of around 0.6 to 0.7 meters (Fig. 10 and Fig. 13). This feature spans a width of 2.5 to 3 meters and a length of 6 meters. Its shape aligns with magnetic anomalies recorded in the same area and is oriented in a northwest-southeast direction. Half of it is located within one of the low-magnetic values swaths (in Fig. 10 represented as the black swath, interpreted as possibly related to cold roasting process). At the northwestern end of this structure lies a pit that is visible on the surface of the site and has been measured in as a topographic feature (Fig. 11). The boundaries the pit do not produce a clear reflection in either the GPR or magnetic results, however it is wholly located within the region of low-magnetic values.

Additionally, a boundary between the low and the high-magnetic values regions, which runs in a northeast-southwest direction, corresponds with the GPR view. The positive magnetic values area is associated with a concentration of highly reflective features, likely stones, and produces an edge that aligns with the mentioned boundary (Fig. 10).

Another rectangular shape has been identified at depth of barely 0.20 - 0.30 meters. One of its sides aligns with the boundary between the low- and high- magnetic values regions, and the feature 'quickly' loses its shape in deeper GPR depth slices. Nevertheless, this may indicate a possible construction formerly standing in that place (Fig. 12).

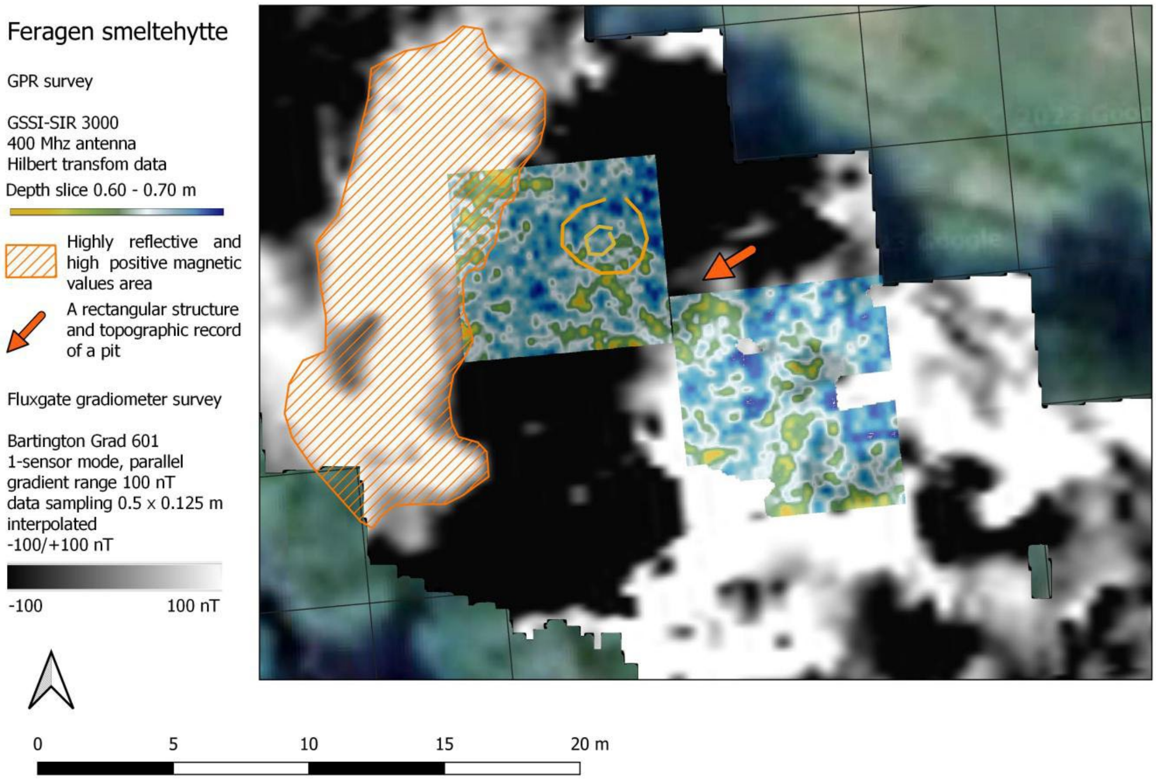


Figure 10: Interpretation of the the GPR survey results in the GPR 1 Area.

Figure 11: Overview of the GPR 1 area and the pit visible on the surface, view towards the southeast.

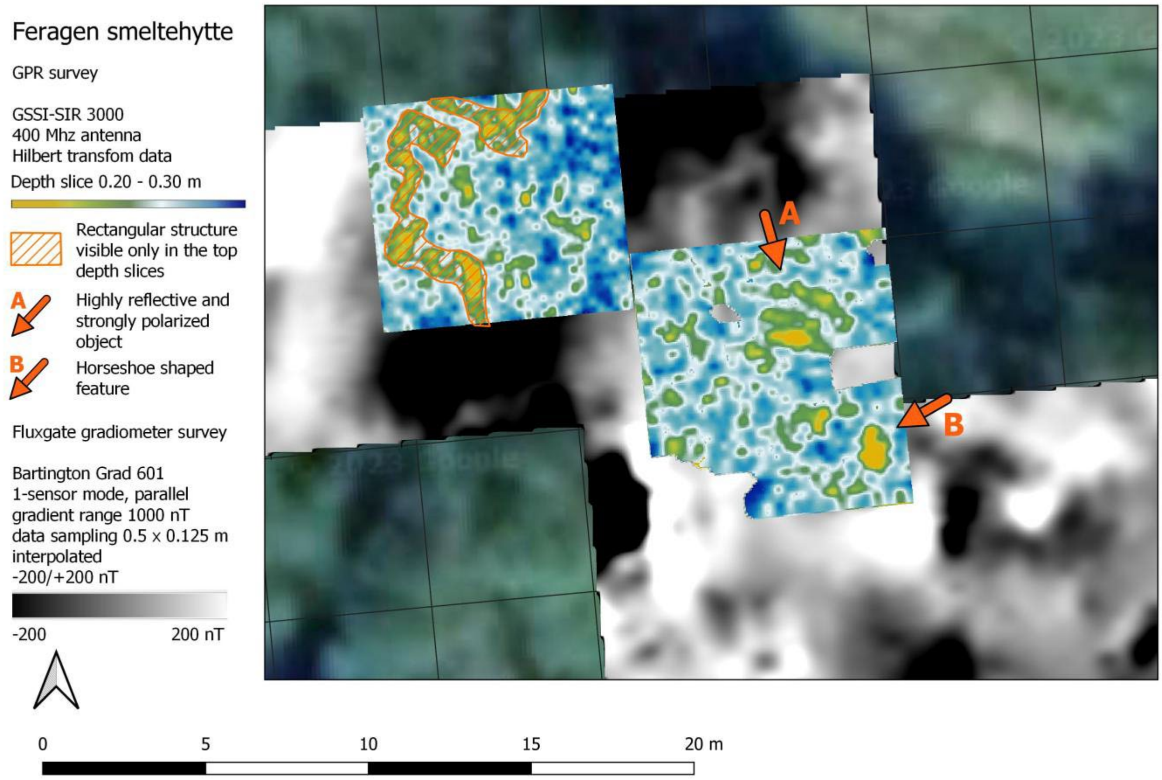


Figure 12: Interpretation of the GPR survey results at GPR 1 and GPR 2 areas.

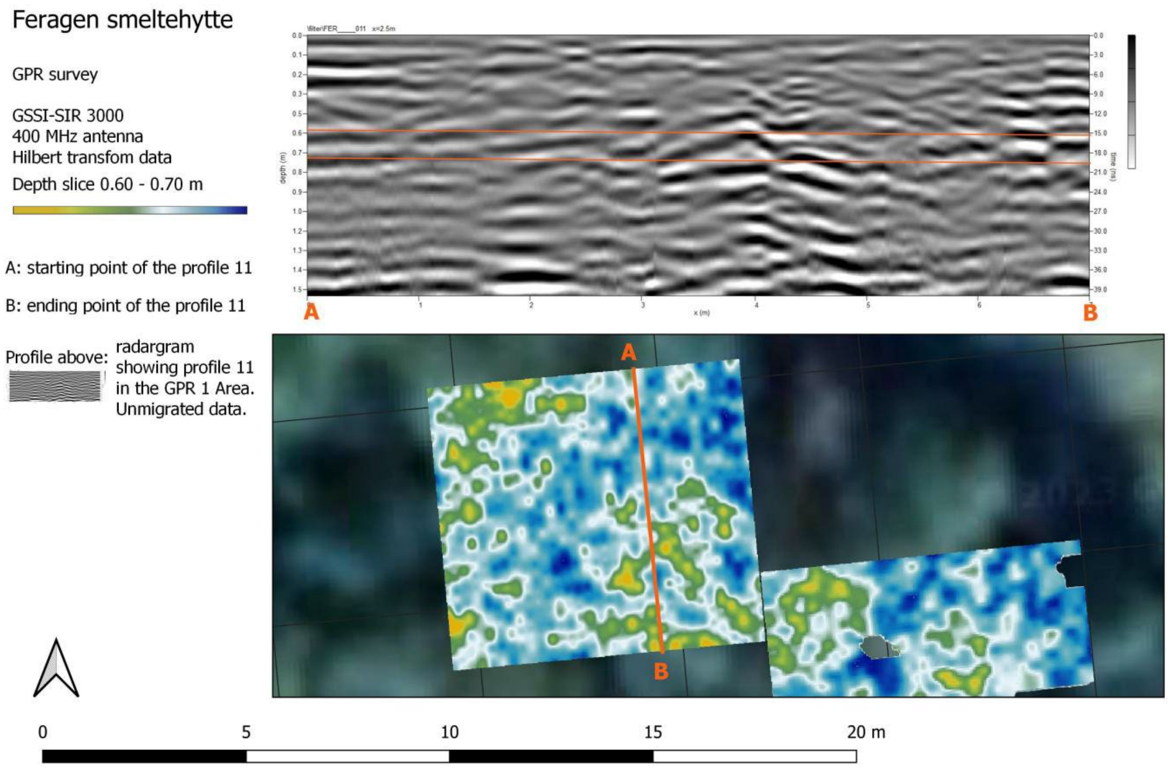


Figure 13: Radargram of profile 11 in the GPR 1 area, crossing the pit and the edge of the rectangular structure.

3.4 GPR Area 2

In the GPR 2 area, at depth of 0.10 to 0.30 m, a highly reflective and strongly magnetized and polarized structure was detected about 1 to 2 meters north of a cluster of stones visible on the surface (marked by the letter 'A' in Fig. 12, and an overview in Fig. 14). The structure itself is round to oval shaped and has dimensions of 2.2 by 2.7 meter. Both the GPR and magnetic responses are confirmed by very high magnetic susceptibility values recorded in the area (Fig. 15), with at least two measurements reaching the level of 800 SI, which is comparable to the values observed on the nearby slag mound.
Interestingly, these stones of the mentioned surface cluster have MS values of 23 and 32, which rules out the possibility that they, and less likely other stones buried in that area, cause the unusual geophysical readings. Instead, these readings are likely to indicate the presence of a kiln or other high-temperature involving installation in the area.
An interesting observation is that the first mentioned outstanding object and the stone group are aligned with a wooden trough sticking out from the ground at the southern end (Fig. 17), providing an excellent suggestion for a clear interpretation of a metallurgic installation spotted in the subsurface. On top of that, at depth of approximately 0.60 to 0.90 m, the GPR depth slice shows a clear picture of a linear, highly reflective structure of size 5.5 by 1.8 m with northeastern end originating at the highly reflective and magnetic structure 'A' (as marked in Fig. 12), crossing the stone cluster and ending with the wooden trough (Fig. 14). More interestingly, the same depth of GPR image also brings again a picture of the original focus object (Fig. 16).
Another feature attracting attention is a horseshoe-shaped, highly reflective structure. It clearly aligns with previously described magnetic anomaly, and its interpretation points towards a furnace or a hearth (Fig. 12).

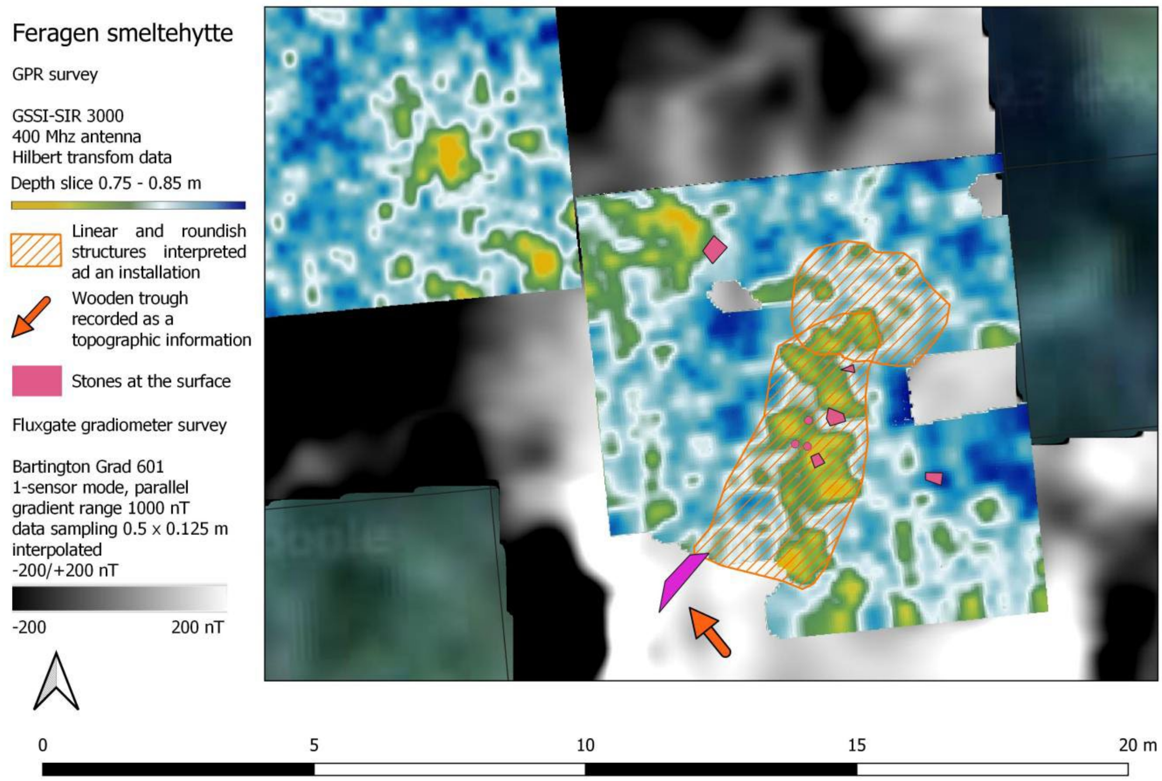


Figure 14: Interpretation of the GPR survey results in the GPR 2 Area.

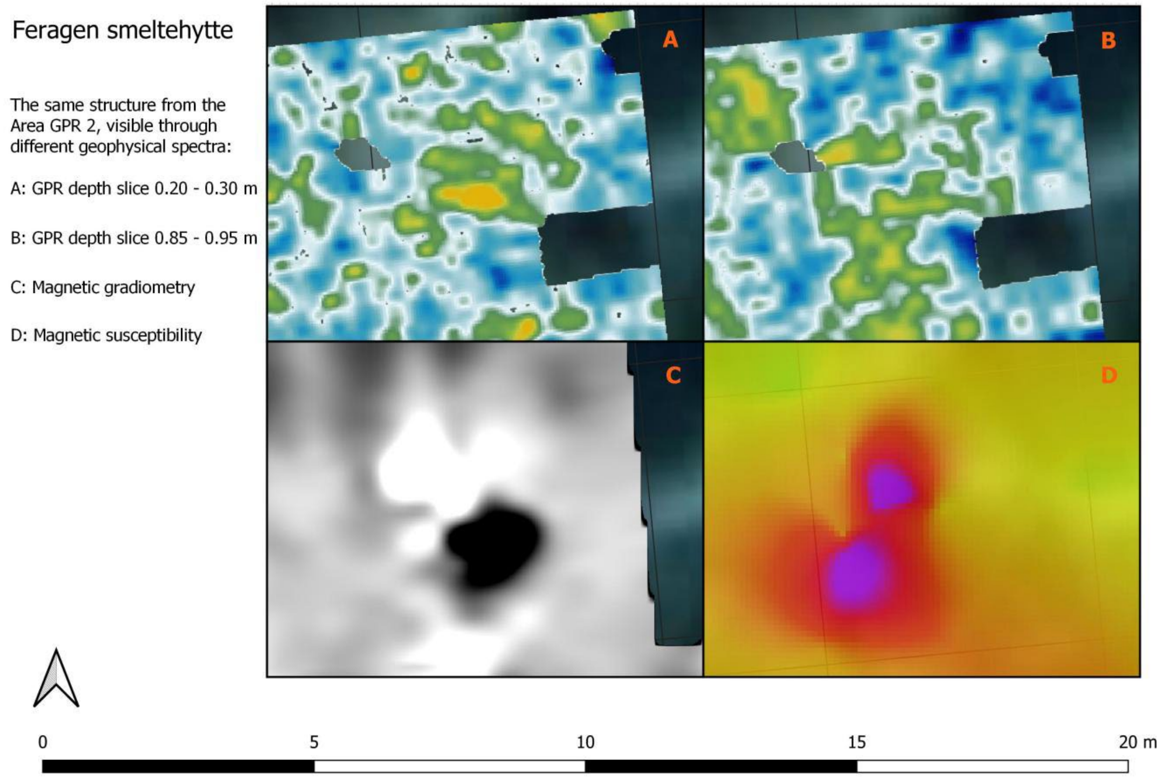


Figure 15: Comparison of the same structure visible through different geophysical spectra.

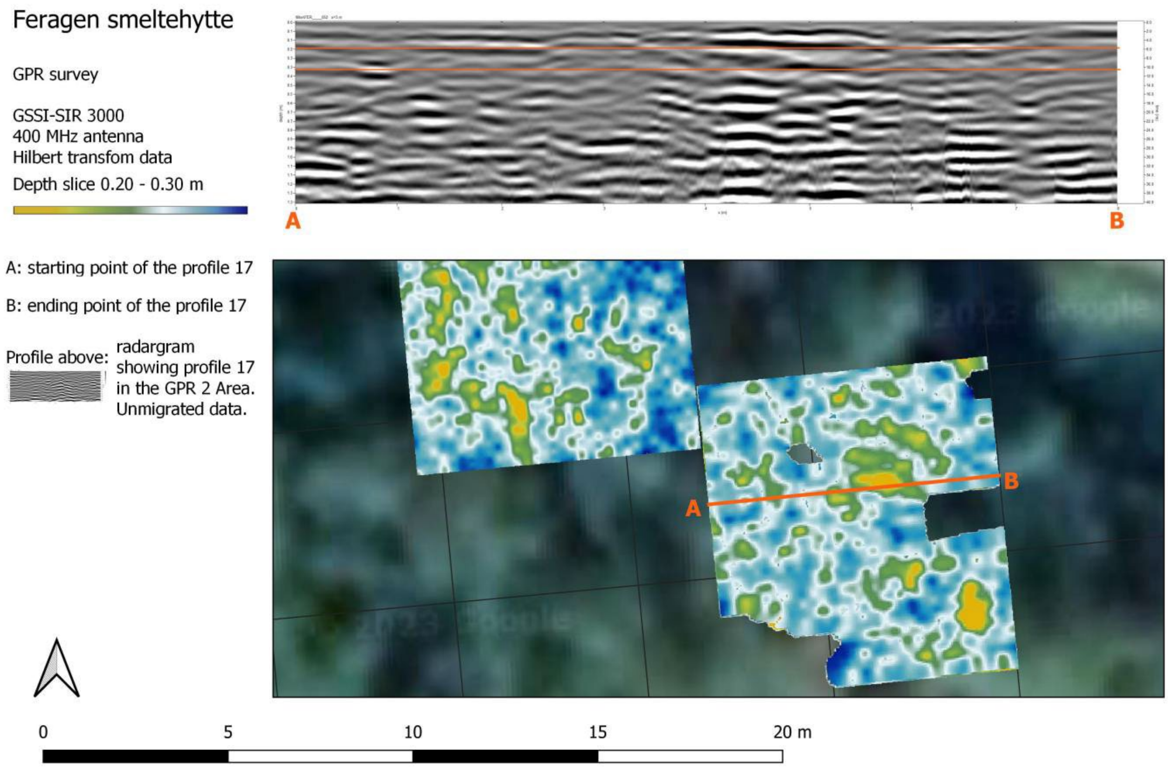


Figure 16: Radargram of profile 17 in the GPR 2 area, crossing the possible furnace installation.

Figure 17: Wooden trough standing out from the ground as the possible end of an installation and a view at the GPR 2 area.

4. Conclusions

Based on the presented information it can be concluded that the geophysical survey delivered a rich spectrum of information about the subsurface remains of the Feragen Smeltehytte. The general orientation of features on the site is northwest-southeast and northeast-southwest, parallel and perpendicular to the Elva stream. The magnetic susceptibility values at the site reveal important information about the limits of the smelting activity in the southern bank of the river and about areas of likely concentration of that activity. The high magnetic susceptibility readings outside the slag mound on both sides of Elva suggest the presence of magnetic materials and potential areas for furnaces, hearths, or roasting places. This data in combination with the results of the magnetic gradiometry survey suggest that the majority of the smelting activity can be located within a 30-meter radius to the northwest of the slag mound. The horseshoe-shaped features observed in this area display high levels of magnetic polarization, typical for objects affected by high temperatures such as furnaces or hearths. These objects were in high-detail recorded by the GPR survey and information about them was successfully compared with topographic information, giving a detailed information about location and outline of smelting installations. Also, areas that are interpreted as potentially roasting areas were located further to the northwest from the possible furnaces. Results of the survey provide valuable insight into the site's boundaries, spatial organization, and specific locations of possible installations which creates a valuable input into further investigation of Feragen Smeltehytte.

5. Literature

Aspinall, A., Gaffney, C., & Schmidt, A. (2009). *Magnetometry for Archaeologists* (First Edition ed.). Plymouth: AltaMira Press.

Austnes, A. (n.d.). Den gamle smelteprosessen; Verdensarven Røros bergstad og Circumferensen. Retrieved from https://verdensarvenroros.no/den-gamle-smelteprosessen

Conyers, L. B. (2012). *Interpreting ground-penetrating radar for archaeology*. Walnut Creek, Calif.: Left Coast Press.

Conyers, L. B. (2013). *Ground-penetrating radar for archaeology* (3rd Edition ed.). Plymouth, United Kingdom: AltaMira Press.

Powell, A. J., McDonnell, J. G., Batt, C. M., & Vernon, R. W. (2002). An assessment of the magnetic response of an iron-smelting site. *Archaeometry, 44*(4), 651-665. doi:10.1111/1475-4754.t01-1-00091

Schmidt, A., Linford, P., Linford, N., David, A., Gaffney, C., Sarris, A., & Fassbinder, J. W. E. (2016). *EAC guidelines for the use of geophysics in archaeology - Questions to ask and points to consider* [2]. In E. Jerem (Ed.), *EAC Guidelines*.

Stamnes, A. A., & Rødsrud, C. L. (2020). 11. Geofysiske undersøkelser av jernvinneanlegg i dyrket mark – observasjoner, analyser og erfaringer fra Ånestad. In C. L. Rødsrud & A. Mjærum (Eds.), *Ingen vei utenom: Arkeologiske undersøkelser i forbindelse med etabliring av ny rv. 3/25 i Løten og Elverum kommuner, Innlandet.* (pp. 221-230). Oslo. : Cappelen Damm Akademisk/NOASP.

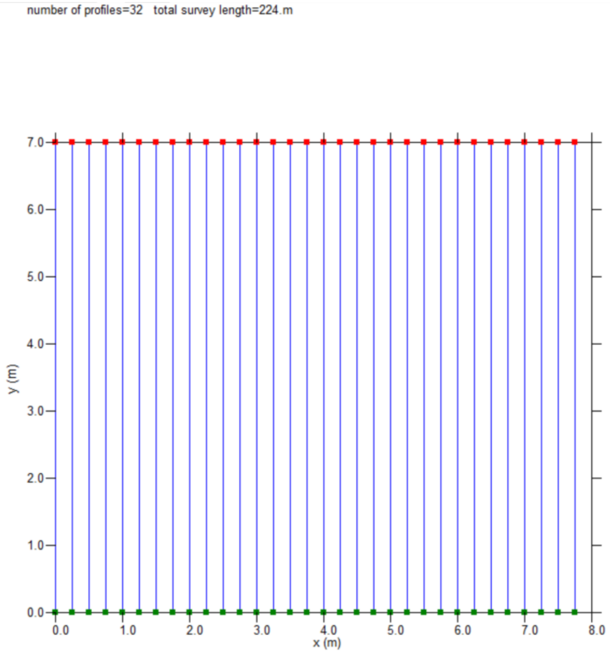
Stamnes, A. A., Stenvik, L. F., & Gaffney, C. (2019). Magnetic geophysical mapping of prehistoric iron production sites in central Norway. *DKNVS Skrifter, 2*, 71-113.

Vernon, R. W. (2004). *Application of Archaeological Geophysical Techniques to the Investigation of British Smelting Sites*. Bradford, England: Department of Archaeological Sciences, University of Bradford.

6. Appendix – extra maps, technical info, all depth slices and radar profiles, and photos from the survey

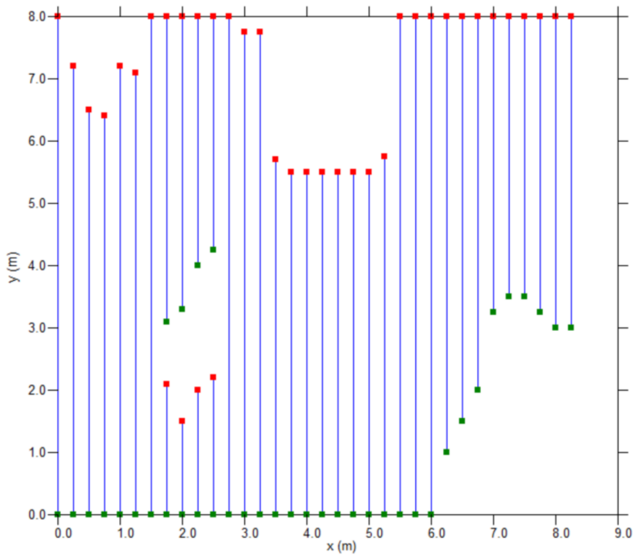
6.1 GPR Grid Plots

GPR 1 Area - Grid Plot

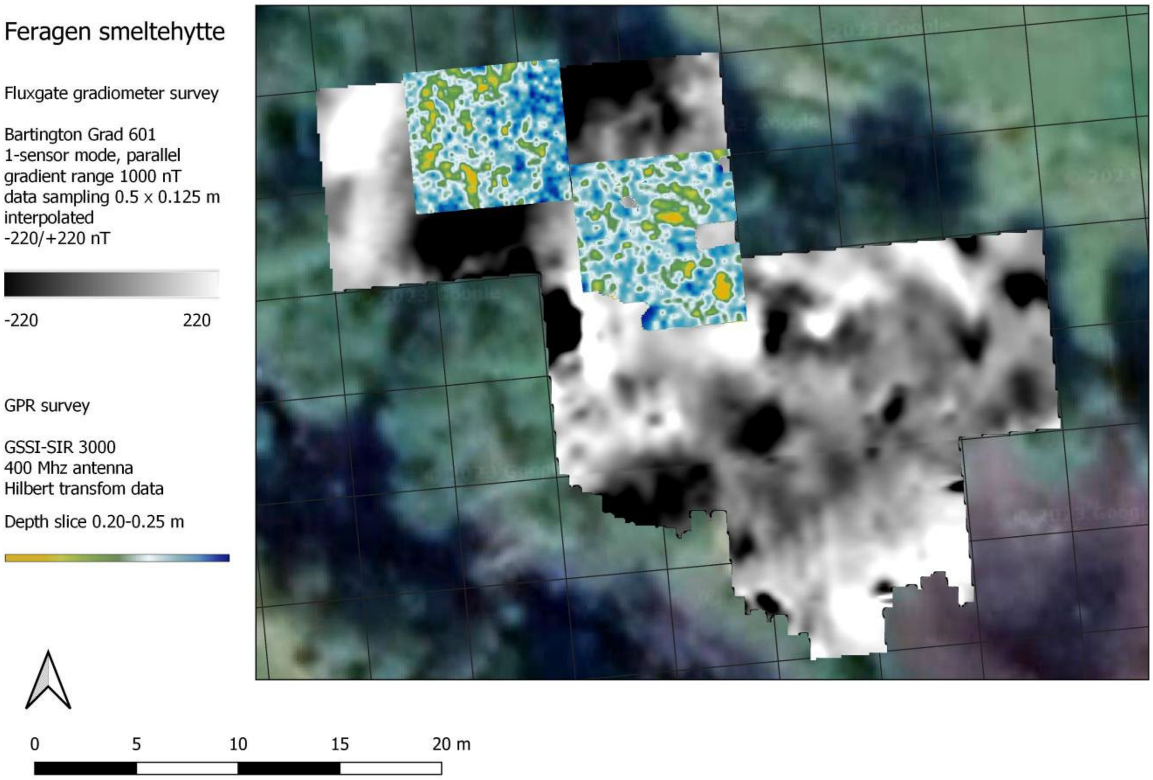


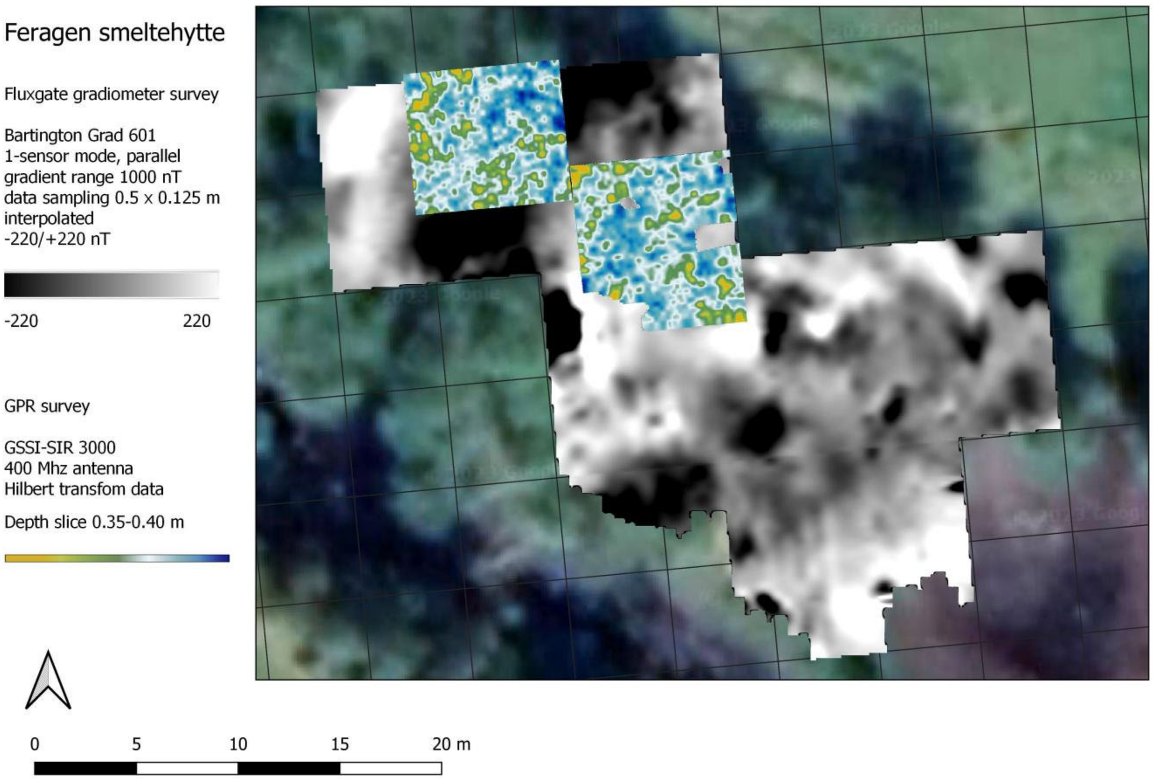
GPR 2 Area - Grid Plot

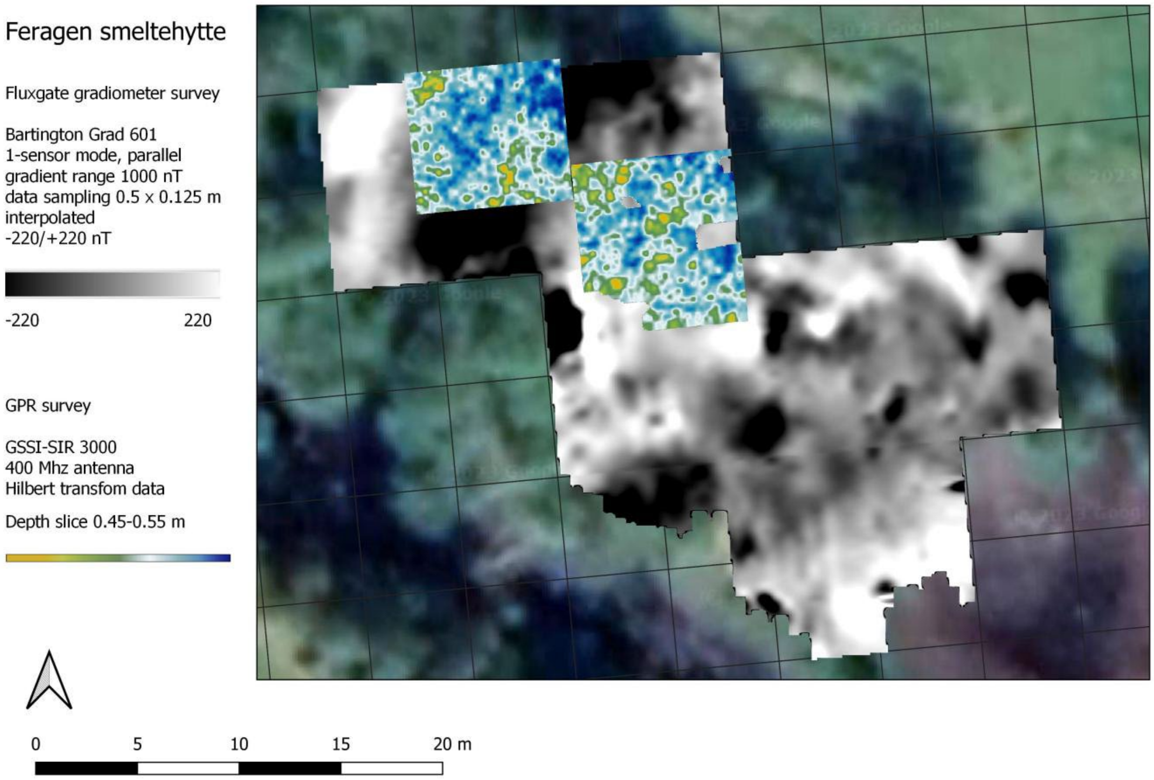
number of profiles=38 total survey length=215.5m

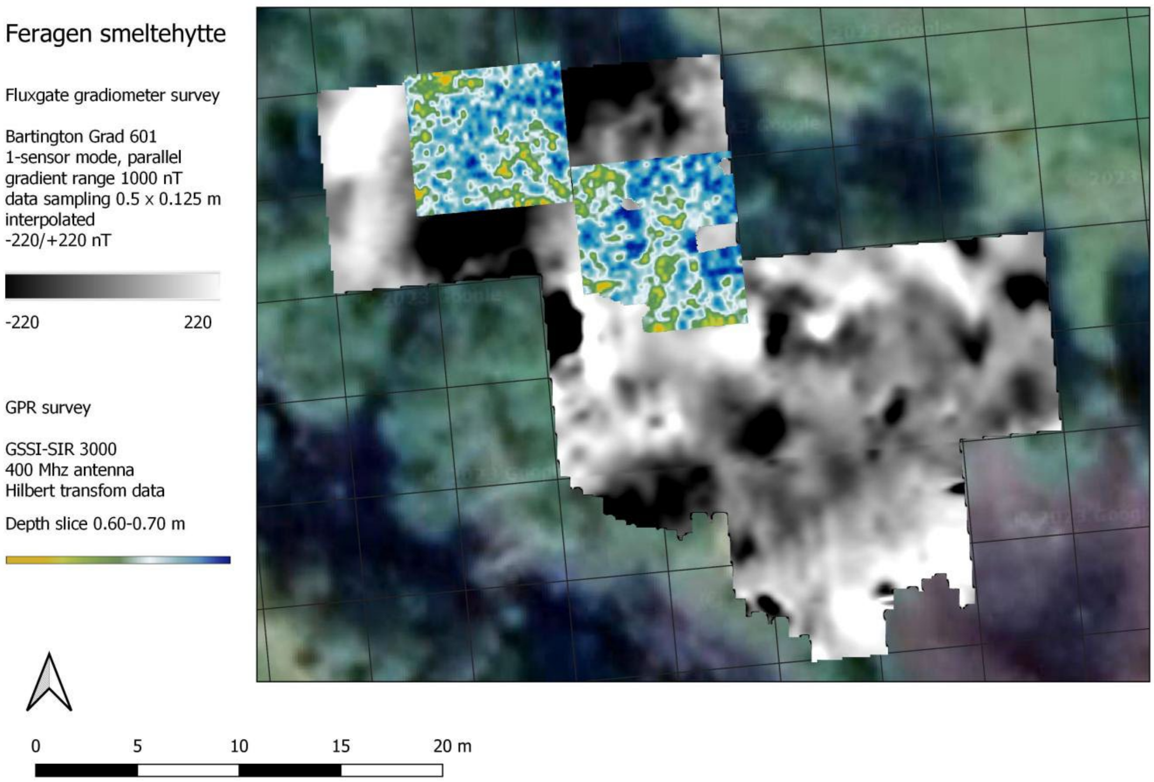


6.2 Chosen GPR depth slices plotted in the map


Feragen smeltehytte
Fluxgate gradiometer survey
Bartington Grad 601
1-sensor mode, parallel
gradient range 1000 nT
data sampling 0.5 x 0.125 m
interpolated
-220/+220 nT
-220
220
GPR survey
GSSI-SIR 3000
400 Mhz antenna
Hilbert transfom data
Depth slice 0.20-0.25 m
0
5
10
15
20 m


Feragen smeltehytte
Fluxgate gradiometer survey
Bartington Grad 601
1-sensor mode, parallel
gradient range 1000 nT
data sampling 0.5 x 0.125 m
interpolated
-220/+220 nT
-220
220
GPR survey
GSSI-SIR 3000
400 Mhz antenna
Hilbert transfom data
Depth slice 0.35-0.40 m
0
5
10
15
20 m


Feragen smeltehytte
Fluxgate gradiometer survey
Bartington Grad 601
1-sensor mode, parallel
gradient range 1000 nT
data sampling 0.5 x 0.125 m
interpolated
-220/+220 nT
-220
220
GPR survey
GSSI-SIR 3000
400 Mhz antenna
Hilbert transfom data
Depth slice 0.45-0.55 m
0
5
10
15
20 m


Feragen smeltehytte
Fluxgate gradiometer survey
Bartington Grad 601
1-sensor mode, parallel
gradient range 1000 nT
data sampling 0.5 x 0.125 m
interpolated
-220/+220 nT
-220
220
GPR survey
GSSI-SIR 3000
400 Mhz antenna
Hilbert transfom data
Depth slice 0.60-0.70 m
0
5
10
15
20 m

Feragen smeltehytte

Fluxgate gradiometer survey

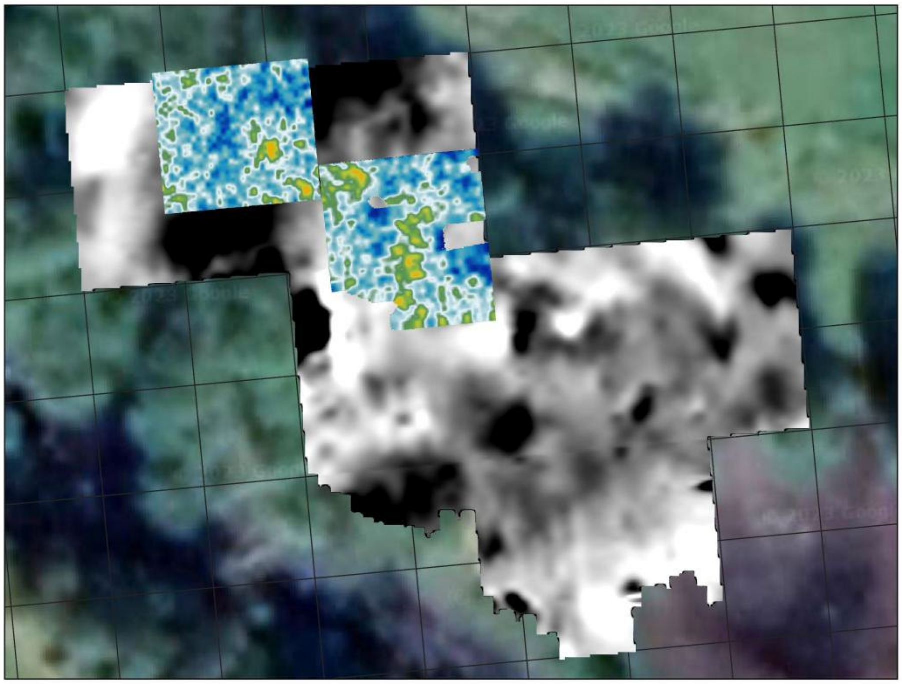
Bartington Grad 601
1-sensor mode, parallel
gradient range 1000 nT
data sampling 0.5 x 0.125 m
interpolated
-220/+220 nT

-220 220

GPR survey

GSSI-SIR 3000
400 Mhz antenna
Hilbert transfom data

Depth slice 0.75-0.85 m



0 5 10 15 20 m

Feragen smeltehytte

Fluxgate gradiometer survey

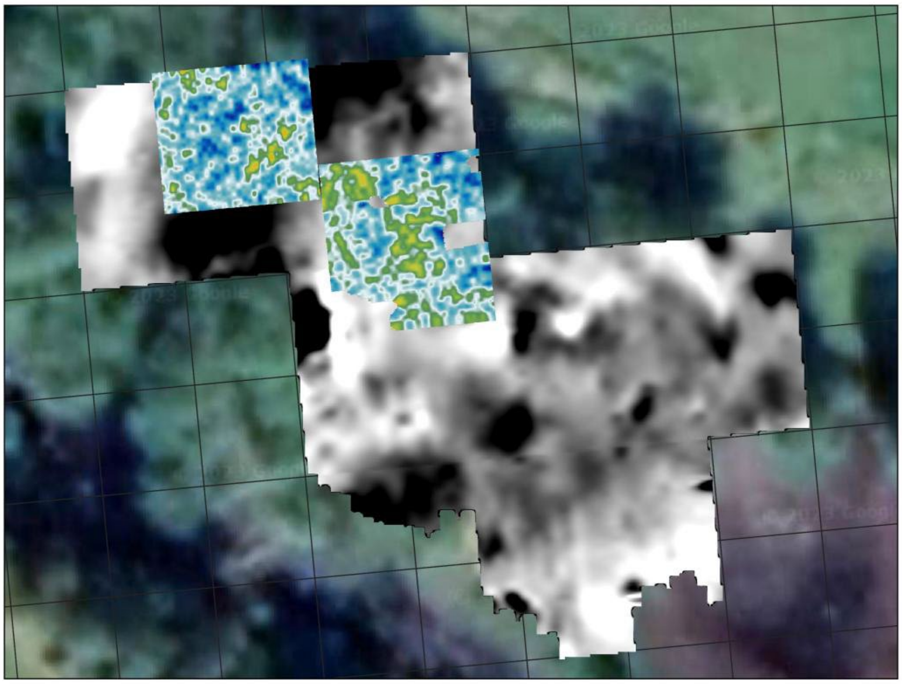
Bartington Grad 601
1-sensor mode, parallel
gradient range 1000 nT
data sampling 0.5 x 0.125 m
interpolated
-220/+220 nT

-220 220

GPR survey

GSSI-SIR 3000
400 Mhz antenna
Hilbert transfom data

Depth slice 0.85-0.95 m

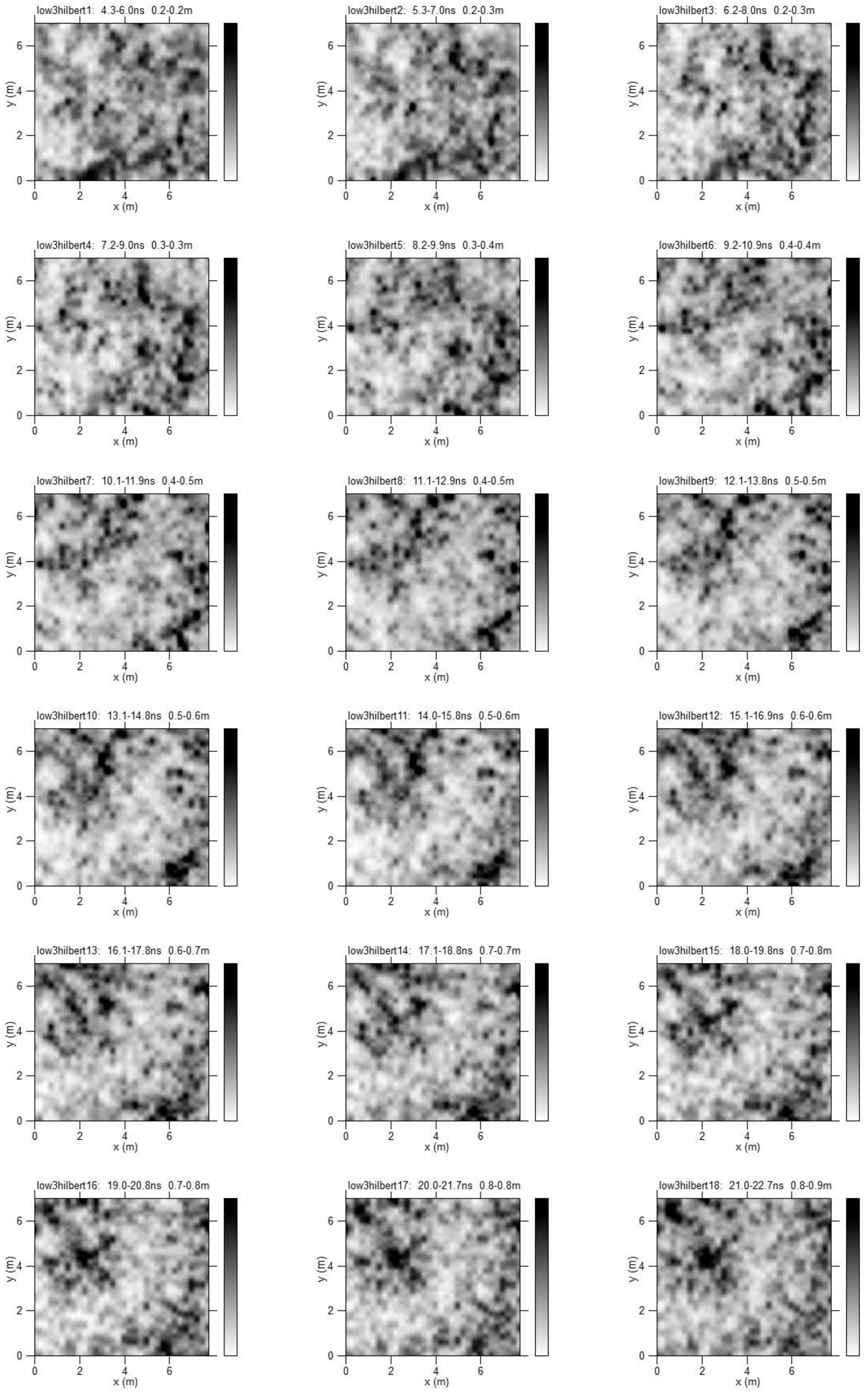


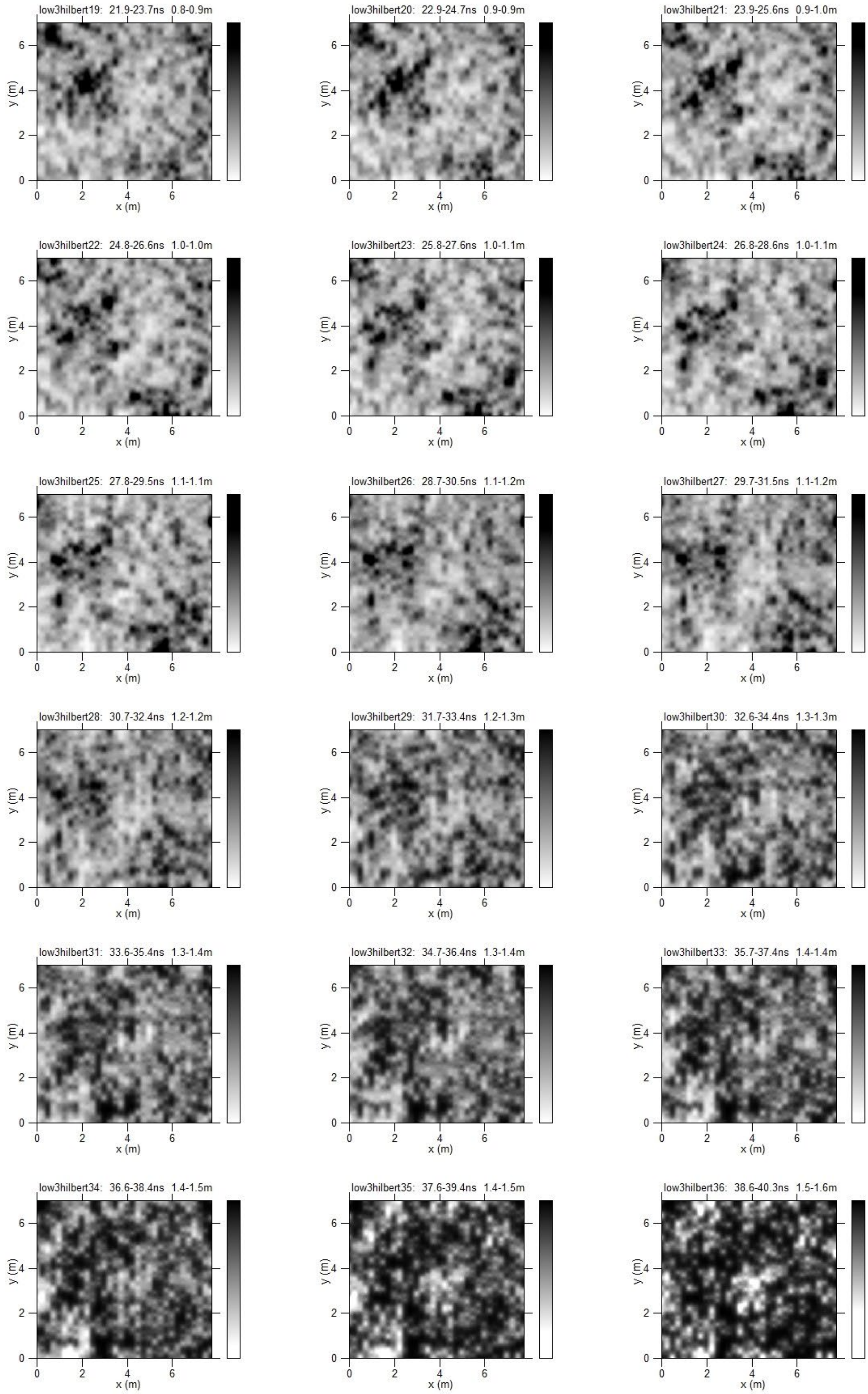
0 5 10 15 20 m

6.3 All GPR depth slices

6.3.1 GPR 1 Area in greyscale

Please note that the orientation of these depth slices is different than in the presented in the report maps. In these depth slices the N arrow would point down.

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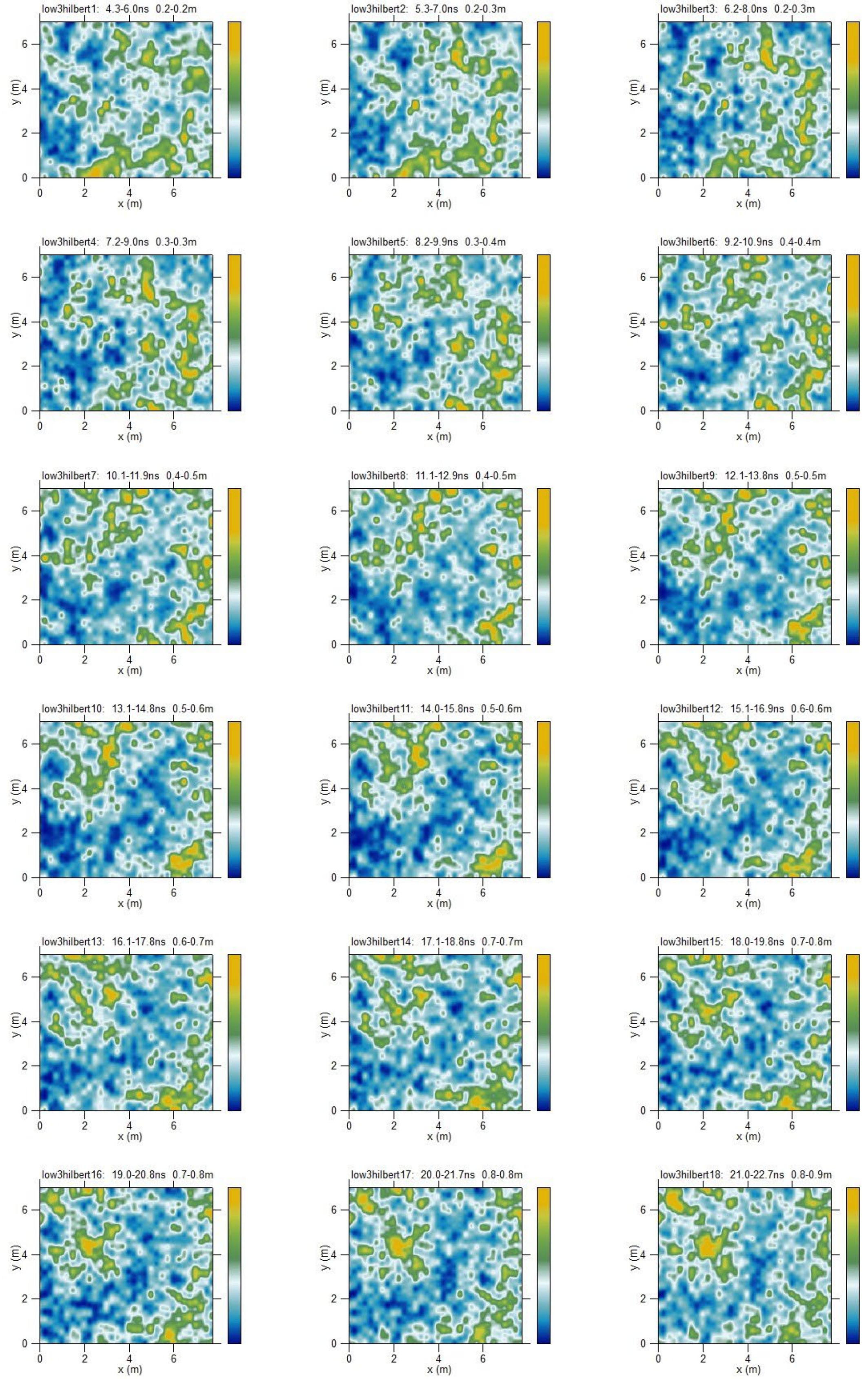
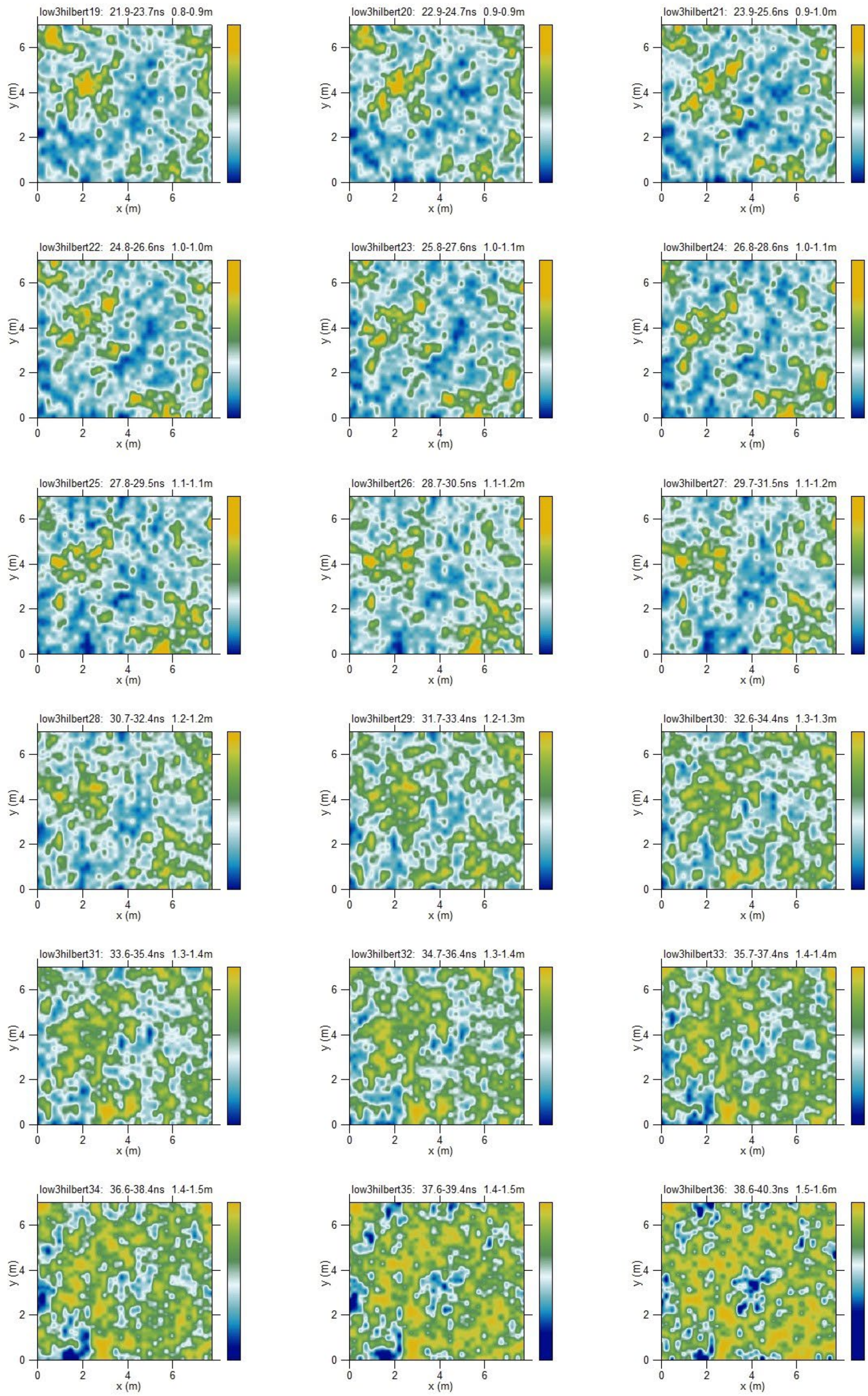
low3hilbert20: 22.9-24.7ns 0.9-0.9m
low3hilbert21: 23.9-25.6ns 0.9-1.0m
low3hilbert22: 24.8-26.6ns 1.0-1.0m
low3hilbert23: 25.8-27.6ns 1.0-1.1m
low3hilbert24: 26.8-28.6ns 1.0-1.1m
low3hilbert25: 27.8-29.5ns 1.1-1.1m
low3hilbert26: 28.7-30.5ns 1.1-1.2m
low3hilbert27: 29.7-31.5ns 1.1-1.2m
low3hilbert28: 30.7-32.4ns 1.2-1.2m
low3hilbert29: 31.7-33.4ns 1.2-1.3m
low3hilbert30: 32.6-34.4ns 1.3-1.3m
low3hilbert31: 33.6-35.4ns 1.3-1.4m
low3hilbert32: 34.7-36.4ns 1.3-1.4m
low3hilbert33: 35.7-37.4ns 1.4-1.4m
low3hilbert34: 36.6-38.4ns 1.4-1.5m
low3hilbert35: 37.6-39.4ns 1.4-1.5m
low3hilbert36: 38.6-40.3ns 1.5-1.6m
x (m)
y (m)

6.3.2 GPR 1 Area in color

Please note that the orientation of these depth slices is different than in the presented in the report maps. In these depth slices the N arrow would point down.

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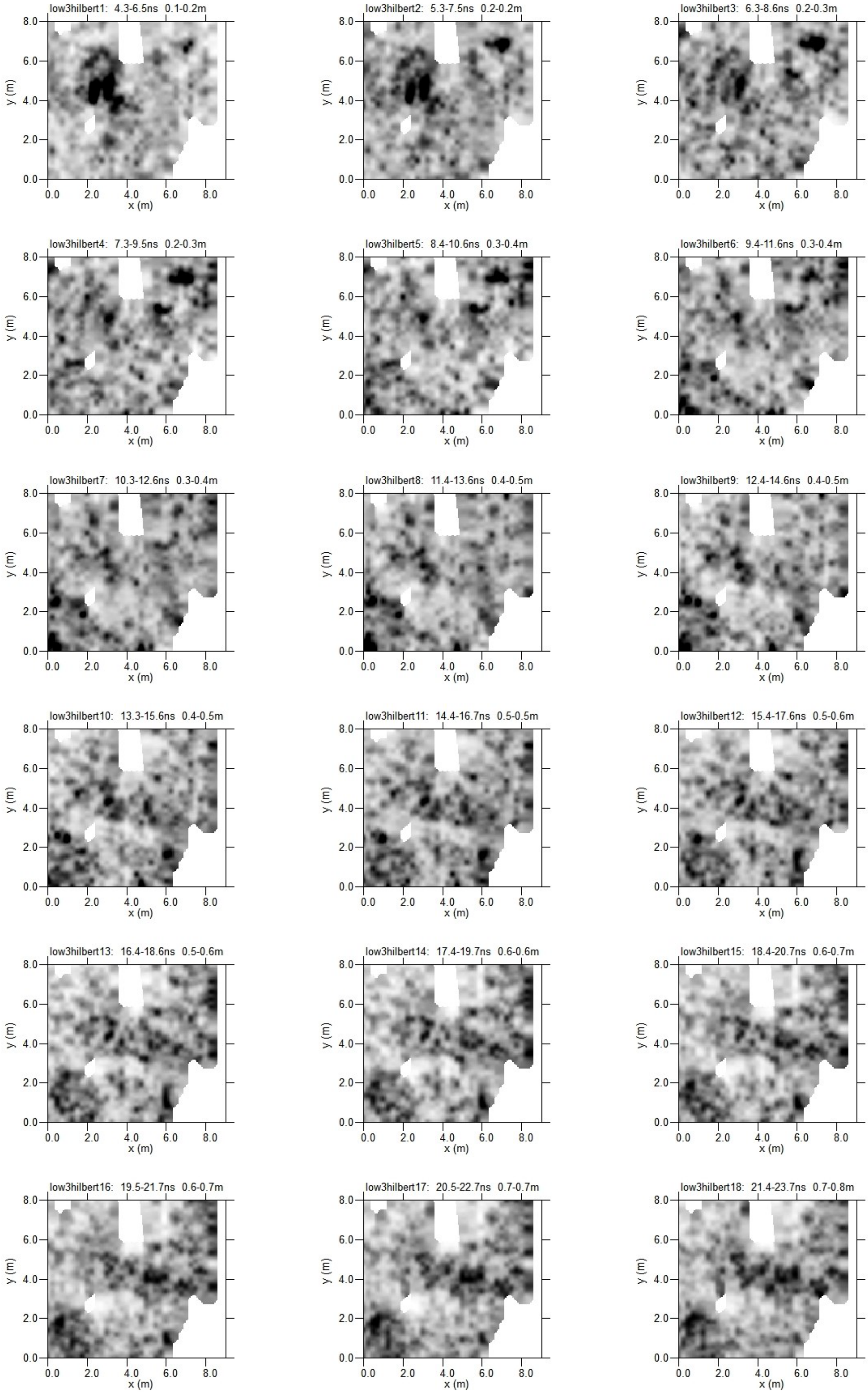
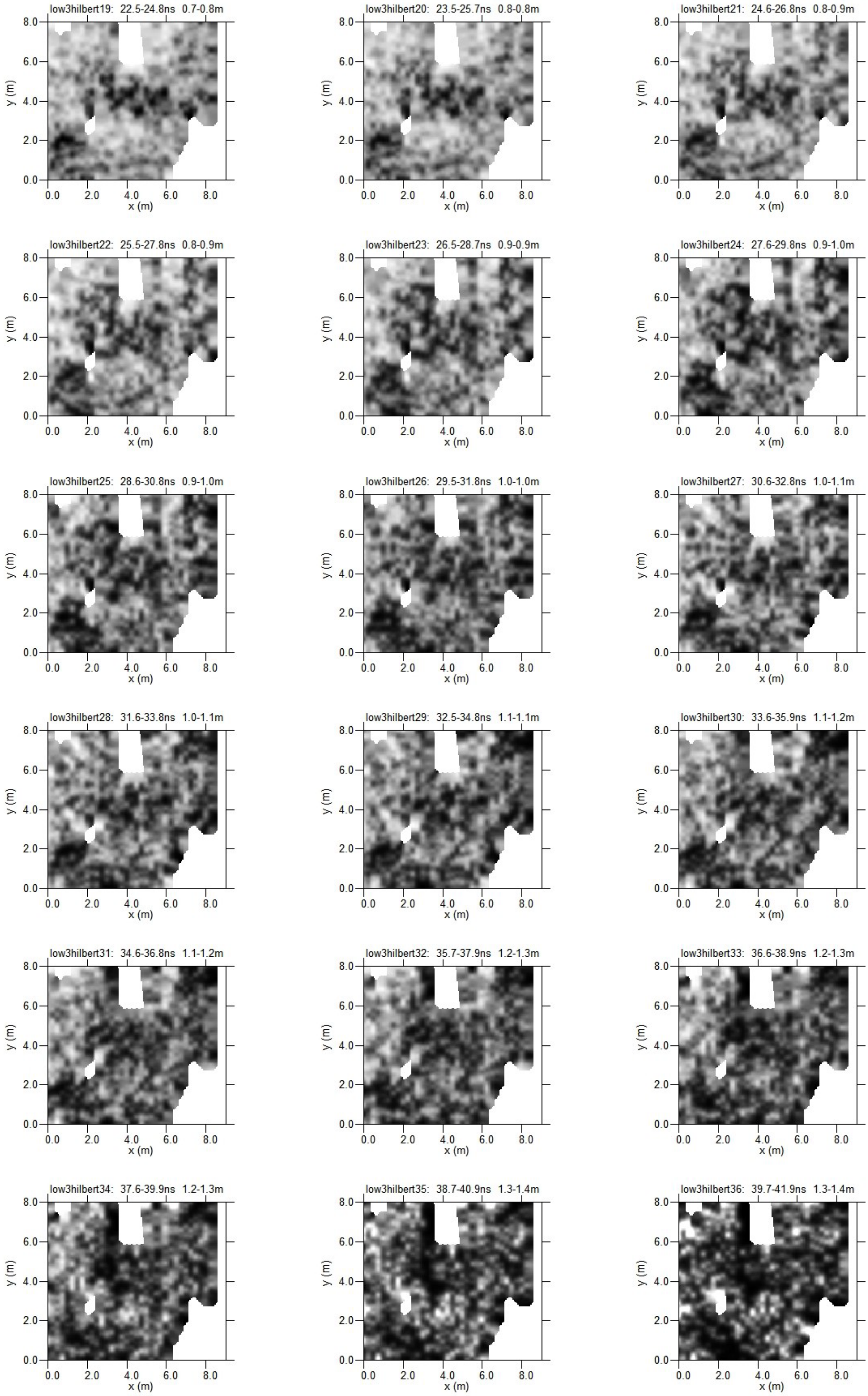
low3hilbert20: 22.9-24.7ns 0.9-0.9m
low3hilbert21: 23.9-25.6ns 0.9-1.0m
low3hilbert22: 24.8-26.6ns 1.0-1.0m
low3hilbert23: 25.8-27.6ns 1.0-1.1m
low3hilbert24: 26.8-28.6ns 1.0-1.1m
low3hilbert25: 27.8-29.5ns 1.1-1.1m
low3hilbert26: 28.7-30.5ns 1.1-1.2m
low3hilbert27: 29.7-31.5ns 1.1-1.2m
low3hilbert28: 30.7-32.4ns 1.2-1.2m
low3hilbert29: 31.7-33.4ns 1.2-1.3m
low3hilbert30: 32.6-34.4ns 1.3-1.3m
low3hilbert31: 33.6-35.4ns 1.3-1.4m
low3hilbert32: 34.7-36.4ns 1.3-1.4m
low3hilbert33: 35.7-37.4ns 1.4-1.4m
low3hilbert34: 36.6-38.4ns 1.4-1.5m
low3hilbert35: 37.6-39.4ns 1.4-1.5m
low3hilbert36: 38.6-40.3ns 1.5-1.6m
y (m)
x (m)

6.3.3 GPR 2 Area in greyscale

Please note that the orientation of these depth slices is different than in the presented in the report maps. In these depth slices the N arrow would point to the left.

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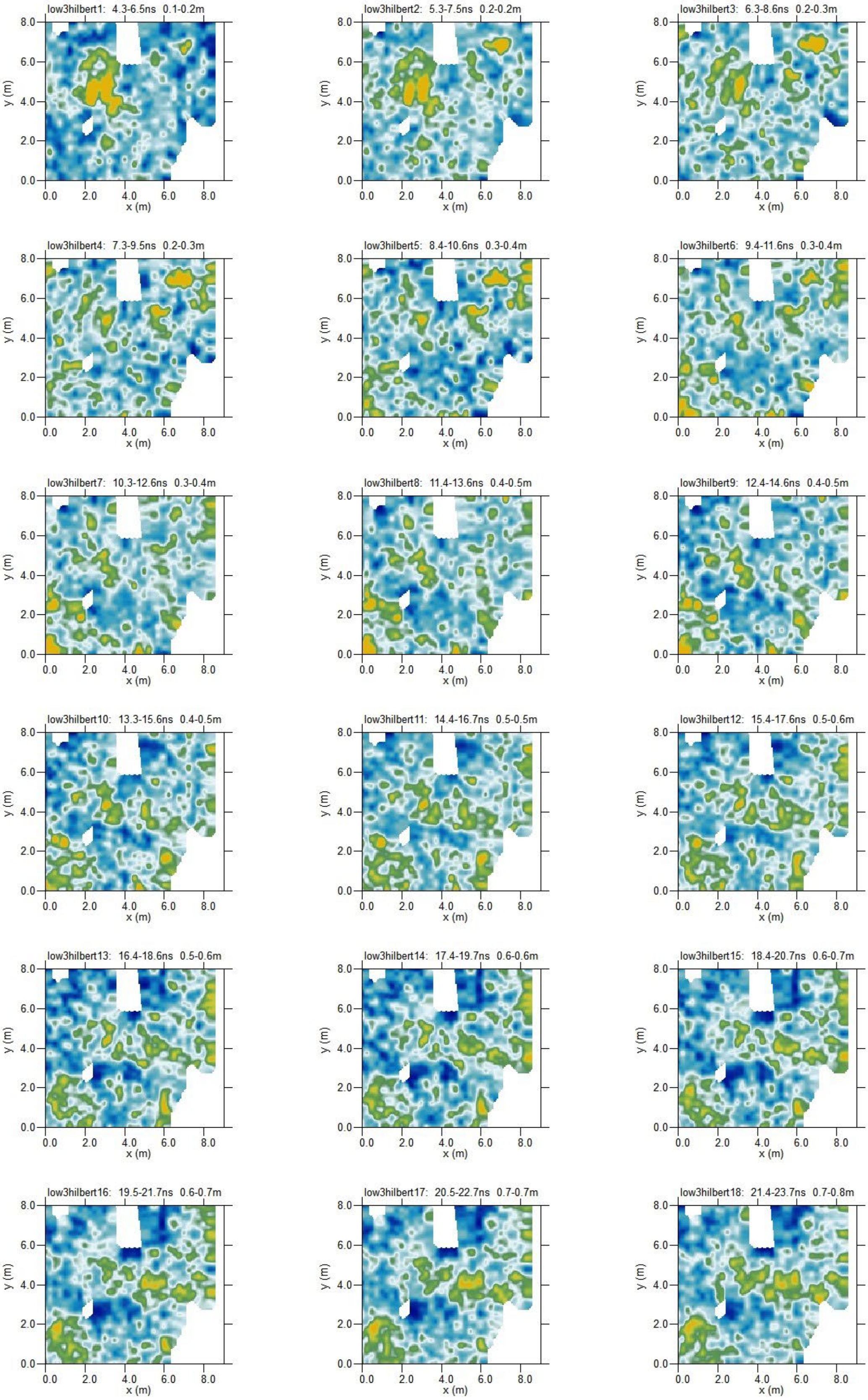
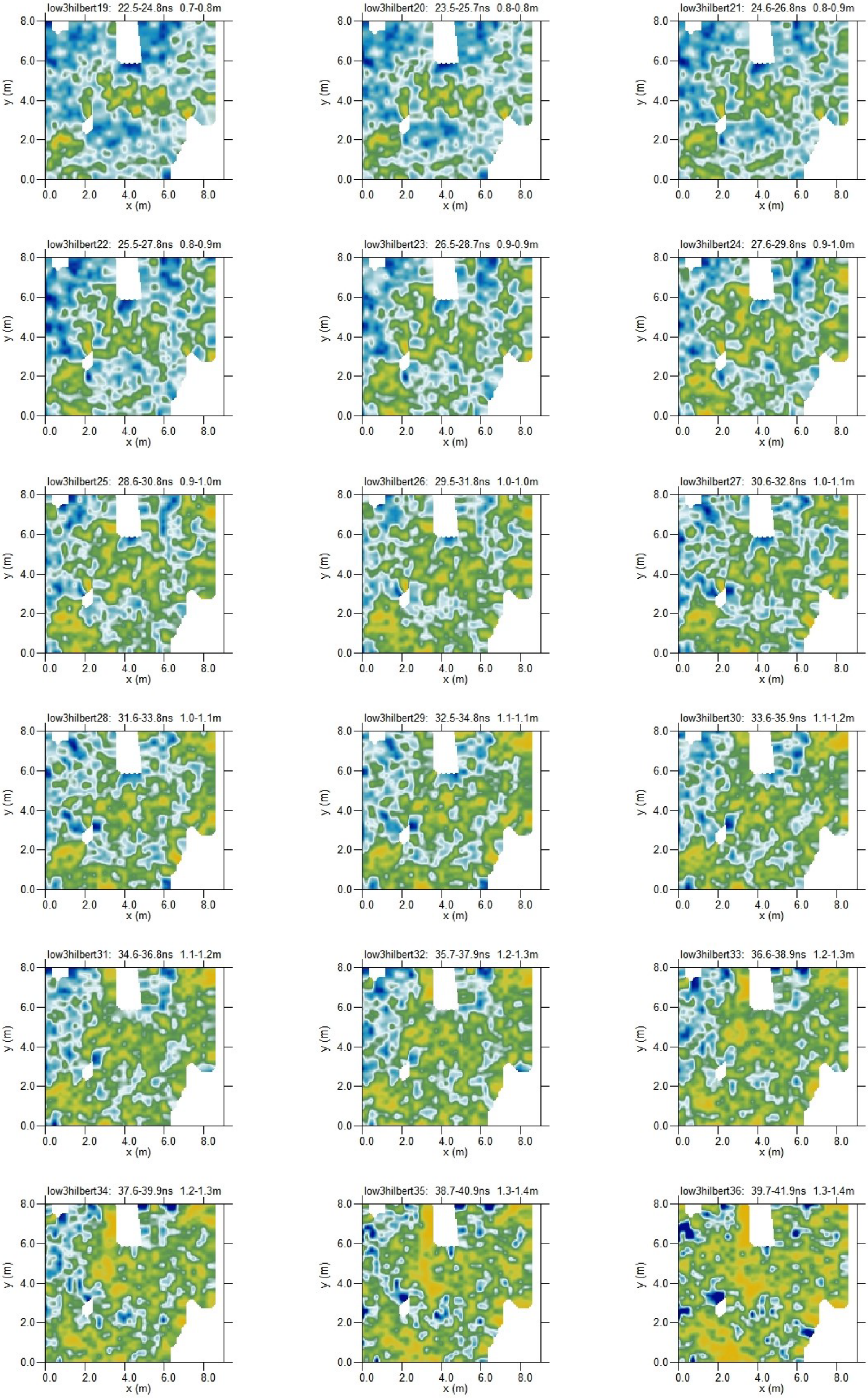
low3hilbert21: 24.6-26.8ns 0.8-0.9m
low3hilbert22: 25.5-27.8ns 0.8-0.9m
low3hilbert23: 26.5-28.7ns 0.9-0.9m
low3hilbert24: 27.6-29.8ns 0.9-1.0m
low3hilbert25: 28.6-30.8ns 0.9-1.0m
low3hilbert26: 29.5-31.8ns 1.0-1.0m
low3hilbert27: 30.6-32.8ns 1.0-1.1m
low3hilbert28: 31.6-33.8ns 1.0-1.1m
low3hilbert29: 32.5-34.8ns 1.1-1.1m
low3hilbert30: 33.6-35.9ns 1.1-1.2m
low3hilbert31: 34.6-36.8ns 1.1-1.2m
low3hilbert32: 35.7-37.9ns 1.2-1.3m
low3hilbert33: 36.6-38.9ns 1.2-1.3m
low3hilbert34: 37.6-39.9ns 1.2-1.3m
low3hilbert35: 38.7-40.9ns 1.3-1.4m
low3hilbert36: 39.7-41.9ns 1.3-1.4m
y (m)
x (m)
0.0
2.0
4.0
6.0
8.0

6.3.4 GPR 2 Area in color

Please note that the orientation of these depth slices is different than in the presented in the report maps. In these depth slices the N arrow would point to the left.



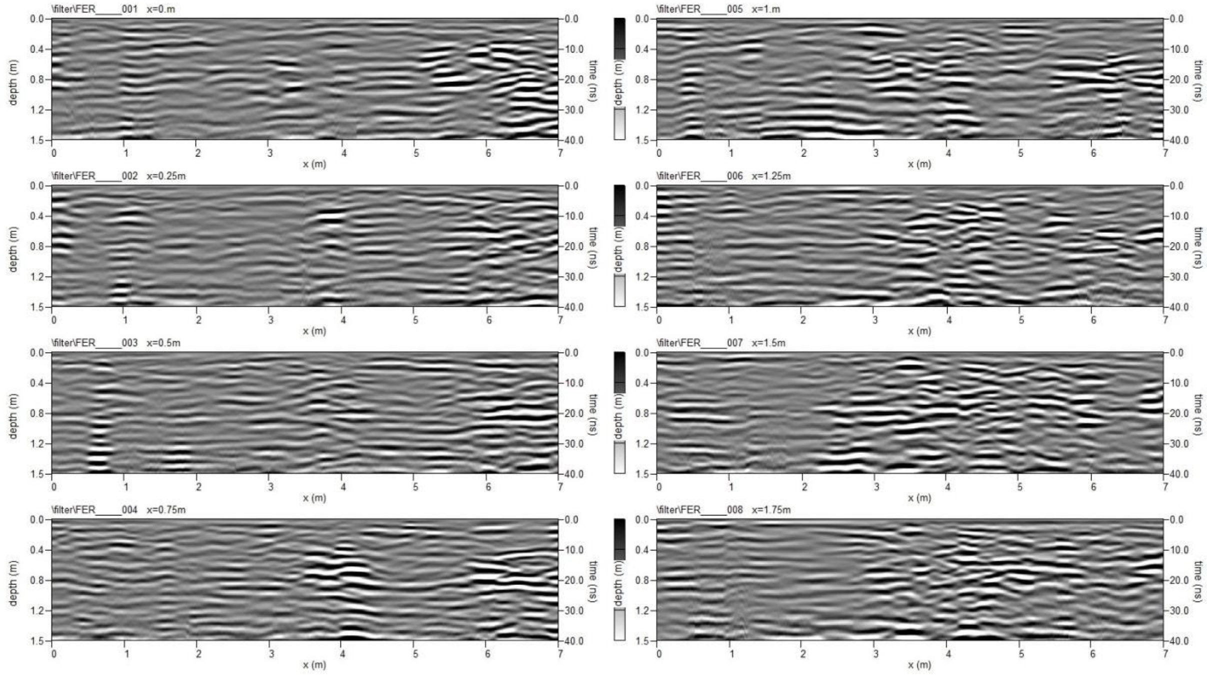


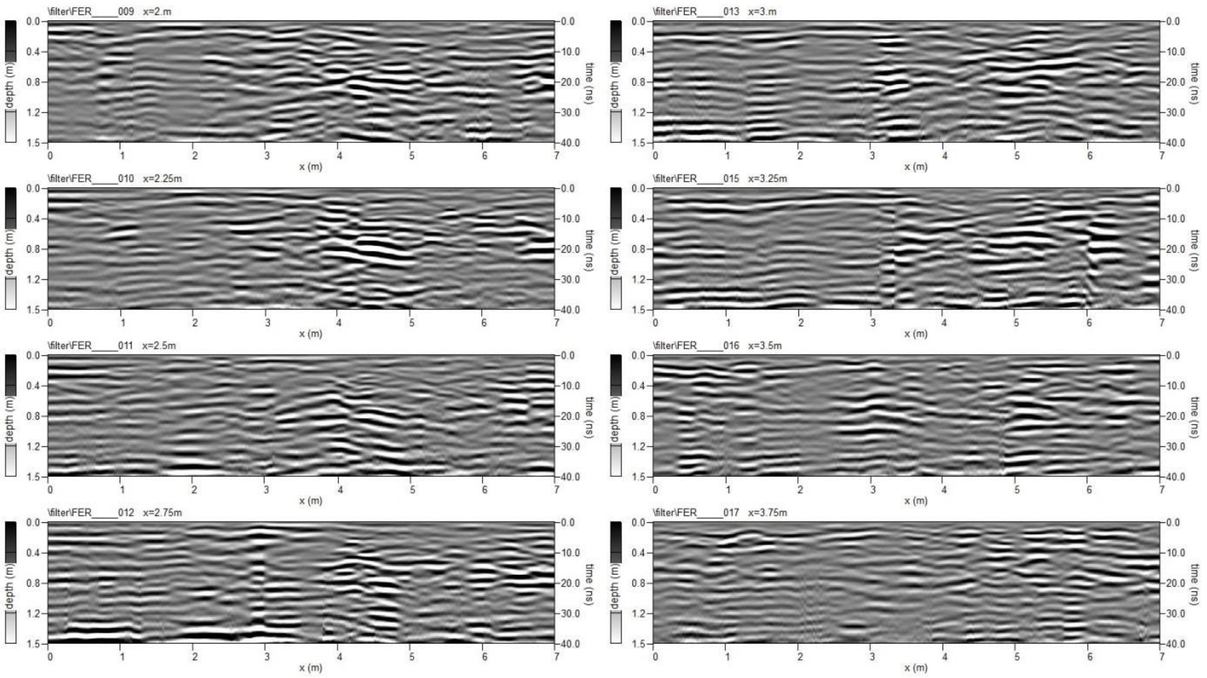
low3hilbert19: 22.5-24.8ns 0.7-0.8m
low3hilbert20: 23.5-25.7ns 0.8-0.8m
low3hilbert21: 24.6-26.8ns 0.8-0.9m
low3hilbert22: 25.5-27.8ns 0.8-0.9m
low3hilbert23: 26.5-28.7ns 0.9-0.9m
low3hilbert24: 27.6-29.8ns 0.9-1.0m
low3hilbert25: 28.6-30.8ns 0.9-1.0m
low3hilbert26: 29.5-31.8ns 1.0-1.0m
low3hilbert27: 30.6-32.8ns 1.0-1.1m
low3hilbert28: 31.6-33.8ns 1.0-1.1m
low3hilbert29: 32.5-34.8ns 1.1-1.1m
low3hilbert30: 33.6-35.9ns 1.1-1.2m
low3hilbert31: 34.6-36.8ns 1.1-1.2m
low3hilbert32: 35.7-37.9ns 1.2-1.3m
low3hilbert33: 36.6-38.9ns 1.2-1.3m
low3hilbert34: 37.6-39.9ns 1.2-1.3m
low3hilbert35: 38.7-40.9ns 1.3-1.4m
low3hilbert36: 39.7-41.9ns 1.3-1.4m
y (m)
x (m)
0.0
2.0
4.0
6.0
8.0

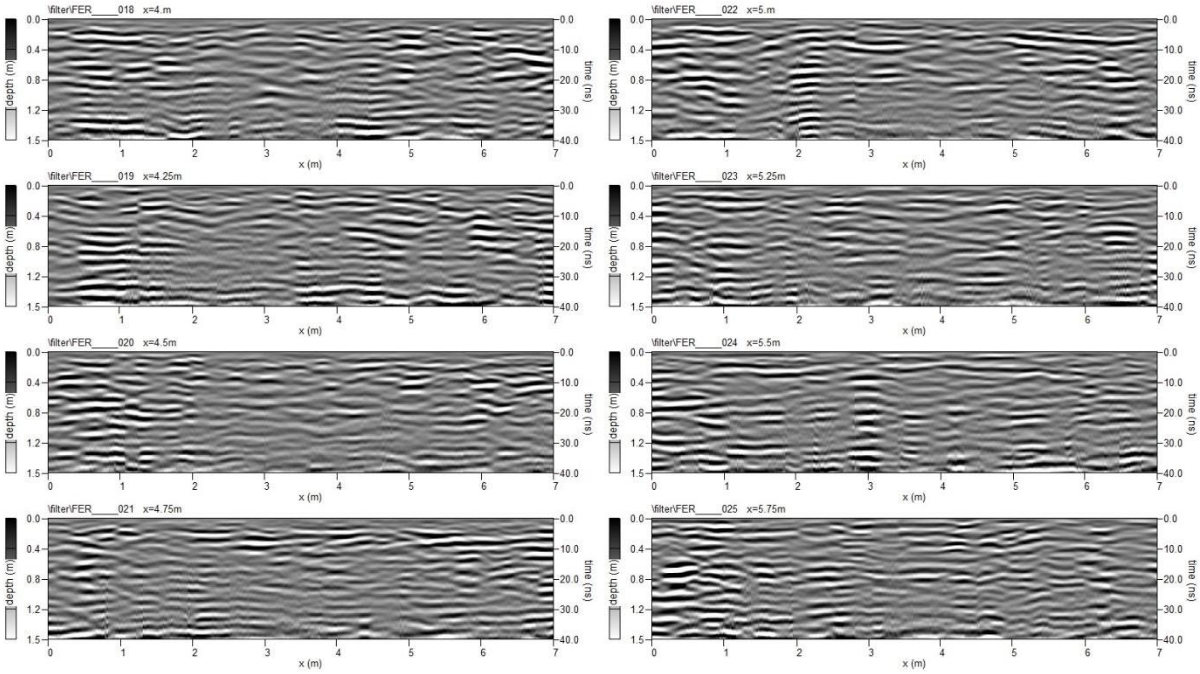
6.6 GPR profiles

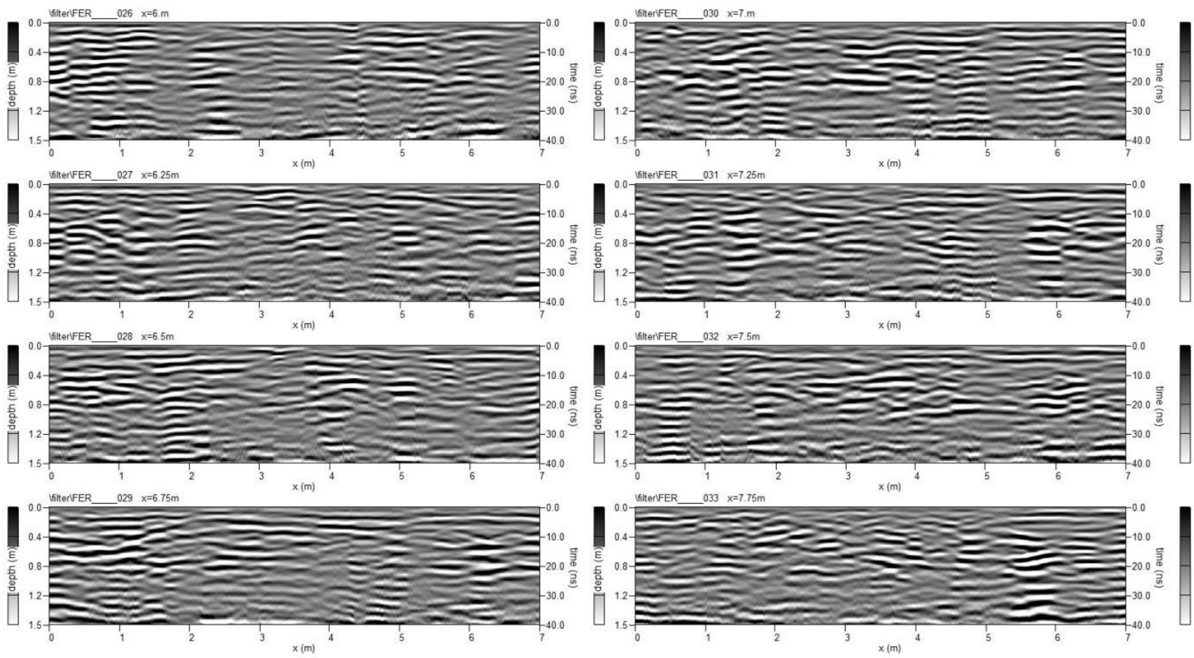
6.6.1 Radar profiles from GPR 1 Area

Presented radargram profiles are processed and filtered through bandpass (approx. 100 - 700 Mhz) and background removal, but before migration and Hilbert transform, which were used for the depth slices.






\filter\FER_____018 x=4.m
\filter\FER_____019 x=4.25m
\filter\FER_____020 x=4.5m
\filter\FER_____021 x=4.75m
\filter\FER_____022 x=5.m
\filter\FER_____023 x=5.25m
\filter\FER_____024 x=5.5m
\filter\FER_____025 x=5.75m
depth (m)
time (ns)
x (m)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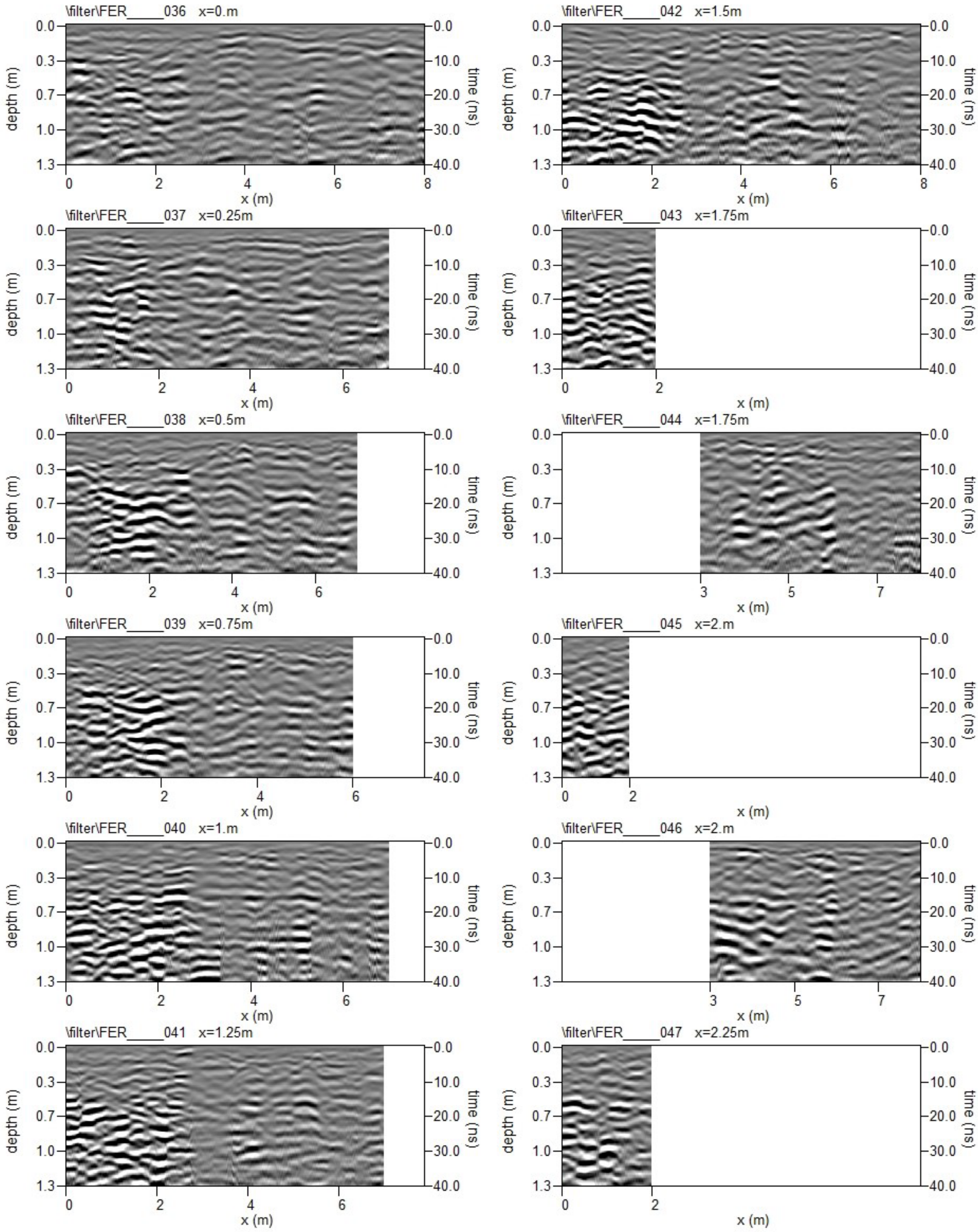
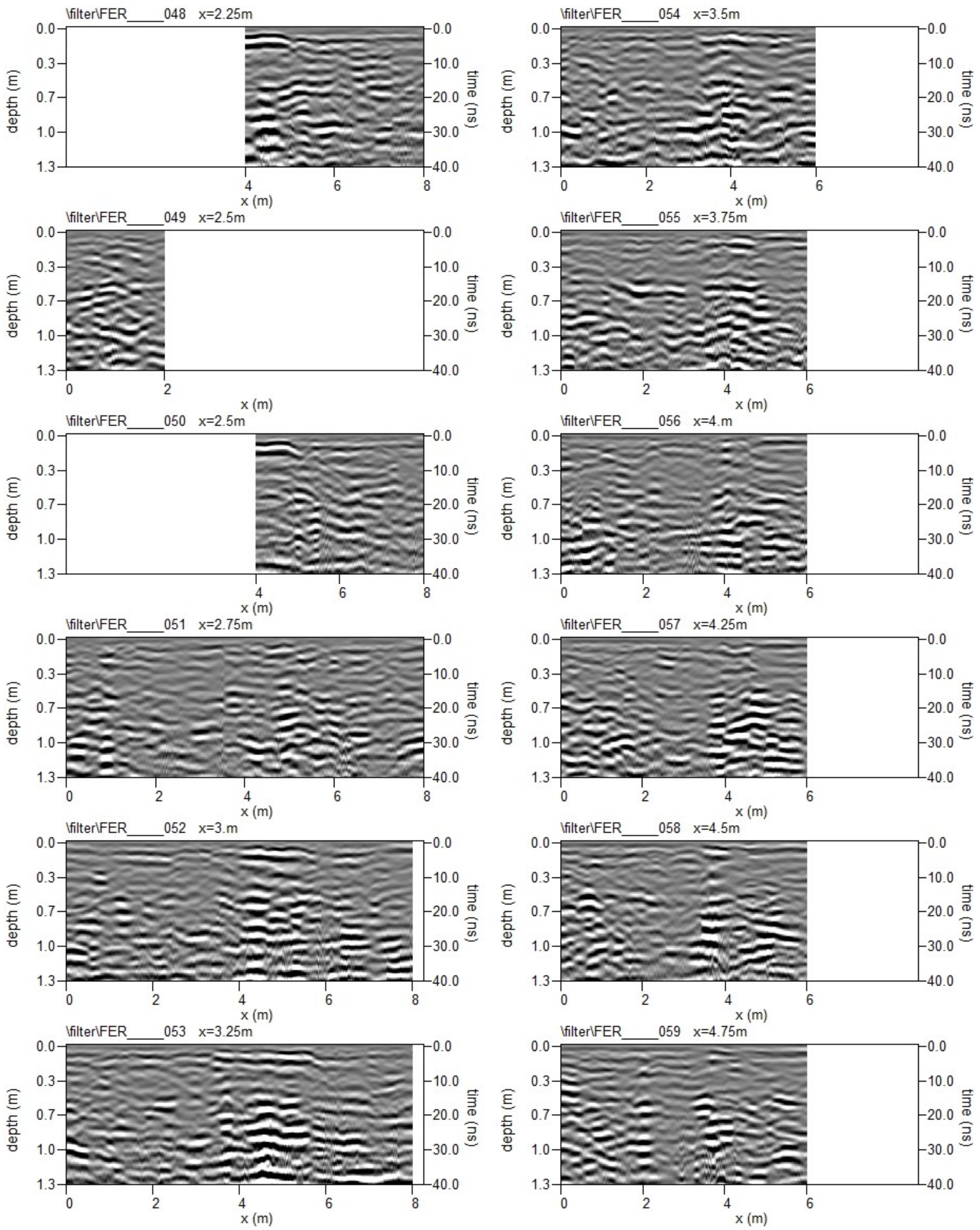
\filter\FER_____027 x=6.25m
\filter\FER_____028 x=6.5m
\filter\FER_____029 x=6.75m
\filter\FER_____030 x=7.m
\filter\FER_____031 x=7.25m
\filter\FER_____032 x=7.5m
\filter\FER_____033 x=7.75m
depth (m)
time (ns)
x (m)

6.6.2 Radar profiles from GPR 2 Area

Presented radargram profiles are processed and filtered through bandpass (approx. 100 - 700 Mhz) and background removal, but before migration and Hilbert transform, which were used for the depth slices.




\filter\FER_____048 x=2.25m
\filter\FER_____049 x=2.5m
\filter\FER_____050 x=2.5m
\filter\FER_____051 x=2.75m
\filter\FER_____052 x=3.m
\filter\FER_____053 x=3.25m
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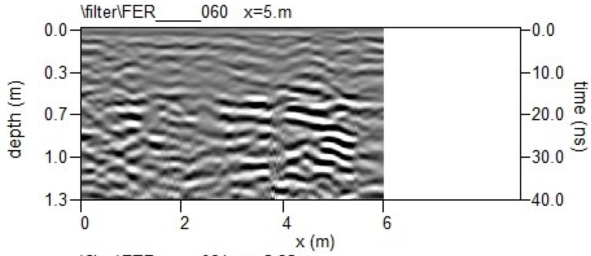
time (ns)
x (m)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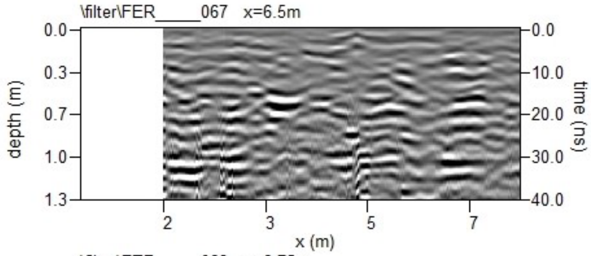
depth (m)
time (ns)
x (m)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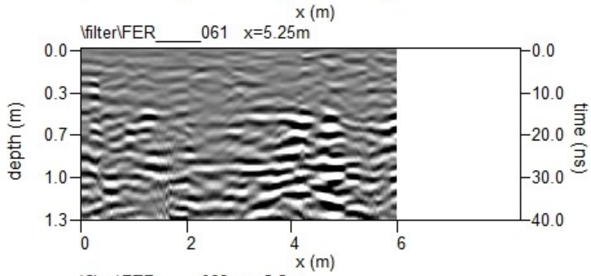
depth (m)
time (ns)
x (m)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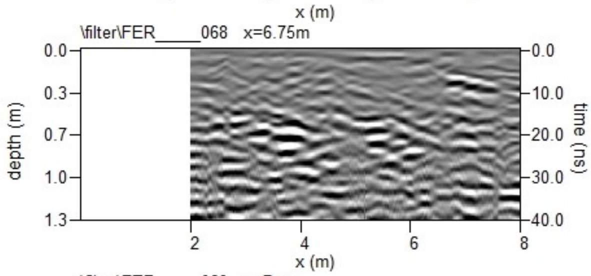
depth (m)
time (ns)
x (m)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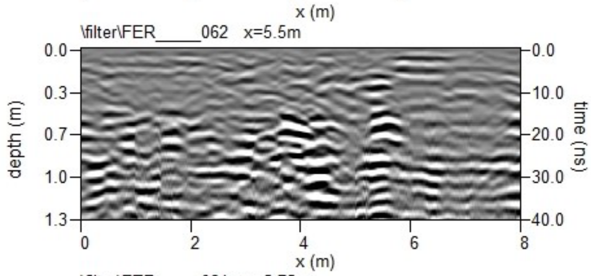
depth (m)
time (ns)
x (m)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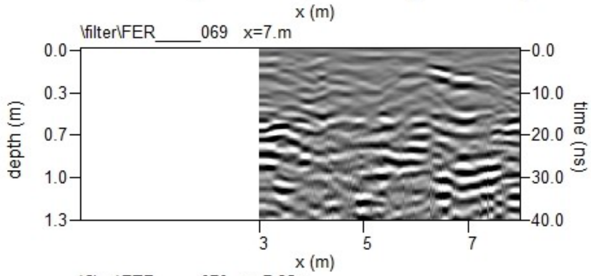
time (ns)
x (m)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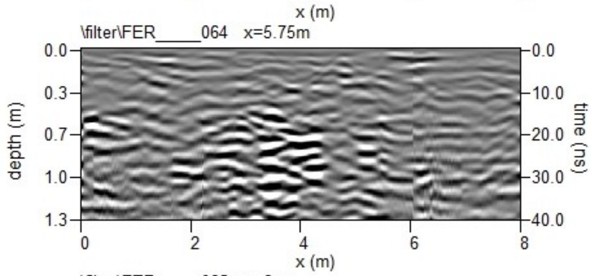
time (ns)
x (m)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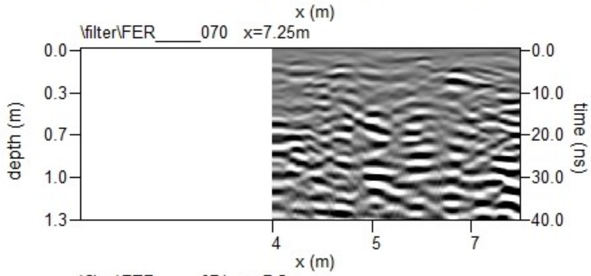
depth (m)
time (ns)
x (m)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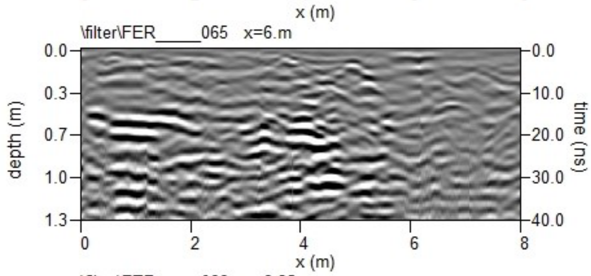
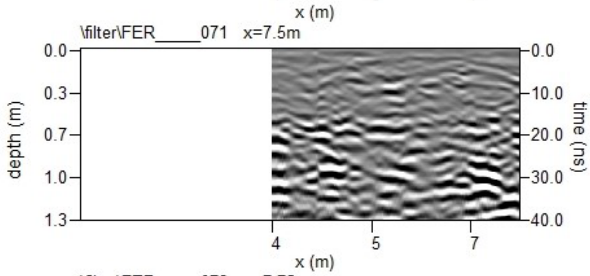
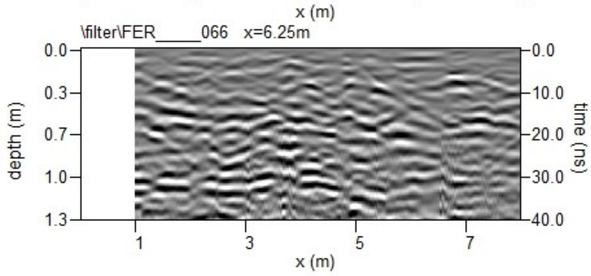
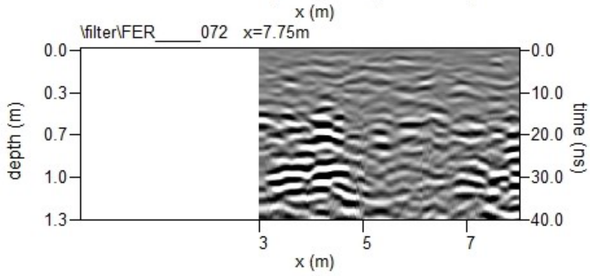
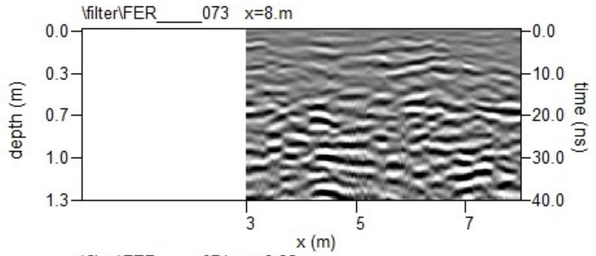
time (ns)
x (m)

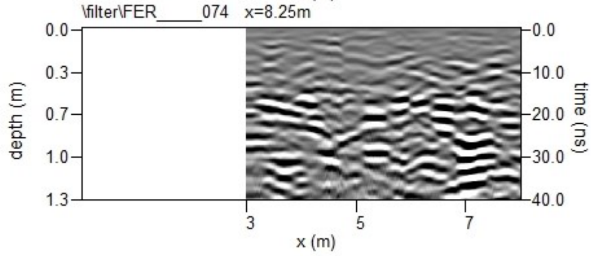

\filter\FER_____065 x=6.m
depth (m)
time (ns)
x (m)


\filter\FER_____071 x=7.5m
depth (m)
time (ns)
x (m)


\filter\FER_____066 x=6.25m
depth (m)
time (ns)
x (m)

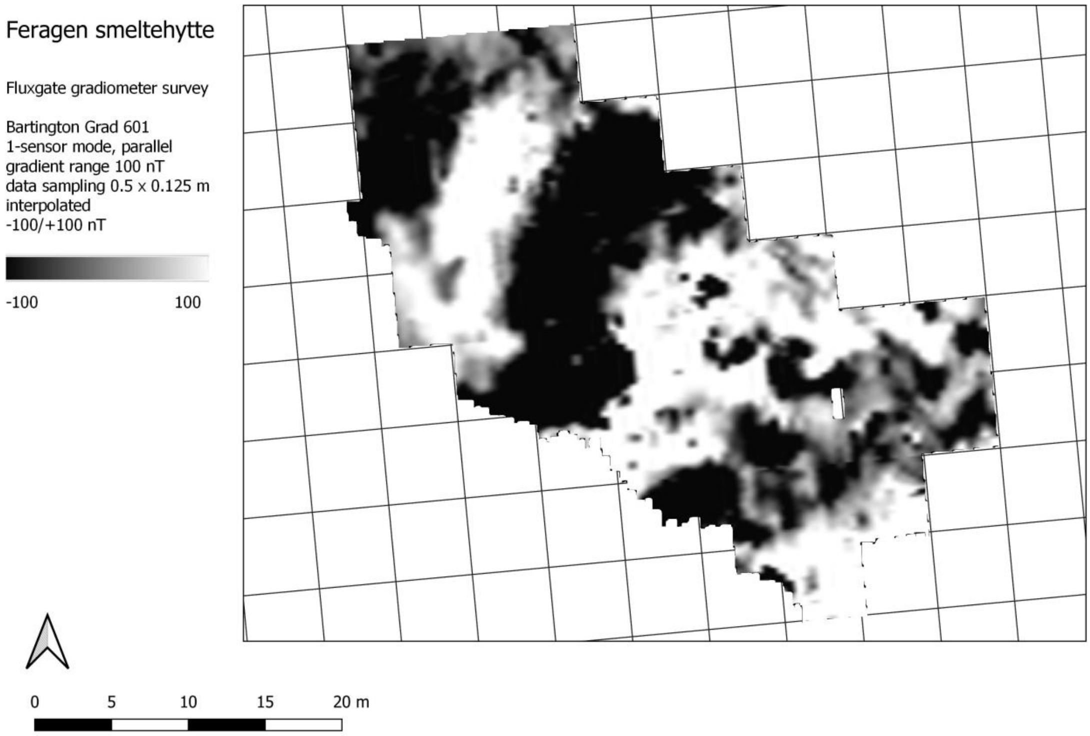

\filter\FER_____072 x=7.75m
depth (m)
time (ns)
x (m)



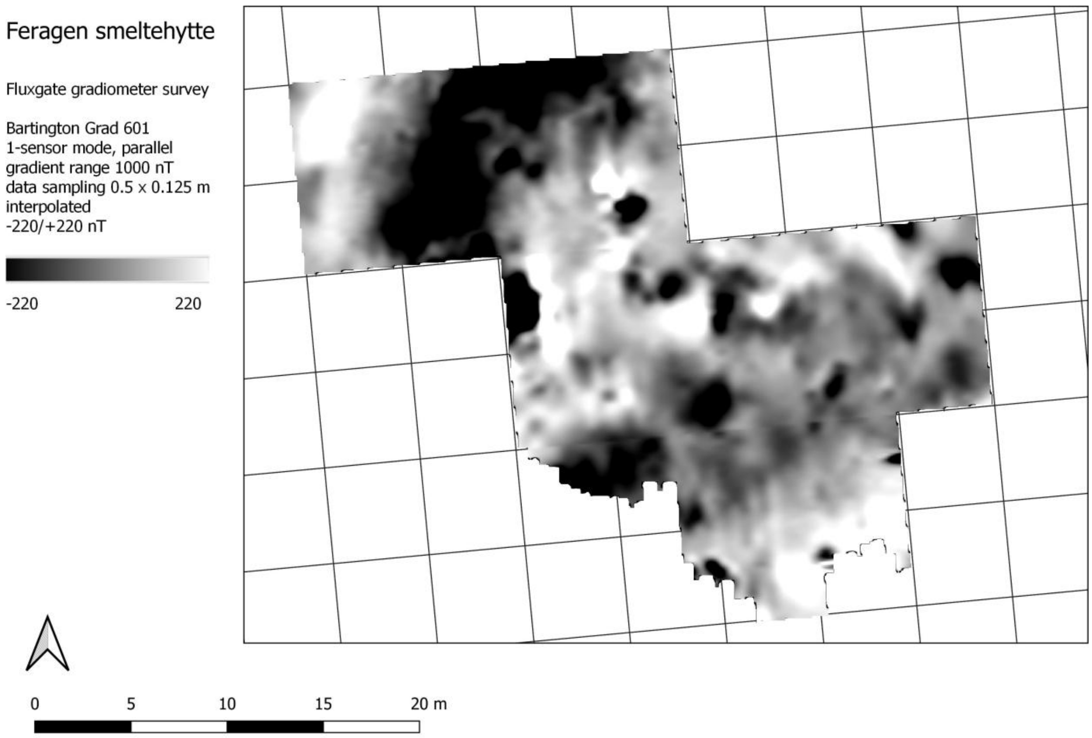


6.5 Magnetic gradiometer survey results without background picture

6.5.1 100 nT gradient range



6.5.2 1000 nT gradient range



6.6 Photos from the survey area

Bartington Grad601 Fluxgate Gradiometer in camouflage

GPR 1 area and the pit, towards NE

GPR 1 area and the pit, towards W

GPR 2 area, view towards SE

GPR 2 area, view towards SW

Middle part of the site, the slope, the wooden trough, GPR areas 1 and 2, view towards NE

Middle part of the site, view from the foot of the slope down from the farm towards SE, slag mound in the background behind the first line of trees

MS area, SE bank of the river, photo 1

MS area, SE bank of the river, photo with view on the slag mound

SE part of the site and the slag mound

SE part of the site, view towards SW

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