

Krzysztof Kiersnowski, Arne Anderson Stamnes

Ground-penetrating radar investigations of the surroundings of Dolm Kirke, Dolmøy, Hitra Municipality

NTNU Vitenskapsmuseet
arkeologisk rapport 2023-13



NTNU Vitenskapsmuseet arkeologisk rapport 2023:13

Krzysztof Kiersnowski and Arne Anderson Stamnes

Ground-penetrating radar investigations of the surroundings of Dolm Kirke, Dolmøy, Hitra Municipality

NTNU Vitenskapsmuseet arkeologisk rapport

Dette er en elektronisk serie fra 2014. Serien er ikke periodisk, og antall nummer varierer per år. Rapportserien benyttes ved endelig rapportering fra prosjekter eller utredninger, der det også forutsettes en mer grundig faglig bearbeidelse.

Tidligere utgivelser: <http://www.ntnu.no/vitenskapsmuseet/publikasjoner>

Referanse

K. Kiersnowski and A. A. Stamnes 2023: NTNU Vitenskapsmuseet arkeologisk rapport 2023:13.
Ground-penetrating radar investigations of the surroundings of Dolm Kirke, Dolmøy, Hitra Municipality

Trondheim, Februar 2023

Utgiver

NTNU Vitenskapsmuseet
Institutt for arkeologi og kulturhistorie
7491 Trondheim
Telefon: 73 59 21 45
e-post: postmottak@museum.ntnu.no

Ansvarlig signatur

Bernt Rundberget (instituttleder)

Kvalitetssikret av

Ellen Grav Ellingsen (serieredaktør)

Publiseringstype

Digitalt dokument (pdf)

Forsidefoto

GPR, surveyed area and Dolm Kirke's wall.

www.ntnu.no/vitenskapsmuseet

ISBN 978-82-8322-364-4

ISSN 2387-3965

Sammendrag

K. Kiersnowski and A. A. Stamnes 2023: NTNU Vitenskapsmuseet arkeologisk rapport 2023:13. Ground-penetrating radar investigations of the surroundings of Dolm Kirke, Dolmøy, Hitra Municipality

Formålet med georadar-undersøkelsene ved Dolm kirke var å undersøke arealet nord for koret og skipet, og avklare hvorvidt det var noen konstruksjonsspor i bakken i dette området. Det er en del konstruksjonsdetaljer i kirkeveggen, og da spesielt nord for koret på kirka, som kan antyde at bygningen har hatt en utvidelse her en gang tidligere. Undersøkelsene viste en konsentrasjon av utslag i den nordvestre ende av kirka, med flere strukturer som kan tolkes som større steinobjekter eller groper eller steinopptrekk fra fjerning av denne typen objekter. Derimot, når man setter de innsamlede profilene sammen til et planbilde av utslag ved ulike dybder, kommer det ikke frem noen linjer eller former som klart indikerer noen konkrete konstruksjonsspor. Det nærmeste en kommer er en nesten rektangulær struktur på ca. fire ganger fire meter, og en to ganger 5 meter nesten lineær form synlig i dybdeskivene. Undersøkelsen viser også mulig plassering av flere umerkede graver i det åpne arealet mellom dagens kirkevegg og steingjerdet i nord.

Stikkord: georadar – romansk kirke – middelalder – steinmur - kirkegård

Arne Anderson Stamnes og Krzysztof Kiersnowski, NTNU Vitenskapsmuseet, Institutt for arkeologi og kulturhistorie, NO-7491 Trondheim

Summary

K. Kiersnowski and A. A. Stamnes 2023: NTNU Vitenskapsmuseet arkeologisk rapport 2023:13. Ground-penetrating radar investigations of the surroundings of Dolm Kirke, Dolmøy, Hitra Municipality

The survey at the Dolm Kirke surroundings was undertaken in order to examine the area for possible existence of construction remains indicated by stones sticking out from the church's wall. The investigations results showed a concentration area located by the northwestern end of the church with several features that could easily be interpreted as rather large stony objects or pits created after removing of such stones. However, in the planar view these structures do not form lines or forms that would clearly indicate construction remains. The closest to it is a four by four meter nearly-rectangular and a two by five meter nearly-linear shapes visible in depth slices. The survey also shows possible location of several unmarked graves in the open area between the church's wall and the stone fence.

Keywords: ground penetrating radar – romanesque church – middle ages – stone wall – churchyard –

Arne Anderson Stamnes and Krzysztof Kiersnowski, NTNU University museum, Department of archaeology and cultural history, NO-7491 Trondheim

Archival references

K. Kiersnowski and A. A. Stamnes 2023: NTNU Vitenskapsmuseet arkeologisk rapport 2023:13.
Ground-penetrating radar investigations of the surroundings of Dolm Kirke, Dolmøy, Hitra Municipality

AskeladdenID 84027
Saksnummer (ePhorte) 2022/52133

Fylke	Trøndelag
Kommune	Hitra
Gårdsnavn	Dolm Prestegård
Gårdsnummer	gnr. 20/bnr 1, Dolm
Lokalitet	Dolmøy - Dolm Kirke
Kulturminnetype	Kirkested
Datering	Middelalder

Innhold

- 1. Background8
 - 1.1 Area Description8
 - 1.2 Cultural-Historical Background.....9
- 2. Survey framework9
 - 2.1 Time and collaborators9
 - 2.2 Aims and objectives.....10
 - 2.3 Method10
 - 2.3.1.Data Collection – methodological approach.....10
 - 2.3.2 Geographical Information System (GIS) and documentation.....12
- 3. Observations, interpretations and discussion12
- 4. Conclusions.....18
- 5. Literature19
- 6. Appendix – extra maps, technical info, all depth slices and radar profiles, and photos from the survey20

Figurliste

- Figure 1: Approximate area to be investigated8
- Figure 2: View at the church's wall with the visible stones standing out from the wall.....9
- Figure 3: GSSI-SIR 3000 GPR system paired with 400 MHz antenna11
- Figure 4: The results of the GPR survey visible at the 0.30 - 0.40 m depth slice.12
- Figure 5: Profile number 7 with the 0.40-0.50 m depth slice13
- Figure 6: Depth slice of 0.30 - 0.40 m depth.....14
- Figure 7: Profile number 3 with the 0.60 m depth slice.....14
- Figure 8 : Profile number 18 with the 0.30 - 0.40 m depth slice15
- Figure 9 : Profile number 23 with the 0.30 - 0.40 m depth slice16
- Figure 10 : Profile number 39 with the 0.30 - 0.40 m depth slice17

1. Background

The survey was done on behalf of the Museums of Southern Trøndelag (MIST – Museene i Sør-Trøndelag), and more specifically for The Coastal Museum of Southern Trøndelag (Kystmuseet i Sør-Trøndelag). Their contact was Jørgen Fjellvær, Museum Director. The aim of the survey was to investigate the north side of the Church, where protruding stones in the church-wall might indicate some form of previous attachment to the existing church (see Figure 2). A Ground-Penetrating Radar survey was considered ideal for investigating the presence of any previously unknown subsoil features in this particular area, and in particular possible unknown graves and stone walls.

1.1 Area Description

Dolm Kirke is a Romanesque-style stone church designed in the long church layout with thick walls. It is located on the southwestern part of Dolmøy Island, between islands Hitra and Frøya. The region assigned for the GPR examination is situated between the northern church's wall and a stone fence that marks the northern boundary of the church's land. The eastern border of the investigated section was marked by a line of gravestones. Within the area, there were two gravestones that could be easily navigated around. The area is level, gently sloping from the fence towards the church, and covered in grass, although there was a 3-5 centimeter layer of snow during the survey.



Figure 1: Approximate area to be investigated



Figure 2: View at the church's wall with the visible stones standing out from the wall

1.2 Cultural-Historical Background

The Dolm Church history is well investigated and documented. The exact age of the church is still discussed, and maybe have been either when the church site of Undås was abandoned around the 13th century, or it might have been built in the mid- to late 15th century, but the origin is still not certain. The church was dedicated to St Colbanus. The church has been damaged several times throughout the 17 and early 18th century, and was totally destroyed by fire after a lightning strike in 1848, rebuilt in 1849, and damaged again by yet another lightning strike in 1920. Only the southern portal contains shaped soapstone elements. The rest of the church is built by coarse stones (Kulturminnesøk – askeladden id. 84027).

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 main parts of the report. The work was undertaken under supervision 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 was undertaken on behalf

of The Coastal Museum of Southern Trøndelag (Kystmuseet i Sør-Trøndelag), which is a part of the Museums of Southern Trøndelag (MIST – Museene i Sør-Trøndelag). Their contact was Jørgen Fjellvær, Museum Director.

The survey at Dolm Kirke was carried out on the 13th of December 2022 in temperatures of around -10 to -13 Celsius degrees with a bit of snow cover laying on the surface and surprisingly little wind.

2.2 Aims and objectives

The purpose of the survey was to determine whether any construction remains related to the church existed. Notably, stones protruding from the northeastern part of the church's wall suggest a possible pre-existing extension of the building in a perpendicular orientation. The ground-penetrating radar (GPR) survey aimed to investigate the surrounding area of the church for any possible traces of construction remains.

2.3 Method

2.3.1. Data Collection – methodological approach

The investigations were undertaken in form of 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.

Ground-penetrating radar 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 (Lawrence B. Conyers, 2012; Larry B. Conyers, 2013). The frequency of the antenna determines the depth of penetration and resolution of the image, while the system processes and records the data. Such ground-penetrating radar survey was conducted at Dolm Kirke northern surroundings. The purpose of this survey was to gather subsurface information and identify any potential archaeological features, with emphasis on possible construction traces of stone walls in the perpendicular direction indicated by the stones standing out from the church's northern wall.

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 of approximately 2 meters.

The survey was carried out over flat and open area in parallel orientation to the church's northern wall, and limited by the stone wall delimiting the church zone. The starting line for the profiles at the eastern edge of the survey area was shaped due to the existing gravestones. The survey covered approximately 250 sq. m. (Fig. 3).



Figure 3: GSSI-SIR 3000 GPR system coupled with 400 MHz antenna during the survey at Dolm Kirke

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.

In this report, we will operate with two concepts - radargram profiles and depth slices. The first ones are the closest to the raw data information images. They show what could be compared to a profile section from archaeological excavations, but through the prism of GPR waves' reflectiveness. The second concept - depth slices, are showing a planar view of desired depth based on merged and processed radargram profiles. Roughly comparing to the excavations example - depth slice of 0.40 m is as if a mechanical layer of 40 centimeters from the surface was removed on the whole area at the same time. And again - what we see in these pictures, is what electromagnetic waves produced and received by a 400 MHz GPR antenna 'see'.

Dolm Kirke
Dolmøy, Hitra kommune
GPR Survey
GSSI-SIR 3000
400 MHz antenna
Hilbert transform data
Depth slice 0.30 - 0.40 m

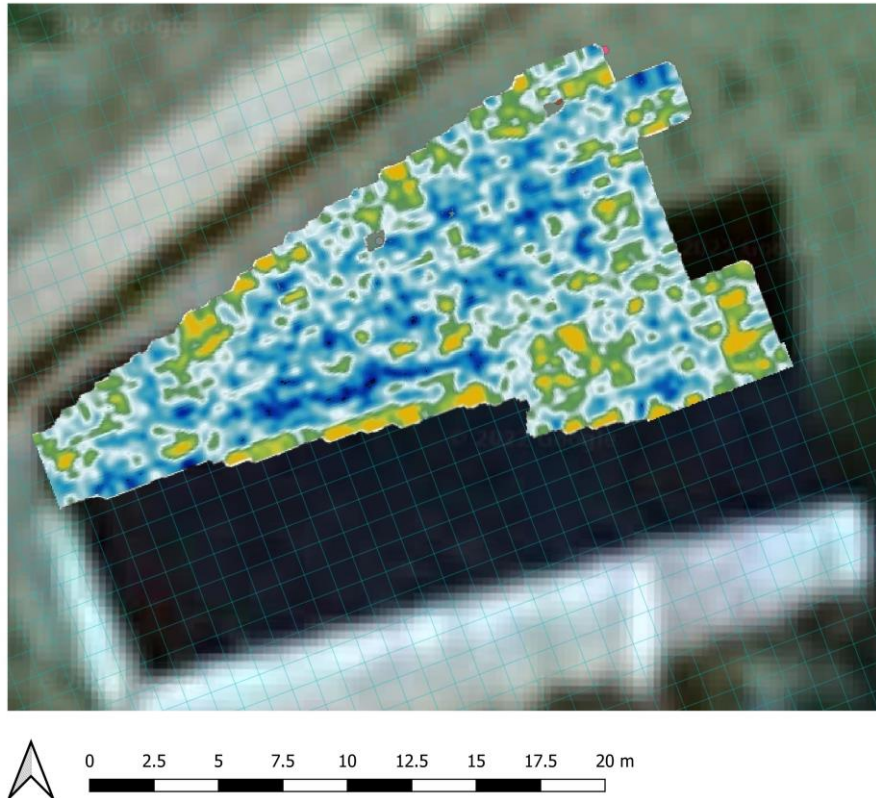


Figure 4: The results of the GPR survey visible at the 0.30 - 0.40 m depth slice.

2.3.2 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 accuracy and precision of the collected data.

All the results of the surveys were assembled and processed into figures in QGIS 3.22 software.

3. Observations, interpretations and discussion

Southeastern part of the investigated area, close to the church, where construction remains were expected to be found, shows indeed a number of features possibly related to construction activity. These features are densely located and vary with their response to the GPR waves. Some of them are highly-reflective and could be interpreted as stones or rocks, while other structures, creating different responses, could be possibly interpreted as pits. That area measures about 5.5 by 8 meters, which is around 55 square meters - a size is similar to the existing narrower, northeastern part of the church (apse). This is a possible indication of former existence of a construction there - a nave of the the church or a belfry?

Although the described area seems to show more activity, in comparison to the rest of the investigated area, and the described features are likely to interpret as construction remains, they do not form lines or forms that could delineate a clear interpretation of former existence of walls, especially thick ones as in romanesque-style. Below, several chosen features are presented.

Dolm Kirke
 Dolmøy, Hitra kommune
 GPR Survey
 GSSI-SIR 3000
 400 MHz antenna
 Hilbert transform data

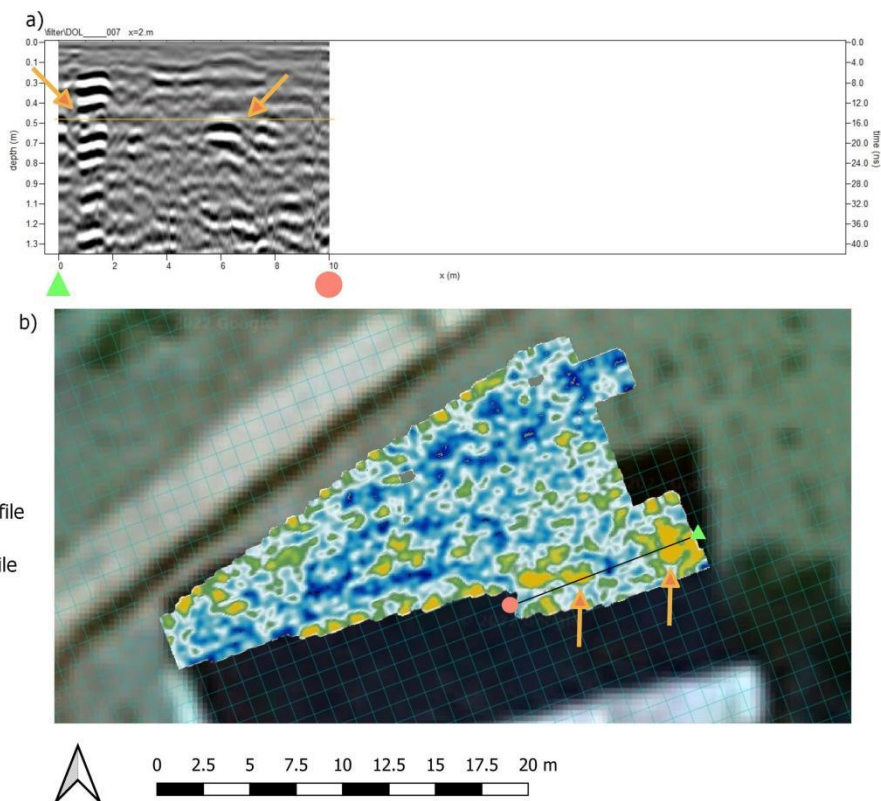


Figure 5: Profile number 7 with the 0.40-0.50 m depth slice showing features possibly related to construction activity

Profile number 7 (Fig. 5) shows a cross section through the described area. In two ends of that area there are highly-reflective features of approximately 1 meter in width, possibly interpreted as the remains of a stone wall or other type of construction. The one located on the eastern edge (on the left side of the radargram section) is visible from a depth of about 0.20 meter to 0.50 or possibly even 0.80 meter. It is also possible to trace a pit or other type of soil disturbance around the reflective feature to a depth of about 0.40 meter. In the western 'limit' of the busy area, a similar pit or another interruption can be traced, with a width of approximately 1.6 to 1.8 meter and about 0.45 meter deep. Underneath it, there is the beforementioned highly-reflective feature, about 1 meter wide and at a depth of ca. 0.45 to 0.75 meter. Also, further west from it (to the right in the radargram), there's possibly another pit, 2 meters wide. The interpretation of these could be the remains of a wall, or a pit created after removal of the wall stones, wholly or partially. However, this picture is not as clear in other neighbouring GPR sections, so it does not create a clear linear structure precisely showing whether the wall remains are present or not. Nevertheless, the example of the profile number 7 is a strong indication of an activity likely connected to the construction of the church. Perhaps the depth slice 0.30-0.40 meter (Fig. 6) can deliver the most suggestive picture of a possible nearly-linear 2 by 5 meter and a nearly-rectangular 4 by 4 meter features, oriented in the desired direction (perpendicular to the church's wall).


Dolm Kirke
Dolmøy, Hitra kommune

GPR Survey

GSSI-SIR 3000
400 MHz antenna
Hilbert transform data

Depth slice 0.30 - 0.40 m



 Interpretation of possible construction remains

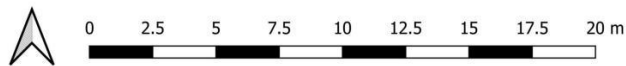
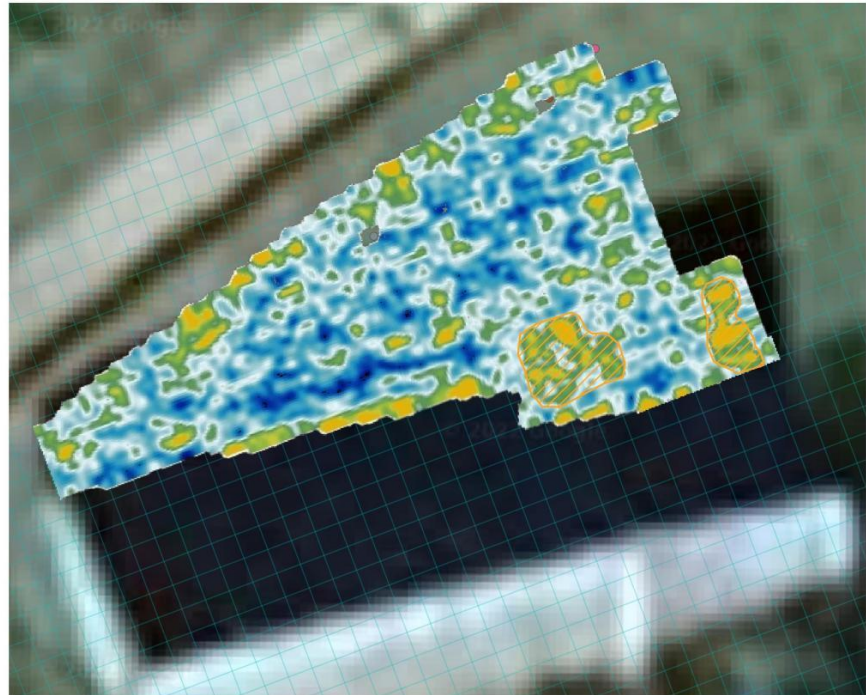
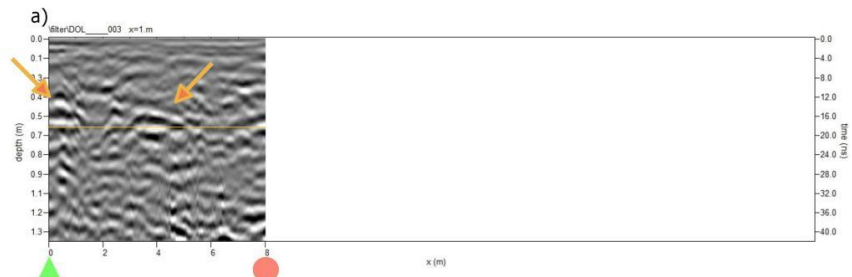


Figure 6: Depth slice of 0.30 - 0.40 m depth with interpretation of possible construction remains

Dolm Kirke
Dolmøy, Hitra kommune

GPR Survey


GSSI-SIR 3000
400 MHz antenna
Hilbert transform data



a) Unmigrated GPR transect no. 3

b) Depth slice 0.60 - 0.60 m



 starting point of the profile

 ending point of the profile

 described features

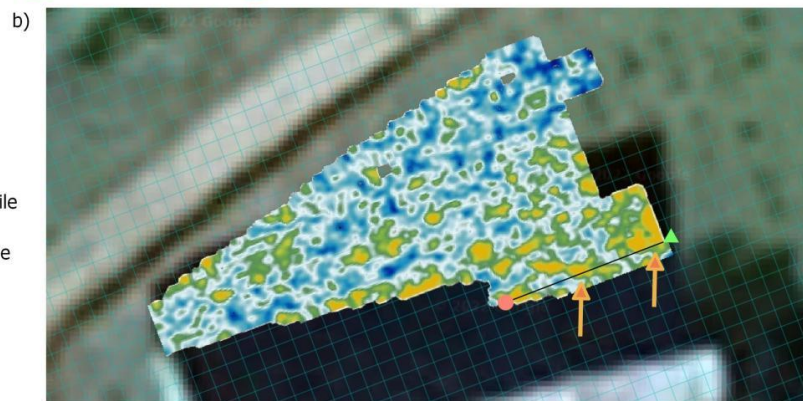


Figure 7: Profile number 3 with the 0.60 m depth slice showing features possibly related to construction activity

The profile number 3 (Fig. 7) shows again a similar type of structure. In the middle part of it, there is a feature that could be interpreted as a rock with relatively flat top or a pit filled-up with material type that is less water-absorbent than the surrounding soil (presence of water in the buried material increases propagation of gpr waves). Both options would match the construction concept, especially the width of that structure is around 1 meter. However, the location does not match with any of the known wall plots. As pictured in the depth slice, it is rather a separated feature, or possibly connected with two other similar features, but in a diagonal orientation (relating to the church's walls orientation) - in which case it could be interpreted as a ditch. The second marked feature in the radargram 3, close to its starting point, is very likely a stony object.

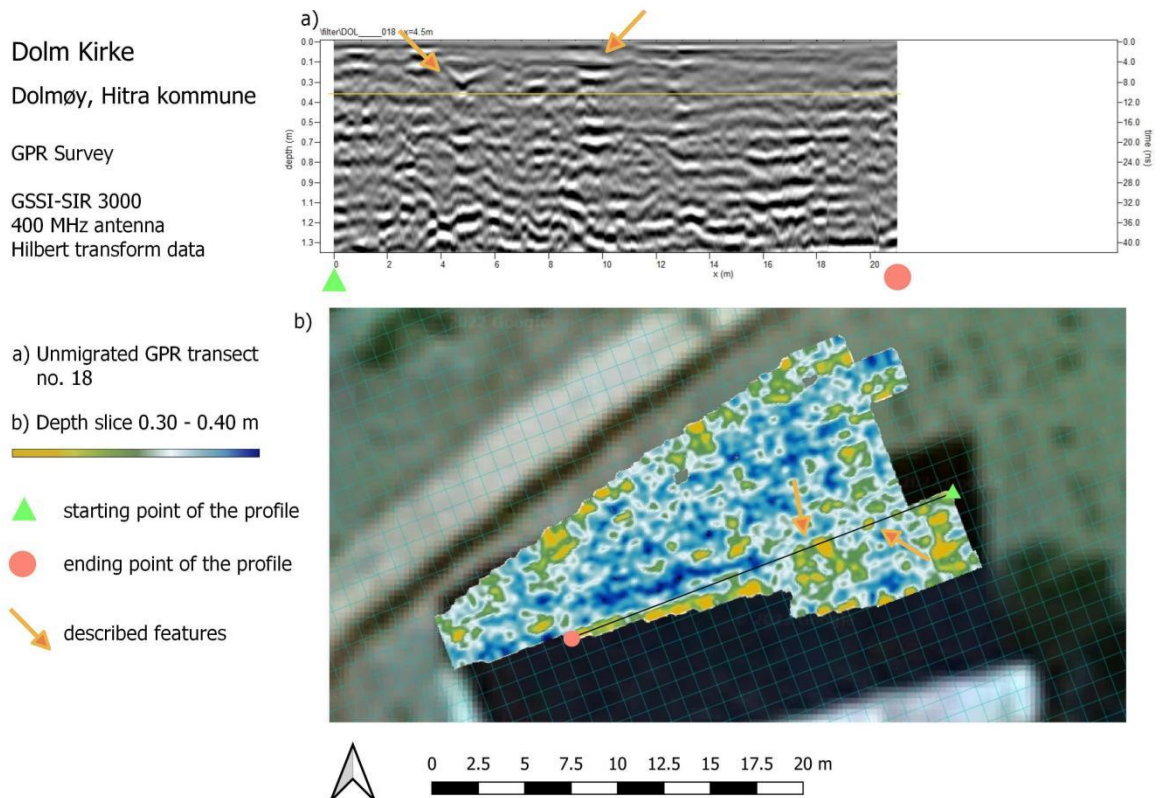
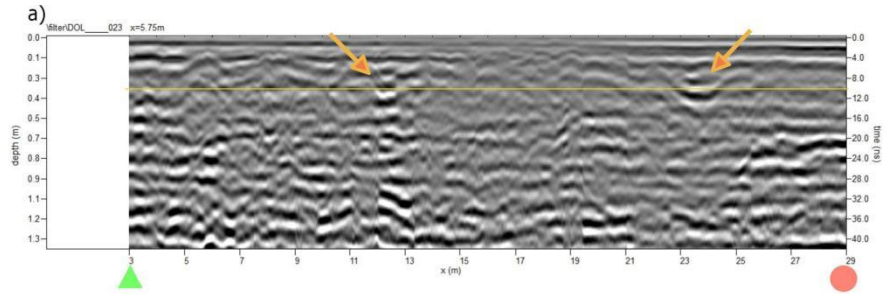


Figure 8: Profile number 18 with the 0.30 - 0.40 m depth slice showing features possibly related to construction activity

Profile 18 (Fig. 8), located on the edge of the described area of increased activity, shows another two interesting objects. First of them (one more to the east, left arrow in the radargram) is cone-shaped with almost pointy bottom part that has a highly-reflective object in it. Possible interpretation of such looking features is often a posthole. The second structure is almost 4 meters wide and consist of many interruptions and changes of GPR waves' propagation. This type of feature is often difficult to interpret, however in this case, it seems to match with/overlap the northern edge of the nearly-rectangular object marked in the Figure 6. Both of the objects marked in the profile 18 are located on a very similar depth, which can indicate similar origin.




Dolm Kirke
 Dolmøy, Hitra kommune
 GPR Survey
 GSSI-SIR 3000
 400 MHz antenna
 Hilbert transform data



a) Unmigrated GPR transect no. 23

b) Depth slice 0.30 - 0.40 m



-  starting point of the profile
-  ending point of the profile
-  described features

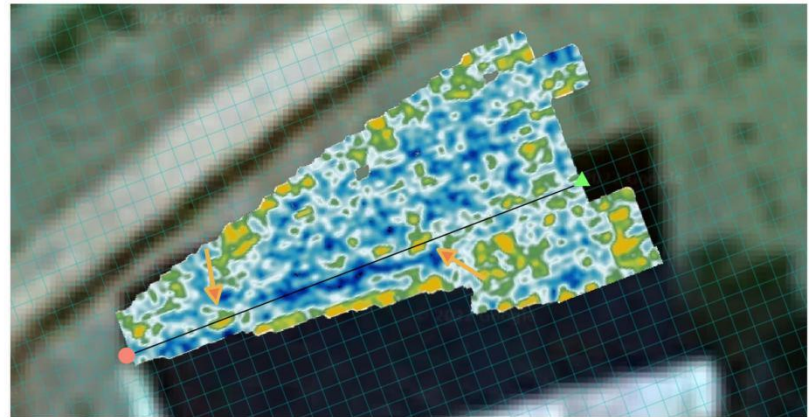
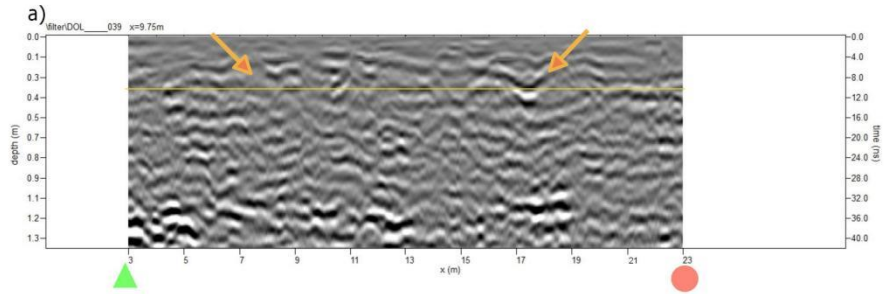


Figure 9: Profile number 23 with the 0.30 - 0.40 m depth slice pointing other objects, possibly interpreted as graves

In the next two profiles - 23 and 39 (Fig. 9 and 10), several singular objects were recorded. They are located separately and seem not to be related with other features. Their geophysical character fits closely a pit definition, which in the context of the area's location could indicate presence of unmarked graves.




Dolm Kirke
 Dolmøy, Hitra kommune
 GPR Survey
 GSSI-SIR 3000
 400 MHz antenna
 Hilbert transform data



a) Unmigrated GPR transect
 no. 39

b) Depth slice 0.30 - 0.40 m



-  starting point of the profile
-  ending point of the profile
-  described features

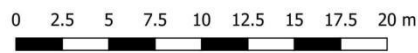
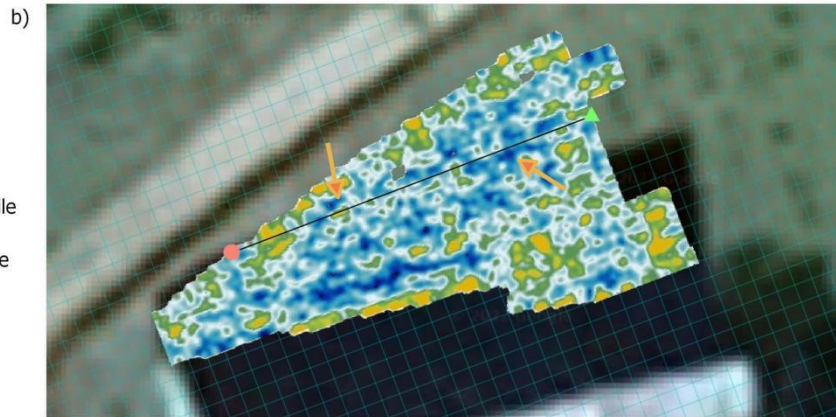


Figure 10: Profile number 39 with the 0.30 - 0.40 m depth slice pointing other objects, possibly interpreted as graves

4. Conclusions

The results of ground-penetrating radar investigation of Dolm Kirke northern surroundings, clearly show an area of ca. 5.5 by 8 meters, located just by the northwestern wall of the church, as an area of increased activity. It is within the potential area where former construction remains would be expected. The area contains a number of features characterized by high-reflectivity, which may indicate presence of stones or other type of structures filled with material which decreases gpr waves' propagation, potentially a secondary fill of pits created after removal of construction stones. Although the character of the features described below would indicate presence of construction remains in that area, the depth slices do not provide an image that would very clearly show a linear feature easily interpreted as remains of a wall. At best, the depth slice of 0.30 - 0.40 m provides an image with a nearly-rectangular 4 by 4 meter and a nearly-linear 2 by 5 meter features within the main activity area.

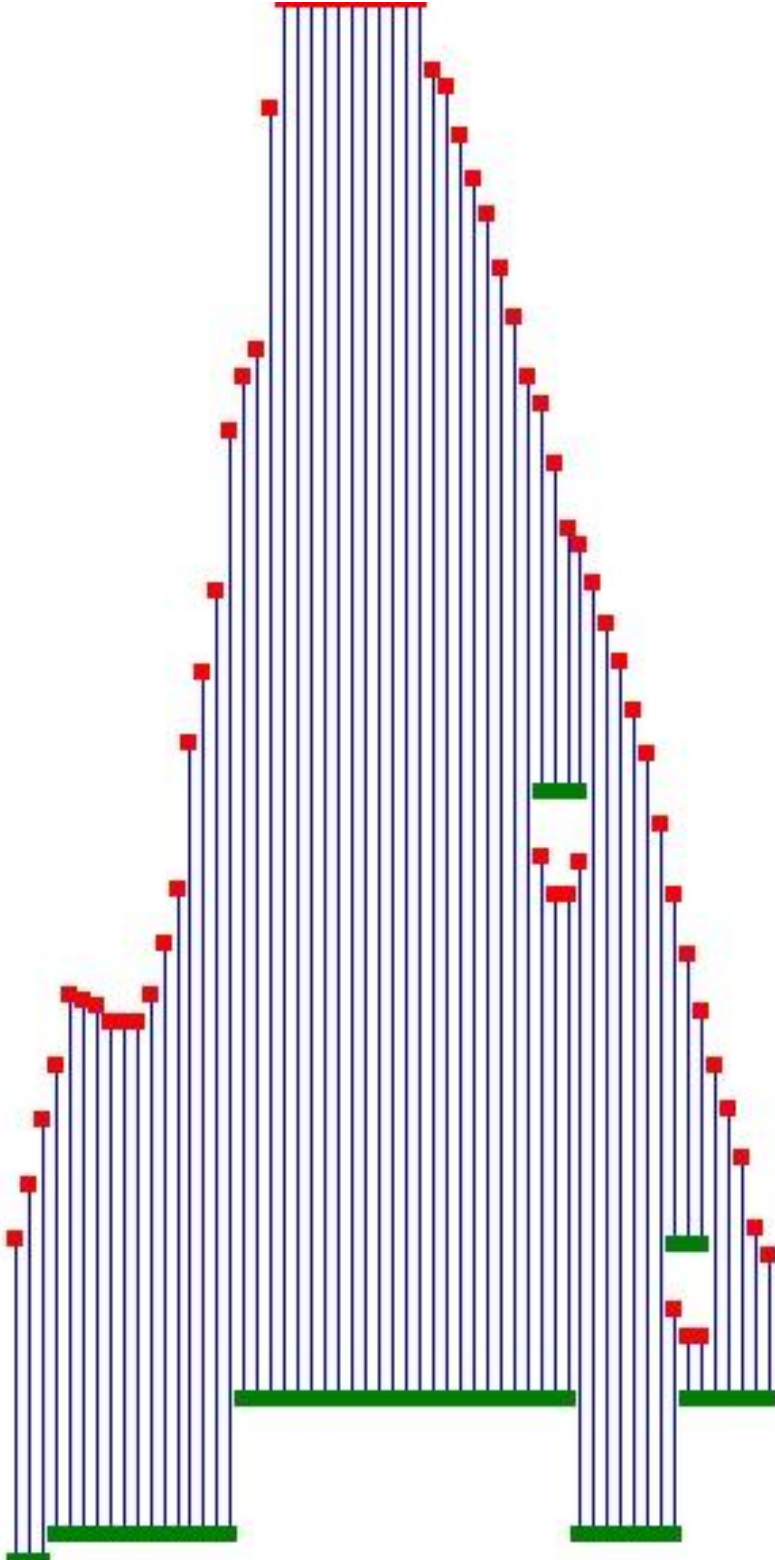
The rest of the investigated area delivers a location of likely several graves that were unmarked, or just structures interpreted as pits.

5. Literature

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

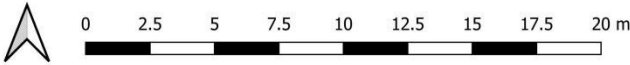
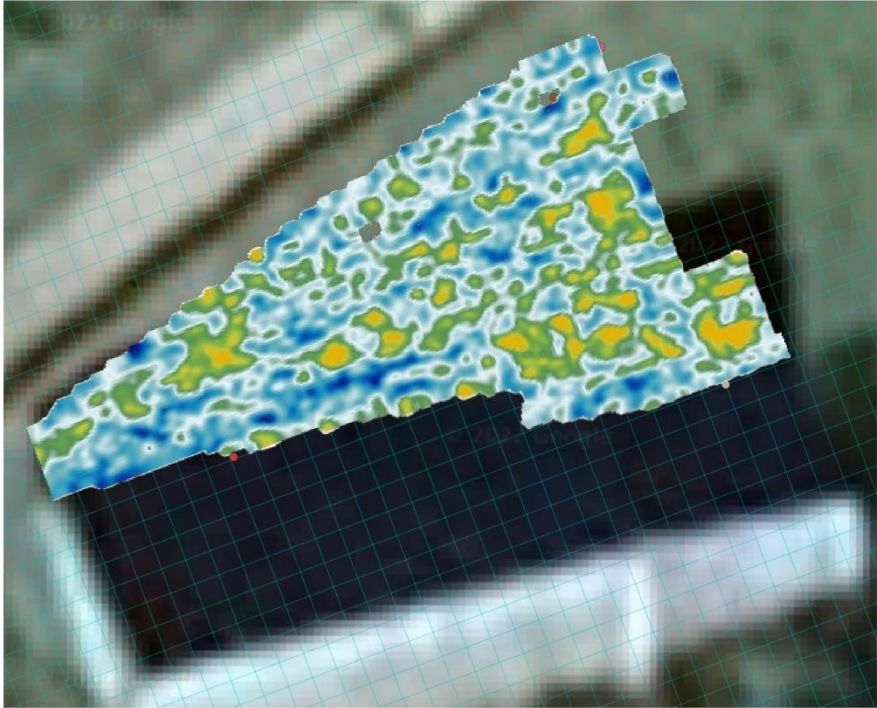
6. Appendix – extra maps, technical info, all depth slices and radar profiles, and photos from the survey

GPR Grid Plot

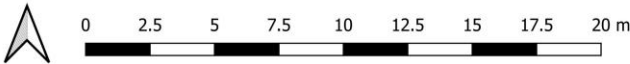
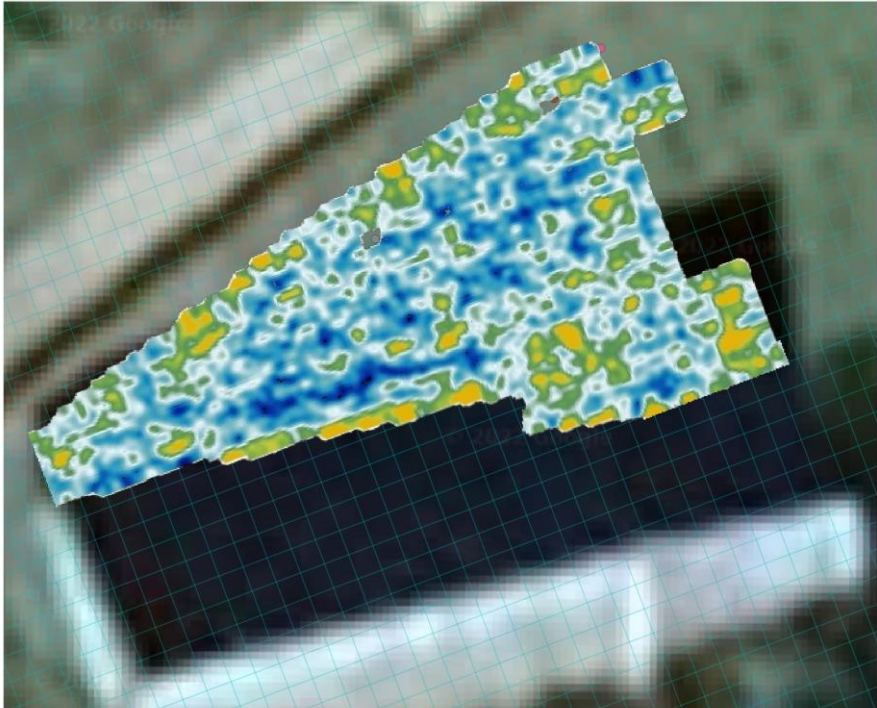


Chosen GPR depth slices plotted in the background map

Dolm Kirke
Dolmøy, Hitra kommune
GPR Survey
GSSI-SIR 3000
400 MHz antenna
Hilbert transform data
Depth slice 0.20 - 0.30 m



Dolm Kirke
Dolmøy, Hitra kommune
GPR Survey
GSSI-SIR 3000
400 MHz antenna
Hilbert transform data
Depth slice 0.30 - 0.40 m



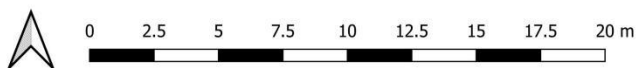
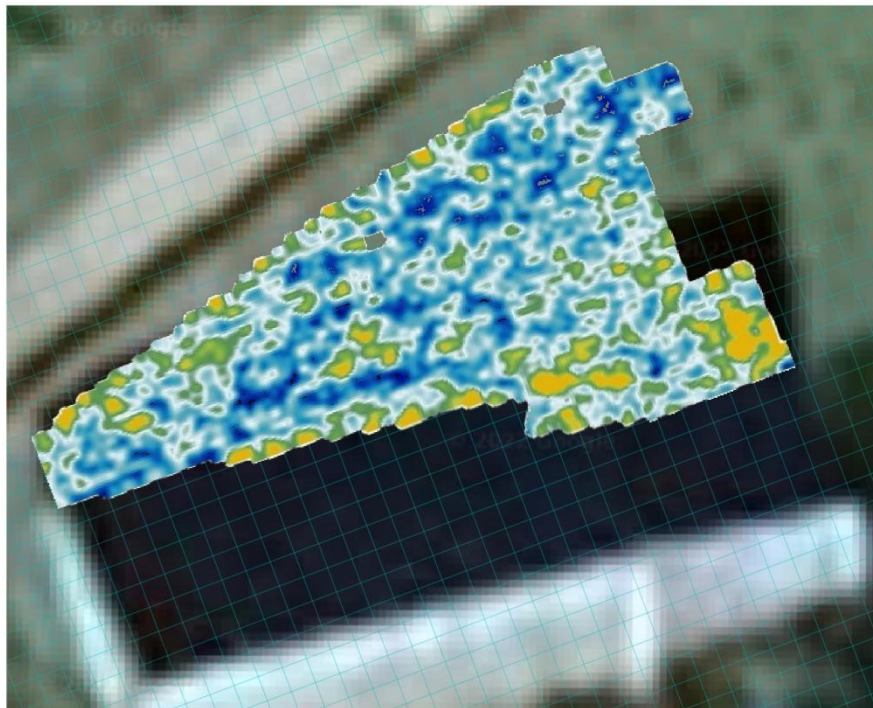
Dolm Kirke

Dolmøy, Hitra kommune

GPR Survey

GSSI-SIR 3000
400 MHz antenna
Hilbert transform data

Depth slice 0.40 - 0.50 m



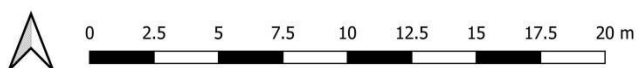
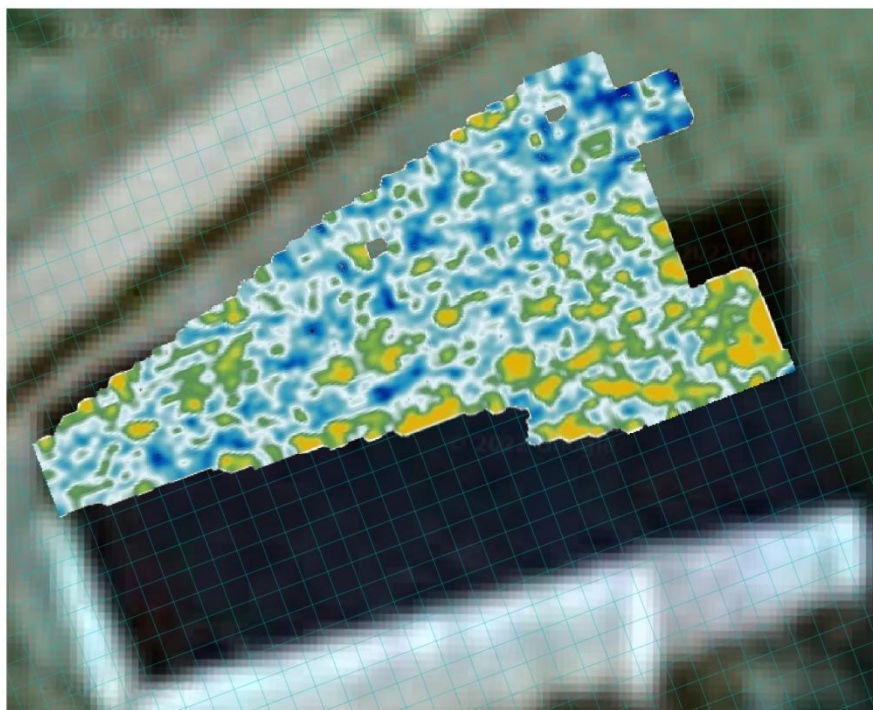
Dolm Kirke

Dolmøy, Hitra kommune

GPR Survey

GSSI-SIR 3000
400 MHz antenna
Hilbert transform data

Depth slice 0.60 - 0.60 m

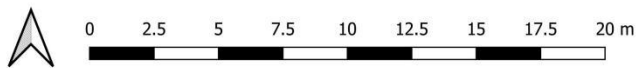
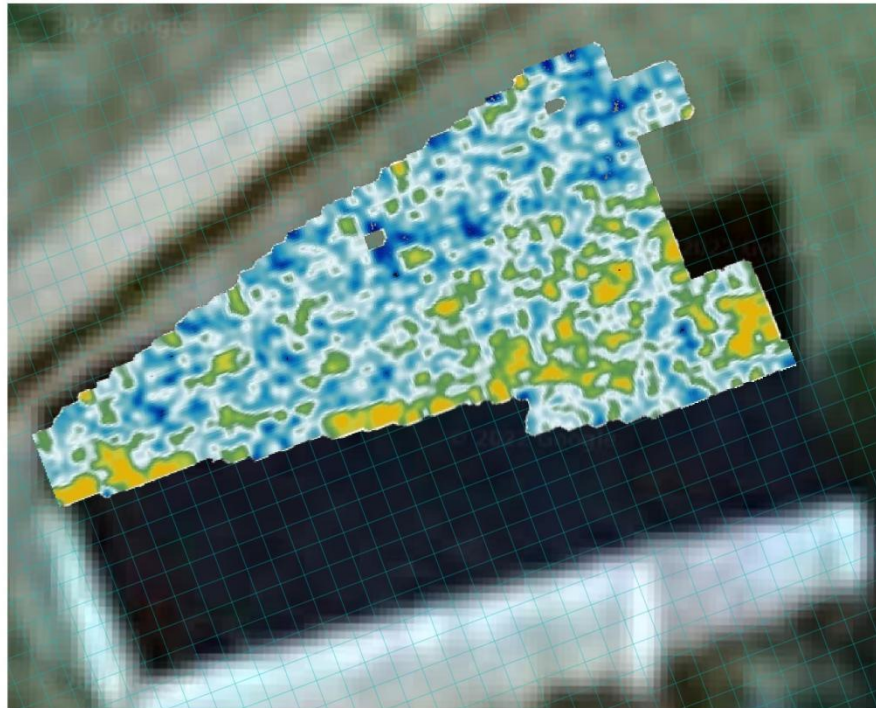


Dolm Kirke
Dolmøy, Hitra kommune

GPR Survey

GSSI-SIR 3000
400 MHz antenna
Hilbert transform data

Depth slice 0.70 - 0.80 m

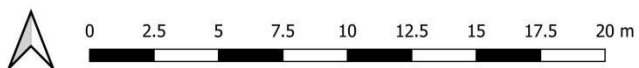
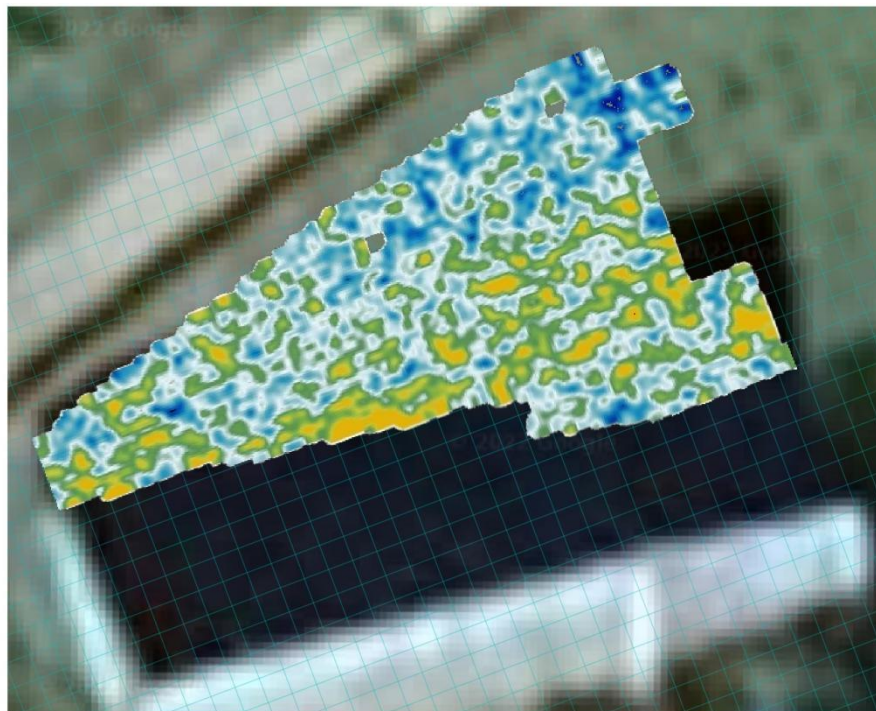


Dolm Kirke
Dolmøy, Hitra kommune

GPR Survey

GSSI-SIR 3000
400 MHz antenna
Hilbert transform data

Depth slice 1.00 - 1.00 m

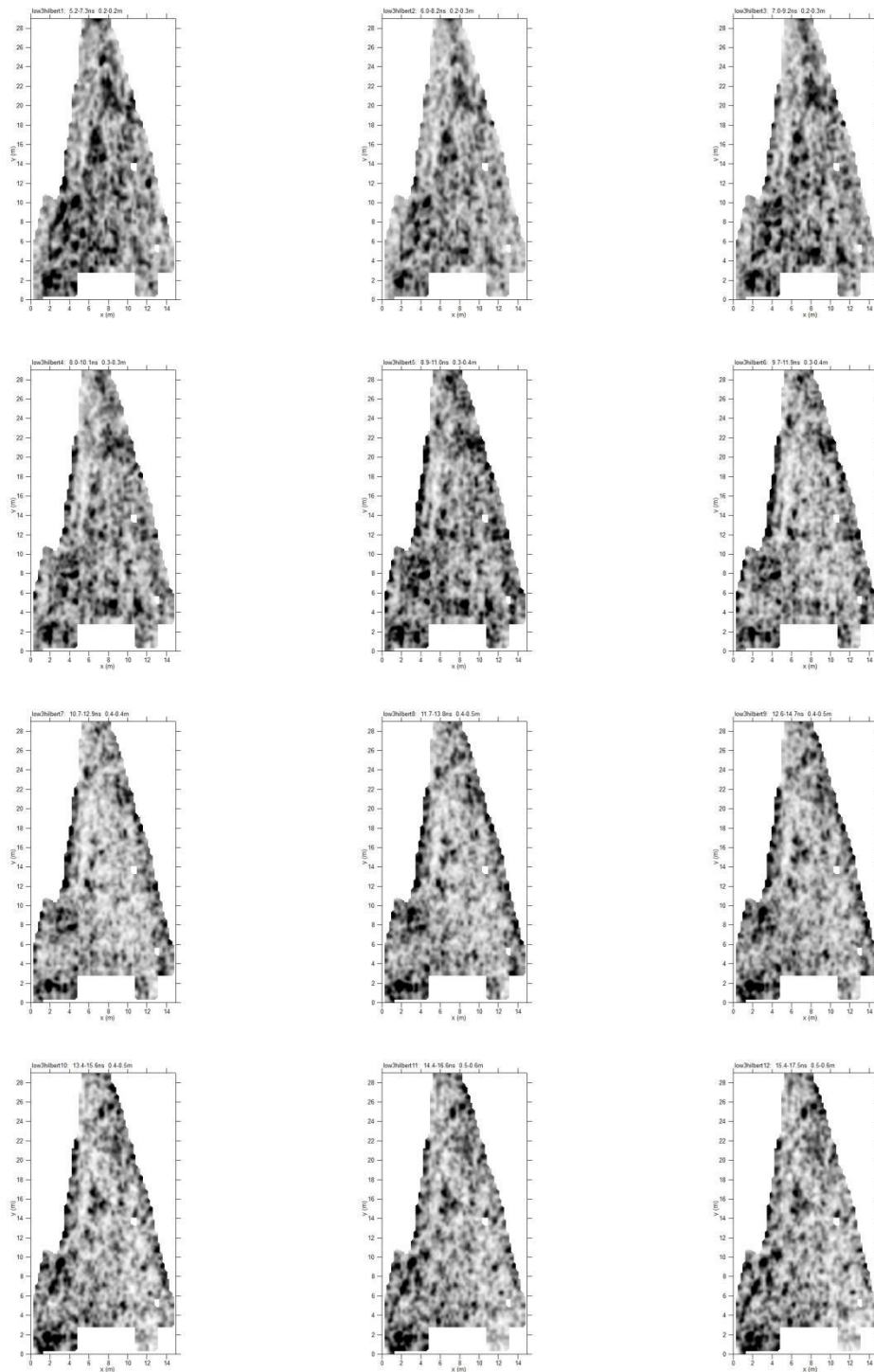


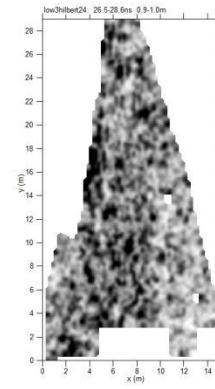
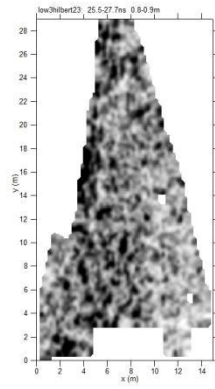
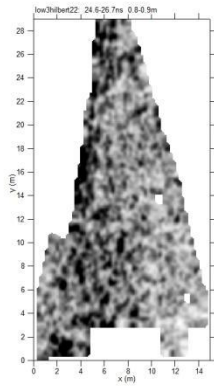
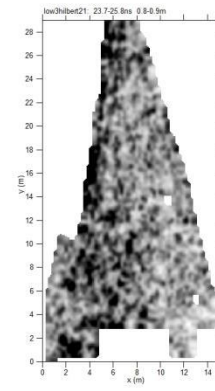
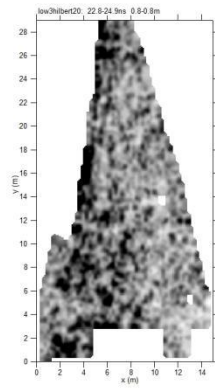
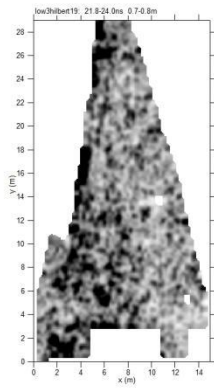
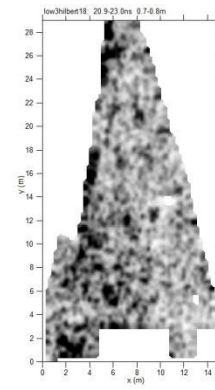
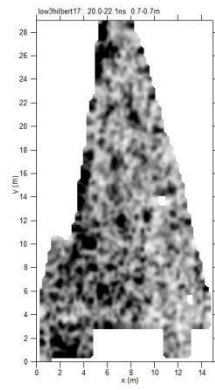
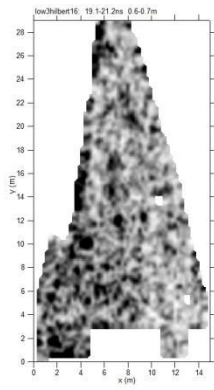
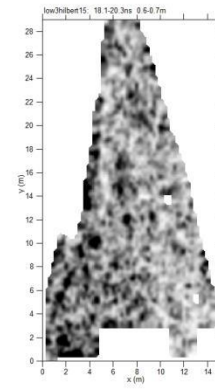
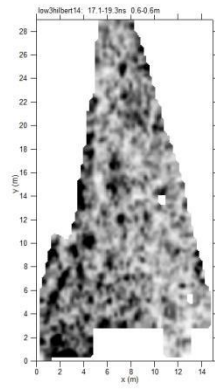
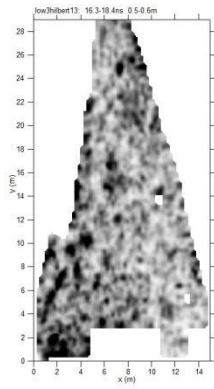
All GPR depth slices

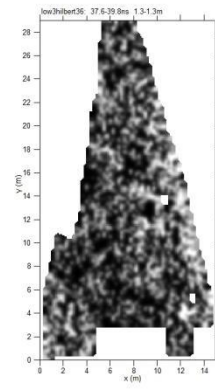
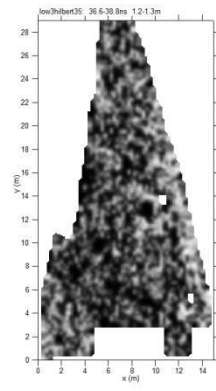
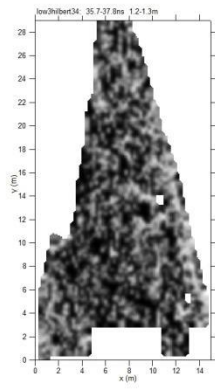
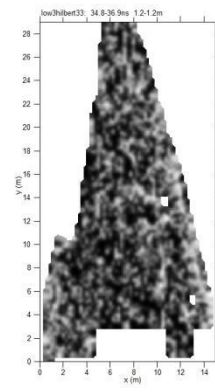
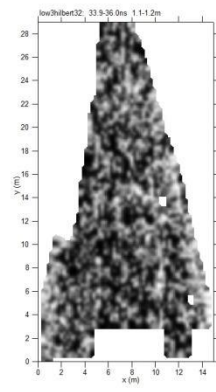
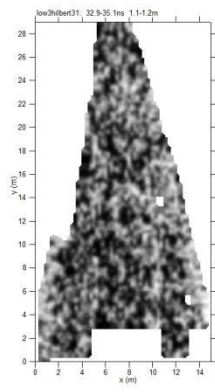
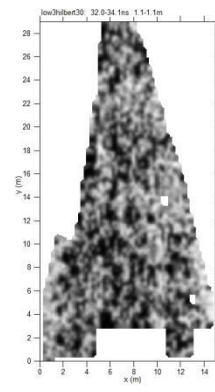
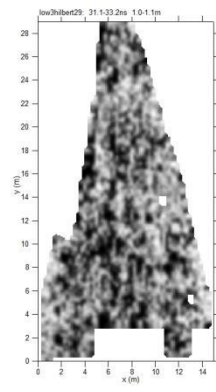
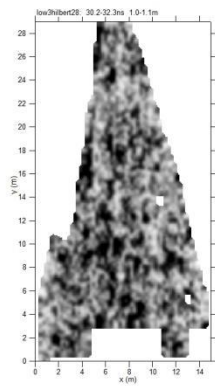
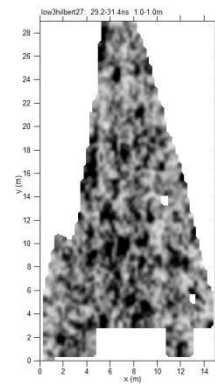
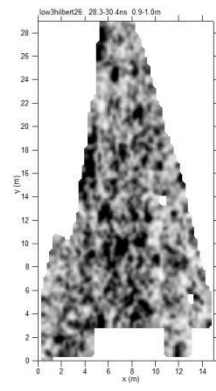
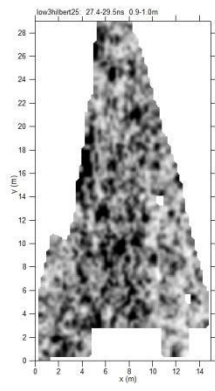
GPR depth slices in greyscale

Presented depth slices are processed through bandpass (approx. 100-700 Mhz), background removal, migration filters and Hilbert transform.

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 bottom right.



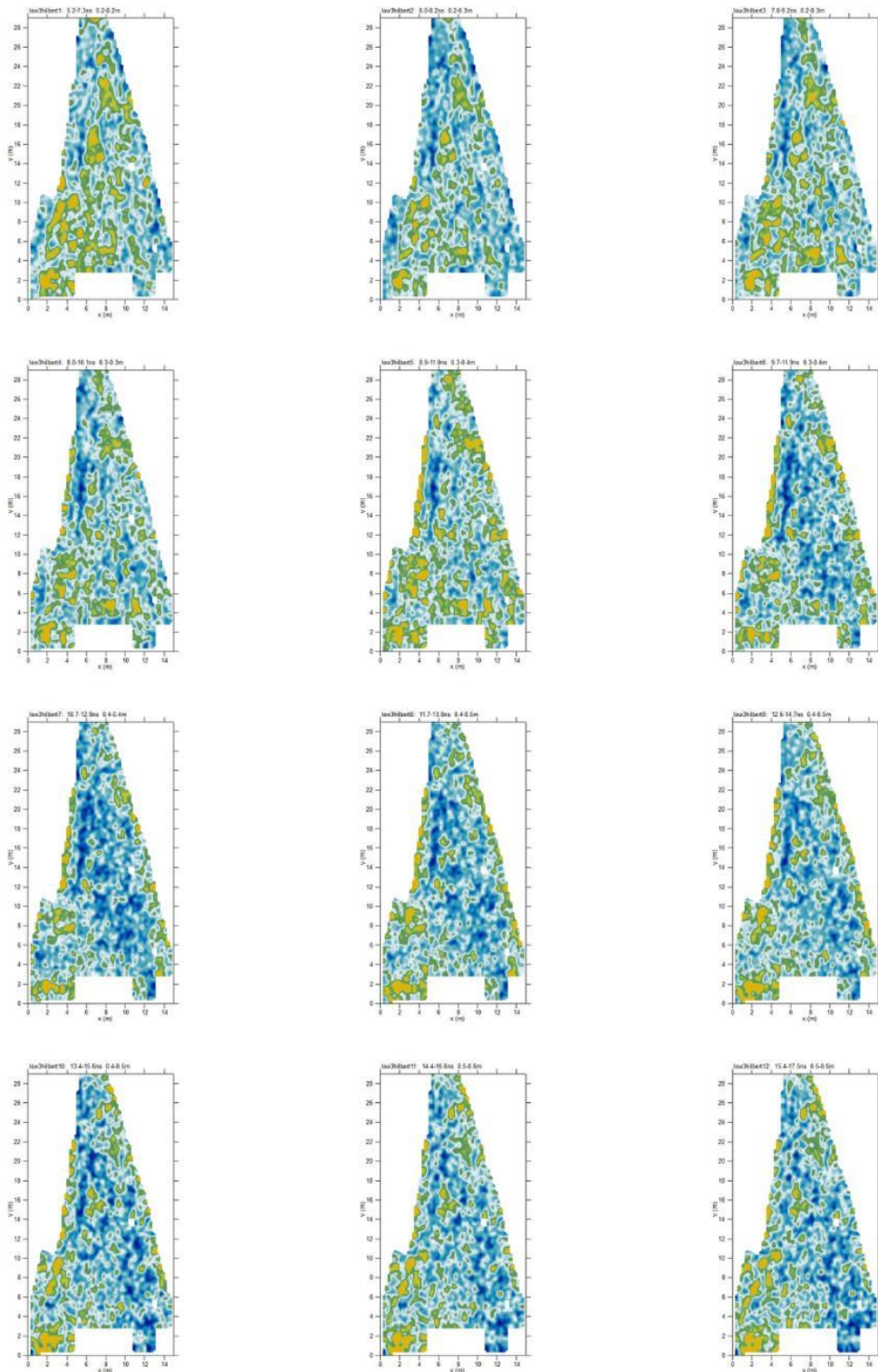


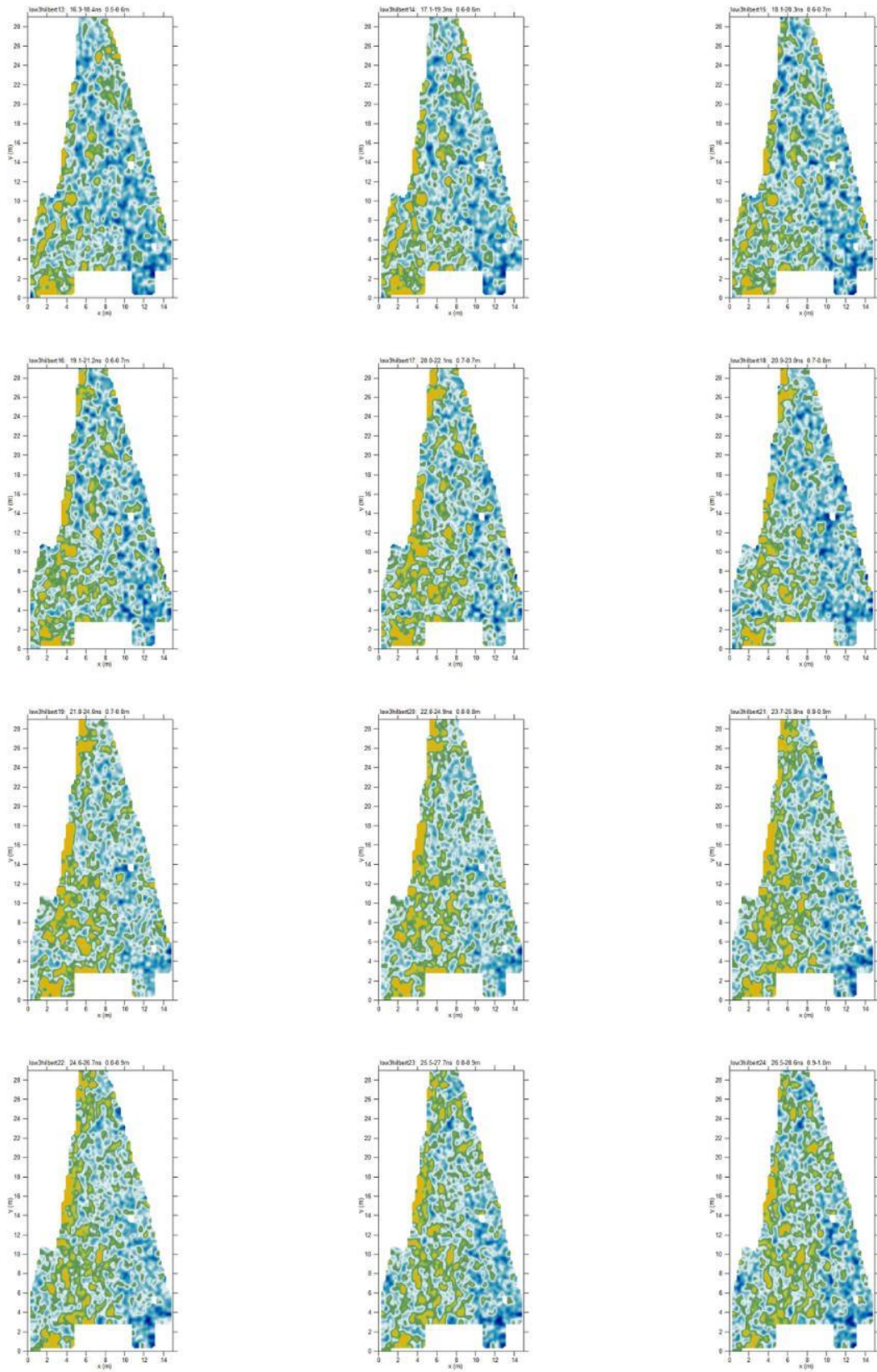


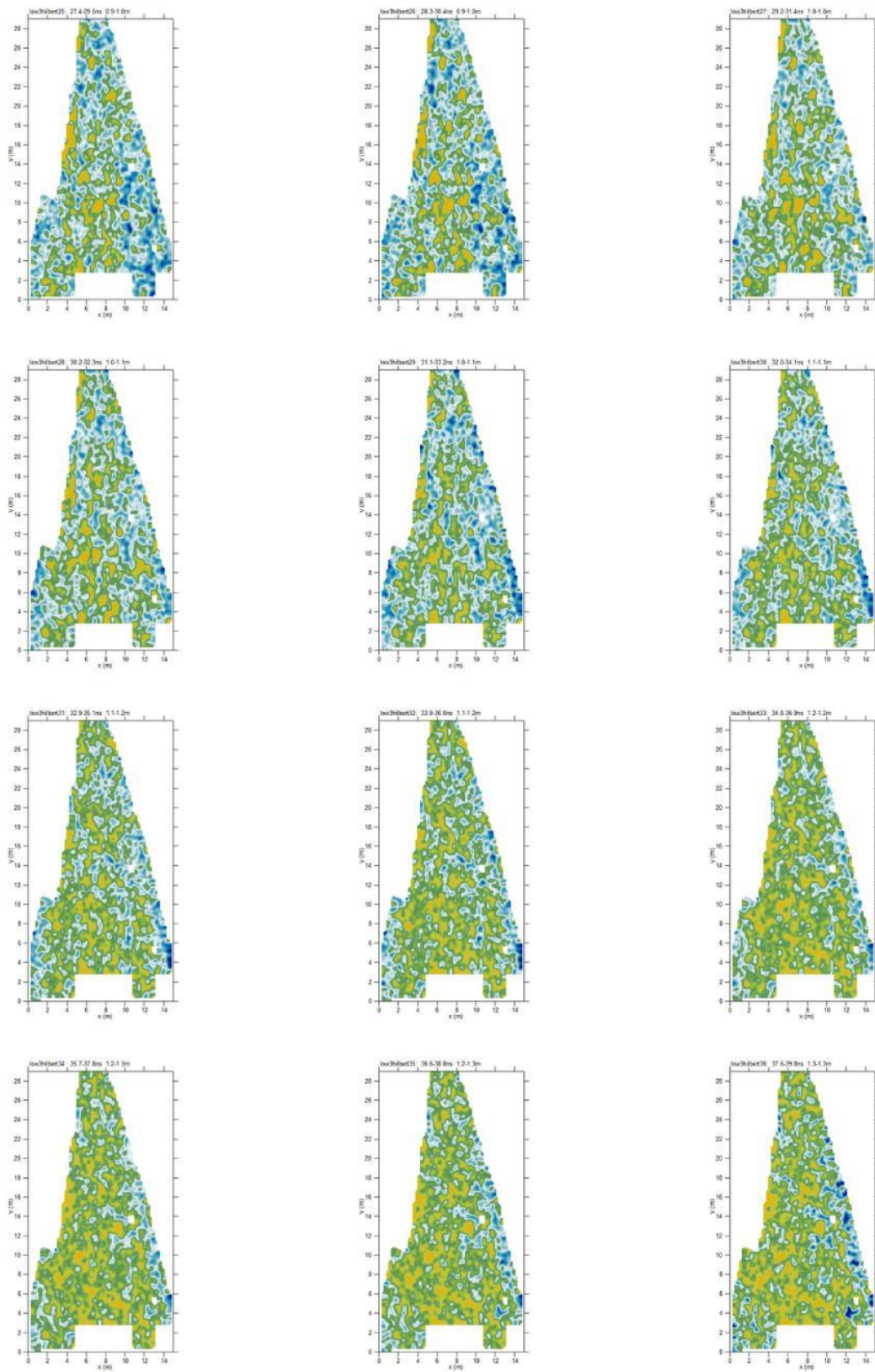
GPR depth slices in color

Presented depth slices are processed through bandpass (approx. 100-700 Mhz), background removal, migration filters and Hilbert transform.

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.

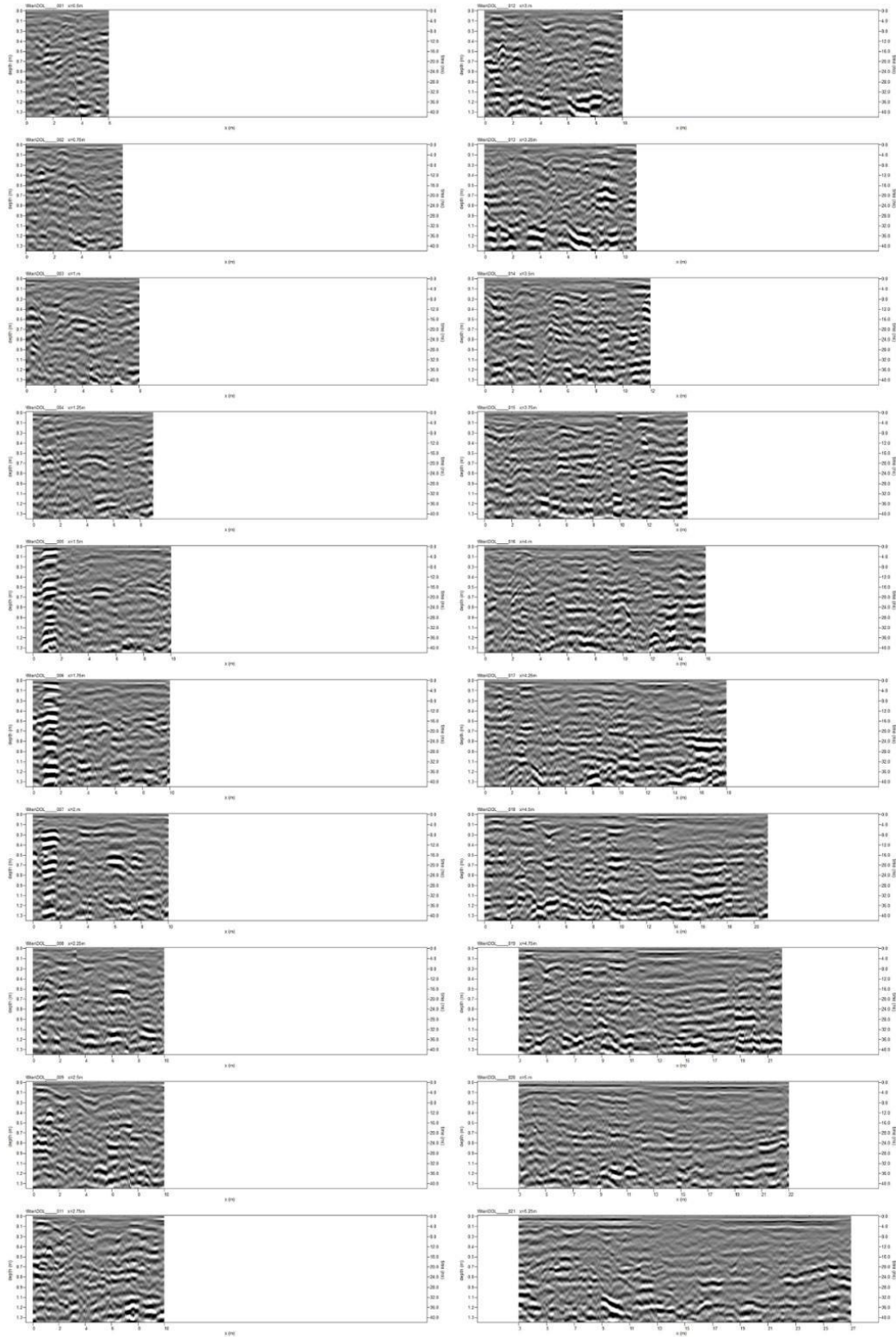


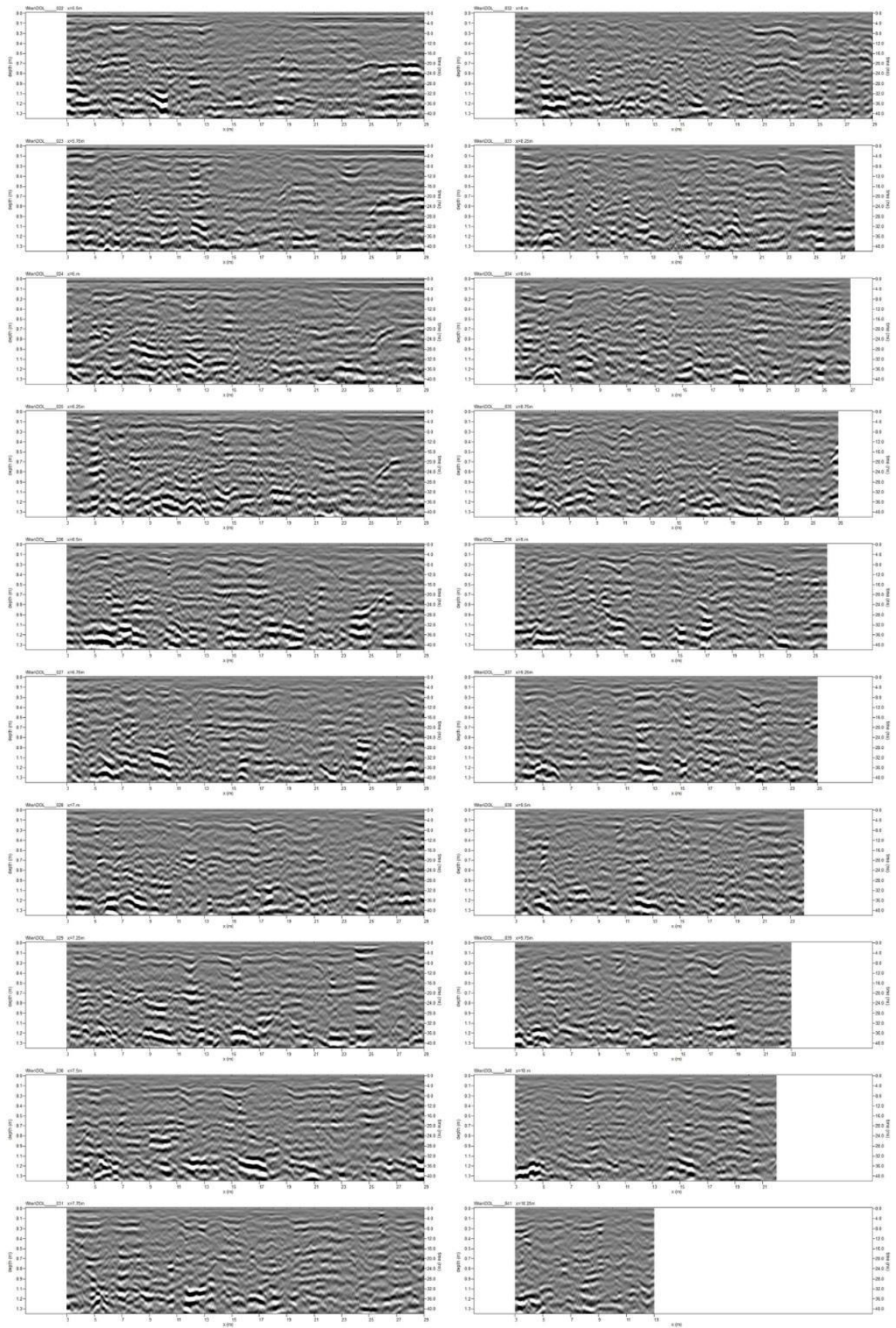


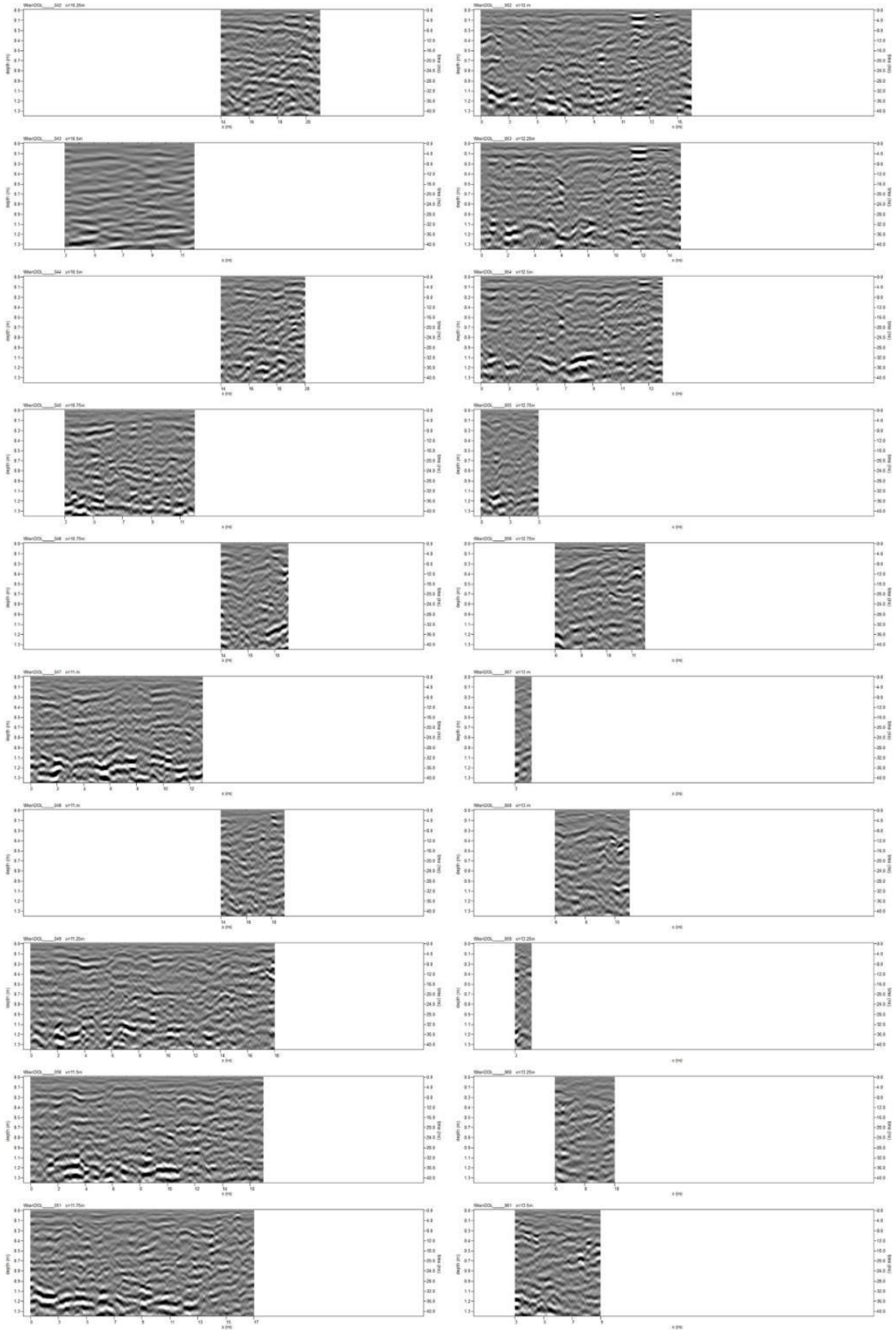


GPR profiles

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.

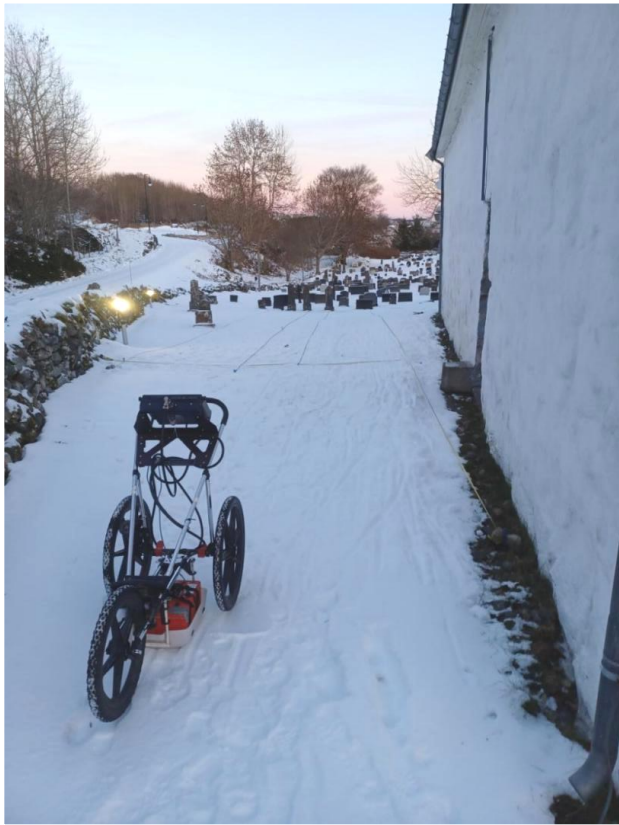






Photos from the survey area









NTNU Vitenskapsmuseet er en enhet ved Norges teknisk-naturvitenskapelige universitet, NTNU.

NTNU Vitenskapsmuseet skal utvikle og formidle kunnskap om natur, kultur og vitenskap. Museet skal sikre og forvalte de vitenskapelige samlingene og aktivisere dem gjennom forskning, formidling og undervisning.

Institutt for arkeologi og kulturhistorie har forvaltningsansvar for automatisk fredete kulturminner og skipsfunn i Nordmøre, Trøndelag, nordlige Romsdal og Nordland til og med Rana. Instituttet foretar arkeologiske undersøkelser på kulturminner over og under vann, i henhold til kulturminneloven.

ISBN 978-82-8322-364-4

ISSN 2387-3965

© NTNU Vitenskapsmuseet
Publikasjonen kan siteres fritt med kildeangivelse

www.ntnu.no/museum