

NTNU/R09/06/05

*Title*            **Geophysical Prospecting at  
Avaldsnes, Karmøy Municipality,  
Rogaland, Western Norway.**

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*Date*            20<sup>th</sup> February 2010

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## 1.0 Background Information

### 1.1 Introduction

In preparation for archaeological excavations at Avaldsnes, Karmøy Municipality, Rogaland in Western Norway that are planned to start in 2010, the Institute of Archaeology, Conservation and History (IAKH) at the University of Oslo wishes to conduct geophysical prospecting on the site. The objective of the geophysical prospecting is to inform the excavation of settlement areas whose location and limits have been defined and refined by the results from test trenching carried out over a number of years.

This geophysical methodology is based on information provided by Prof. Dagfinn Skre (IAKH) in an original email containing background information, suggested survey methods and questions concerning the technical specifications of the survey. Prof. Skre subsequently provided certain further information consisting of digital LiDAR and mapping data and copies of reports on previous geophysical surveys carried out at Avaldsnes. The previous geophysical surveys are summarised in Appendix 1. In addition general information on the targets being sought was described as postholes, pits and hearths associated with settlement. Approximate dimensions of anticipated features were provided together with background information on a stone-lined underground passageway.

Specific archaeological information such as the precise location of excavation trenches and the results from the excavations were not revealed until after an initial draft interpretation of the geophysical results was presented. The intention was to test the reliability of data from geophysical surveys in the absence and subsequent presence of archaeological information from trenching. This is not normal practice. All available geological and archaeological data should be considered in the development of a geophysical survey specification in order to maximise the potential geophysical responses and the subsequent interpretation of the field data. Accordingly, this report presents the results of the draft interpretation modified as appropriate where the excavation results clarify the original interpretation.

### 1.2 Archaeological potential

Avaldsnes was a royal farm in the Early and High Middle Ages and the site has produced prestigious finds back to the Roman Iron Age, among them the famous Flagghaug burial, probably the richest male burial in Scandinavia from this period.

Through the digging of excavation trenches (Fig 1) a settlement area has been identified (Fig 2). Dating evidence associated with the settlement ranges from c. 200 BC up to the present day.

Prior to the geophysical survey the settlement area was estimated to cover c. 33,000 sq. m. of flat or gently sloping ground. It is divided into four areas separated by fences and a road (Fig 2). There is no evidence of the settlement area found in aerial photographs or from cropmarks (Skre, pers. comm.). Subsequent to the geophysical survey the area was adjusted to cover 35,690 sq. m. with an additional area of some 1,300 sq. m. covering Flagghaug. The revised settlement area is shown in Fig 2.1.

### 1.3 Geophysical survey area

The total survey area initially extended over c. 20,000 sq. m. within four areas (Fig 2). Three of the areas are open grass fields used for sheep pasture and hay or silage. The fourth (the north-easterly, called "Parkeringsplass" and "Pakterhage" in Fig 2) is a parking area and a garden with two buildings and some trees. The area also contains Kuhaugen, a burial mound. The parking area is surfaced with gravel and contains at least one buried cable. The garden contains a lawn. There are metal fences dividing the area and some buried services such as pipes and cables. Flagghaug, an excavated mound, lies in the graveyard to the north of the carpark area.

Some adjustments were made to the size and layout of the survey areas as a result of access difficulties due to buildings, trees, fences etc and also in the light of results from the early phases of the survey. The approximate area covered with each survey technique is given in Appendix 2.

## 2.0 Geophysical Prospectivity

### 2.1 Introduction

In considering the prospectivity of the area it is necessary to jointly consider the possible geophysical response(s) of the potential archaeology against the background geophysical response(s) due to the host soils and sediments and the underlying bedrock geology. In addition there may be background responses caused by the modern day environment which may contain underground services such as ducts, pipes and cables and above ground features such as metal/electric fences and overhead power cables.

### 2.2 Geology

The general bedrock geology is shown in Fig 3. The rocks of the area are metamorphic with a contact (likely inferred) lying in a SW to NE trend south of the access road to Avaldsnes church and the Nordvegen Historic Centre.

The geology map is largely based on coastal outcrop evidence likely to be supplemented by inland outcrops and information obtained during drilling or trenching activities carried out for development projects. The degree of detail in the map is governed by the geographic spread of outcrop evidence. Where there is no outcrop there is interpolation between outcrops based on the predicted geological structure of the area. In metamorphic terrains the prediction of the geological structure is very difficult in the absence of outcrop and drilling or trenching evidence. For the latter reasons, as there was no specific information about the bedrock geology underlying each of the four survey areas, the available geological information could only be regarded as being of a general nature.

The map indicates that the general bedrock of the area is composed of metamorphic rock types each of which could have a variety of magnetic responses or none. Metamorphic rocks can have their origins in sedimentary sequences which can be very variable in their lithology and mineralogy. Metamorphic processes can concentrate minerals and, if there are significant magnetic minerals present, they can appear as magnetic anomalies. These anomalies can have different degrees of intensity depending on the mineralogy, lithology and structure of the original sedimentary sequence. Variable intensity magnetic anomalies can exhibit very localised as well as broader scale patterns. These can range from small closures, of the order of one or two metres in diameter, to large sinuous responses extending over tens and hundreds of metres which may reflect more magnetic horizons in the original sedimentary sequences.

### 2.3 Soils

Prior to the geophysical survey, from excavation evidence, the type of soil was described as mainly moraine, mixed sand, gravel and stones with some clay (Skre, pers. comm.). The thickness varied from 0 to 1 m, rarely more, generally at the shallower end of the spectrum. The clay component in the soil is regarded as being constant except in the "Parkeringsplassen" where the original topsoil has been removed and an up to 0.4 m thick layer of crushed stones of gravel/sand size has been overlaid.

During the geophysical survey a chance encounter with some gravediggers revealed that soils in the graveyard had been augmented by up to 1.5m. From conversation with the gravediggers it appears that, due to shallow bedrock in the area, there is a history of soil augmentation.

Prior to the geophysical survey, in relation to the three areas under pasture, they appeared not to have been ploughed in living memory. In the latter stages of the survey a chance encounter with the former landowner revealed some information on the modern land use in the area. There was a ploughing regime introduced in the pasture fields which resulted in the ploughing and re-seeding of the fields on

a regular cycle. The farmer also spoke about colour changes in the plough soil but couldn't be specific as to the location within each field.

In some cases, where there are shallow soils, ploughing can assist in bringing deeper archaeological material into the topsoil within the plough zone and making the area more prospective using geophysical methods. If there is significant soil augmentation only deep ploughing may introduce material into the topsoil. It may be that in some locations the shallow nature and type of the soil in the area has resulted in the use of the land being more suited to pasture.

## 2.4 Geological implications for geophysical prospectivity

The implications for the geophysical prospectivity of the pasture area arising from the background response of the bedrock and the thickness and nature of the overlying soils largely concern likely magnetic, earth resistance and ground penetrating responses and the clay content. Given the metamorphic nature of the bedrock, the magnetic response could not be predicted in advance of survey. If there is a significant bedrock magnetic response, previous work in Norway has shown that this may not necessarily prevent a magnetic response due to sub-surface archaeology. This is particularly so where significant burning is associated with the archaeological feature. In relation to clay, if it is marine clay, it will not have an influence on magnetic methods but may influence the earth resistance and ground penetrating radar methods. Where the fill is composed of low resistance clay, it will provide a good geophysical contrast against the higher resistance of the moraine, mixed sand, gravel and stones. The relatively low clay component and resistive nature of the overlying soils will facilitate good penetration with ground penetrating radar (GPR) and electrical resistivity tomography (ERT).

## 2.5 Potential archaeological targets

The settlement area is expected to contain potential archaeology such as post holes, hearths and pits. On the "Parkeringsplass" an underground passage with walls and roof made from stone slabs has been discovered.

The underground passage is likely to have been constructed by digging a trench and inserting the walls and roof before it was covered over. The present excavated depth and length of the passage are 1.5m and 35m respectively. The excavated cavity of the passage largely contained soil. The passage is projected to extend outside the excavated area.

## 2.6 Potential geophysical responses

In addition to the possible responses due to the bedrock and overlying soils, the geophysical prospectivity and response to cut features such as post holes, pits and inserted underground passages will depend on their dimensions, depth of burial, the material or fill they might contain. The latter responses will also be influenced by the type of and spatial resolution of the survey method being used.

From excavation evidence at Avaldsnes the post holes found so far are from a few cm preserved depth to some 20-30 cm with widths normally from 20 to 50 cm. Some of the pits found are cooking pits whilst others are of unknown use. Most of them are less than a metre wide. Most geophysical methods used in archaeological applications have a depth of investigation of at least 50 cm and, depending on the method, can have a depth of investigation up to many metres. Assuming there is a measurable contrast between the prospective archaeology and the background, the most difficult prospecting targets are isolated, single features less than 30cm in diameter. Where the spatial sampling is sufficient and geophysical contrasts exist, features of the order of 30cm diameter found in alignments, groups or clusters offer a better possibility of detection.

The fill of post holes and pits, if it contains burnt material, offers a potential target using magnetic methods such as magnetic susceptibility and magnetic gradiometry. Areas containing burnt material and hearths will often show zones of magnetic susceptibility enhancement (Slater et al., 1996; Barton & Stenvik, 2008). Reconnaissance magnetic susceptibility surveys often inform and assist in the implementation and interpretation of subsequent detailed magnetic gradiometry surveys.

In relation to cut and burnt features, a survey strategy using multiple survey methods has been found to offer the best possibility of detection of archaeological targets both in Ireland and in Norway (Barton & Fenwick, 2005; Barton & Stenvik, 2008; Barton et al., 2009). In these cases a combination of magnetic susceptibility, magnetic gradiometry, earth resistance, GPR and ERT methods detected settlement activity, post holes, pits and hearths in fields that had been or are currently under cultivation. In the case of Haug (Barton & Stenvik, 2008) there is an agricultural layer some 25cm thick overlying archaeological features lying on and cut into a sandy, gravelly subsoil. The change of landownership at Avaldsnes could possibly have led to a change in cultivation methods thus reducing the geophysical response of sub-surface archaeology.

The Parkeringsplassen area, where an underground passage has been discovered and excavated, is now composed of 'made ground' which should show a disturbed response on GPR data. Where the passage is reputed to extend further in the Parkeringsplassen area and into farmland there should be a GPR response in the former and a GPR, earth resistance and/or ERT response in the latter. In the case of the GPR response it will be due to the contrast between the stones and slabs used in the construction, the fill surrounding them and the combination of air, stone and soil which may form the interior of the passage. The earth resistance method, if applicable, will largely respond to the variation in soil moisture conditions caused by the presence of the passage. ERT will respond both to the variation in soil moisture conditions and the contrast between the stones and slabs used in the construction, the fill surrounding them and the combination of air, stone and soil which may form the interior of the passage.

Selected ERT transects have been shown to assist in the interpretation of GPR sections where the underlying sediments such as sands and gravels are not well stratified. In addition, in surveys where air and/or soil filled cavities within stone-lined features are being sought, ERT can help to resolve GPR interpretation issues (Barton et al., 1999).

### 3.0 Geophysical Survey Strategy

#### 3.1 Outline strategy

A systematic survey strategy was adopted in the survey of the three areas under pasture. A Phase 1 reconnaissance magnetic susceptibility survey was carried out to indicate if there is a magnetic response or enhancement related to the settlement area as defined by the test trenching and to assist in the interpretation of a subsequent higher spatial resolution Phase 2 magnetic gradiometry survey. A Phase 3 earth resistance survey was carried out over areas of significant magnetic response and in a number of control areas where no significant magnetic response was detected. A Phase 4 GPR survey was carried out based on the results of Phases 1, 2 & 3. The GPR survey was used to further define and refine features detected.

The fourth survey area, mainly south of Avaldsnes church, was also surveyed in a systematic manner using Phase 1, 2, 3 & 4 techniques appropriate for the targets being sought and the field conditions. The area consisted of a carpark containing a known underground passage and its possible extension, a small field, a large garden, Kuhaugen mound and Flagghaug mound in the graveyard to the east of the church. The carpark area was surveyed with GPR only. In the case of the underground passage this involved an initial series of test GPR transects over and close to the known location of the passage in order to select appropriate instrument settings. These settings were then used to prospect for the passage extension on transects spaced up to 5m apart. Where there was a significant variation in the route of the passage, the transect spacing was reduced. Where any features indicating there might be a chamber or widening of the passage was recognised, a small grid of closely spaced transects was surveyed in order to produce horizontal time slices. The small field was surveyed with GPR and a combined ERT and GPR transect. The large garden, Kuhaugen and the area surround in it were surveyed with an appropriate combination of selected Phase 1, 2, 3 & 4 techniques. Kuhaugen and Flagghaug mounds were surveyed with combination of Phase 4 single ERT and GPR transects to provide sections through them.

#### 3.2 Detailed survey methodology and specification

##### 3.2.1 Georeferenced survey grids, transects, basemaps and excavation trenches

The overall survey area is shown in Fig 4 which is a georeferenced, shaded relief image of LiDAR data. The data are illuminated from the NE at 30 degrees above the horizon. The coastline, access road to Avaldsnes church and its surrounding graveyard, some field boundaries and areas of higher elevation can be seen. The footprints of a large barn, a house and Avaldsnes church have been blanked out due to their topographic complexity.

The geophysical surveys were tied into the available mapping and the processed data are compatible with ArcGIS. This was done using a Global Positioning System operating in differential mode (DGPS) to acquire DGPS fixes that define the UTM co-ordinates of the corners the grids on which the geophysical surveys were carried out. The sizes of the grids depended on the geographical extent and shape of the three areas under pasture and typically were 20m x 10m or 50m x 50m. For GPR and ERT surveys carried out along transects DGPS or total station fixes were made at the ends and where there was a significant departure from a straight line. The GPS receiver was a Trimble ProXRS with the differential correction being obtained from the OmniStar satellite network. The location accuracy of the system is sub-metre and typically about 0.3m. Where it was not possible to directly obtain DGPS fixes e.g. over most of the carpark area, a total station was used to tie in survey points. The instrument used was a Sokkia Set 500 with Sokkia SDR33 datalogger.

The geophysical processing software used generally allowed each measurement point to be ultimately georeferenced in UTM co-ordinates based on the survey grid upon it was collected. This allowed the

raw and processed data to be merged and presented as georeferenced digital data in x, y, z format. A georeferenced basemap in ArcGIS format was provided (Skre, pers. comm.) and the processed data was displayed on basemaps in this format. The simplified basemap linework showing the principal visible features and overlain on the LiDAR data is shown in Fig 5. In Fig 5 the access road, principal field boundaries, buildings, grave mounds and the graveyard have been displayed and presented using edited versions of the simplified basemap linework.

The four interpreted settlement areas (Fig 2) are contained within the four geophysical survey areas numbered 1 to 4 (Fig 6).

Subsequent to the geophysical survey ArcGIS maps were supplied which included known archaeology and the location of the test trenches as shape files (Fig 6.1).

*The corners of each test trench were georeferenced in the UTM grid by the municipality's staff. The trenches are not always as regular and rectangular as displayed in the shape files and therefore the borders are not very precise. Features within the trenches are digitalized from the sketches and located as precise as possible based on the sketches and coordinates of the corners. Consequently, there may be some inaccuracies both in the location of the trench borders and archaeological features within trenches, I would guess maximum c. 50 cm. (Skre, pers. comm.)*

### 3.2.2 Phase 1 Reconnaissance magnetic susceptibility survey

This survey measures the ability of the ground to be magnetised. This ability is influenced in archaeological terms by any enhancement in topsoil susceptibility due to settlement, industrial or agricultural activity. The depth of investigation is 0.1m where products derived from archaeological activity will be incorporated into the top soil due to agricultural and/or biogenic activity. The technique, when used on a reconnaissance basis, indicates zones of susceptibility enhancement due to burning, burnt products and occupation debris that contain ferrous material and minerals related to settlement, industrial or agricultural activity. This reconnaissance survey was carried out on a 5m x 5m grid in Areas 2 to 4. In Area 1, the survey was carried out on a 2m x 2m grid where it was possible to survey on grass and away from visible sources of magnetic noise. The survey instrument was a Bartington MS2 with MS2D fieldloop connected to a DGPS receiver. The measurements are in SI x 10E-05 units. The data were processed, interpreted and presented as georeferenced, colour-coded images.

### 3.2.3 Phase 2 Magnetic gradiometry survey

This non-ground contacting survey measures the variation in the vertical component of the Earth's magnetic field to a resolution of 0.1 nanoTesla (nT). The depth of investigation is typically less than 1m. Buried features such as walls, ditches and pits and post holes of a detectable diameter and objects with a ferrous or burnt content will produce small variations in the Earth's magnetic field that can be detectable using the gradiometry technique. The survey in Areas 1 to 4 was carried out on traverse lines spaced 0.5m apart with a maximum reading interval of 0.125 m along each line. The data density was 24 points per sq. m. In order to maximize the survey area to be covered in relation to field shape and obstacles such as fences, a single survey instrument was hand-carried. The latter was important in Area 1 where small grids had to be used in order to obtain coverage. The instrument was a GeoScan FM256 magnetic gradiometer. The measurement units are nanoTesla (nT). The data were processed, interpreted and presented as georeferenced, greyscale-coded images.

### 3.2.4 Phase 3 Earth resistance survey

This ground contacting method measures the electrical resistance of the sub-surface to depths from 0.5m to 1m depending on the equipment setup. The earth resistance method essentially measures the

variation in moisture in the sub-surface. Features such as walls and compacted ground will contain less moisture and will exhibit a high resistance whilst ditches, pits and cut features will likely contain more moisture and will have a lower resistance. The technique measures a volume resistance and relies on there being a very strong or sharp contrast between buried archaeological features and the host soil. (See Barton et al., 2009 - Fig 3a for the response due to a possible cooking pit using a 0.5m x 0.5m spacing). In Areas 1 and 2 the traverse line interval was 0.5m with a reading interval of 0.5m. The data density was 9 points per sq. m. The survey instruments used were GeoScan RM15 and TRS/CIA resistance meters with 0.5m twin-probe arrays. The measurement units are Ohms. The data were processed, interpreted and presented as georeferenced, greyscale-coded images.

### 3.2.5 Phase 4 Ground penetrating radar surveys

This electromagnetic (EM) method measures the travel time of pulses of EM energy that are transmitted into the ground. Energy is reflected and/or refracted back to a surface receiver/display unit from boundaries and structures that have different EM propagation properties or contrasts. These boundaries and structures can be geological and/or archaeological. Generally speaking, surveys over dry, higher resistivity soils and sediments have a greater depth of investigation than those with an appreciable clay content that will have a low resistivity. The different travel times to sub-surface features can be processed to produce a pseudo-image of the sub-surface that can be later reprocessed and interpreted in terms of the possible real geological and/or archaeological features that may exist. The data can be presented as a travel time section or in map or horizontal time slice form if a closely spaced series of transects are collected. If there is good quality information on the propagation velocity of the EM data, it may be possible to scale the depth sections and horizontal slices in metres below the ground surface. It should be noted however that in many cases there is a large margin of error in the depth scale as representative velocity information is difficult to obtain.

For GPR surveys carried out on a grid to produce horizontal slices a 0.5 m, 1m or 5m line spacing with a 0.02m measurement interval was used. There are 150 points per sq. m. for a 0.5m line spacing. The choice of line spacing depended on whether the GPR was used in prospecting mode or to provide detailed images of features detected using Phase 1, 2 or 3 methods. For prospecting lines in Areas 1 and 2, a line spacing of 1m and 5m respectively was used. Detailed surveys used a 0.5m line spacing. The GPR system was a GSSI SIR 3000 with a 400 MHz centre frequency antenna mounted on a cart. Survey and excavation experience in Norway using a 400 MHz antenna on high resistivity soils largely composed of sands and gravels with moderate clay content shows depths of investigation of up to 1.5m can be achieved (Barton et al., 2009). The measurement units are in nanoseconds (ns). The data were processed, interpreted and presented as georeferenced greyscale coded, sections or horizontal slices.

### 3.2.6 Phase 4 Electrical resistivity tomography survey

The ERT method uses a series of electrodes inserted in the ground and connected to a multicore cable to collect resistivity data. The multicore cable was connected to a resistivity meter controlled by a laptop computer that also logged the measured data. The data collected was subsequently used to construct a pseudo-depth section that was modelled and interpreted in terms of sub-surface features. The depth of investigation is largely a function of the electrode separation and for archaeological purposes, separations of 1m and 2m will provide modelled sections to depths of 3m and 6m respectively. The method is not greatly affected by the clay content of the sub-surface as is the case with GPR and often can provide information where a GPR survey has a reduced depth of investigation. The horizontal resolution of features is less than that obtained using GPR but this is often an advantage in assisting with the interpretation of complex GPR sections. The survey instrument was a Campus Geopulse connected to an Imager cable with an electrode spacing of 1m. The data was processed, interpreted and presented as colour-coded, pseudo-depth sections upon which the topography of the ground surface was draped.

#### 4.0 Phase 1 Reconnaissance Magnetic Susceptibility Survey

The results of the survey are given in Fig 7. The range of the data is perhaps not particularly high given the top soil is likely to have been derived from the underlying possibly magnetic, metamorphic bedrock and from soils that may have been introduced by glacial or human activity. The overall response in each of the four survey areas is quite different.

The lowest overall response is in Area 3 whilst the highest is in Area 4. In Area 3 there are low values over most of the field with an isolated high south of the centre. These persistent low values may be related to the inferred geological contact shown in Fig 3 which is sub-parallel to the road. The implication is that rocks to the south of the contact are less magnetic or there is a significant thickness of non-magnetic soil covering the bedrock. Given the overall appearance of the susceptibility data, with much higher values in the other 3 areas, the possibility also exists that the soil in this field has been introduced from another location. In Area 3 there are also some isolated single point anomalies and a significant area of higher enhancement to the south of the area, at the field boundary. Given the 5m x 5m sampling, isolated single point anomalies should be treated with caution but the higher values south of the centre and at the south may be significant.

The next highest response is seen in Area 2 where there is a general enhancement over most of the area with perhaps a SW – NE trend in the higher values. Within the zone of enhancement there are amorphous areas of slightly higher values which may relate to some dispersal of susceptible material from a zone of particularly high values. This could be geological and/or archaeological.

During the course of the survey the survey team were approached by a farmer who had previously owned or worked the land in Area 2. He told us that the land had been extensively ploughed on a 4 to 5 year cycle and the ploughing had been sometimes in different directions. He also said he had seen darkened areas of soil but couldn't remember exactly where they were.

Close to or at the margins of the field there are a number of small areas of consistently high values e.g. at the NE and SW. The proximity of these high values to the field boundary may be significant in that they may be due to agricultural practices. The larger area of higher values at the northern fence may be significant.

Area 4 has the largest area of high values. The susceptibility survey was extended westward outside the area boundary to investigate the distribution of these high values. There are four main areas of enhancement, at the SW, along the western margin, at the northern margin and in the SE where the higher values appear to continue into Area 3. The area in the SW appears to have a consistent SW – NE response and maybe geological and/or archaeological. The western margin enhancement is likely to be due to geology. The northern margin anomaly has a consistent SW – NE response and maybe geological and/or archaeological. It is interesting to note that the anomalies at the SW and at the northern margin are quite well aligned in a SW – NE direction and this may point to a geological source. The area to the SE has an amorphous enhancement distribution that appears to cross the road. It is unclear what the source of this anomalous area is and a geological source should not be ruled out.

In addition to the four main areas of enhancement, there are a group of three smaller areas which may be aligned and which run close to or along the NE boundary of the field. The two northerly areas are close to the field boundary and perhaps also close to a previous excavation at Kongshaug (Fig 2).

The survey in Area 1 was carried out on a 2m x 2m grid and there appears to be a slightly curving zone of enhancement northwards from the barn towards the SW edge of Kuhaugen into the garden called Prestegårdshage. The data appear quite variable or 'noisier' compared to the responses seen in Areas 2, 3 & 4 with a number of small scale anomalies. These could be related to a combination of a smaller 2m x 2m grid, modern ground disturbance and ferrous litter due to the proximity to the road, carpark,

housing and the church grounds. A more detailed discussion on the susceptibility results from Area 1 is given in section 6.1.

The location of the excavation trenches in Areas 1 to 4 is given in Fig 7.1. Area 1 has the largest number of trenches which cut small anomalies seen in the susceptibility data. There are two long trenches in Area 2 with the westerly one cutting from higher to lower enhancement from south to north respectively. The eastern trench lies almost entirely in an area of higher enhancement. There are a number of trenches in Area 3, those in the NE lie in an area of low susceptibility, one in the SE lies in a zone of higher susceptibility of about 50 SI units and a trench at the NW of the area lies in a transition zone from lower to higher susceptibility. Area 4 has a trench in an area of higher susceptibility which lies just to the north of the road. A second trench lies to the SW in a zone of moderately high enhancement. A third trench, at the NE of the area, cuts a discrete area of higher susceptibility.

In the absence of detailed soils information from the trenches there are a number of zones of enhancement seen in the susceptibility data which could be tested with small 1m x 1m cuttings. These cuttings could inform a larger scale excavation if the source of the enhancement is due to an archaeological source. In addition a number of control cuttings could be opened in areas where there is low response in particular in Area 3. If these cuttings are opened, soil samples should be taken for laboratory magnetic susceptibility and, if archaeological in nature, phosphate analysis.

#### 4.1 Discussion

The Phase 1 reconnaissance magnetic susceptibility survey gave an indication of the magnetic enhancement of the soils in the areas surveyed. It also indicated that there were marked differences in enhancement both in individual fields and between the fields. These differences ranged from low background values to higher value enhancement. The question arose, in the absence of archaeological information, as to whether the zones of enhancement were defining settlement, agricultural or industrial areas, were related to bedrock, glacial or modern farming activities or a combination of all of these activities and processes. Information on soil augmentation opened the possibility that some of the variation in enhancement could be due to imported soils.

In the absence of any archaeological information it was decided to proceed to the Phase 2 magnetic gradiometry survey. This survey would provide higher spatial resolution data that would investigate the background and enhanced zones in greater detail and perhaps differentiate the possible sources of the susceptibility enhancement. The balance of probability, based on the general geology map and the susceptibility results, was that there were going to be areas of magnetic bedrock overlain by soils which had a variable magnetic response.

## 5.0 Phase 2 Magnetic Gradiometry Survey

The results of the survey are given in Fig 8 and are discussed in more detail in the respective section for each survey area. The data range is quite large with dominant high gradient responses characteristic of magnetic soils and bedrock. The data have been displayed within a large range in order to display the broad magnetic characteristics of the four survey areas.

The response in Area 3 is interesting in that it is quite different from that of the magnetic susceptibility survey except in the northern and SW parts of the field. The 'quieter' areas magnetically may indicate a change in bedrock lithology with lower or no magnetic expression and/or thicker soils in these areas. Here, the possibility of introduced soils in these areas should not be ruled out. The majority of the area exhibits a strong response which is sinuous in nature and is due to magnetic bedrock.

The response in Area 2 for the most part is relatively 'quiet' perhaps indicating deeper bedrock (>0.5 m) with thicker soils, masking the magnetic response. There are some dominant responses in the NW corner of the area which are likely to be due to geology. Careful examination of the data shows there to be some isolated anomalies of positive gradient that normally indicate cut features such as pits. These anomalies are predominantly at the eastern and SE side of the area.

The response in Area 4 shows the area to the NW to be 'quieter' magnetically with high values in the S and SE. The large 'noisy' area in the SE correlates with the susceptibility enhancement seen in this area. The isolated anomaly to the N, close to the eastern boundary, correlates with an isolated zone of enhancement seen in the susceptibility data.

Area 1 was difficult to survey due to visible metal objects such as fences and street furniture and also obstacles such as trees, bushes and fences. The only significant area available for survey was in the garden and this is discussed in more detail in section 6.2

The location of the excavation trenches in Areas 1 to 4 is shown in Fig 8.1. The trenches in Area 2 appear to lie in magnetically 'quiet' areas, especially the eastern trench. The trenches in Area 3 appear to cut a range of magnetic responses ranging from the 'quiet' area in the NE, to the sinuous features which populate most of the area. Trenches in Area 4 cut an area of high magnetic intensity north of the road, lower intensity to the SW and a relatively 'quiet' area to the NE.

### 5.1 Discussion

The magnetic gradiometry confirmed that there was a variable pattern of very high magnetic gradients due to the bedrock. These high gradients sometimes correlated with enhanced susceptibility values such as in the SE corner of Area 4. There were areas which had high bedrock gradients but low susceptibility enhancement such as in the majority of Area 3. There were also areas of low gradients and low susceptibility values such as in the NE corner of Area 3. There were also areas of low bedrock gradient and high susceptibility enhancement such as in the eastern part of Area 2. Low apparent bedrock gradient and high susceptibility enhancement might indicate thicker soils masking the bedrock response or the higher susceptibility might be due to anthropogenic activity if the bedrock was non-magnetic and did not contribute to the susceptibility enhancement. In the latter case the anthropogenic activity could be recent due to soil augmentation or be related to historic settlement. Thicker soils would facilitate agriculture and settlement.

It was decided to test the soils on the eastern side of Area 2 with a Phase 3 earth resistance survey which would not be influenced by the soil magnetic properties.

## 6.0 Area 1 Geophysical Surveys

Area 1 posed a challenge to survey with different types of archaeological target and very different field conditions ranging from a gravelled carpark, a graveyard, an unkempt garden and grassed/gravelled areas in the vicinity of a house and barn. There were also many immovable metal objects and underground cables and pipes in Area 1 which would produce spurious results. Not all geophysical techniques could be used in these field conditions and selected appropriate techniques were deployed individually or in combination depending on the survey requirements and field conditions. The deployment of the various techniques was integrated into the overall survey programme of four Phases and the results are described below.

### 6.1 Detailed magnetic susceptibility survey

The Phase 1 data are presented in Fig 9. The survey was carried on a 2m x 2m grid in accessible grassed areas. There is a curving zone of enhancement with the highest internal values extending from the barn in the south, skirting Kuhaugen and the dwelling house and ending in the SE of Prestegårdshage. This zone could in fact extend further to the northern margin of Prestegårdshage if one considers the overall zone of enhancement.

The zone comprises a number of individual zones of high values that may not be connected and whose sources might be quite different. The most southerly zone near the barn could be due to ferrous litter or debris. The ground is very rough with matted grass in this area with piles of earth and rubbish. To the north of the latter lies Kuhaugen which has been landscaped with cultured grasses. The grave mound has been disturbed in the past and the higher values here could be due to burnt and/or construction debris due to soil disturbance from landscaping and excavations. It is interesting to note that there is a zone of low enhancement on and to the E of Kuhaugen. This may indicate that this area is less disturbed. The high values associated with the access road could be due to the gravel material from which it and the carpark are constructed. The gravel is also to be found in patches inside the margin of the garden. It is interesting to note that the susceptibility survey using the EM38 showed a pervasive increase in background susceptibility values in the gravelled carpark area (Appendix A1.2).

The source of the enhancement in Prestegårdshage is problematic. The farmer who had previously worked the land also told us that his mother had tended the garden. She regularly used to dispose of ashes from her fire in pits dug in the garden and also scattered the ashes over flower beds. It is quite possible that some, or all, of the zone of enhancement is due to the dumping of burnt products i.e. ashes in the garden.

The location of test trenches in Area 1 is given in Fig 9.1 with some detail of features found in Fig 9.2. A sampling scale of 2m x 2m will not resolve individual features unless they are of at least the same scale as the 2m x 2m grid. However, the 't-shaped' trench in Prestegårdshage appears to be cut into a zone of enhancement which may in part be due to the soil disturbance due to the excavation and/or to the modern disbursal of ashes in this area. The excavation trench to the SW of Kuhaugen, which cuts a discrete area of higher susceptibility, contains 4 to 5 postholes and a modern ditch (Skre, pers. comm.) Here the anomaly could be due to shallow bedrock, ferrous debris found in the vicinity of the barn lying to the SW and/or, based on the excavation results, magnetic upcast from the modern ditch or burning associated with the postholes.

### 6.2 Magnetic gradiometry survey

The complete Phase 2 dataset is presented in Fig 10. The area was quite difficult to survey with many obstacles and sources of magnetic 'noise'. The survey was conducted in two accessible areas, Prestegårdshage to the W and Kuhaugen to the E. The generally accepted minimum area that should be surveyed to detect coherent geophysical anomalies against a background response is 40m x 40m. The

surveyed area to the E does not meet these criteria whilst the area to the E goes some way to satisfying the criteria. There appears to be a zonation in the magnetic data which approximates to the higher susceptibility areas (Fig 9).

High positive values are seen to the E of the survey area. In the eastern area, there is a magnetically disturbed zone in the south which corresponds with the area of disturbed ground and ferrous debris. Just to the north of this are two narrow negative anomalies which might be buried cables or wire. To the north again there is a very narrow area over Kuhaugen which has positive gradient and whose northern edge curves to the NE. It is difficult to assess these data due to enforced narrowness of the survey strip but the curving edge may be marking the top surface of the mound. Further to the N, there is an isolated positive anomaly which could be a pit. At the end of the surveyed area, over the road, there is a dipolar anomaly which could be related to a buried gas pipe.

The area surveyed in the west, in Prestegårdshage, is magnetically very 'quiet' with a distinct fringe of positive gradient to the east, a curving series of connected dipolar anomalies in the centre and some small isolated positive anomalies in the NW. The area in the east could be related to digging, the dipolar anomalies are due to a metal pipe and the isolated anomalies could be due to pits. The interpretation of the latter is problematic due to the disposal of ashes in pits in the garden area.

In order to further investigate this dataset, the data were clipped to remove values greater than 40 nT and the resulting data is presented in Fig 10.1. The data in the eastern area surveyed contained many high values and the clipping has not revealed any further features. In the western area the clipping has revealed the NE of the area to be quite 'noisy' magnetically, this could be due to any or all of dumped soil/gravel, disturbed ground and ferrous litter deposited over the boundary fence. To the NW further isolated positive pit anomalies have been revealed. The interpretation is again problematic due to the possible dumping of ashes in pits in the garden.

There are a number of zones of susceptibility enhancement and possible pit anomalies seen in the magnetic gradient data which could be tested with small 1m x 1m cuttings to inform a larger scale excavation if the source of the anomalies is due to archaeological features. This is especially so in Prestegårdshage. In addition a limited number of control cuttings could be opened in areas where there is a low or no response in particular in Prestegårdshage. If these cuttings are opened, soil samples should be taken for laboratory magnetic susceptibility determinations and, if archaeological in nature, phosphate analysis.

The location of excavation trenches and features noted are given in Figs 10.2 and 10.3 respectively. The 't-shaped' trench in Prestegårdshage shows correlation with the strong magnetic anomaly due to the pipe. The trench contains features such as stone paving, walling and other trenches. It is possible that some of the stone could be magnetic and this is causing the slightly more 'noisy' response over the trench but the response could equally be due to soil disturbance.

### 6.3 Earth resistance survey

This Phase 3 survey was carried out in two sub-areas to the west in Prestegårdshage and to the east near Kuhaugen (Fig 11). The resistance response in the western area is quite 'smooth' with an N to S gradation from low resistance to high defining areas of coherent response. There is a well defined zone of higher resistance response with a curving edge which could mark the edge of a flowerbed. This area is cut in an N – S direction by a linear zone of low resistance which marks the trench containing the pipe interpreted from the magnetic data (Fig 10). Where the pipe enters the possible flowerbed there is a subtle zone of higher resistance which may be due to spoil or fill material associated with digging the pipe trench. The overall lower resistance in the north of Prestegårdshage may be indicating more moist and/or clayey soils.

The area surveyed to the east contains a number of complex high and low resistance features. The sharp N – S line composed of parallel high and low resistance is an artefact of survey whereby the survey was conducted over a number of days during which time it rained causing soil moisture conditions to change. Near the barn there is an area of high resistance due to spoil and rubbish dumped there. To the east of the spoil is an area of low resistance made ground which may contain or have contained buried cables or wires. To the N of the latter lies an area of high resistance which fringes a platform attached to the house. A short linear of high resistance runs towards the platform, this could be a backfilled trench containing services such as water or electricity. This platform is not shown on the digital mapping supplied. To the east of the house is an area of high resistance at or near the base of Kuhaugen. This could be associated with the construction of the mound. On the top surface of the mound there are two distinctive ‘edges’ which form a right angle containing higher resistance. This could be indicating some inner construction detail or be an artefact of previous landscaping of the mound. Within the higher resistance there an amorphous zone of higher resistance which could be construction detail and two isolated zones of low resistance which could be pits. To the east of the line of trees which cuts the top of the mound the resistance response is quite subdued. This could indicate that this part of the mound is less disturbed and correlates with the area of lesser enhancement recognised in the susceptibility data (Fig 9).

The location of the excavation trenches and features recognised are given in Figs 11.1 and 11.2. The ‘t-shaped’ trench contains stone paving and walling and lies close to the northern limit of a well defined zone of pervasive higher resistance. This higher resistance could be mapping the zone of paving or where there is more compacted ground. To the SE of the road the excavation trench which contains 4 to 5 postholes and a modern ditch (Skre, pers. comm.) straddles a narrow higher resistance zone between two zones of lower resistance. These low resistivity zones could be due to clays or more saturated ground. From the excavation results the narrow high resistance zone could be stone or gravel fill in the modern trench cut into the low resistivity clays.

#### 6.4 Ground penetrating radar survey

The Phase 4 GPR survey was carried out mainly in the carpark and Prestegårdshage areas of Area 1. The carpark had to be closed for nearly three working days in order to carry out the GPR survey. In order to carry out and process the survey in manageable blocks it was conducted in a series of nine sub-grids which are shown in Fig 12 together with the excavation trenches and features recorded. The grids used the kerbing of the graveyard surround as a baseline and are accordingly skewed from the UTM grid. All survey lines in the carpark are spaced 0.5m apart while the survey in Prestegårdshage had a line spacing of 1m. The lines in grids 1, 2, 4, 5, 7 and 8 were orientated N to S and in grids 3, 6 and 9 they were W to E. All lines were collected in parallel mode to minimise jitter in the horizontal time slices. A standardised processing sequence produced 30 non-overlapping time slices of 2 to 3 ns thickness for each survey.

Selected non-georeferenced time slices were presented in the draft report. An attempt to convert the time slices to depth slices was made using the trench depth information supplied with the archaeological data. Unfortunately no distinctive depth markers were found that existed over the carpark area which could be confidently used to perform a statistically valid time to depth conversion. Accordingly, all the GPR data presented are based on time in nanoseconds. For each grid a series of 30 horizontal time slices were produced and presented as thumbnail images. These images were reviewed and significant single images or slices were selected for further presentation and discussion as individual overlays on the GPR basemap. For clarity these slices are also presented as larger scale single slices after Fig 21.3 at back of this report. For convenience the individual figure numbers used in the main body of the report have been preserved but with the addition of a prefix letter ‘A’.

Grid 1 (Fig 12) lies to the NW of the carpark and includes part of the access road to the graveyard. The time slices are presented in Fig 12.1. There are a number of features recognisable and slices 5

and 6 contain the major ones. Slice 5 (Fig 12.1.1) shows the grassed area and bank at the south of the slice with a W to E pipe or cable running through 17N. To the N of this is an arcing linear which may be the former line of the kerbing which surrounds the graveyard toilets. Slice 6 (Fig 12.1.2) shows a coherent reflecting surface between 3 - 12 E and 8 - 13N which may relate to the foundations of the road through the carpark. The western end of this feature appears to be discontinuous.

Grid 2 (Fig 12.2) lies to the south of the kerbing surrounding the graveyard toilets and north of the boundary to Prestegårdshage. This is quite a small grid with a limited number of major features one of which is illustrated in Slice 7 (Fig 12.2.1). The southern edge of the slice shows the grass margin to Prestegårdshage with a harder, linear reflecting surface (10 - 26 E, 13 - 15 N) immediately to the north. This could be some reinforcing or strengthening material used in the foundation of the road or an underground duct.

Grid 3 (Fig 12.3) lies on the grass verge parallel to the outer graveyard wall. The grid is quite small (15m x 4m) and shows a number of features. Slice 7 (Fig 12.3.1) illustrates one of the recognisable features. In this slice there is a discontinuous N – S anomaly (5 – 7 E, 0 - 4N) which seems to divide the grass verge into two types of response. These are single point anomalies to the W and a subdued response to the E. The transition between the responses varies in successive slices.

Grid 4 (Fig 12.4) runs south from the graveyard kerbing to south of a historic wooden building. It was immediately north of this wooden building that the W –E underground passage was exposed. This grid was laid out to investigate the GPR response of the passageway. There are a number of largely linear features apparent in the time slices. Slice 5 (Fig 12.4.1) illustrates the main features. The footprint of the historic wooden building is shown between 10 - 16 E and 0 – 14 N. The W - E passageway can be clearly seen from 0 – 20E and 13 -15N. To the E of the building there are a number of linears orientated SW – NE and NW – SE which might be services such as pipes and cables. There is a N – S linear extending from the NW corner of the building towards the church, another one parallel to this on the western side (along 4E) and possibly another broader one to the east (17.5E – 20E). Slice 6 (Fig 12.4.2) shows some additional detail with a sub-parallel linear (0 – 20E, 20 – 21N) running to the N of the passageway. This could be a separate feature such as a trench or duct or mark the southern edge of a zone of coherent reflection.

Grid 5 (Fig 12.5) runs at the eastern end of the carpark and is terminated by kerbing and a fence boundary to a small field or garden which lies further to the east. There are some strong linear and rectilinear features in the time slices. Slice 10 (Fig 12.5.1) illustrates a strong, discontinuous linear feature running WSW – ENE (0E, 15N – 15E, 18N) which may be pipe or cable. To the north of the latter lies a rectangular feature (9 – 13E, 24 – 30N) which could be a foundation. Slice 21 (Fig 12.5.2) shows two intersecting rectangular features, each some 2m in apparent width. The northerly one, lying W - E is the footprint of an excavation trench. This trench (8 – 19E, 30 – 32N) has well defined edges whilst that intersecting it from the south has less clear edges. This may be an artefact of the N to S GPR lines or post excavation ground disturbance. The arrangement of these possible trenches is puzzling as only one trench, from W to E, is shown in the trench maps supplied with the archaeological data. The area at the NE of Grid 5 provides a natural route for buried pipes and cables. It may be that the area has been disturbed over a long period of time as cables and pipes have been laid and re-laid. The footprint with possible depth of features in this NE area is very clear on successive time slices. On later slices there may be further trenches connected to that running W – E.

During the survey of grids 4 and 5 it became apparent there were a number of features in these grids that were orientated in an N – S direction. In addition, during the course of the GPR survey, a sketch showing the layout of possible nineteenth century farm buildings within the confines of the present day carpark came to light. A scanned copy of the sketch (Fig A3.1) is presented in Appendix 3. The building labelled 'Stabbur' is the historic wooden building which is still found in situ in the carpark area.

Grid 6 (Fig 12.6) is an additional grid added to the GPR survey programme to investigate the N – S features by orientating survey lines in a W – E direction.

There are some strong features apparent in the time slices and slice 6 (Fig 12.6.1) illustrates some of them. Three N – S trending features are apparent at 4E, 9E and 16E, the first and second could be buried cables and pipes with the third being more substantial in response. There is also a W – E trending linear from 0 – 22E along 5N. Slice 7 (Fig 12.6.2) illustrates a patch of response which is possibly rectangular in shape. The patch is at 20 – 25E, 12 – 21N and it could be the response from a foundation of a building or be construction detail associated with the carpark. Slice 17 (Fig 12.6.3) illustrates a number of features with different orientations. The previously described N – S linear at 16E is very clear in this slice and may be a substantial duct or trench carrying pipes and/or cables to the church. The excavation trench previously described in Fig 12.5.2 is also seen in this slice. There is a possible circular feature centred on 19E, 14N which lies close to the previously mentioned duct or trench. A discontinuous, sinuous feature appears to run sub-parallel with the SE edge of the survey area. This could be a cable or be an older boundary to the field or garden that lies immediately to the east. Slice 24 (Fig 12.6.4) is relatively deep and is near the limit of investigation of the GPR system. There is a possible circular feature centred on 27E, 15N which may be a coherent response or an artefact of data processing.

Grid 6 clearly illustrates that there are many pipes and cables in this area and that the ground has been considerably disturbed over a long period of time. The discovery of the sketch thus allowing for the possibility of remnants of building foundations in this area adds to the possible complexity and disturbance of any sub-surface features in this area.

Grid 7 (Fig 12.7) is a small grid located in the field or garden east of the carpark. The field had had trees growing in it in the past and these had been felled. The area is therefore likely to contain stumps and root bowls from the felled trees. This grid was surveyed to investigate the possible extension of the passageway to the east. There appears to be no distinctive response to the passage as seen in Fig 12.4.1 but Slice 8 (Fig 12.7.1) shows a zone of response which may be associated with a possible passage. This W – E trending zone (0 – 5E, 7 – 10N) could be related to the passage or perhaps to a building which was demolished in this area. Slice 13 (Fig 12.7.2) shows a distinctive angular feature (1 – 4E, 7 – 12N) which might be the foundation of a building. Slice 18 (Fig 12.7.3) illustrates a series of W – E responses (along 1 – 3N) which could also be related to the passage. They are from a deeper slice and, although they appear somewhat discontinuous, could relate to a passage.

Grid 8 (Fig 12.8) was surveyed along a very narrow strip of ground to the S of the ‘Stabbur’ wooden building. The grid runs S across the entrance path to the Nordvegen Historic Centre and onto the western slope of Kuhaugen. Slice 5 (Fig 12.8.1) shows a very strong linear extending SW – NE from 0E, 36N which is likely to be a gas pipe known to cross this area. This linear is aligned with a SW – NE excavation trench which could have been dug during the laying of the gas pipe. A possible house foundation was identified in this trench. There is a narrow NW – SE linear crossing the main feature at 6E, 42N. Further to the S (4E, 28N) is the response due to the path and kerbing associated with the entrance to the Historic Centre. Slice 18 (Fig 12.8.2) shows a response (0 – 6E, 6 – 10N) from Kuhaugen which may show some internal construction detail.

Grid 9 (Fig 12.9) was surveyed along W – E lines in Prestegårdshage. The area was difficult to survey with uneven ground, spoil heaps, trees, tree stumps and bushes. The survey lines are spaced 1m apart. Slice 10 (Fig 12.9.1) shows the trench containing the metal pipe, identified in the magnetic and resistance surveys, curving southwards from 20E, -2N to 11E, -31N. Within the limited area that could be surveyed there appears to be no other coherent responses in the data except for perhaps an area in the NW corner where later time slices may be indicating a rectangular feature.

## 6.5 ERT & GPR Transects over Kuhaugen and Flagghaug

A Phase 4 ERT and GPR transect was surveyed across Kuhaugen and Flagghaug (Fig 13). ERT 1 ran SW – NE across Kuhaugen and ERT 2 was orientated S – N across Flagghaug. The ERT depth sections indicate the broad sub-surface structure along the respective transects whilst the GPR time sections sometimes provide more detail. It should be noted that GPR is an electromagnetic method and ERT is a resistivity method and their respective responses can sometimes be different depending on the depth, space form and nature of sub-surface soils, rock and archaeological features.

Figs 13.1 and 13.2 show the ERT and GPR sections across Kuhaugen. The ERT and GPR sections are 72m in length. Both sections have been corrected for topography. For the purposes of this interpretation the mound is thought to extend from about 30m to 55m along each line. The exact location of the edges of the mound is difficult to determine given that the area has been altered by landscaping.

The ERT section from 0 to 30m (Fig 13.1) is characterised from 0 to about 16m by an intermittent pattern of moderately high resistivity overlying a lower resistivity zone which could be due to a variable, clay in-filled or weathered bedrock surface. It should be noted however that the area close to the barn, in the vicinity of the start of the section, is likely to have been heavily disturbed due to the re-building of the barn. This disturbance could include the backfilling of the area. From 16m to 30m there is a more consistent zone of moderately high resistivity overlying an irregular high resistivity surface perhaps indicating weathering or joints in a shallowing bedrock. It is in this area that paving slabs were recorded in a narrow trench (Fig 13).

From 30m to 55m the presumed zone of the mound shows an irregular pattern of resistivity distribution with some ‘pockets’ of low resistivity material. These pockets could represent back-filled pits or a ‘shaft’ dug into the mound. This ‘shaft’ could be related to a potato cellar recorded in the trench that was excavated on the top of the mound (Fig 13). Shallow, higher resistivity within this zone could represent the construction material of the mound or be artefacts of landscaping. The NE face of the mound from about 48m onwards has a thickening sequence of low resistivity material which could be clay used in landscaping. The section crosses the path to the Historic Centre at 56m and passes into a small field in which GPR Grid 7 was surveyed. From 56m to the end of the section there is generally lower resistivity material representing a thicker sequence of low resistivity soils which could be significant if the underground passageway was dug in this area.

The GPR section from 0 to 30m is characterised by shallow bedrock from 0 to 10m and the intermittent loss of the bedrock reflector to about 30m. This could be caused by weathering or joints in the bedrock surface. There is a distinct, NE dipping reflector from about 33m onwards which coincides with the base of the low resistivity zone seen in the ERT section. The presumed area of the mound from about 30 to 55m is underlain by this distinct reflecting surface. This might be indicating that this is the original land surface which has been built up with low resistivity clays to form the mound. At 56m the section passes over the access path to the Historic Centre and into the field or garden to the east of the carpark. There is the distinct signature of a trench between 56 and 59m which must relate to the installation of services to the Historic Centre. There is an indication of some shallow disturbances in the remainder of the section which could be due to ground disturbance due to tree roots. There is no strong indication of the GPR section intersecting an underground passage.

The location of the ERT and GPR transect across Flagghaug is shown in Fig 13. Figs 13.3 and 13.4 show the ERT and GPR sections respectively. The ERT section is 72m in length and the GPR is 50m. In order to obtain a greater depth of investigation over Flagghaug the ERT electrode separation was increased to 2m giving modelled depths up to 6m. This increased depth of investigation is at the expense of lower resolution as the basic sampling interval was 2m. The GPR line could not be

extended beyond 50m due to thick bushes. For the purposes of this interpretation the mound is thought to extend from about 22m to about 58m along the ERT line. The exact location of the edges of the mound is difficult to determine given that the area has been altered by excavation, possible soil removal and landscaping.

The ERT section from 0 to 40m is characterised by a northwards thinning sequence of low resistivity material due to shallowing soils. This is underlain by a generally flat-lying high resistivity zone due to the bedrock surface. From 40m onwards there are two shallow higher resistivity features separated by a low resistivity zone some 15m in width which lies at the northern edge of the mound. The high resistivity zone centred at 48m correlates with the zone of the strong GPR reflector discussed below. Given the mound has been excavated and that material has been removed perhaps to augment the shallow soils in the graveyard, it is likely that this pattern of high and low resistivity represents the foundation level of the mound. This may indicate that the foundation was built on the higher resistivity bedrock which is seen at depth in this area. The high resistivity feature could relate to a re-inforcement of the mound using stone or compacted material. The high resistivity zone found at the end of the section is likely to relate to shallow bedrock geology.

The GPR section from 0 to 22m at the southern edge of the mound is characterised by a subdued response which contains a number of single source hyperboles. These hyperboles at 8m and 15m could be the response to boulders or unmarked graves. This zone is underlain by an undulating reflector which is likely to be the bedrock surface. This correlates with the undulating high resistivity seen in the ERT section. From 22m to 40m there is an irregular zone of small 'noisy' reflectors which rise to the surface at 40m. This correlates well with the northward thinning soil sequence seen in the ERT section. At 40m there is a very distinct band of reflectors perhaps due to good coupling of the GPR signal into the ground. This could be indicating a filled or compacted area which correlates with the higher resistivity seen in the ERT section. The strong signal could indicate a more solid mass. From 42m to the end of the section at 50m there are a series of reflectors dipping northwards which could represent the underlying sedimentary sequence of the original ground surface prior to the construction of the mound or the layering of sediments in the construction of the mound if it was built on the bedrock surface.

## 6.6 Discussion

Area 1 was the most difficult to geophysically survey and also to interpret the data gathered. The difficulties stem from modern manmade and natural obstacles impeding and limiting the collection of data and 'noise' due to metal fences, electric cables, ferrous litter and backfilled or augmented soils. A multi-method geophysical survey strategy was essential in surveying this area whereby techniques appropriate to the archaeological targets and the field conditions were deployed.

The carpark area was successfully surveyed with GPR which has imaged many features which have both modern and possible archaeological sources. The area has been extensively disturbed through the construction and maintenance of the foundations of the parking area and the installation of services such as sewers, pipes and cables. This disturbance has undoubtedly impacted on any sub-surface archaeology that existed or exists in the area. The GPR survey detected areas of disturbance due to construction and many pipes, cables and their ducts. The GPR data were difficult to interpret. There was no direct geophysical correlation with features found in the excavation trenches. However, the underground passageway was imaged immediately to the north of the historic wooden building 'Stabbur' and its track possibly found in the direction of a small field lying to the east of the carpark. There are also features which may relate to the foundations of nineteenth century farm buildings (Fig A3.1) and old borders and boundaries associated with the carpark.

The area of Prestegårdshage and its immediate surroundings was surveyed to different degrees with susceptibility, gradiometry, earth resistance and GPR. No coherent geophysical anomalies that could

be immediately interpreted as being due to undiscovered archaeological features were identified in this area. The interpretation of magnetic anomalies in the garden area is problematic due to uncertainty in the layout of flowerbeds and the spreading and dumping of ash from domestic fires. Given there has been disposal of waste in the general area, it is also possible that construction waste has been dumped in the garden. There is a tentative correlation with paving found in an excavation trench and a higher resistance anomaly which could be mapping the extent of the paving. There is a pipe running through the garden area.

The combined ERT and GPR survey of Kuhaugen revealed that the mound is likely to have been constructed of lower resistivity clays on a small rise in the bedrock surface. There is evidence for a possible vertical shaft or pit in the approximate centre of the mound.

Flagghaug was surveyed with ERT and GPR. The data revealed thicker soils to the south in which there could be a number of unmarked graves. The soils thin considerably northwards approaching the remnant of the mound. The data indicate deeper lying bedrock beneath the northern edge of the mound. This may indicate that the mound was founded on and built up from low lying bedrock.

Any excavation in the carpark or garden area should be informed by a short programme of test pitting to eliminate any modern features or damage to buried services. The geophysical data may help to target less disturbed areas and also prevent damage to underground services. Prior to any excavation in the carpark area it would be prudent to compile an up to date map of buried services based on information from the service providers and the GPR slices.

## 7.0 Area 2 Geophysical Surveys

### 7.1 Reconnaissance magnetic susceptibility survey

The Phase 1 survey data are presented in Fig 14.

Area 2 has the second highest response of the areas surveyed. There is a general enhancement over most of the area with perhaps a SW – NE trend in the higher values. Within the zone of enhancement there are amorphous areas of slightly higher values which may relate to some dispersal of susceptible material from a zone of particularly high values. This could be geological and/or archaeological.

During the course of the survey the survey team were approached by a farmer who had previously owned or worked the land in Area 2. He told us that the land had been extensively ploughed on a 4 to 5 year cycle and the ploughing had been sometimes in different directions. He also said he had seen darkened areas of soil but couldn't remember exactly where they were.

Close to or at the margins of the field there are a number of small areas of consistently high values e.g. at the NE and SW. The proximity of these high values to the field boundary may be significant in that they may be due to agricultural practices. The larger area of higher values at the northern fence may be significant.

Figs 14.1 and 14.2 respectively show the location of the excavation trenches and features found.

The western trench straddles high, medium and low susceptibility enhancement from south to north. The pattern of enhancement associated with the trench, given the 5m x 5m reconnaissance sampling, does not immediately indicate the presence of archaeology. The excavation evidence indicates a possible cremation was found in this trench. A cremation would result in burnt products which would lead to an enhanced susceptibility. If the evidence is for a single cremation, the susceptibility response would be very localised and unlikely to be detected in a reconnaissance survey. However, if this area was the site of many cremations then there could be a zone of enhancement possibly dispersed by the ploughing regime indicated by the former landowner. It would be worth investigating the description of the soils found in the trench or if, this information is not available, a small 1m x 1m test pit could be opened near the southern end of the trench to investigate the source of the enhancement.

The eastern trench contains a number of pit or hearth features which seem to coincide with the edges of the zone of enhancement and also close to a central area of high enhancement. There may be no significance in this apparent correlation, again further investigation of the soils found in the trench or a test pit could be opened to investigate these areas of enhancement. In addition, in advance of excavation a series of test pits could be opened to inform any future excavation programme.

### 7.2 Magnetic gradiometry survey

The Phase 2 data are presented in Fig 15.

The response in Area 2 for the most part is relatively 'quiet' perhaps indicating deeper bedrock (>0.5 m) with thicker soils, masking the magnetic response. There are some dominant responses in the NW corner of the area which are likely to be due to geology. Careful examination of the data shows there to be some isolated small diameter anomalies of positive gradient that normally indicate cut features such as pits. These anomalies are at the eastern and SE side of the area.

In order to further investigate this dataset the data were clipped to 40 nT to remove larger responses which may be swamping more subtle responses which might be due to archaeological sources. The clipped data are presented in Fig 15.1. The clipping has highlighted a number of positive magnetic

anomalies which could be due to pits or cut features. These are predominantly at the eastern side of the survey area.

A possible settlement model for this field could be that it is archaeologically more prospective as there may be thicker soils, especially on the eastern side which would be suitable for agriculture. Augmentation of the soil must also be considered in this area which could lead to masking of magnetic anomalies due to deep sources which could be due to a combination of geological and archaeological features.

The location of excavation trenches and the features found are given in Figs 15.2 and 15.3 respectively. The western trench is in an area of high magnetic gradient which is the likely response to magnetic bedrock. This gradient is swamping any low or subtle responses that could be due to archaeology such as a hearth related to the possible cremation indicated in this trench.

The eastern trench is in an area of relatively uniform magnetic response upon which there are superimposed a number of small anomalies of positive gradient. These could relate either to cut features or a very localised magnetic effect due to concentrated mineralization in the bedrock. There is no strong correlation with pit and hearth features found in the trench except for an area near the southern end. Before any substantial excavation in this area is undertaken it would be prudent to test a number of localised positive gradient anomalies to identify their source.

### 7.3 Earth resistance survey

In order to assess the soils on the eastern side of the survey area a Phase 3 earth resistance survey was carried out. The data are presented in Fig 16. The overall response is of low resistance which may indicate soil to a depth of at least 0.5m. There is a linear higher resistance anomaly in the SE of the survey area which is likely due to a shallow rib of bedrock. High resistance bedrock is also found at the northern end of the area surveyed.

The location of excavation trenches and the features found are given in Figs 16.1 and 16.2 respectively. The eastern trench barely clips the edge of the resistance grid. The linear higher resistance anomaly is possibly aligned with a delimited zone in the trench and it would be worth investigating if bedrock, stone or compacted ground was encountered in this zone.

The resistance data supports the argument for thicker soils and this area should be tested by a series of test pits to inform any future excavation in this area.

### 7.4 Ground penetrating radar survey

A Phase 4 reconnaissance survey was carried out in this area with W – E lines spaced 5m apart. The survey was carried out to assess the soil thickness in a larger area than was possible to survey in the time available using the resistance method. The survey area is shown in Fig 17. The horizontal time slices from GPR grid 10 are presented in Fig 17.1. Slice 4 (Fig 17.2) shows a broad area of homogenous response which supports the idea of thicker soils in this area. The ‘central’ area of homogenous response is fringed by irregular responses possibly due to shallowing bedrock. Slice 14 (Fig 17.3) is from a deeper level and shows the response from the bedrock. The apparent west – east lines of small, largely white ‘spots’ seen in both slices are artefacts of data processing and do not relate to any archaeological features.

The location of excavation trenches and the features found are given in Figs 17.2.1 & 17.2.2 respectively for Slice 4 and Figs 17.3.1 & 17.3.2 for slice 14. In Slice 4 there is a very tentative broad correlation with thicker soils and areas in the trenches which have encountered archaeological features. This tentative correlation can be seen in Fig 17.2.2 where the archaeology in the western trench is

found in a homogenous area and in the eastern trench where the delimited zone lies between two areas of higher response. Note the small anomaly lying immediately to the east of the western trench and the zone of the possible cremation. This may be due to an isolated boulder or an area of compacted ground.

### 7.5 Discussion

No coherent geophysical anomalies that could be immediately interpreted as being due to undiscovered archaeological features were identified in Area 2. The geophysical responses can be attributed to variably magnetic soils overlying magnetic bedrock. The responses and their patterns seen both in the susceptibility and gradiometry data support magnetic soils and bedrock. There are some tentative geophysical correlations with features found in excavation trenches. There appears to be deeper soils to the east of the area. This is supported by gradiometry, resistance and GPR data. It is in the deeper soils that sparse archaeology has been encountered in a trench. It is unknown whether all or some of the soil in the area has been transported from elsewhere and is masking deeper responses due to geology and/or archaeology. The deeper soils would make the area more prospective for agriculture and associated settlement. Within this area of deeper soils, there are a number of areas of susceptibility enhancement and isolated gradiometry anomalies which should be investigated by test pits in advance of any substantive excavations.

## 8.0 Area 3 Geophysical Surveys

### 8.1 Reconnaissance magnetic susceptibility survey

The Phase 1 data are presented in Fig 18. The overall lowest susceptibility response is in this area. In Area 3 there are low values over most of the field with an isolated high south of the centre. These persistent low values may be related to the inferred geological contact shown in Fig 3 which is sub-parallel to the road. The implication is that rocks to the south of the contact are less magnetic or there is a significant thickness of non-magnetic soil covering the bedrock. Given the overall appearance of the susceptibility data, with much higher values in the other 3 areas, the possibility also exists that the soil in this field has been introduced from another location. In Area 3 there are also some isolated single point anomalies and a significant area of higher enhancement to the south of the area, at the field boundary. Given the 5m x 5m sampling, isolated single point anomalies should be treated with caution but the higher values south of the centre and at the south may be significant.

The location of excavation trenches and features recorded is given in Figs 18.1 and 18.2 respectively. There are a number of trenches in Area 3 that lie in zones of low, medium and higher susceptibility enhancement. A trench in the SE corner of the field lies on medium and low enhancement and found some localised, small pits and a sunken feature. There does not appear to be any correlation with the susceptibility data. A second trench in the NW of the field straddles low, medium and high susceptibility enhancement. In this trench there are very localised pit features which lie in the low enhancement zone. In the NE of the field, in a significant area of low susceptibility, there is a single pit found in a trench. Other trenches in this locality were empty. If information on the soils recorded in these trenches is available, it would be worth investigating if the soils in the NE corner of the field differ greatly from those found elsewhere in the field. This may help to resolve where the soil in the NE has been introduced from another locality and may mask any underlying archaeology.

### 8.2 Magnetic gradiometry survey

The Phase 2 data are presented in Fig 19. The response in Area 3 is interesting in that it is quite different from that of the magnetic susceptibility survey except in the northern and SW parts of the field. The 'quieter' areas magnetically may indicate a change in bedrock lithology with lower or no magnetic expression and/or thicker soils in these areas. The possibility of introduced soils in these areas should not be ruled out.

In order to further investigate the magnetic response in this area the data were clipped to 40 nT and the results are presented in Fig 19.1. The overall pattern of response is the same as for the complete dataset. There are some single point positive gradient anomalies present in the 'quiet' zone at the NE end of the survey area. It is not clear if these could be due to geology or archaeology.

The location of excavation trenches and features recorded is given in Figs 19.2 and 19.3 respectively. Given the strong magnetic gradient in this field, it is quite difficult to detect small scale features such as pits and hearths that may have a magnetic expression. Accordingly, it is not possible to draw any conclusions as to whether the archaeological features found in the SE and NW trenches have a geophysical response. The trench in the NE corner of the area lies in a magnetically quiet area that has a number of isolated single point positive gradient anomalies which could be due to pits or localised magnetic minerals in the soil or bedrock.

### 8.3 Discussion

No coherent geophysical anomalies that could be immediately interpreted as being due to undiscovered archaeological features were identified in Area 3. The high gradient magnetic response is similar to that found in the NW corner of Area 2. The high magnetic background over most of the field prevents the detection of any magnetic anomalies that may be due to pits or hearths. The area to the NE has a consistent low magnetic background which could be due to a change in bedrock type or thicker soils. This area appears more magnetically prospective with a number of isolated positive gradient anomalies which could be initially investigated by test pits.

## 9.0 Area 4 Geophysical Surveys

### 9.1 Reconnaissance magnetic susceptibility survey

The Phase 1 data for Area 4, which has the largest area of high values, are presented in Fig 20. The susceptibility survey was extended westwards outside the area boundary to investigate the distribution of these high values. There are four main areas of enhancement, at the SW, along the western margin, at the northern margin and in the SE where the higher values appear to continue into Area 3. The area in the SW appears to have a consistent SW – NE form and maybe geological and/or archaeological. The western margin enhancement is likely to be due to geology. The northern margin anomaly has a consistent SW – NE form and maybe geological and/or archaeological. It is interesting to note that the anomalies at the SW and at the northern margin are quite well aligned in a SW – NE direction and this may point to a geological source. The area to the SE has an amorphous enhancement distribution that appears to cross the road. It is unclear what the source of this anomalous area is and a geological source should not be ruled out.

In addition to the four main areas of enhancement, there are a group of three smaller areas which may be aligned and which run close to or along the NE boundary of the field. The two northerly areas are close to the field boundary and perhaps also close to a previous excavation at Kongshaug (Fig 2).

The location of excavation trenches and features recorded is given in Figs 20.1 and 20.2 respectively. There are three trenches in this area. The trench in the NE of the area was empty whilst the second in the SE corner contained a large single pit with two other small diameter pits. This trench lies in an area of high susceptibility enhancement which cannot be attributed to the features found in the trench. The third trench contains a linear arrangement of small pits/postholes, which are aligned N – S, a nearby larger pit and a possible activity area to the south. None of the latter features can be directly attributable to the low, medium and high zones of enhancement in which the trench is located.

### 9.2 Magnetic gradiometry survey

The Phase 2 data are presented in Fig 21. The response in this area shows the area to the NW to be ‘quieter’ magnetically with high values in the S and SE. The large ‘noisy’ area in the SE correlates with the susceptibility enhancement seen in this area. The isolated anomaly to the N, close to the eastern boundary, correlates with an isolated zone of enhancement seen in the susceptibility data.

In order to further investigate this area, the data were clipped to 40 nT. The ‘quiet’ zone is still apparent and may contain thicker soils masking the possible magnetic response of the underlying bedrock. There are a number of single point positive anomalies in this zone which could be related to pit or cut features which could be test pitted.

The location of excavation trenches and features recorded is given in Figs 21.2 and 21.3 respectively. The gradiometry data do not fully cover the empty trench in the magnetically quiet area in the NE corner of the field. However, there are some isolated single point positive gradient anomalies which coincide with the location of the trench. As no archaeology was reported in this trench these anomalies do not have archaeological sources.

Given the strong magnetic gradient in the southern part of the field, it is quite difficult to detect small scale features such as pits and hearths that may have a magnetic expression. Accordingly, it is not possible to draw any conclusions as to whether the archaeological features found in the two southern trenches have a detectable geophysical response. The trench in the NE corner of the area lies in a magnetically quiet area that has a number of isolated single point positive gradient anomalies which could be due to pits or localised magnetic minerals in the soil or bedrock.

### 9.3 Discussion

No coherent geophysical anomalies that could be immediately interpreted as being due to undiscovered archaeological features were identified in Area 4. The high gradient magnetic response in the southern part of the field is similar to that found in the NW corner of Area 2 and majority of Area 3. The high magnetic background over most of the field prevents the detection of any magnetic anomalies that may be due to pits or hearths. The area to the N has a consistent low magnetic background which could be due to a change in bedrock type or thicker soils. This area appears more magnetically prospective with a number of isolated positive gradient anomalies which could be initially investigated by test pits.

## 10.0 Conclusions

- In Area 1 geophysical anomalies which may relate to building foundations were detected in the carpark. The carpark area contains many buried services such as pipes and cables.
- In Area 1 a previously discovered underground passage in the carpark was detected by GPR survey. The survey has possibly tracked the passageway eastwards into a small field at the boundary of the carpark. A westward and/or northward extension was not proven.
- In Area 1 a high resistance anomaly may relate to stone paving discovered in an excavation in the garden area
- In Area 1 the location of a possible shaft reputed to be associated with a potato cellar was detected on Kuhaugen.
- In Area 1 on a GPR transect over Flagghaug possible unmarked graves were detected
- In Area 1 selected techniques using a multi-method geophysical survey were the solution to surveying in different survey environments such as in a carpark, in a garden, in a graveyard and close to buildings.
- In Area 1 GPR in the carpark area detected an excavation trench. Other trenches were not detected.
- In Area 1 there was no strong correlation between features identified in the excavation trenches and the geophysical responses over the same areas when using magnetic and GPR methods
- In Areas 2, 3 and 4 no coherent geophysical anomalies that could be immediately interpreted as being due to undiscovered archaeological features were identified.
- Areas 2, 3 and 4 are underlain by metamorphic bedrock which exhibits strong magnetic gradients that obscure possible weak magnetic gradients due to sub-surface archaeology
- In Areas 2, 3 and 4 the soils in each area exhibit variable susceptibility enhancement. The source of enhancement could be geological or archaeological or be due to imported soil or a combination of all three.
- In Areas 2, 3 and 4 there was no strong correlation between features identified in the excavation trenches and the geophysical responses over the same areas when using magnetic and GPR methods
- The most archaeologically prospective area from a geophysical perspective is Area 1 followed in order by Areas 2, 3 and 4.

## 11.0 Recommendations

- In Area 1 Investigation of geophysical responses in the carpark area by excavation should be informed with an up to date map of underground services based on the GPR results and maps obtained from the service providers
- In Area 1 Garden area a short programme of test pitting on geophysical anomalies should be used to inform any subsequent investigation by excavation.
- In Area 1 Graveyard a test GPR survey should be run to see if the method can detect unmarked graves.
- If excavation is planned in Areas 2, 3 & 4, test pitting on and off geophysical anomalies should be carried out to inform the excavation programme.
- If test pitting or excavation is carried out, soil samples should be measured for magnetic susceptibility to confirm the source of magnetic anomalies.
- The interpretation given in this report to be refined based on future excavation evidence.

Prof Dagfinn Skre is thanked for initiating and supporting this survey. Marit Synnøve Svea, formerly with the Nordvegen Historic Centre, provided support and initial information on Avaldsnes. Arnfrid Opedal of the Nordvegen Historic Centre organized day-to-day support during the course of the survey. She is especially thanked for lonely duty on the barricades when the carpark had to be closed to facilitate the GPR survey. The friendly and helpful staff at the Nordvegen Historic Centre speedily fulfilled our requests for storage and office facilities. J.A. Hveding of Karmøy Kommune provided aerial photographs and co-ordinates of the fixed points at Avaldsnes.

The survey was carried out in good humour with the enthusiastic support of the survey team of James Bonsall of Earthsound Associates and Kristin Foosnæs and Arne Anderson Stamnes of NTNU. Finally, Lars Stenvik of NTNU is acknowledged for his support and organizational skills in providing resources to carry out this archaeological geophysics survey.

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## **A1.0 Introduction**

A number of geophysical surveys have been carried out at Avaldsnes. These surveys were carried out by a GPR equipment developer/manufacturer, a geophysical contractor, and by staff attached to university departments. The surveys were carried out independently of each other in 2004, 2006 and 2009 and mainly investigated areas referred to as Areas1 and 2 in this report. In most cases the data were recorded and/or compiled digitally and in some cases should be available in a georeferenced format.

An attempt was made to obtain further technical information and access to the digital data for most of the previous work. This was done in order to attempt to compare the results, possibly integrate them with the work described in this report and to form a digital archive of geophysical surveys carried out at Avaldsnes. Unfortunately none of the workers contacted would release the digital data and therefore their data have not been incorporated in this report.

The previous work is contained in unpublished reports which are briefly described below. Interpretive comments made in this Appendix are made largely in the absence of technical information on the surveys themselves and knowledge of prior or subsequent excavation results.

### **A1.1 August 2004 – 3-D Radar Survey by 3-d Radar AS, Norway**

This GPR survey was carried out using a step frequency radar system which utilised a towed array of multiple transmitter receiver pairs. The results and interpretation are contained in an unpublished report. The array is quite large (about 2.4m in width), is more suited to large open areas and this may have restricted access to certain parts of the areas surveyed. Some part of the survey appears to have been carried out in a period of heavy rain which may have resulted in saturated ground conditions and standing surface water. This may have reduced the GPR response.

The work is largely presented as horizontal depth slices and accompanying depth sections derived from an unspecified band of stepped operating frequencies. It is not clear as to how the depth information were derived that are used in the presentation of the data; it appears default values for common geologic materials have been used. Depths quoted in the report therefore should be viewed with some caution and none are quoted in this summary. The data presented are not georeferenced.

Six areas are discussed in the report :

Kongshaugen  
Parkeringsplass  
Kauhaugen  
Kirkegård  
Prestegårdshage  
Tilførselsvei

The Kongshaugen survey appears to have detected a circular feature some 25m in diameter which contains a smaller oval shaped area some 15m x 10m in dimensions. This could be the footprint of a mound with some internal structure.

The survey at Parkeringsplass was carried out in 3 survey panels or blocks and they have been compiled into a series of individual and combined horizontal slices. The surveys appear to have detected a number of relatively shallowly buried services such as cables and pipes with some deeper linear features. The presented depth sections may also show some modern or ancient construction detail with a possible ditch or cut and the foundation on which the carpark was constructed.

The data from Kuhaugen comprise a narrow survey strip with accompanying horizontal slice and section. There is appreciable topography over Kuhaugen which has not been incorporated into the processing of the GPR data. The slice and section presented therefore may have an inherent distortion. There appears to be an area of disturbance seen in the slice, which does not appear coherent, but may reflect the random internal distribution of the material used in the mound construction and/or be evidence of post-construction disturbance. The section shows a strong, apparent horizontal reflector which may be the foundation of the mound. The 'horizontal' nature of the reflector is likely to be distorted due to no topographic correction having been applied.

The Kirkegård survey appears to have yielded no useable data due to lack of penetration of the radar signal and no results are reported for this area.

A narrow N-S survey strip was carried out at the western side of Prestegårdshagen with an amorphous zone of disturbance apparent at the northern end of the horizontal slice. The sections show an irregular reflective layer with a discrete reflector (5m along the section) at depth which coincides with the zone of disturbance shown on the horizontal slice.

Two GPR sections are presented for the profiles along Tilførselsvei. They both show an irregular band of reflectors at a relatively shallow depth which likely are from the road foundations.

The 3-d Radar AS survey undoubtedly collected good quality data which may contain more information than has been presented in the report. It is unclear as to whether an archaeologist or someone with archaeological training was involved in the processing and interpretation of the data. Given the advantages of good quality multi-frequency data being available and that the surveys were mostly in Area 1, it would be worth considering a fresh look the 3-d Radar dataset.

3-d Radar were not contacted to find out if they would release their digital data as there were difficulties with obtaining them in a suitable format for re-processing. There are very recent developments in making 3-d Radar data compatible with industry standard software and, should a fresh look at the data be required, it is very likely the data would be made available in a suitable format.

#### **A1.2 April 2006 – Electromagnetic EM 38 and GPR surveys by GeoFysica, Sweden**

These surveys were carried out in Area 1 as designated in this report. . The results and interpretation are contained in an unpublished report. The surveys used a combination of electromagnetic techniques to collect electrical conductivity, magnetic susceptibility and GPR data in seven sub-areas. The electrical conductivity and magnetic susceptibility data were collected using a Geonics EM 38 instrument and the GPR used a Malå Geoscience system with 500 MHz centre frequency antenna. The depth of investigation of the EM38 may be about 1 to 1.5m below the instrument whilst a 500 MHz GPR system may have a depth of investigation of less than 2m.

The EM 38 datasets are presented as combined contoured and greyscale plots. The GPR work is largely presented as horizontal depth slices and accompanying depth sections. It is not clear as to how the depth information were derived that are used in the presentation of the GPR data; it appears default values have been used. Depths quoted in the report therefore should be viewed with some caution and none are quoted in this summary. The data presented are not georeferenced.

The general survey areas are :

Area 1 – Parkeringsplass

Areas 2 & 7 – Platå vid historiskt senter/barn/Kauhaugen

Areas 3, 4 & 5 – Prestegårdshage

Areas 6 – Garden SE of Parkeringsplass

Area 1, Parkeringsplass, was surveyed using EM 38 and GPR. The EM38 magnetic susceptibility data largely show amorphous zones of susceptibility enhancement with one isolated area of more intense enhancement near the SE corner of the area. There is a pervasive weakly enhanced background over the whole survey area and this may be due to the surface dressing of the carpark area. In August 2009 the dressing was stone chips and, if a similar dressing material was in place in 2006, it is possible the response could be due to the stone dressing. One larger distinct zone of enhancement lies in the SW corner of the surveyed area and coincides with the NE corner of Prestegårdshage. The electrical conductivity data show two distinct linear anomalies, one lying N – S and the other cutting the latter in a WSW - ENE direction. These anomalies are likely to be caused by buried services such as pipes and cables.

The GPR data is displayed in the form non-overlapping horizontal slices. The data show a number of features including the NE corner of Prestegårdshage and a W – E linear which could be a trench. There are other zones which could be coherent zones of response but there is little or no consistent supporting evidence from the EM38 data. It could be that there has been a large degree of periodic ground disturbance in this area due to installation/maintenance of the carpark and the burying of underground services.

Area 2, Platå vid historiskt senter, is a 3m wide strip which was surveyed using the EM38 and GPR. From the location map in the report, it is difficult to see where this survey is precisely located such that anomalies in the data can be discussed. There is a significant area of susceptibility enhancement at the northern end of the survey area which could be due to geology, metallic debris, burning or a combination of all of the latter. There is a weaker zone of response lying at the SW corner of the area. The electrical conductivity data show a weak response correlating with the northern end of the area and a much stronger one at the SW corner. The lack of mapping detail and the narrow width of the area surveyed make it difficult to draw any firm conclusions on the cause of the anomalies.

The GPR data do not appear to have a strong correlation with the EM38 data. There are some discrete anomalies in the northern and SW parts of the area which are within the zones of magnetic susceptibility enhancement and electrical conductivity anomalies. Again, the lack of mapping detail and the narrow width of the area surveyed make it difficult to draw any firm conclusions on the cause of the anomalies. In addition there is a possible NW to SW trend of discrete anomalies with depth which can be seen in the first six slices. These form a linear trend which may be of geological or archaeological significance. From slice 6 onwards there is a consistent discrete anomaly which is seen at about 15m north.

Areas 3, 4 & 5, Prestegårdshage, are comprised of two N- S survey strips and an adjoining small rectangular area. These strips and adjoining area were sited between the mature trees and shrubs which are found in this area.

The magnetic susceptibility survey detected a significant area of enhancement in the NW of the survey area with other smaller amorphous zones spread over most of the remaining area. The susceptibility background is relatively low in this area and the NW anomaly could be equally due to geology or burning. The interpretation of magnetic susceptibility data in this area is problematic due to its use as a garden and being subject to periodic ground disturbance. The electrical conductivity response largely mirrors the magnetic susceptibility response with the exception of the curvilinear anomaly that spans areas 4 & 5. This response is likely to be due to a pipe or cable.

The GPR data show a number of isolated anomalies, amorphous areas of response and a curvilinear anomaly. Slices 2 and 3 can be correlated with the susceptibility and conductivity anomalies found in the NW of the area. An area in the south of slices 4, 5 and 6 possibly correlates with amorphous responses found in the susceptibility data. The curvilinear anomaly correlates with a similar feature seen in the conductivity data and the source of the anomaly is likely to be a pipe or cable.

Area 6 is a small field or garden that lies to the SE of Parkeringglass. Here an EM38 survey was carried out over the complete area and a GPR survey in a smaller rectangular area within it. The magnetic susceptibility survey shows a pervasive elevated response over most of the area and five small, discrete areas of anomalous response. These discrete responses could equally be due to geology, a ferrous object or burning or a combination of all of the latter. The electrical conductivity data has four or perhaps six small, discrete anomalous responses. Two of the responses can be correlated with two of the five susceptibility anomalies whilst two others are in the vicinity of susceptibility anomalies. Where there is a correlation, this could indicate the source may be ferrous metal or geology containing ferrous minerals. In August 2009 there were a number of tree stumps and loose rocks and small boulders in this area and it is possible that they may be influencing the susceptibility and conductivity responses. The pervasive elevated response could indicate an activity area which may contain burnt or occupation debris disseminated in the topsoil.

There is a strong conductivity response at the SW side of the survey area which is likely to be due to the metal mesh fence which forms the boundary to the field. There is a distinct N – S linear zone of low conductivity which divides the survey area in half. With the assumption that this feature is not an artefact of survey data collection, this may indicate near surface geology, a buried wall or area composed of electrically resistive material such as a path or track or backfilled trench.

The GPR data presented for this area is in the form of horizontal slices. There appears to be no strong correlation with the EM38 data. In general the data are composed of single point anomalies which could be due to small stones or cobbles. There is a tenuous correlation with the N-S linear seen in the conductivity data where in the GPR data there is a higher density of single point anomalies aligned in a N – S direction. This alignment lies immediately to the east of the location of the conductivity linear.

Area 7 lies and extends in a NE direction from the barn. The area, in August 2009, had a significant amount of fill material in the immediate vicinity of the barn, was bisected by a small graveled track further to the NE and formed part of the lawn surrounding the house that lies immediately to the NW of the survey area.

The magnetic susceptibility data show the NW edge of the area to be a zone of enhancement containing a number of single point anomalies. Some of these anomalies have a regular spacing and may be due to backfilled or silted pits defining a curvilinear feature such as a ditch or trench. There were pieces of armoured cable, wire scattered on the ground surface in August 2009, and the likelihood is that there is or was a buried cable in this area. The pattern of conductivity response in this area correlates with the susceptibility data with a number of highly conductive single point anomalies. This supports the idea that there is significant modern metal debris in this area.

There appears to be a contradiction in the presentation of the magnetic susceptibility and electrical conductivity data for Area 7. The data are presented (Fig 18) as contoured maps in a local grid system with 0,0 being located at the SW corner of the map. In these plots, which are described above, the anomalous zones are found at the western side of the area. In a composite plot (Fig 20) showing the respective susceptibility and conductivity plots for all seven areas, the anomalous zones for Area 7 appear on the eastern side of the map. It appears as if the respective plots for Area 7 in Fig 20 have been inverted.

The GPR data are presented as horizontal slices. The overall appearance of the data is of small patches of anomalous response with a higher density of response lying to the north. There is a marked zone without response in the south of slices 2, 3, 4 & 5. This may co-incide with the area of the fill material observed in August 2009. Slices 6, 7 & 8 may show some correlation with the EM38 data with the possible cable or cable trench apparent as a curvilinear sequence of small patches of anomalous response.

### **A1.3 April 2009 – GPR survey by the University of Vienna, Austria**

The survey was carried out on an 80m x 50m grid in the northern part of Area 2 as designated in this report. No report is available, just a DVD with georeferenced horizontal slices and an animation of the slices. Accordingly, no technical information on the survey is available but it is understood that the survey was carried out with a Sensors & Software, Noggin GPR system with 500 MHz centre frequency antenna.

The slices are tagged with depth intervals but it is not clear how the depths were assigned. The slices show a number of coherent linear and point source features in a slowly changing even textured background which is likely due soils overlying bedrock. Given the homogenous nature of the background response, it is likely there is an appreciable thickness of soil in the northern part of Area 2. Successive slices show the development of a small, natural basin that possibly contains the thicker soils.

### **A1.4 June 2009 – Magnetic, EM38 and earth resistance surveys by Geosight, USA and Moesgård Museum, Denmark.**

This work is described as a geophysical evaluation and is reported in an unpublished preliminary report. The data presented were largely in an unprocessed format with further work to be carried out for inclusion in a final report. A series of test surveys were carried out in the northern part of Area 2 as designated in this report (Hovedområdet 1 in the preliminary report) and on Flagghaug. The surveys are not georeferenced in the preliminary report but it is understood that co-ordinates in UTM, recorded later by a GPS, are available for selected grid pegs used in the surveys. There were some technical problems with the instruments and methodology used in the survey. These problems appear not to have affected the quality of the data collect using the magnetic method as artefacts of survey were to be removed in final processing. The EM38 data were influenced by the zeroing of the instrument in susceptibility mode and from some spurious spikes whose cause was unknown.

A total field magnetic survey was carried out on the same 80m x 50m grid as the GPR survey by the University of Vienna. A recording base station was used to record diurnal changes in the Earth's magnetic field which were removed from the field data. The resulting data were contoured. The magnetic map shows a broad N – S stripping of high and low values upon which there are superimposed a number of single point anomalies. The interpretation draws attention to three single point anomalies, two lie to the east of the survey area and one to the west. The anomalies could be due to cooking pits or hearths. There are a number of other features seen in the data which could be due to archaeological sources. These are other single point and broad anomalies and some that describe a possible linear pattern.

A brief comparison with the GPR survey described above was made and this showed some large differences in the datasets. The pattern of magnetic anomalies in general does not correlate with the images in the GPR horizontal slices. There is however correlation with two of the single point magnetic anomalies and single point responses in the GPR data. This correlation is with anomalies found in the eastern part of the survey area. It is also noted in the report that the GPR survey has detected features not seen in the magnetic data.

The EM38 survey in Area 2 was confined to a 16 m x 50m N- S strip at the eastern side of the coincident magnetic and GPR grids. A second, more detailed survey was carried out in part of the latter grid. Initial tests with the instrument in electrical conductivity mode showed the soils to be very resistive (low conductivity). The variability of the measurements made was at or below the detection threshold of the instrument. For the latter reason electrical conductivity measurements were not made.

The data from the EM38 magnetic susceptibility survey were considered to be noisier than those from the total field magnetic survey. There was correlation with two of the single point anomalies found at the eastern side of the survey grid. The latter was confirmed by a more detailed susceptibility survey in a 10m x 10m area targeted over one on the total field anomalies.

A 30m x 30m grid which spanned the boundary wall to the graveyard was set out at Flagghaug and a total field magnetic survey and five resistivity transects were carried out. The magnetic survey showed some differentiation in response across the boundary wall. To the west, inside the graveyard, there is a complex anomaly pattern which is interpreted to be possibly due to graves, soil variability due to the construction of the mound or boulders. The magnetic response to the east of the boundary wall, outside the graveyard, possibly shows a different pattern. This response is near N – S in orientation and may be due to the removal of soil from the mound or from its original construction.

The resistivity survey was carried out along five transects which are difficult to interpret in terms of the source of resistivity variation due to the limited sampling interval of the transects and their spatial coverage. There appears to be a difference in response between the western and eastern sides of the boundary wall. There is higher resistivity on the western side which is attributed to shallow bedrock. On the eastern side the resistivity values are lower with some possible distinctive minor variations which might be related to archaeology.

The conclusion of the geophysical evaluation at Hovedområde 1 was that the EM 38 in both susceptibility and conductivity modes is not suitable for survey on this site. A resistivity survey would detect bedrock and may find shallow trenches and post holes, although its capability in detecting the latter were not proven. A magnetic survey at 0.5m spacing was shown to be appropriate on the site. A GPR survey with a higher frequency antenna offers some potential for detecting small features. No cultural patterns were detected by the GPR; small features detected could have geological or cultural sources. There was little correlation between the GPR and magnetic data in Area 2 and the interpreted settlement area. This is summed up by a statement in the report..... “Both surveys also appear to have contradicted the findings of the excavation trenches in saying that cultural features to be about equally-distributed across the field of Hovedområde 1.”

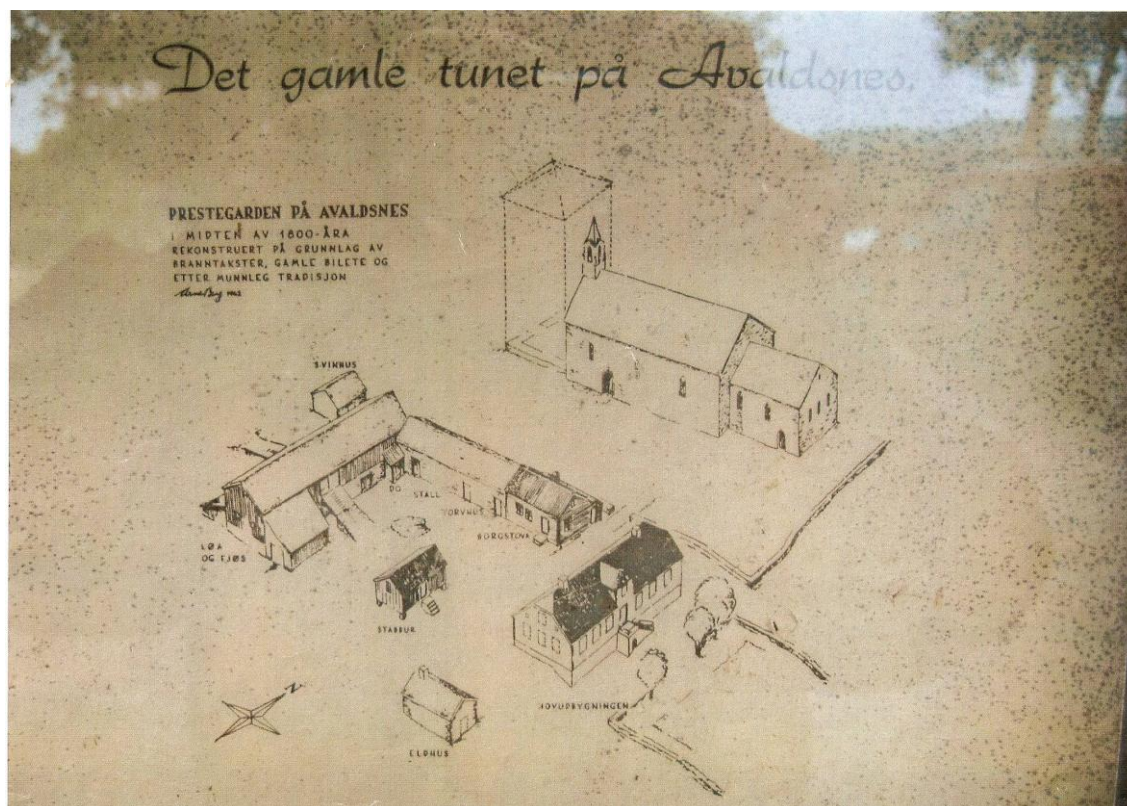
Flagghaug was a difficult location for a geophysical survey. There may be complex geophysical patterns resulting from the building and subsequent removal of the mound.

The overall conclusion of the evaluation was that there was uncertainty in the findings of the surveys and it was uncertain whether magnetic or GPR would be more suited for a wide-area survey. It was suggested that some test excavations should take place to inform a decision on the most appropriate survey method for a wide-area survey. One of the single point anomalies detected by all three methods in Hovedområde 1 should be tested along with anomalies detected by the individual instruments. A test should also be made where no anomalies were detected. The surveys carried out have not detected geometrical patterns that would identify former houses. It is likely that future surveys will fail to be certain in their identification of these historic remains of buildings. Geophysical surveys may locate features that may be a guide to the locations of some houses.

## Appendix 2 – Ground coverage of geophysical surveys

<b>Geophysical Method</b>	<b>Area 1 Sq m or m</b>	<b>Area 2 Sq m</b>	<b>Area 3 Sq m</b>	<b>Area 4 Sq m</b>	<b>Totals</b>
<b>Magnetic Susceptibility</b>	4725	10,000	9500	10,000	34225
<b>Magnetic Gradiometry</b>	1500	10,000	9500	5250	26250
<b>Earth Resistance</b>	2100	1600	-	-	3700
<b>Ground Penetrating Radar</b>	3505	6500	-	-	10005
<b>Electrical Resistivity Tomography</b>	144m	-	-	-	144m
<b>Totals</b>	<b>11830</b>	<b>28100</b>	<b>19000</b>	<b>15250</b>	<b>74180</b>

Appendix 3 – Fig A3.1 Sketch showing possible farm buildings in the vicinity of the carpark



Figures

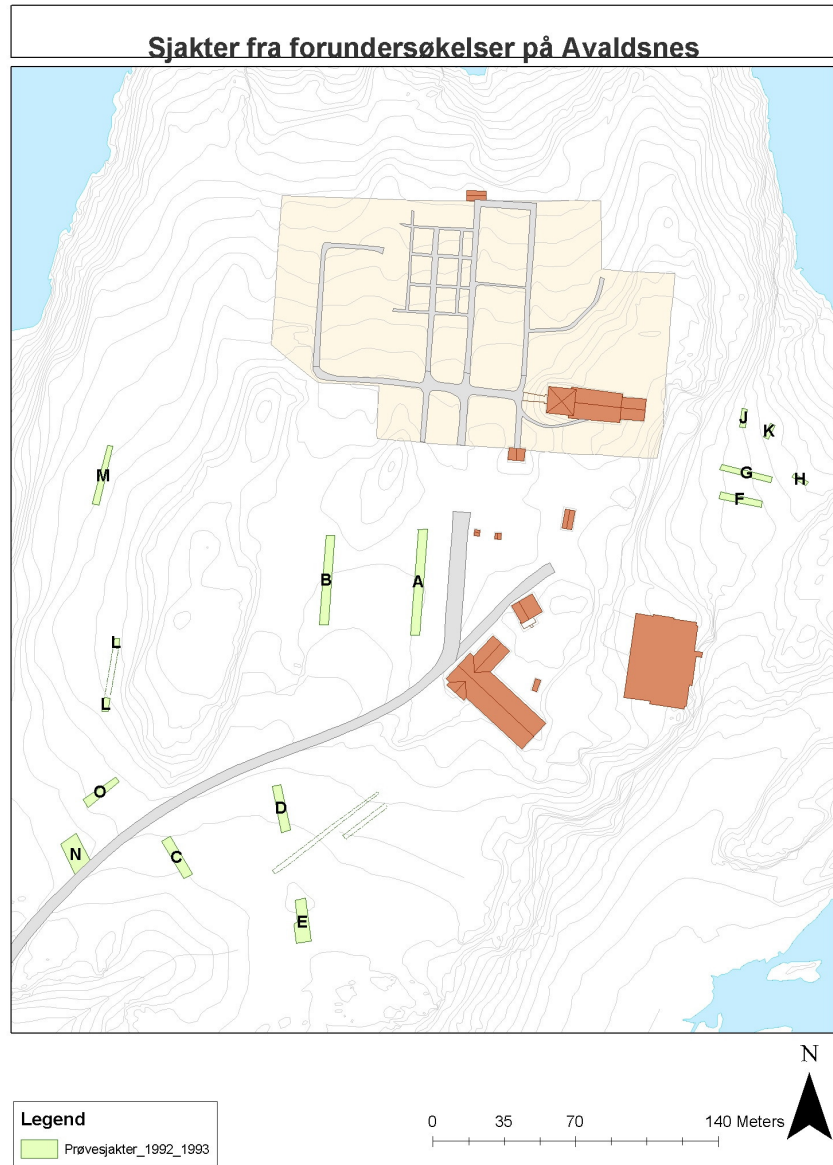


Fig 1 : Excavation trenches used to define the settlement area (Skre, pers comm)

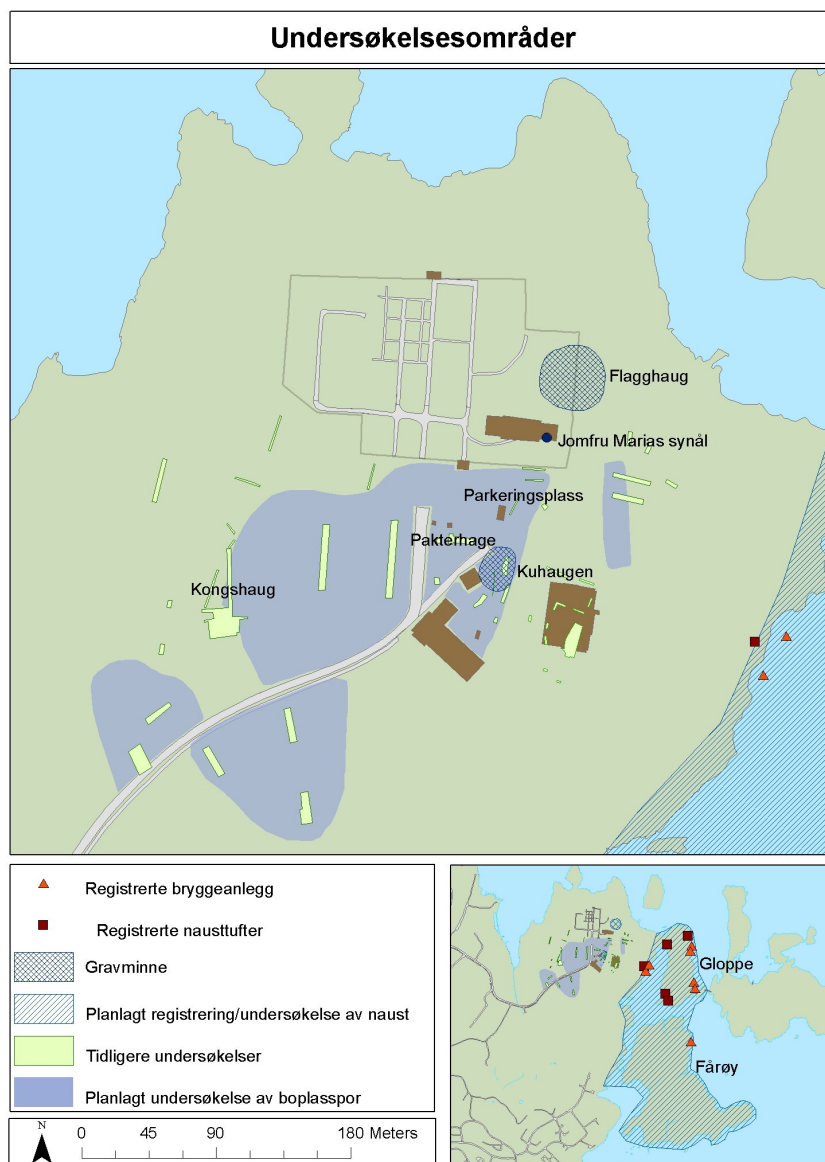


Fig 2 : Map showing the interpreted settlement areas, test excavation trenches and principle visible features (Skre, pers comm.)

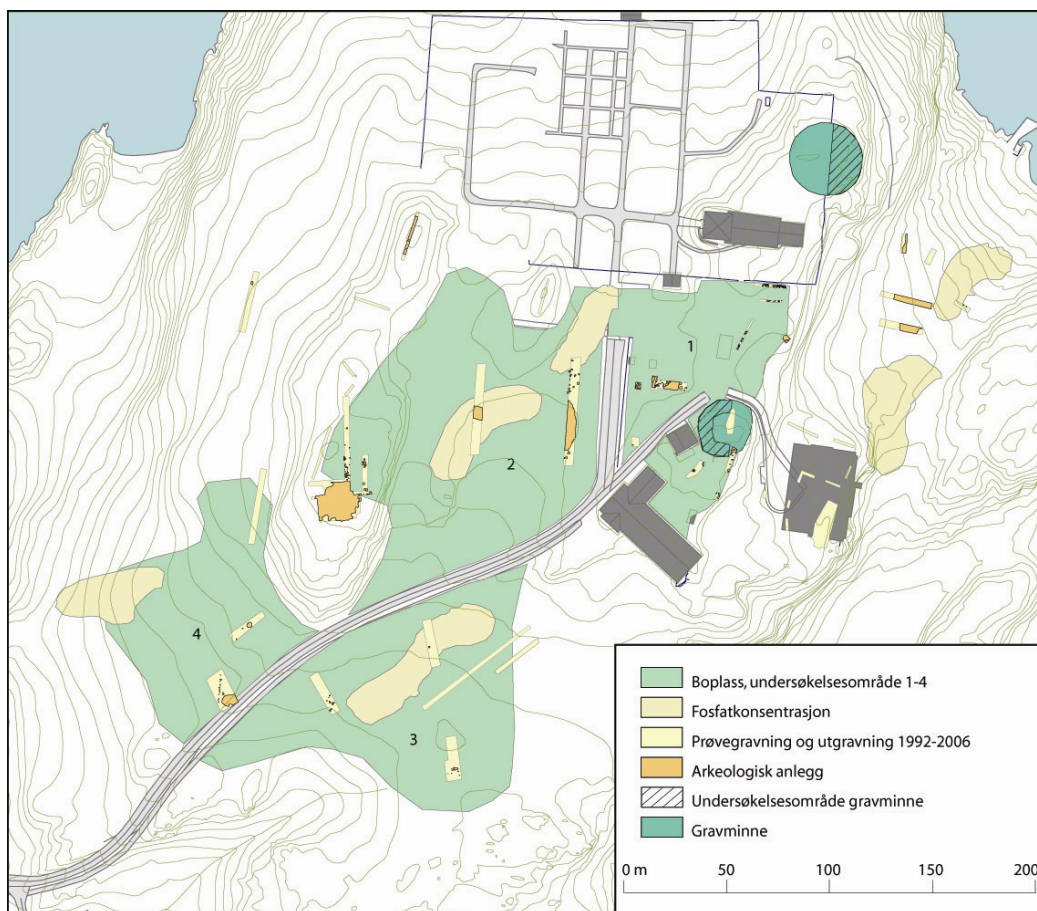
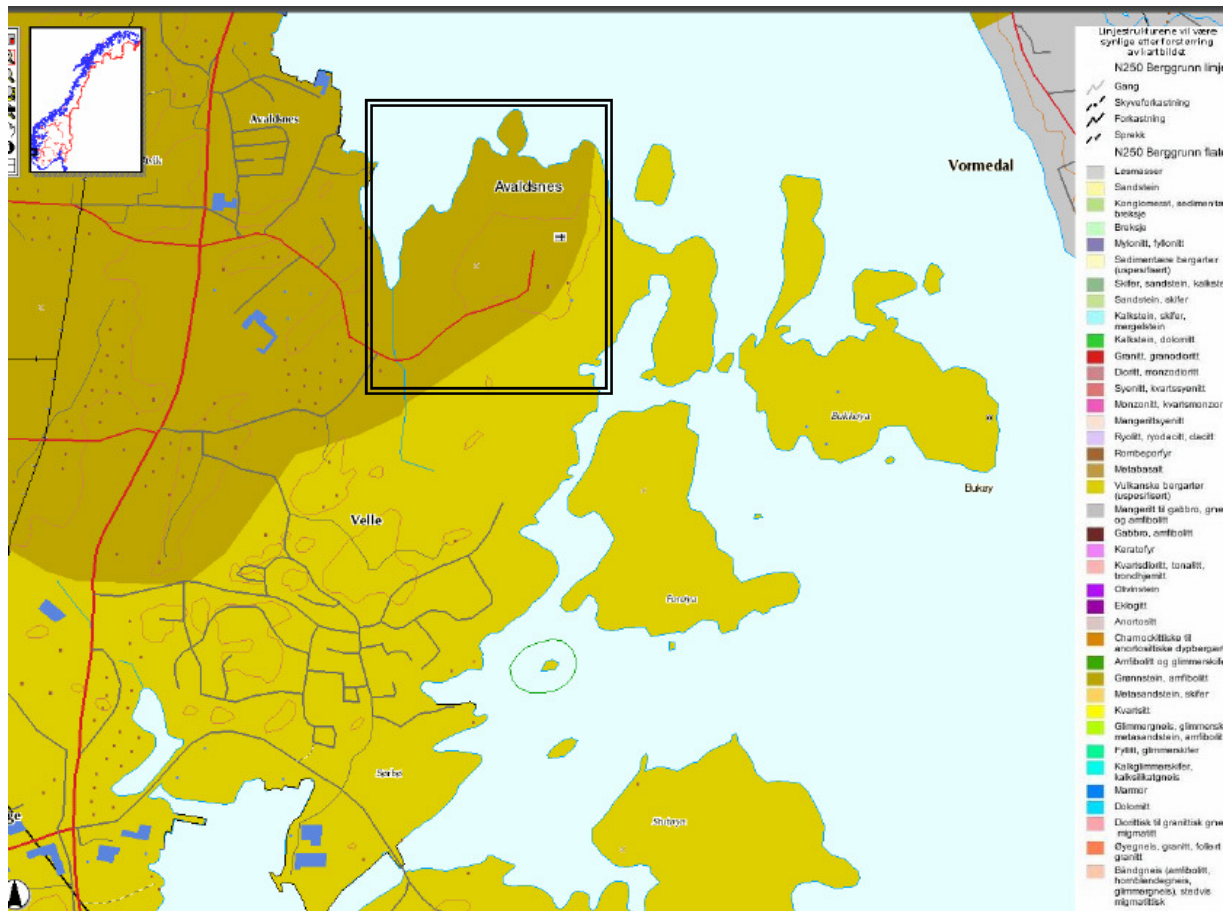
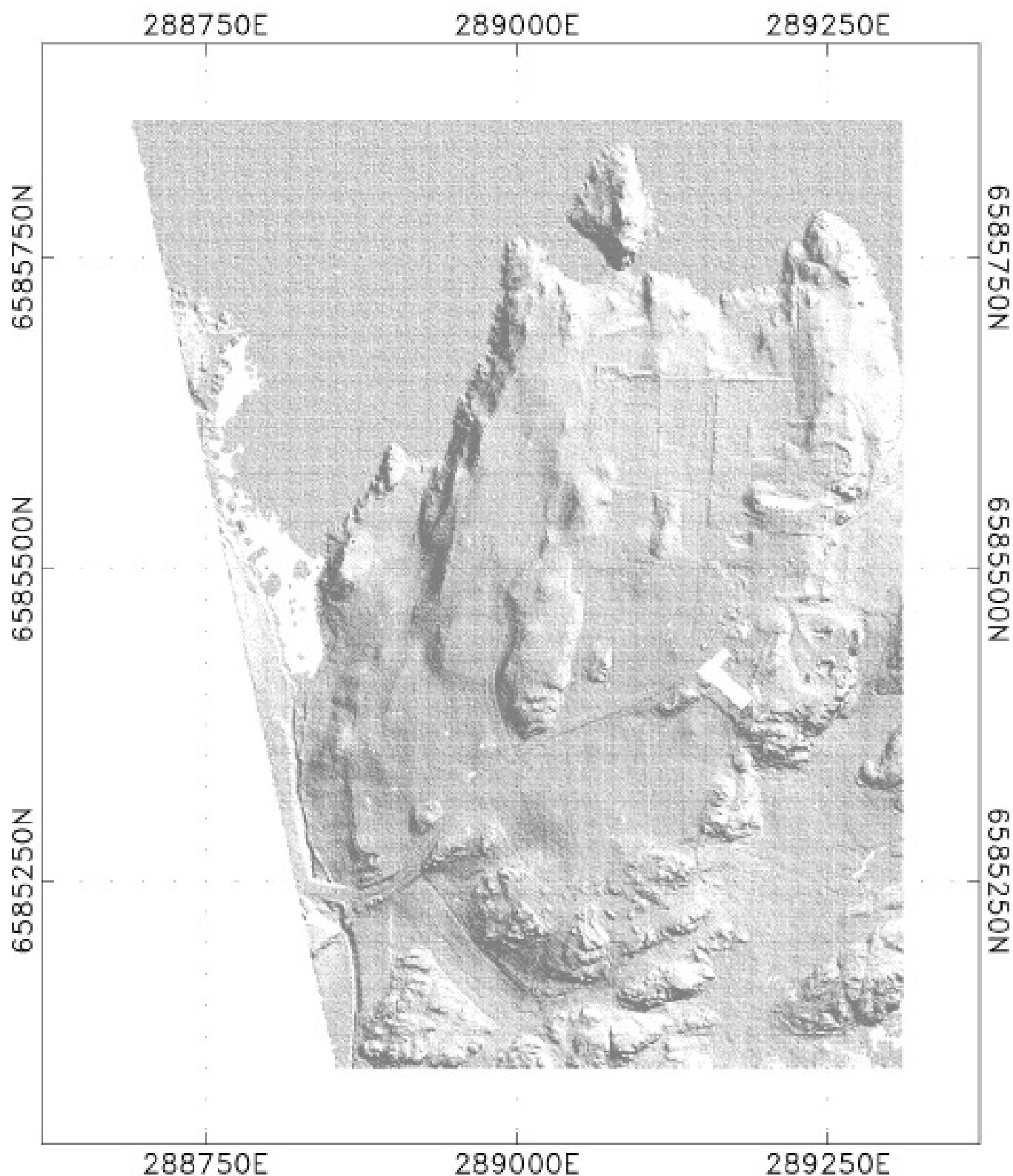


Fig : 2.1 Revised interpreted settlement areas, test excavation trenches and principle visible features (Skre, pers. comm.)



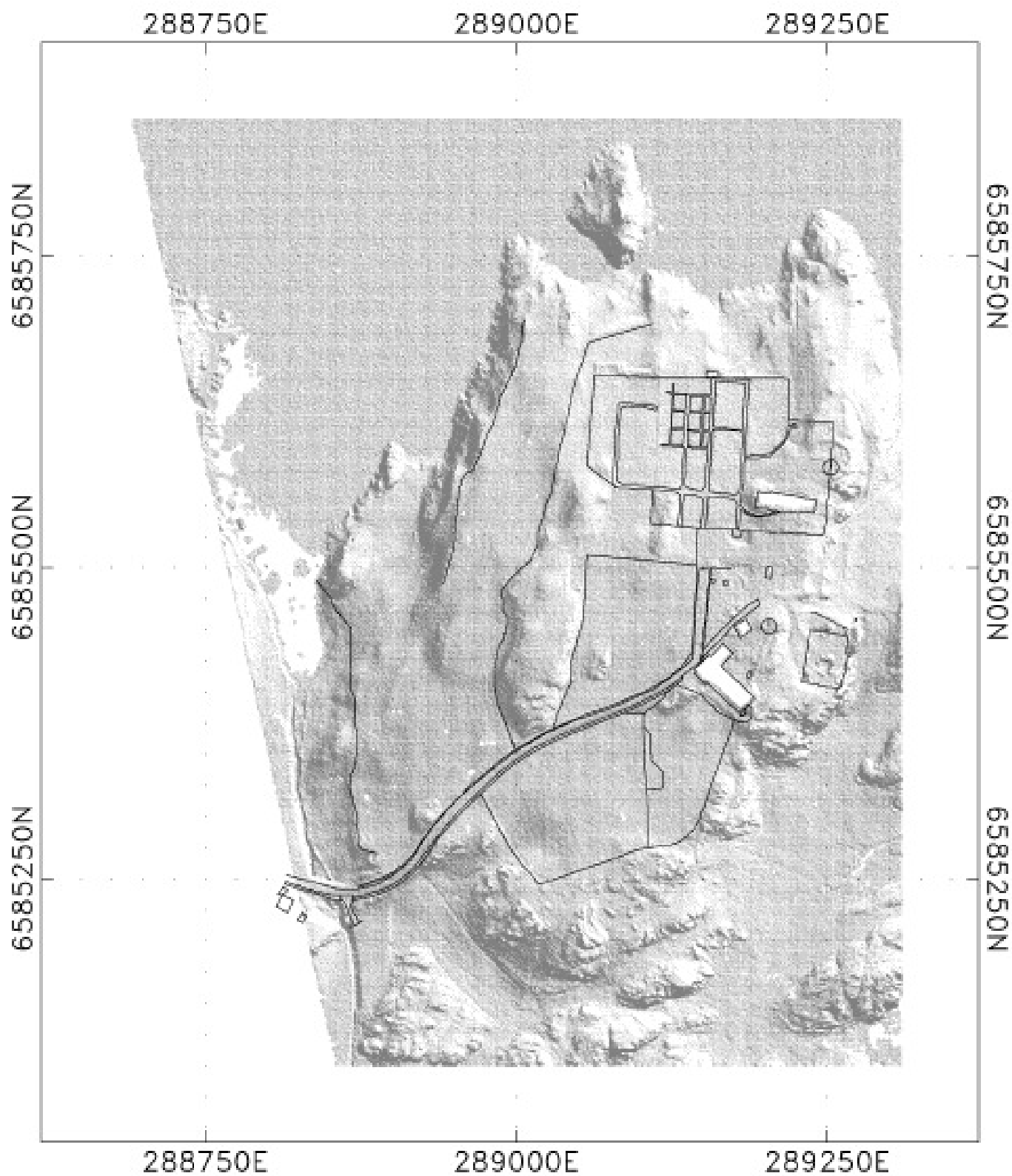


**Fig 4 : Avaldsnes Geophysical Survey**

**LIDAR Data – Shaded Relief Image, Illuminated from NE**

**Kevin Barton, NTNU/EA, September 2009**

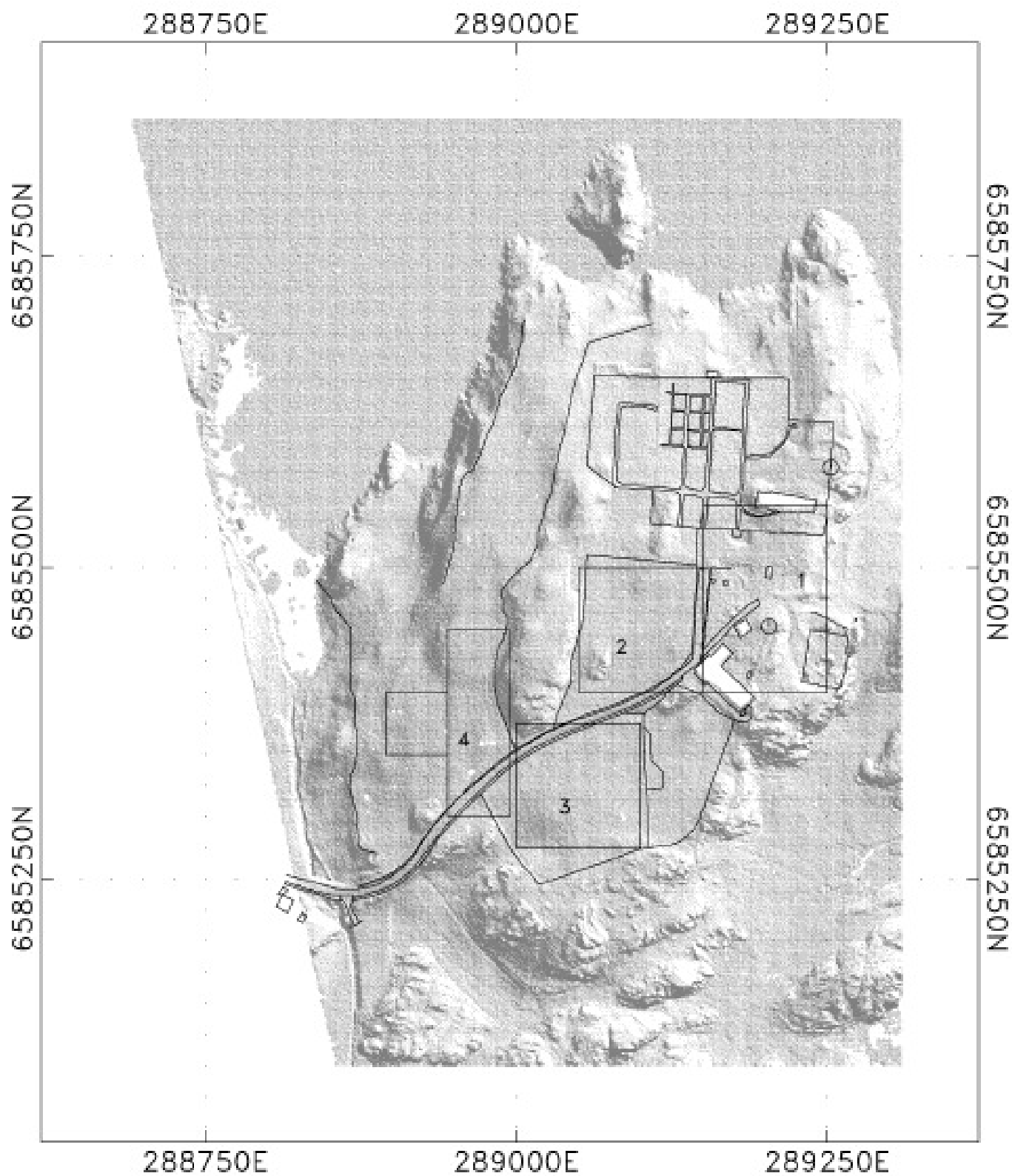




**Fig 5 : Avaldsnes Geophysical Survey**  
**Principal Visible Features**

**Kevin Barton, NTNU/EA, September 2009**



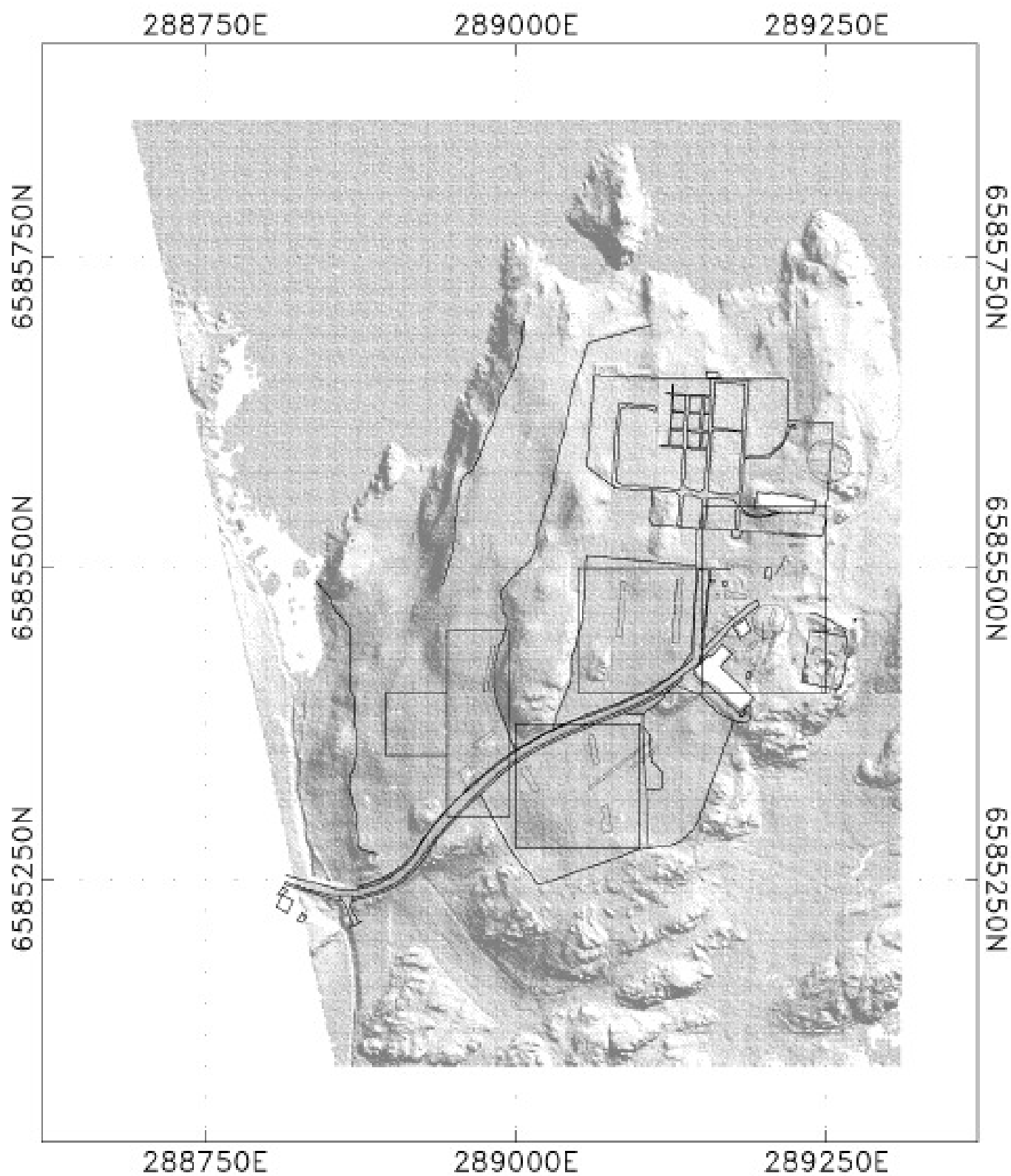


**Fig 6 : Avaldsnes Geophysical Survey**

**Geophysical Survey Areas**

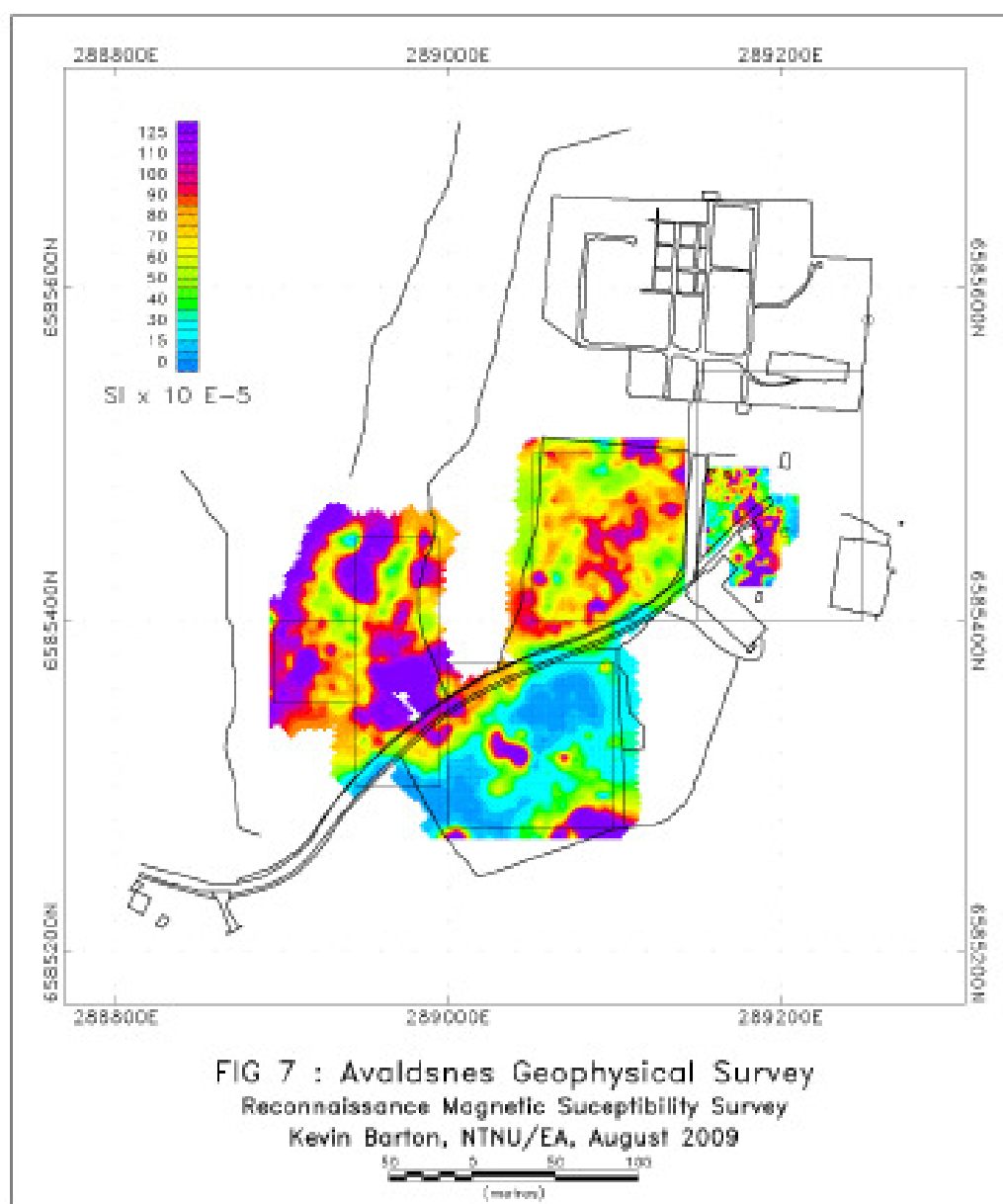
**Kevin Barton, NTNU/EA, September 2009**

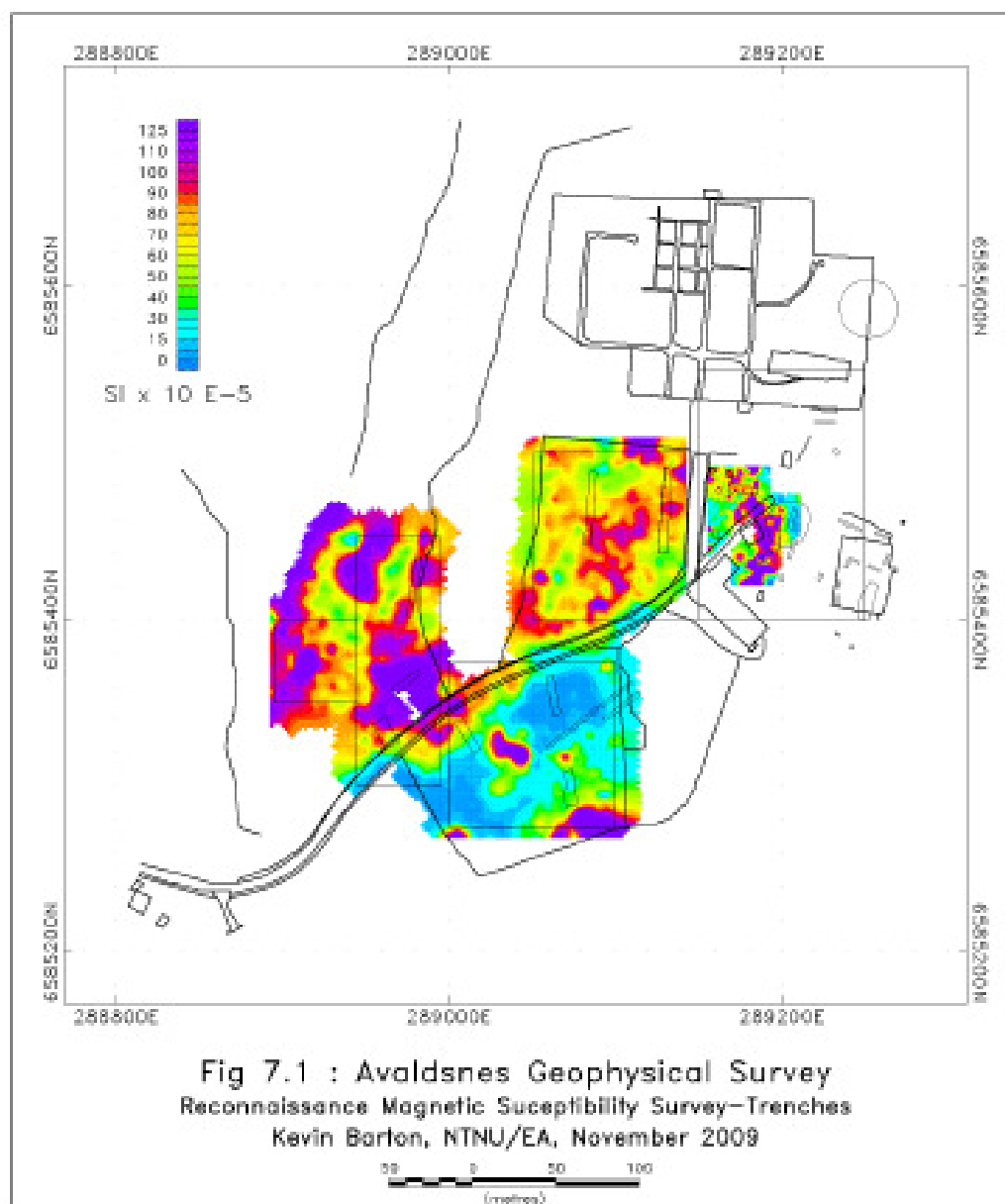


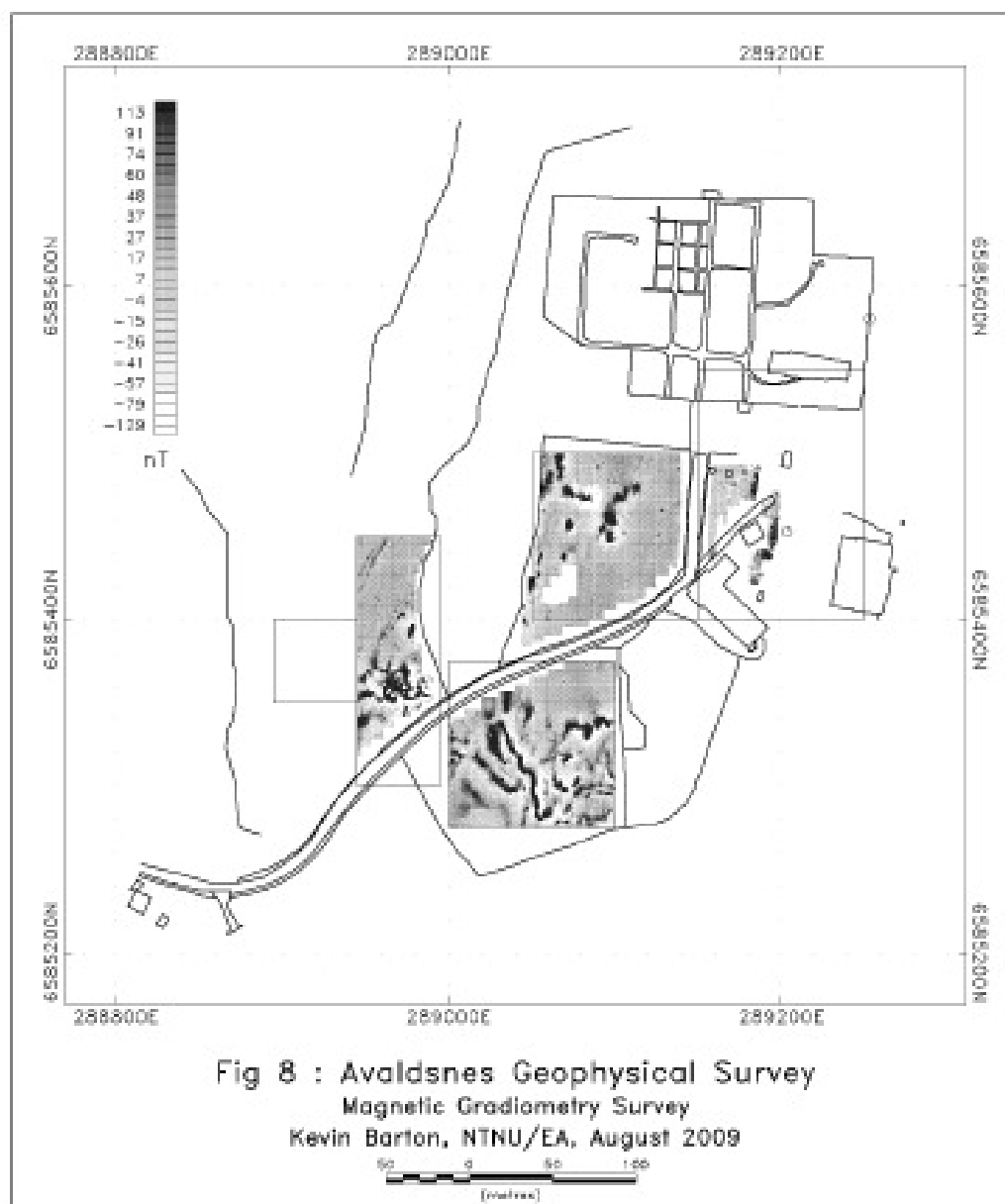


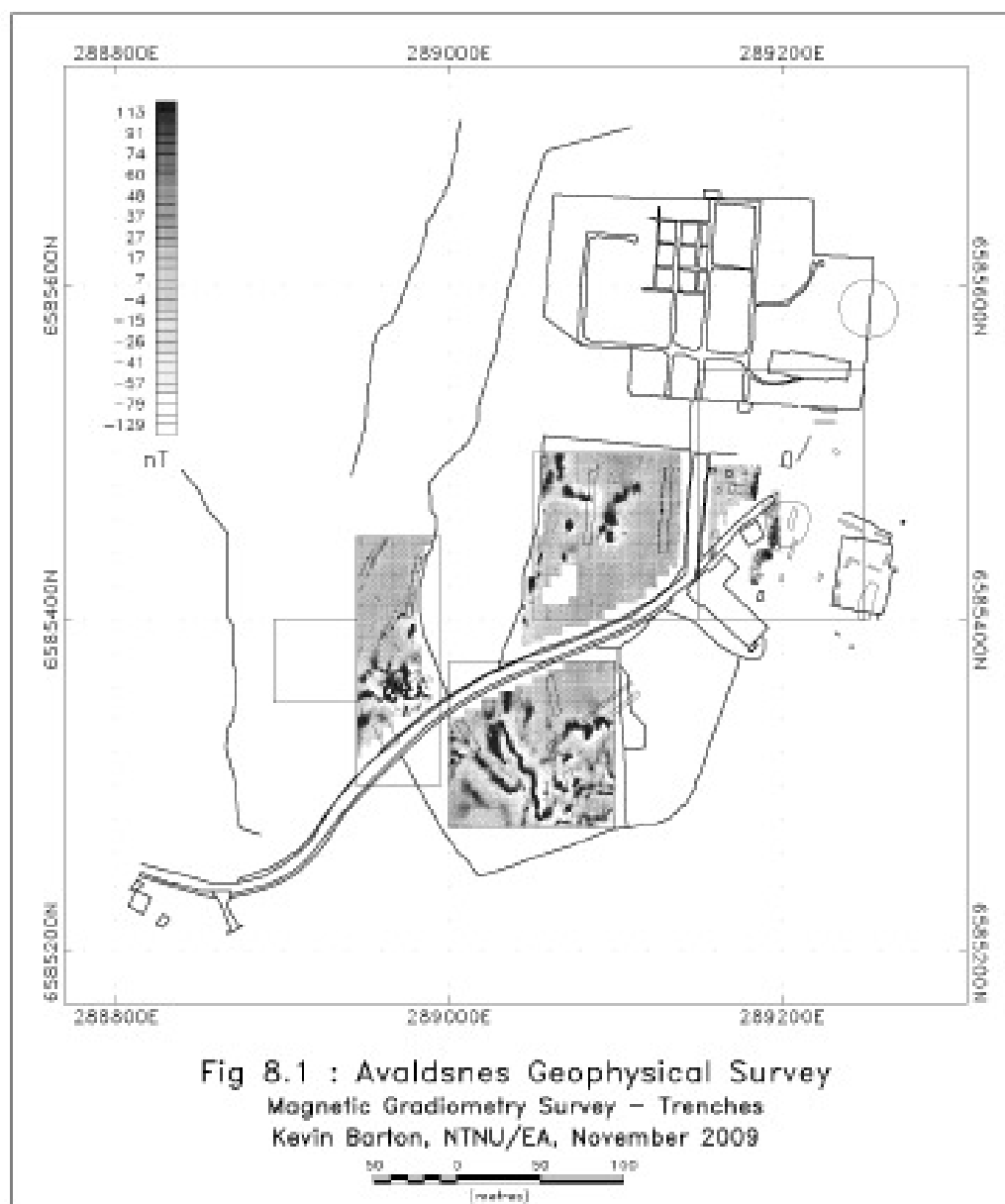
**Fig 6.1 : Avaldsnes Geophysical Survey**  
**Geophysical Survey Areas – Trenches**  
**Kevin Barton, NTNU/EA, November 2009**

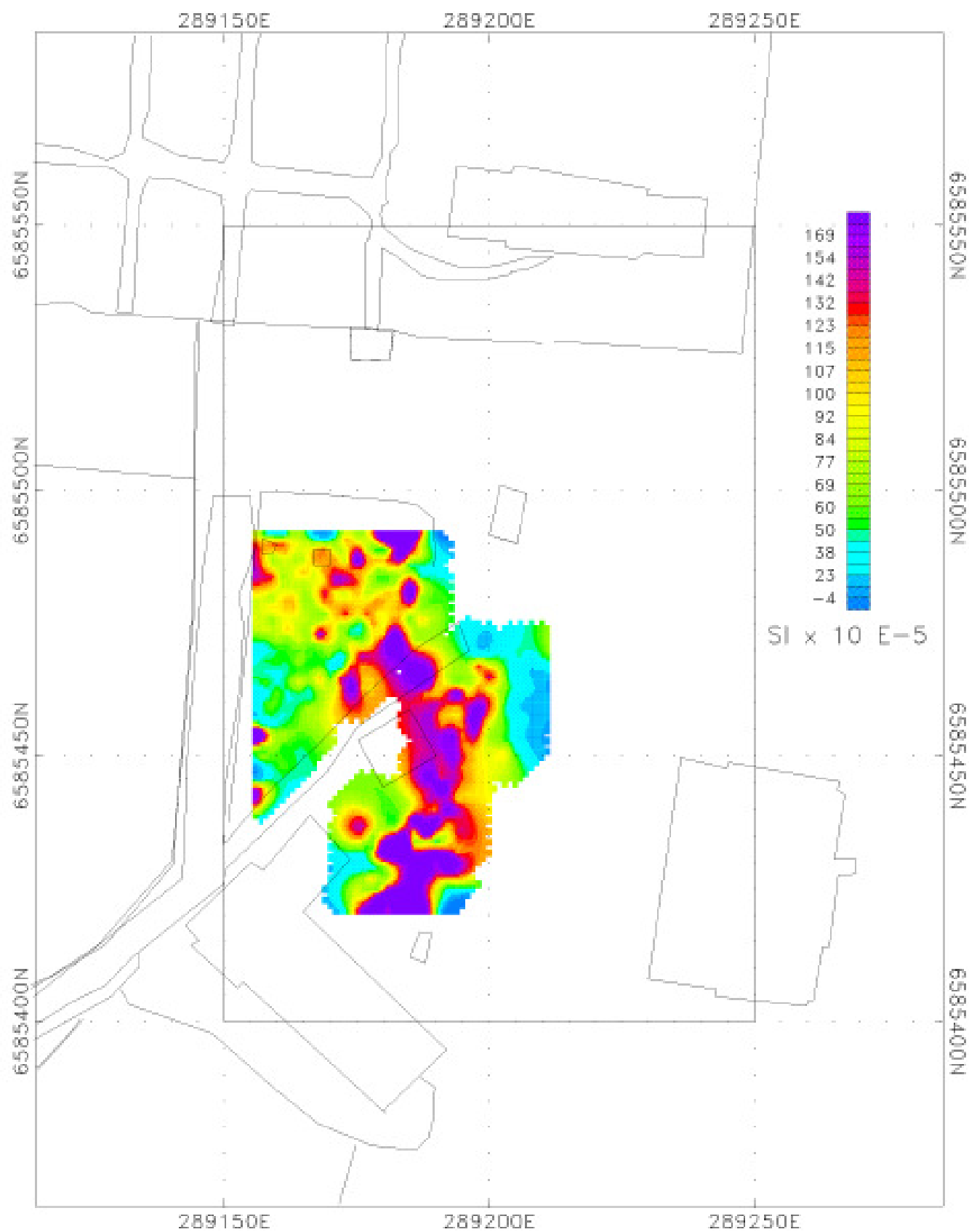










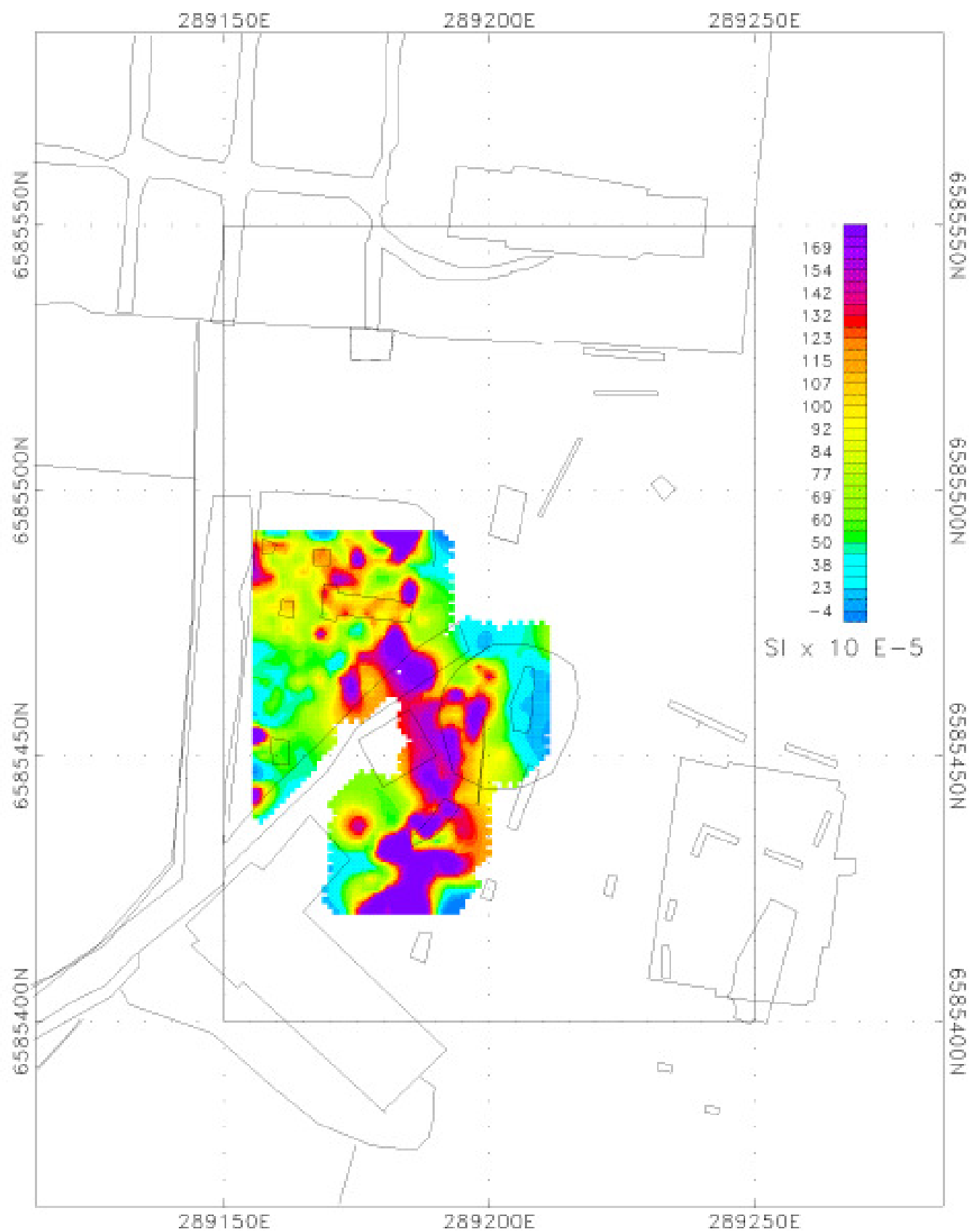


**Fig 9 : Avaldsnes Geophysical Survey – Area 1**

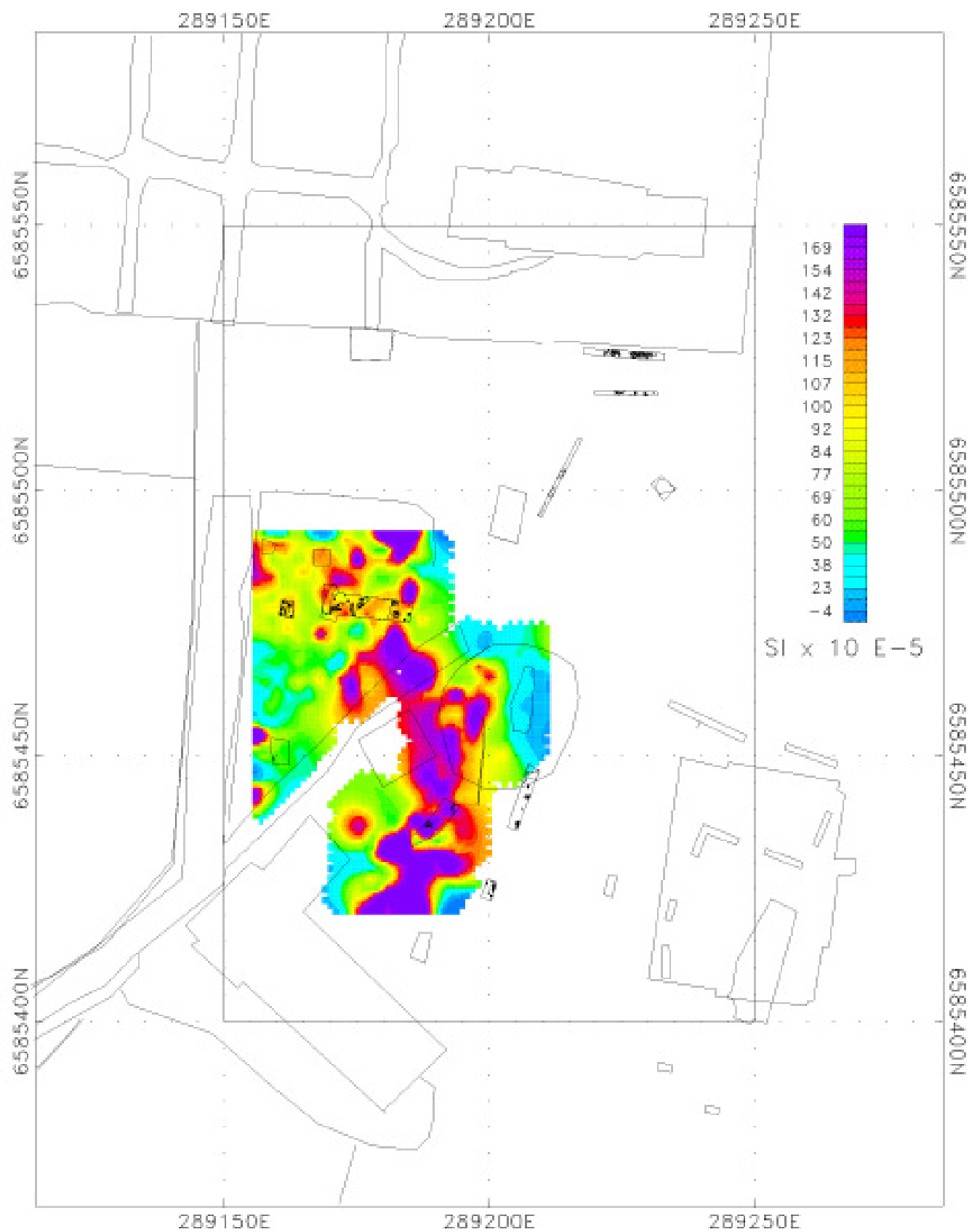
Detailed Magnetic Susceptibility Survey

Kevin Barton, NTNU/EA, August 2009

25 0 25  
(metres)



**Fig 9.1 : Avaldsnes Geophysical Survey – Area 1**  
**Detailed Magnetic Suceptibility Survey–Trenches**  
**Kevin Barton, NTNU/EA, November 2009**



**Fig 9.2 : Avaldsnes Geophysical Survey – Area 1**  
**Detailed Magnetic Suceptibility Survey-Features**  
 Kevin Barton, NTNU/EA, November 2009



**Fig 10 : Avaldsnes Geophysical Survey – Area 1**

**Magnetic Gradiometry Survey**

**Kevin Barton, NTNU/EA, August 2009**

25 0 25  
(metres)



**Fig 10.1 : Avaldsnes Geophysical Survey – Area 1**

Magnetic Gradiometry Survey – Clipped 40 nT

Kevin Barton, NTNU/EA, September 2009

25 0 25  
(metres)



**Fig 10.2 : Avaldsnes Geophysical Survey – Area 1**  
**Magnetic Gradiometry Survey – Trenches**  
**Kevin Barton, NTNU/EA, November 2009**

25 0 25  
(metres)



**Fig 10.3 : Avaldsnes Geophysical Survey – Area 1**  
**Magnetic Gradiometry Survey – Features**  
**Kevin Barton, NTNU/EA, November 2009**

25 0 25  
(metres)



Fig 11 – Avaldsnes Geophysical Survey – Area 1

Earth Resistance Survey

Kevin Barton, NTNU/EA, September 2009

25 0 25  
(metres)



**Fig 11.1 – Avaldsnes Geophysical Survey – Area 1**  
**Earth Resistance Survey – Trenches**  
**Kevin Barton, NTNU/EA, November 2009**

25 0 25  
(metres)



**Fig 11.2 – Avaldsnes Geophysical Survey – Area 1**  
**Earth Resistance Survey – Features**  
 Kevin Barton, NTNU/EA, November 2009

25 0 25  
 (metres)



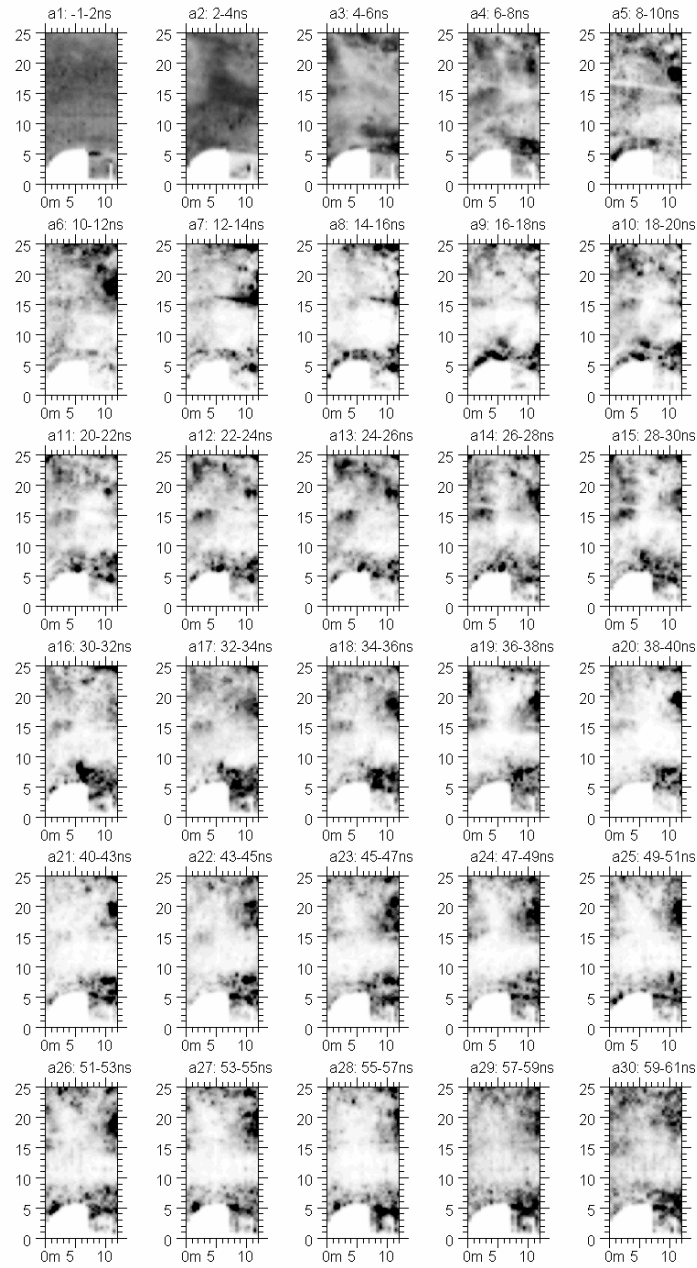


Fig 12.1 : Avaldsnes Geophysical Survey; Area 1  
Grid 1 – GPR Horizontal Slices



Fig 12.1.1 : Avalsnes Geophysical Survey – Area 1  
 GPR Grid 1 = Horizontal Slice 5 = Trenches = Features  
 Kevin Barton, NTNU/EA, February 2010

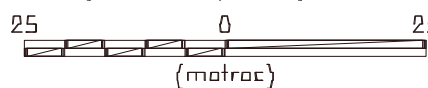




Fig 12.1.2 : Avaldsnes Geophysical Survey - Area 1  
 GPR Grid 1 - Horizontal Slice 6 - Trenches - Features  
 Kevin Barton, NTNU/EA, February 2010



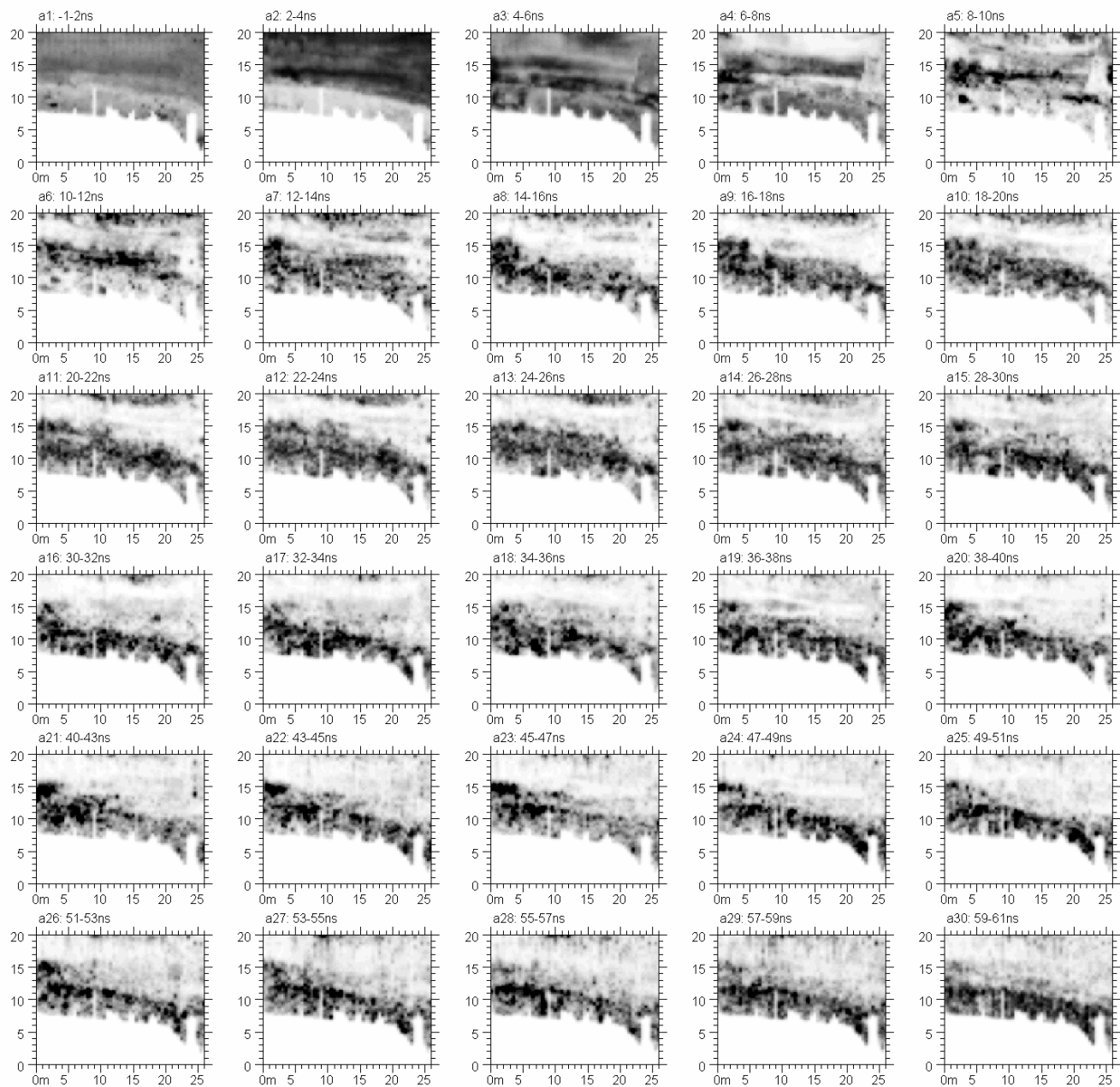


Fig 12.2 : Avaldsnes Geophysical Survey; Area 1  
Grid 2 – GPR Horizontal Slices



Fig 12.2.1 : Avaldsnes Geophysical Survey – Area 1

GPR Grid 2 = Horizontal Slice 7 = Trenches = Features

Kevin Barton, NTNU/EA, February 2010



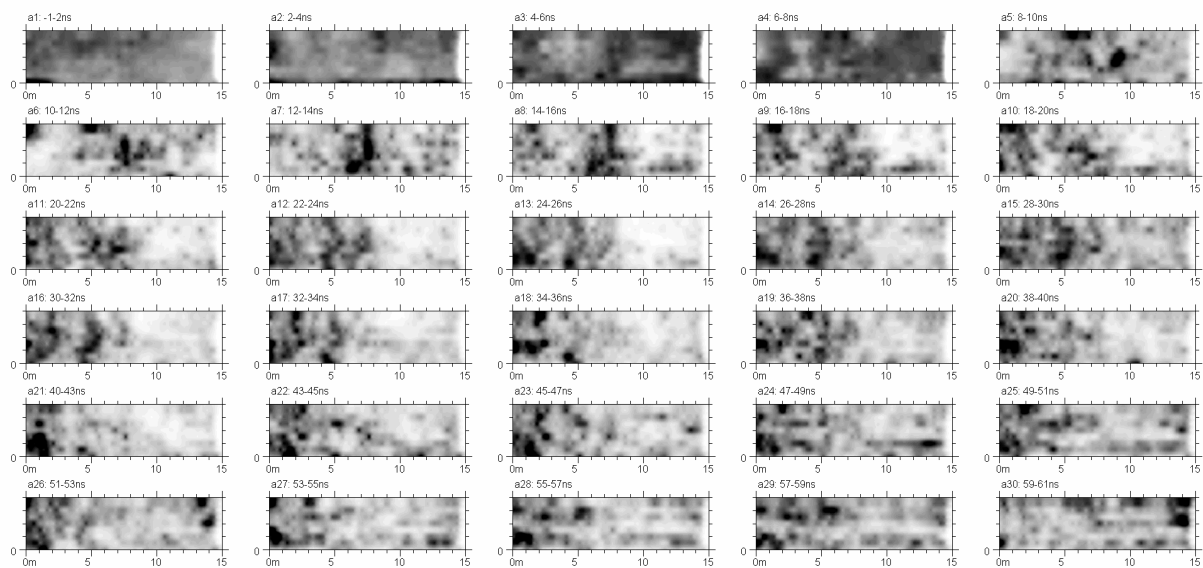


Fig 12.3 : Avaldsnes Geophysical Survey – Area 1  
Grid 3 – GPR Horizontal Slices



Fig 12.3.1 : Avaldsnes Geophysical Survey – Area 1

GPR Grid 3 = Horizontal Slice 7 = Trenches = Features

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Fig 12.4 : Avaldsnes Geophysical Survey – Area 1  
Grid 4 – GPR Horizontal Slices



Fig 12.4.1 : Avaldsnes Geophysical Survey – Area 1

GPR Grid 4 = Horizontal Slice 5 = Trenches = Features

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Fig 12.4.2 : Avaldsnes Geophysical Survey – Area 1

GPR Grid 4 □ Horizontal Slice 6 □ Trenches □ Features

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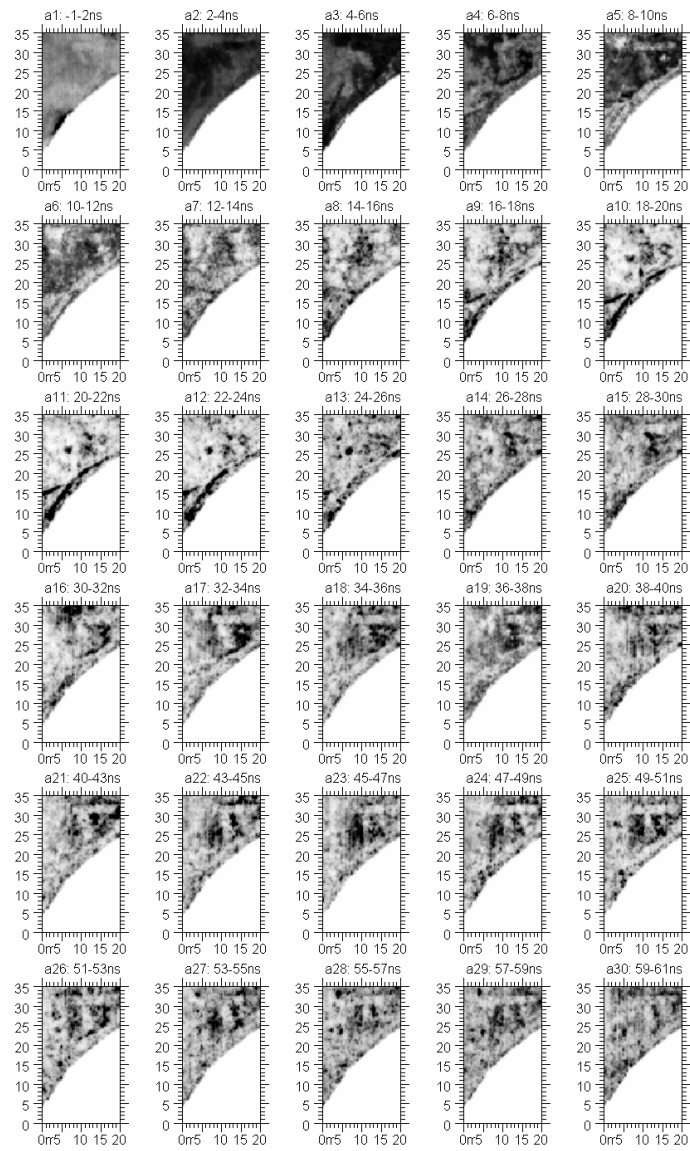


Fig 12.5 : Avaldsnes Geophysical Survey; Area 1  
Grid 5 – GPR Horizontal Slices



Fig 12.5.1 : Avalsnes Geophysical Survey - Area 1

GPR Grid 5 - Horizontal Slice 10 - Trenches - Features

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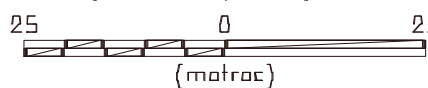




Fig 12.5.2 : Avaldsnes Geophysical Survey – Area 1

GPR Grid 5 □ Horizontal Slice 21 □ Trenches □ Features

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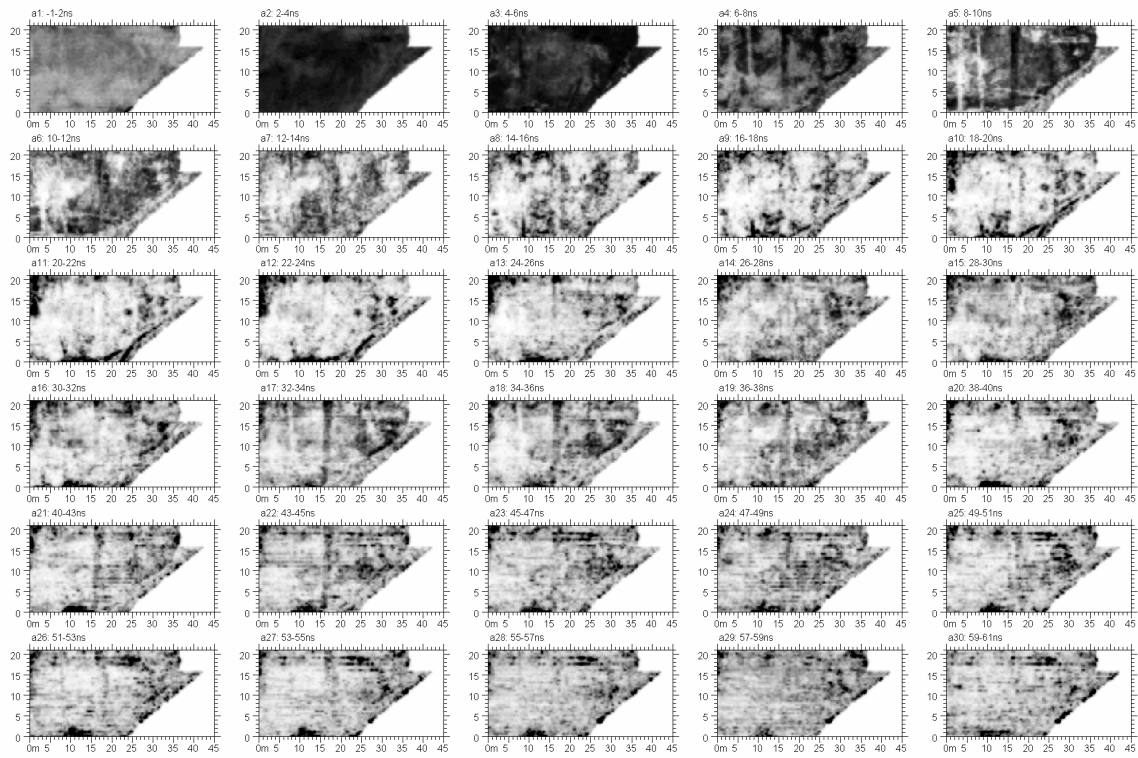


Fig 12.6 : Avaldsnes Geophysical Survey; Area 1  
Grid 6 – GPR Horizontal Slices



Fig 12.6.1 : Avalsnes Geophysical Survey – Area 1

GPR Grid 6 □ Horizontal Slice 6 □ Trenches □ Features

Kevin Barton, NTNU/EA, February 2010





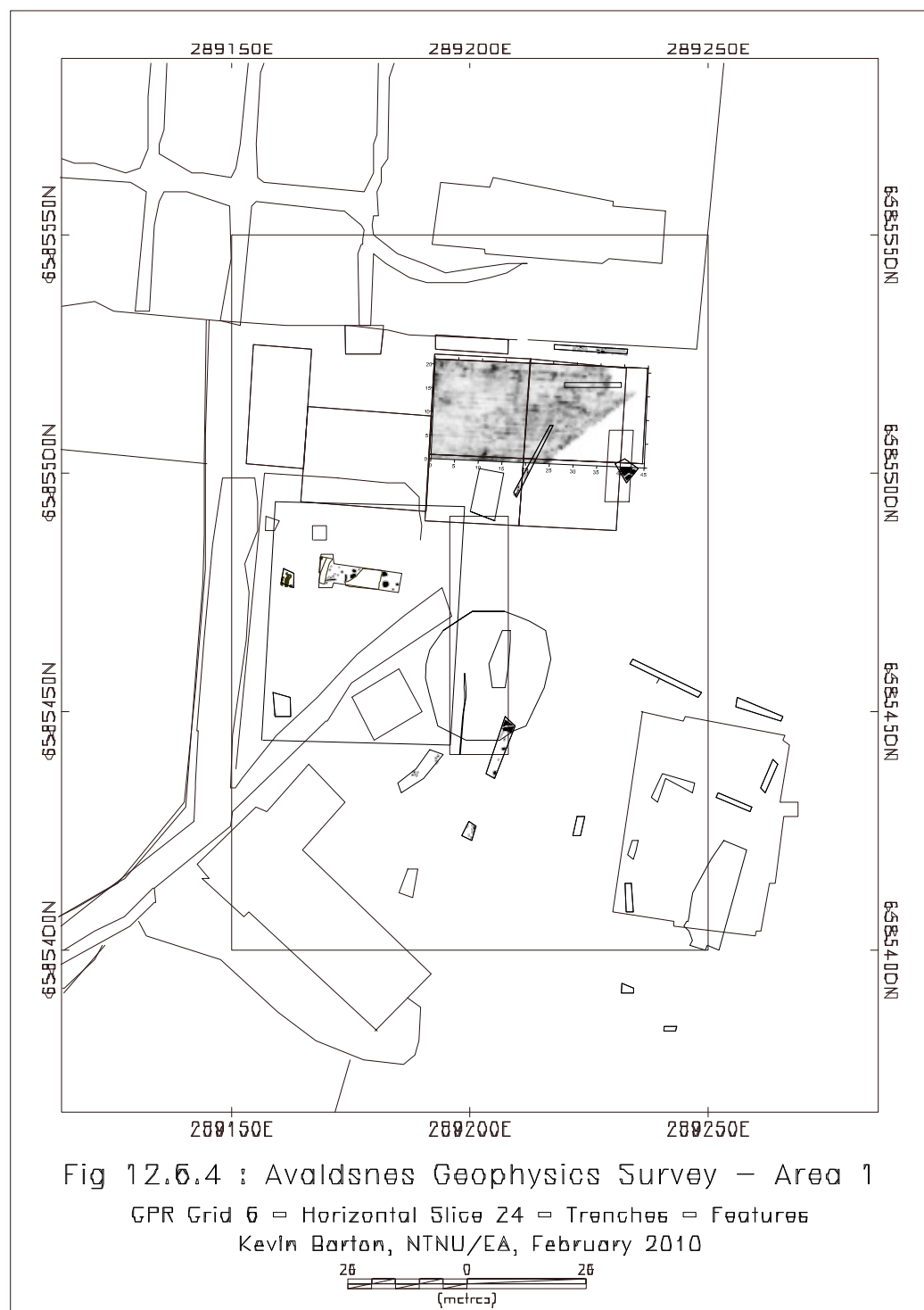


Fig 12.6.3 : Avaldsnes Geophysical Survey – Area 1

GPR Grid 6 = Horizontal Slice 17 = Trenches = Features

Kevin Barton, NTNU/EA, February 2010





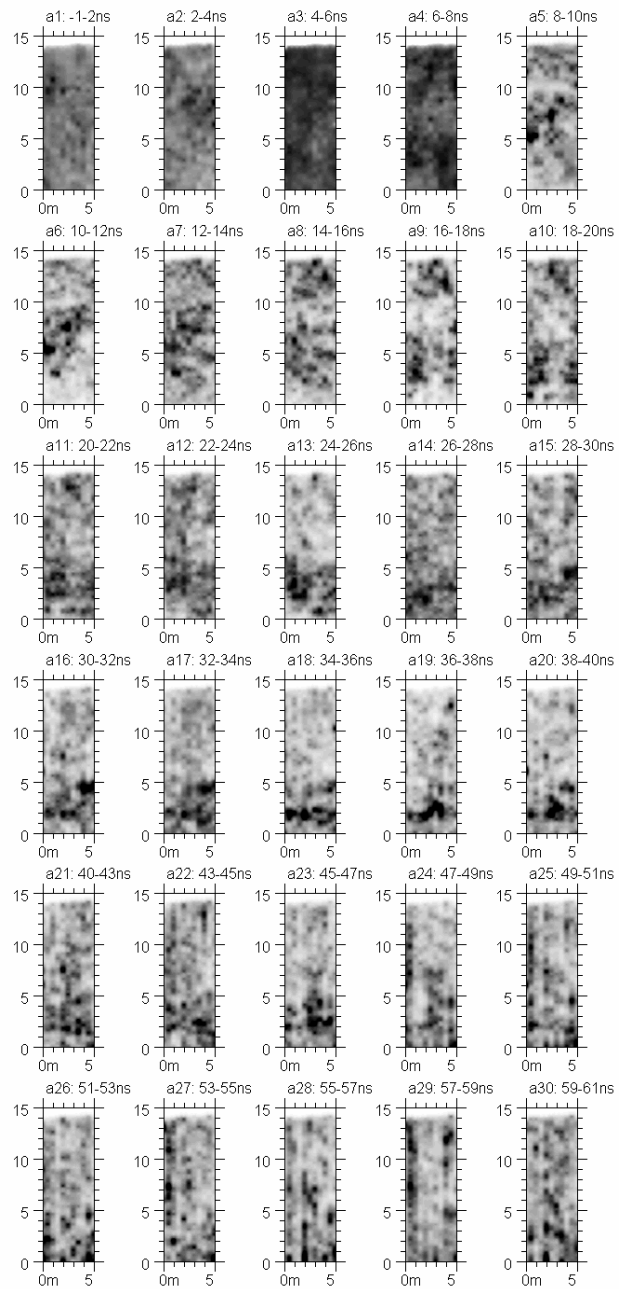
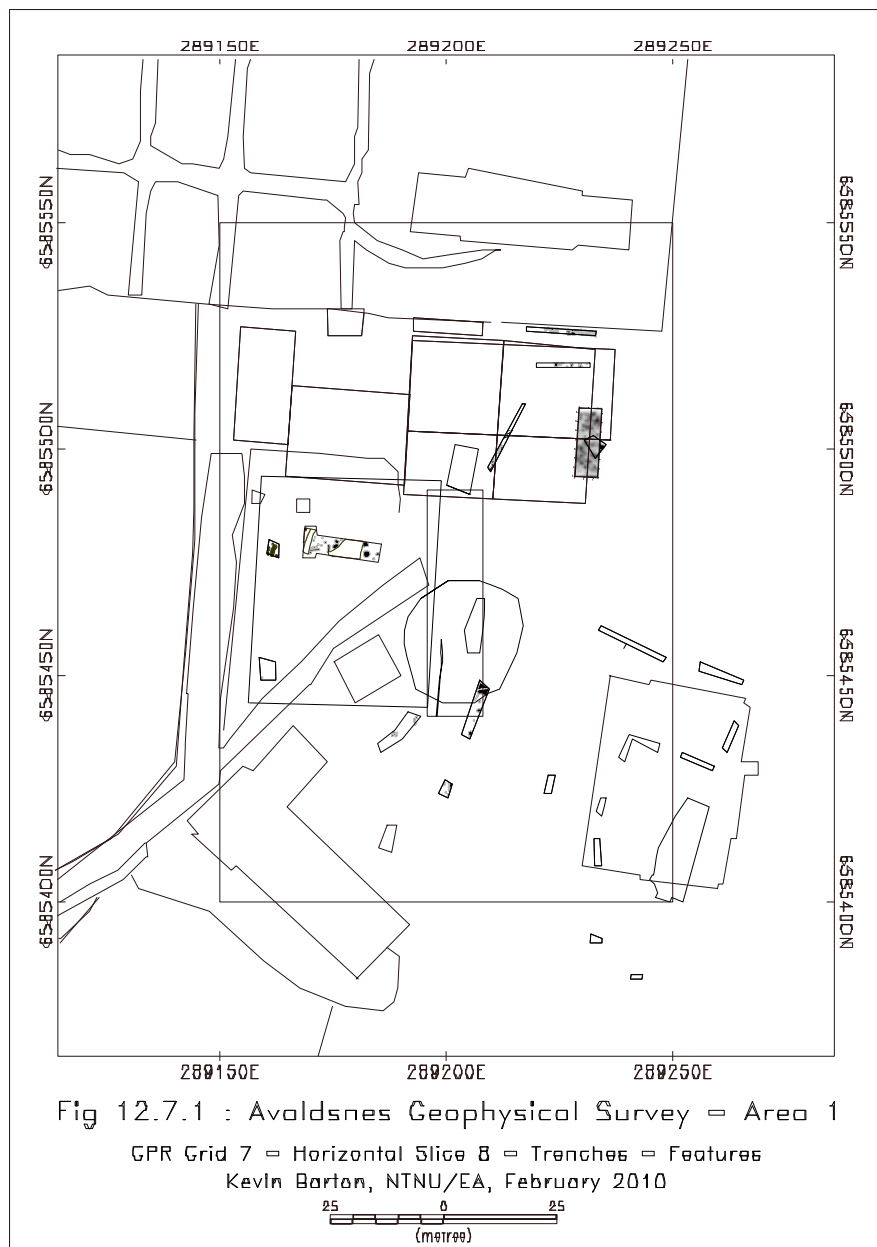
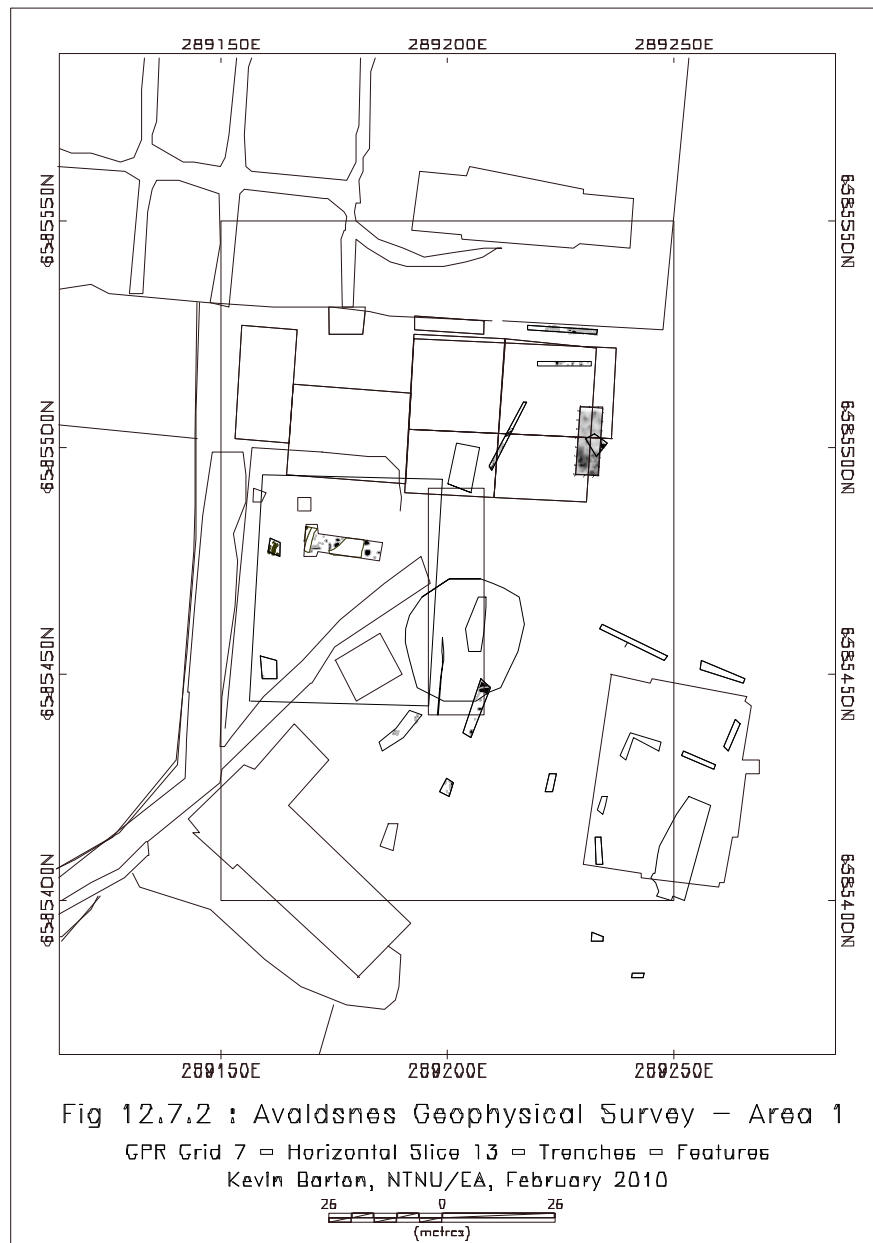
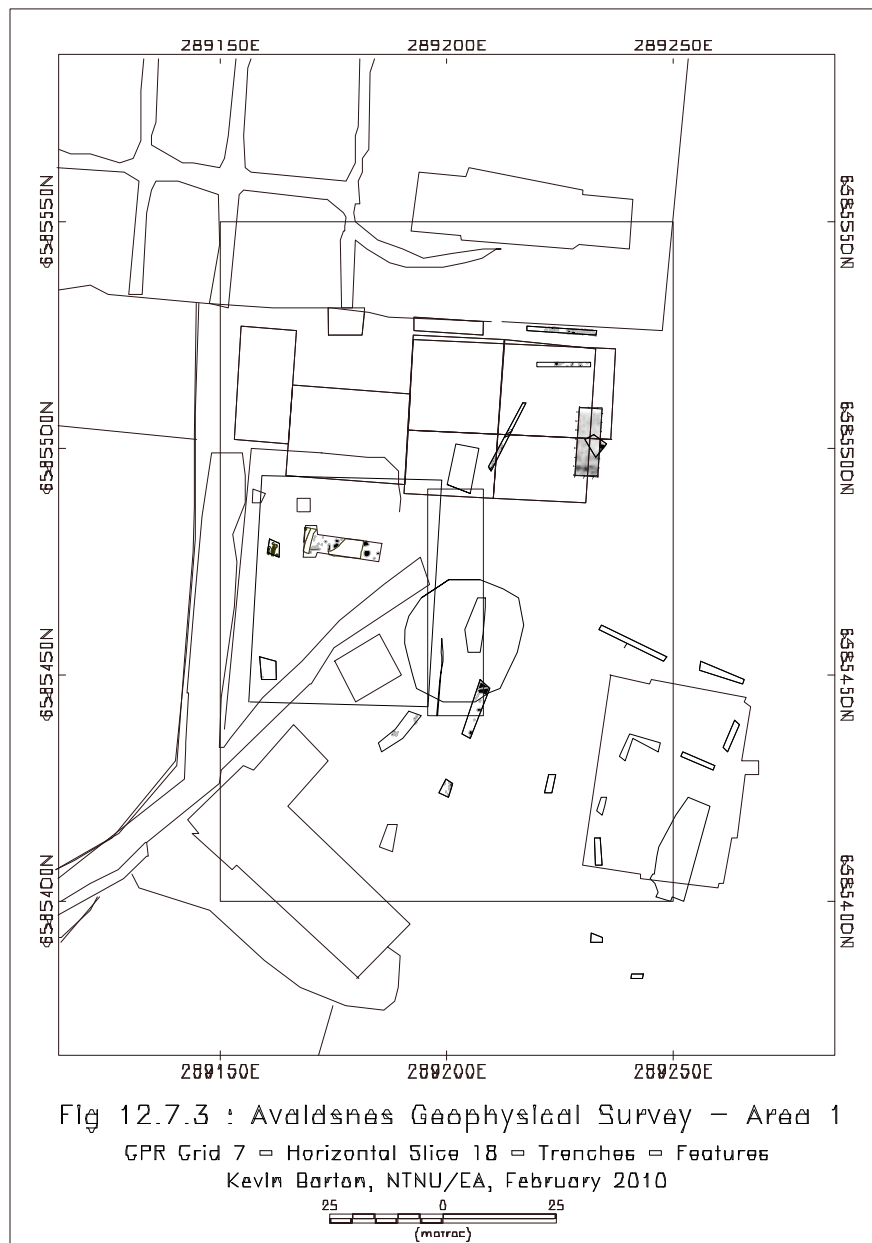


Fig 12.7 : Avaldsnes Geophysical Survey; Area 1  
Grid 7 – GPR Horizontal Slices







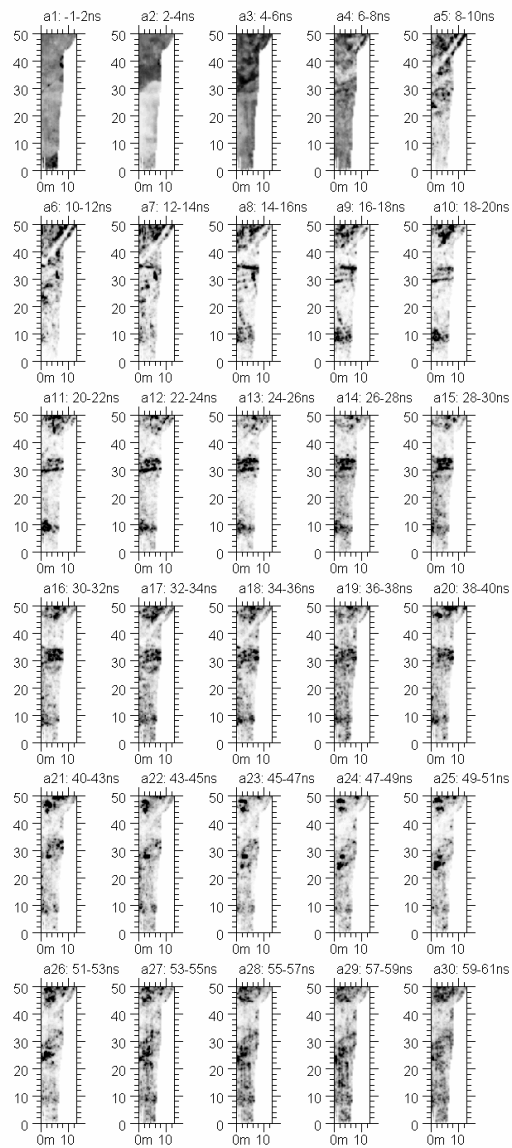
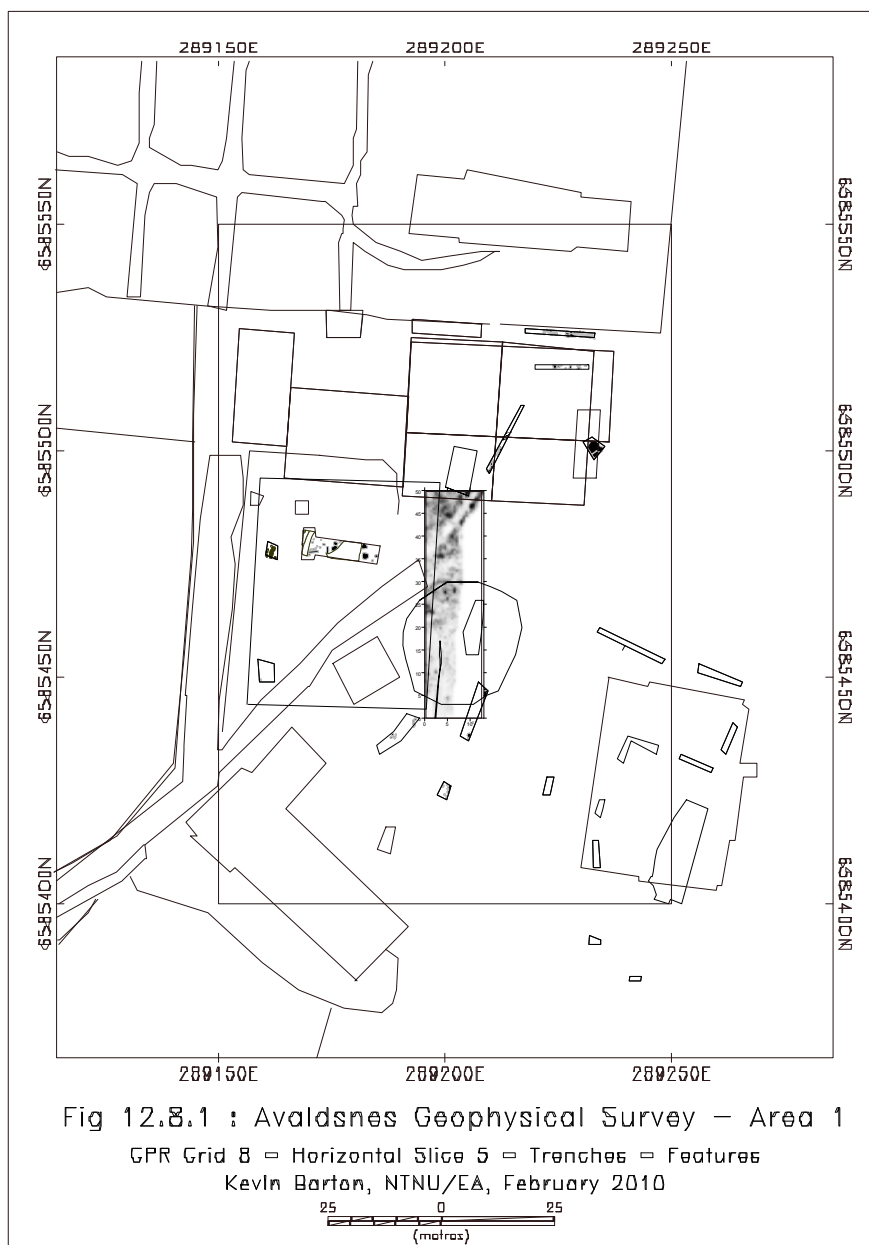


Fig 12.8 : Avaldsnes Geophysical Survey; Area 1  
Grid 8 – GPR Horizontal Slices



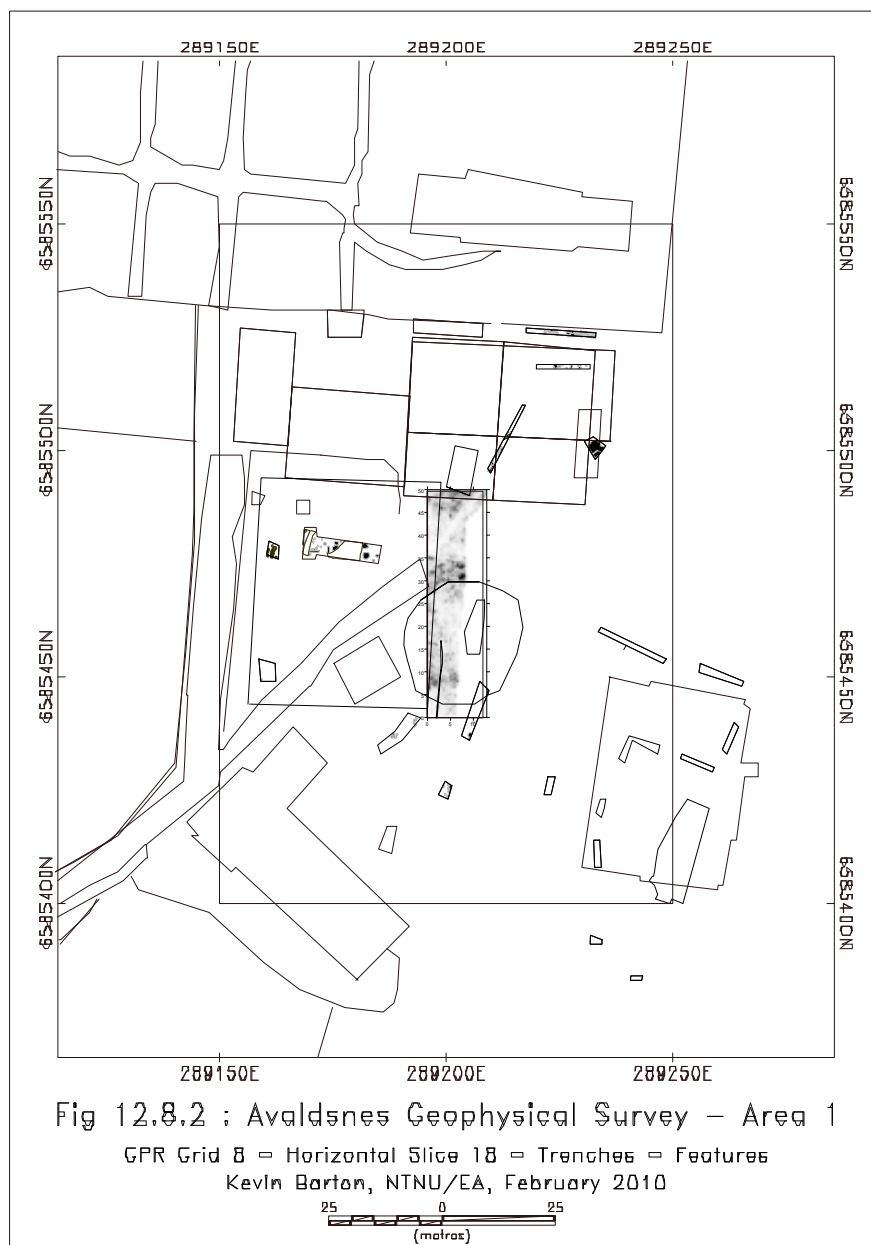
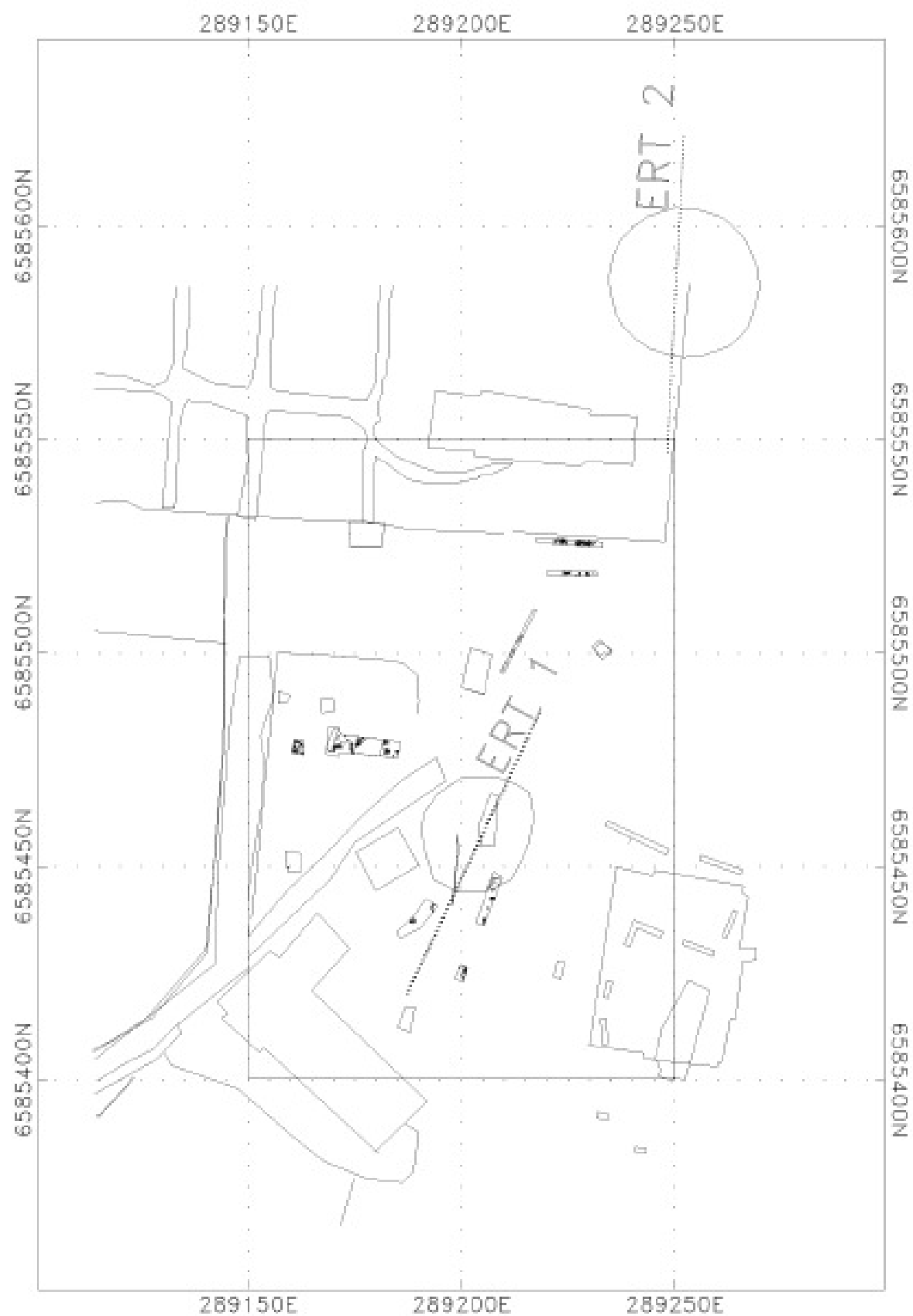




Fig 12.9 : Avaldsnes Geophysical Survey ; Area 1  
Grid 9 – GPR Horizontal Slices





**Fig 13 : Avaldsnes Geophysical Survey – Area 1**  
**ERT & GPR Transects – Trenches & Features**  
**Kevin Barton, NTNU/EA, November 2009**

25 0 25  
(metres)

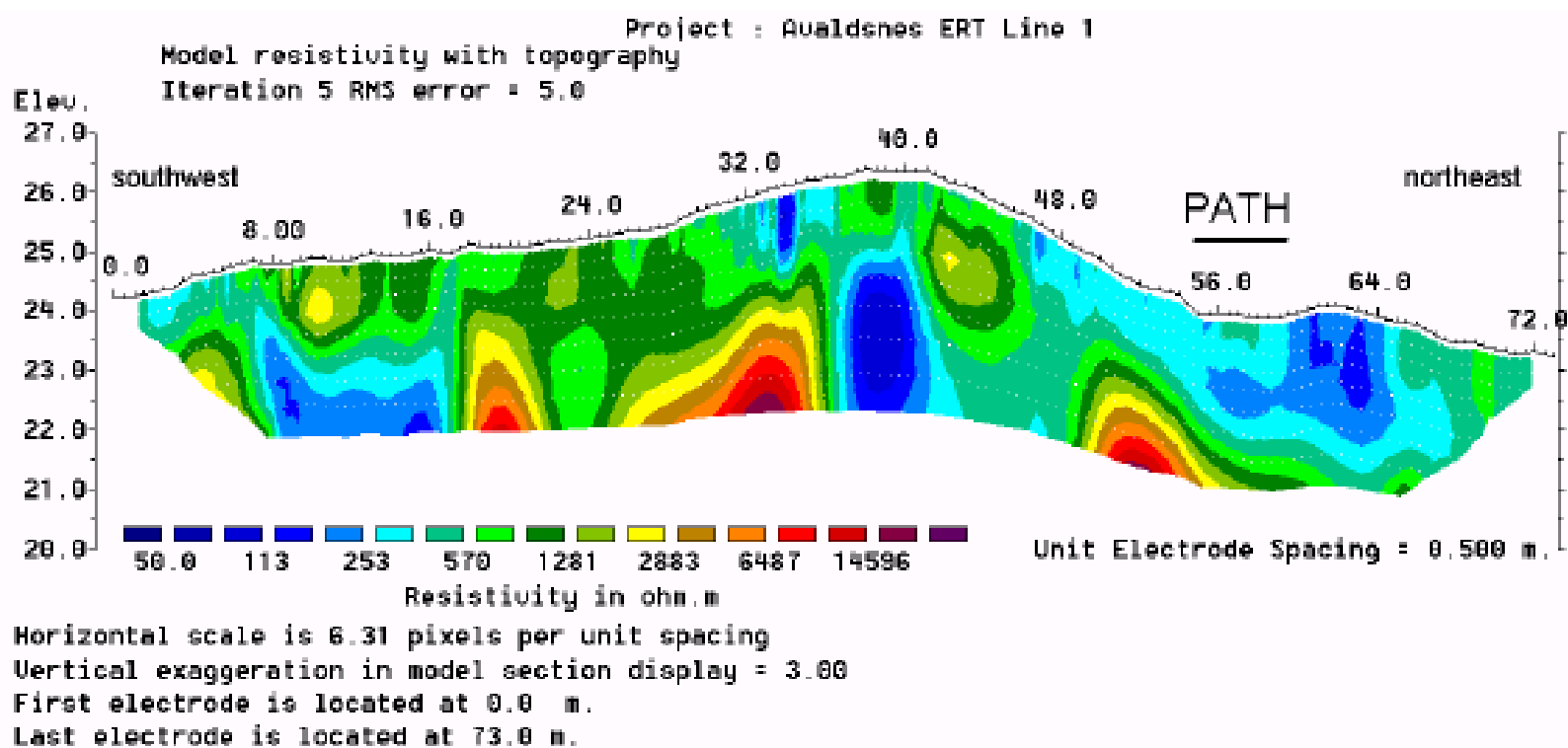


Fig 13.1 : Electrical resistivity tomography section across Kuhaugen

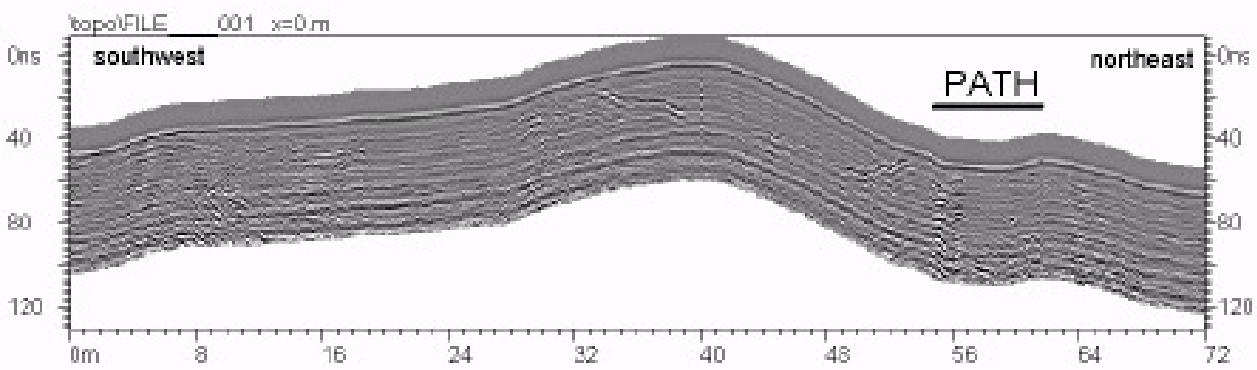


Fig 13.2 : Ground penetrating radar section across Kuhaugen

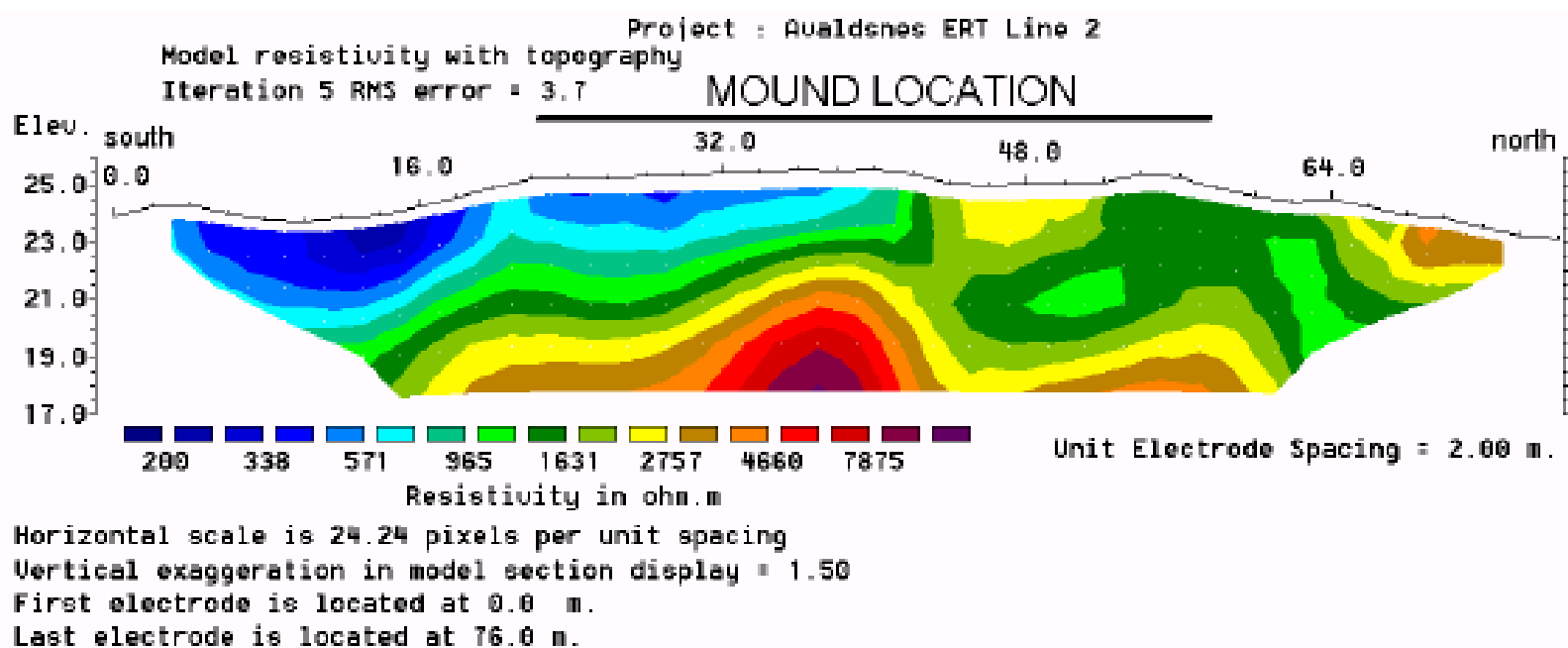


Fig 13.3 : Electrical resistivity tomography section across Flaghaug

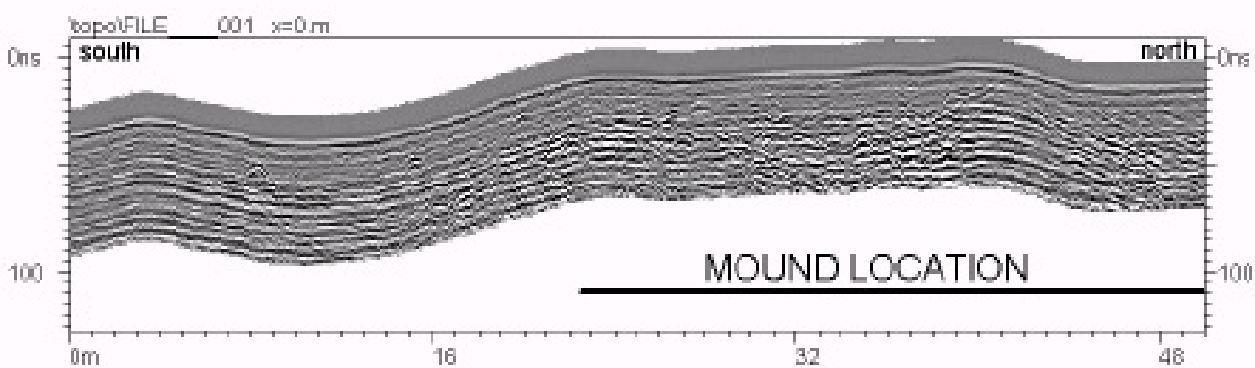
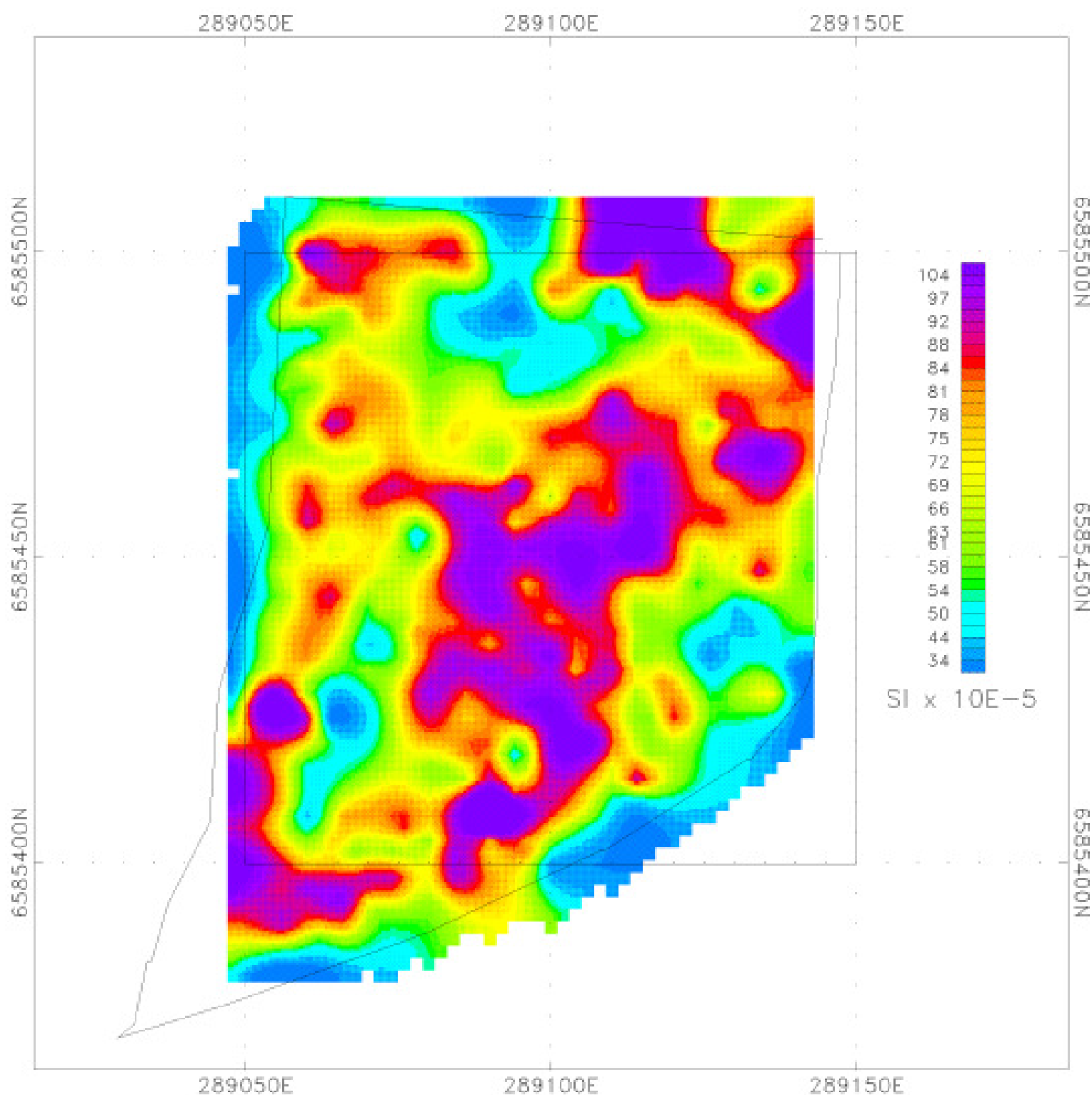
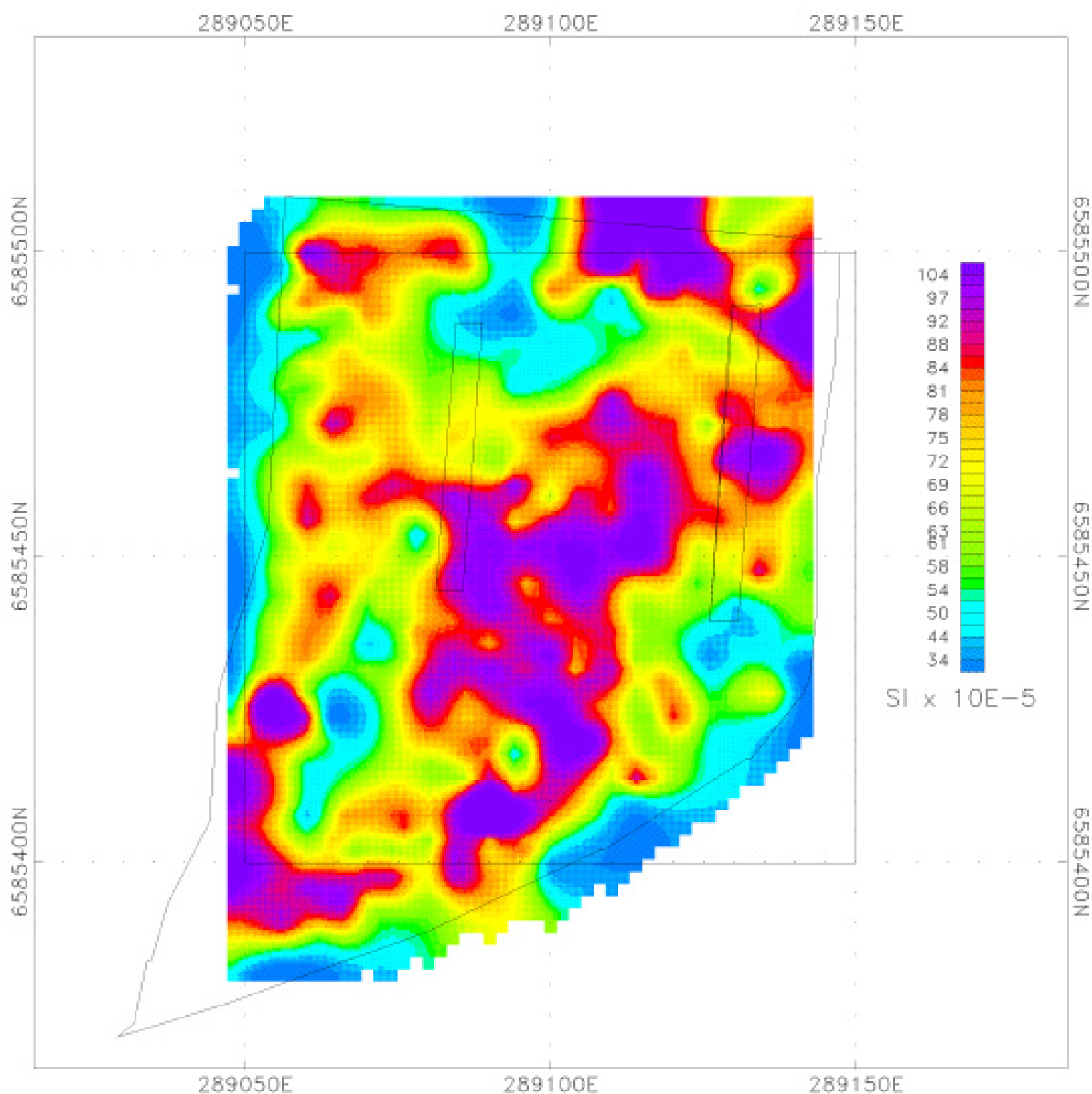


Fig 13.4 : Ground penetrating radar section across Flaghaug



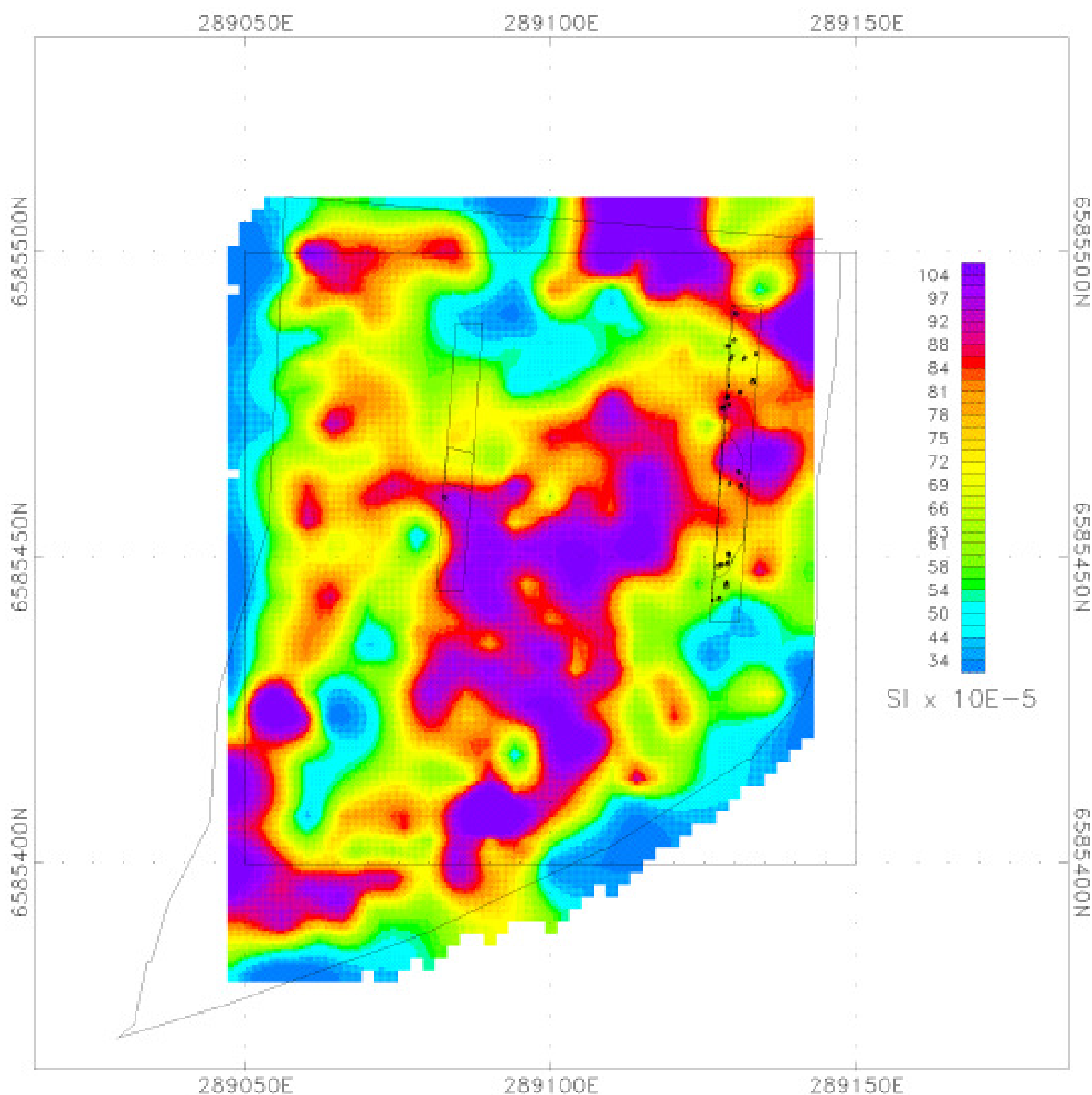
**FIG 14 : Avaldsnes Geophysical Survey – Area 2**  
**Reconnaissance Magnetic Suceptibility Survey**  
**Kevin Barton, NTNU/EA, August 2009**

10 0 10 20 30  
(metres)



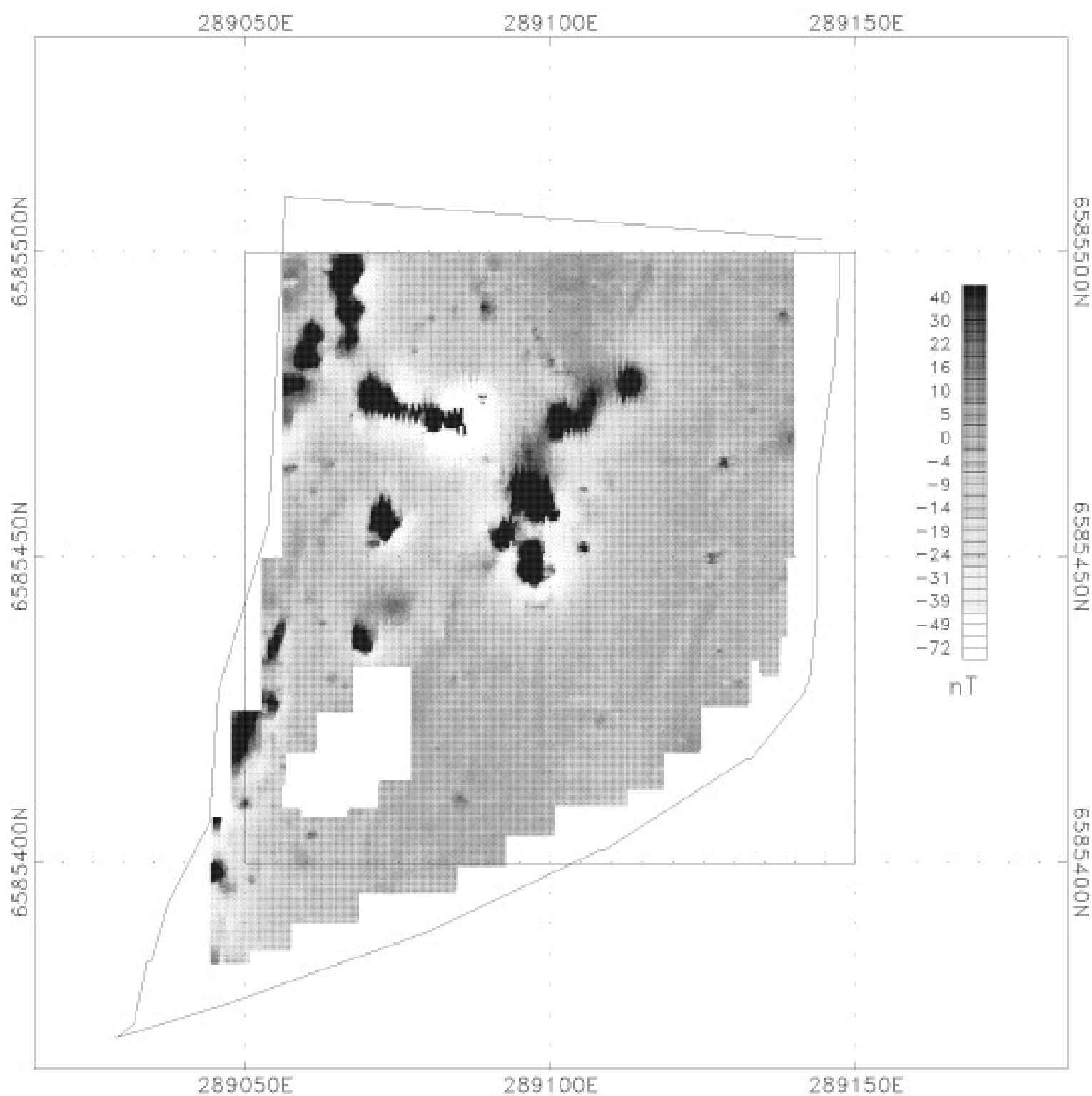
**Fig 14.1 : Avaldsnes Geophysical Survey – Area 2**  
**Reconnaissance Magnetic Suceptibility Survey-Trenches**  
**Kevin Barton, NTNU/EA, November 2009**

10 0 10 20 30  
 (metres)



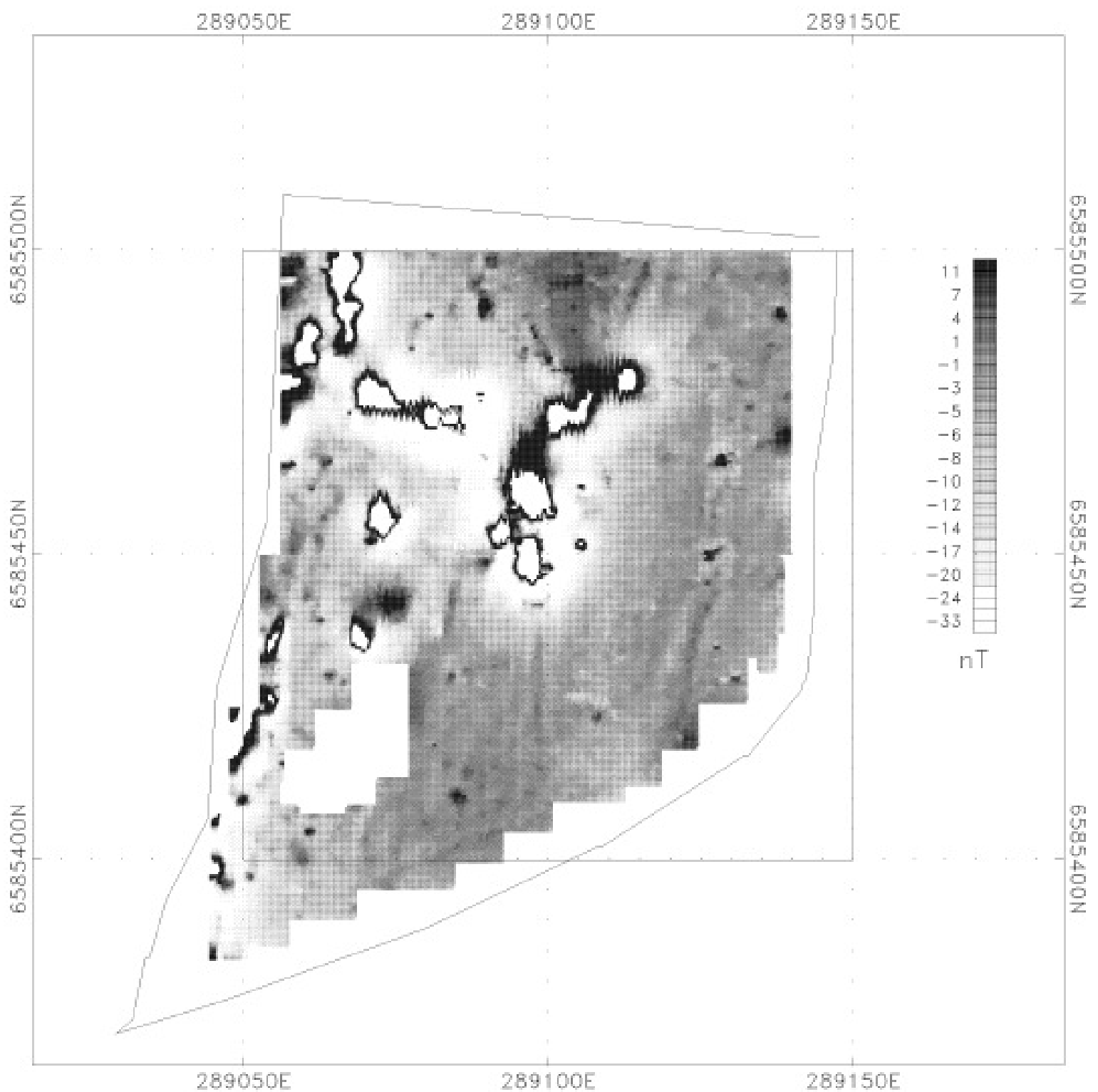
**Fig 14.2 : Avaldsnes Geophysical Survey – Area 2**  
**Reconnaissance Magnetic Suceptibility Survey–Features**  
Kevin Barton, NTNU/EA, November 2009





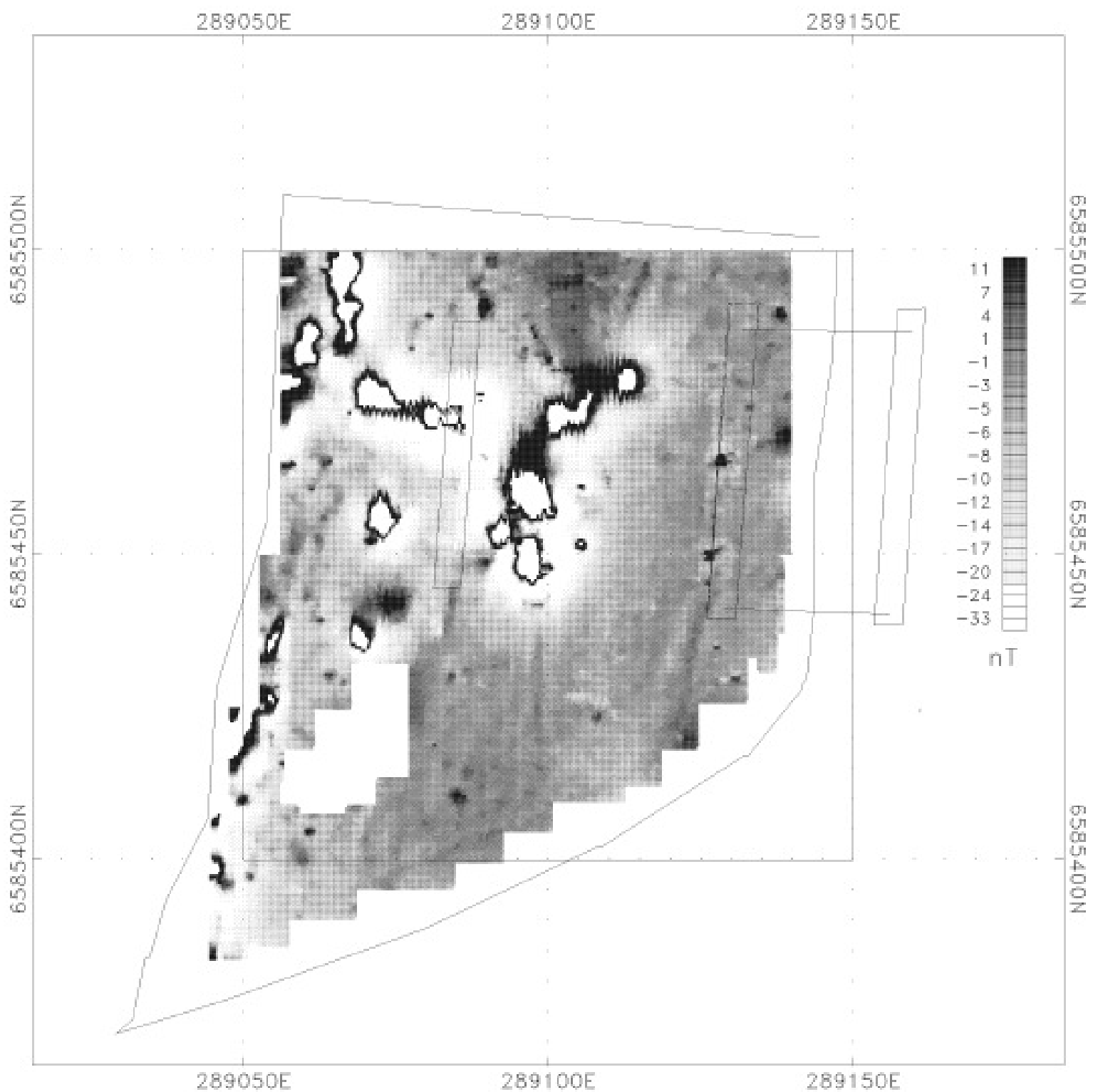
**Fig 15 : Avaldsnes Geophysical Survey – Area 2**  
**Magnetic Gradiometry Survey**  
**Kevin Barton, NTNU/EA, August 2009**

10 0 10 20 30  
(metres)



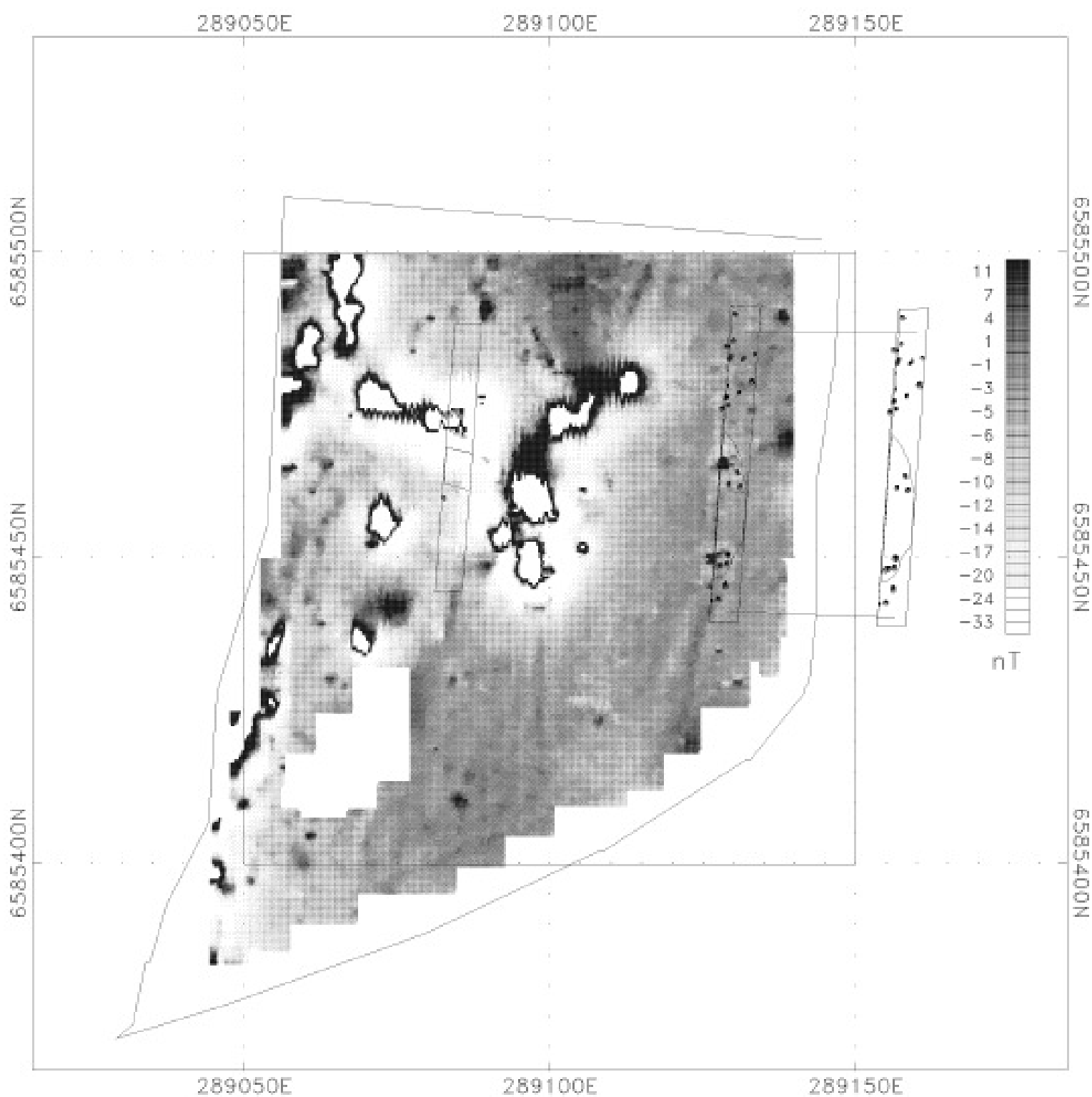
**Fig 15.1 : Avaldsnes Geophysical Survey – Area 2**  
**Magnetic Gradiometry Survey – Clipped 40 nT**  
**Kevin Barton, NTNU/EA, September 2009**

10 0 10 20 30  
(metres)



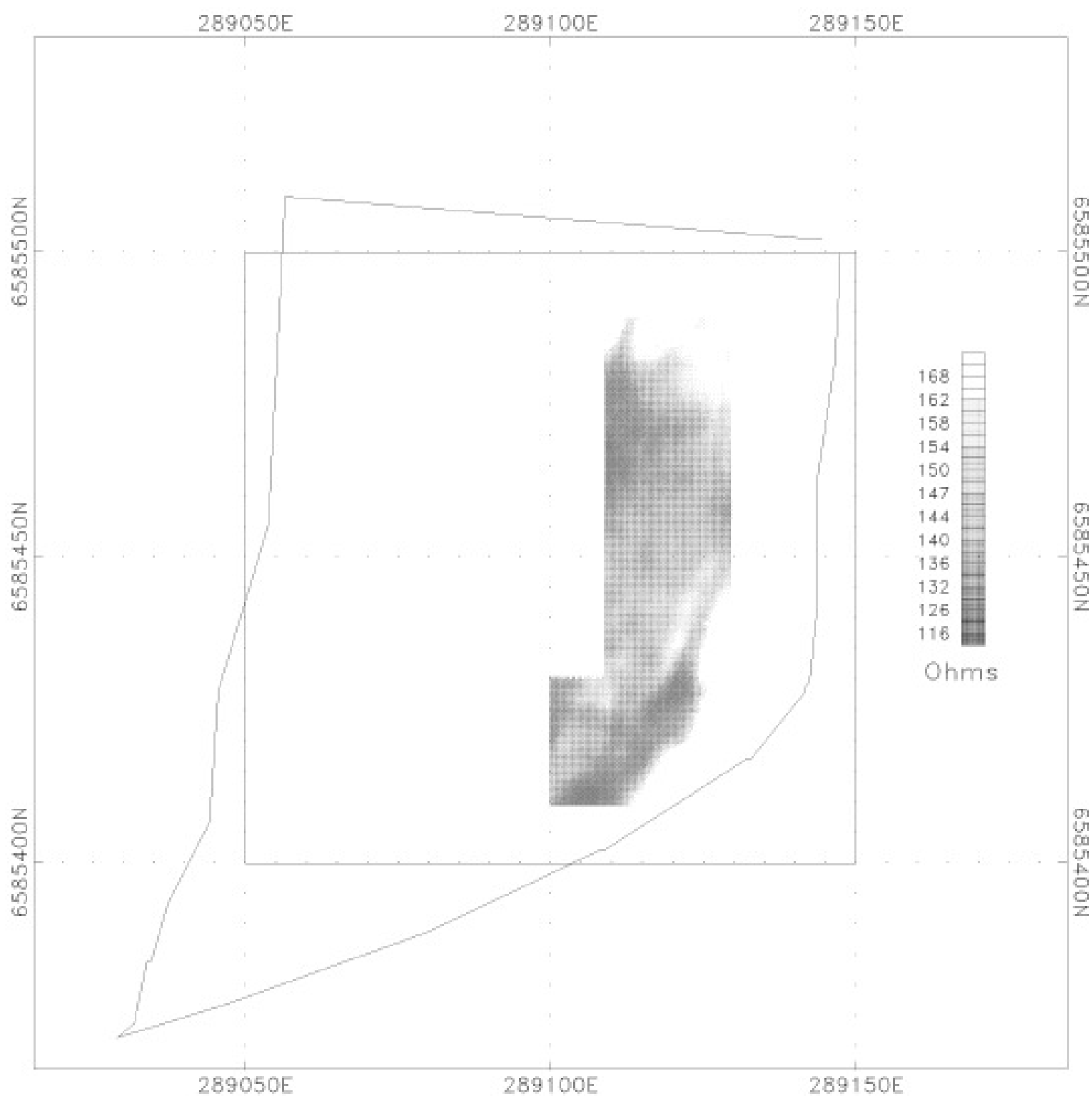
**Fig 15.2: Avaldsnes Geophysical Survey – Area 2**  
**Magnetic Gradiometry Survey – Trenches**  
**Kevin Barton, NTNU/EA, November 2009**

10 0 10 20 30  
(metres)



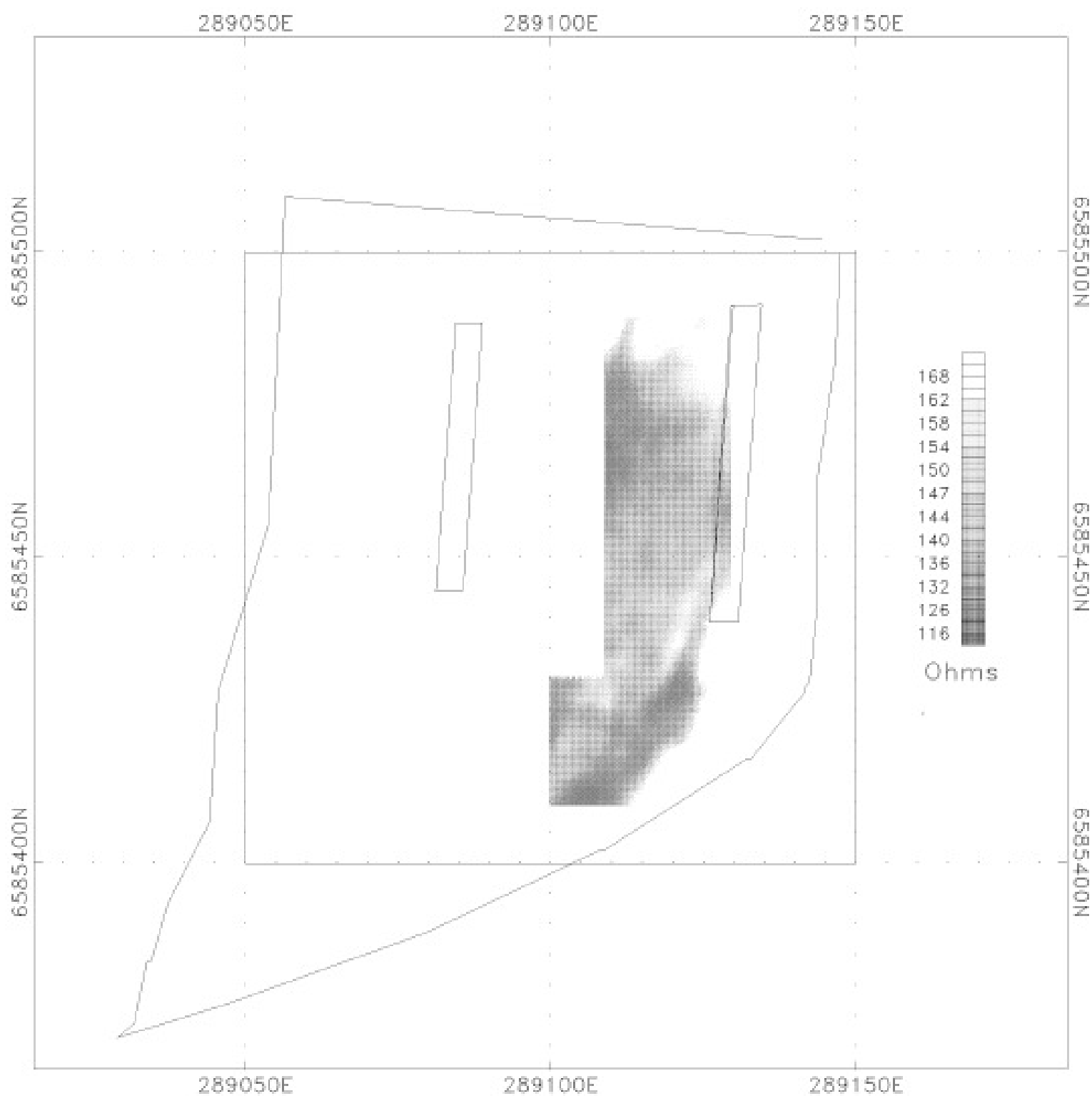
**Fig 15.3: Avaldsnes Geophysical Survey – Area 2**  
**Magnetic Gradiometry Survey – Features**  
**Kevin Barton, NTNU/EA, November 2009**

10 0 10 20 30  
(metres)

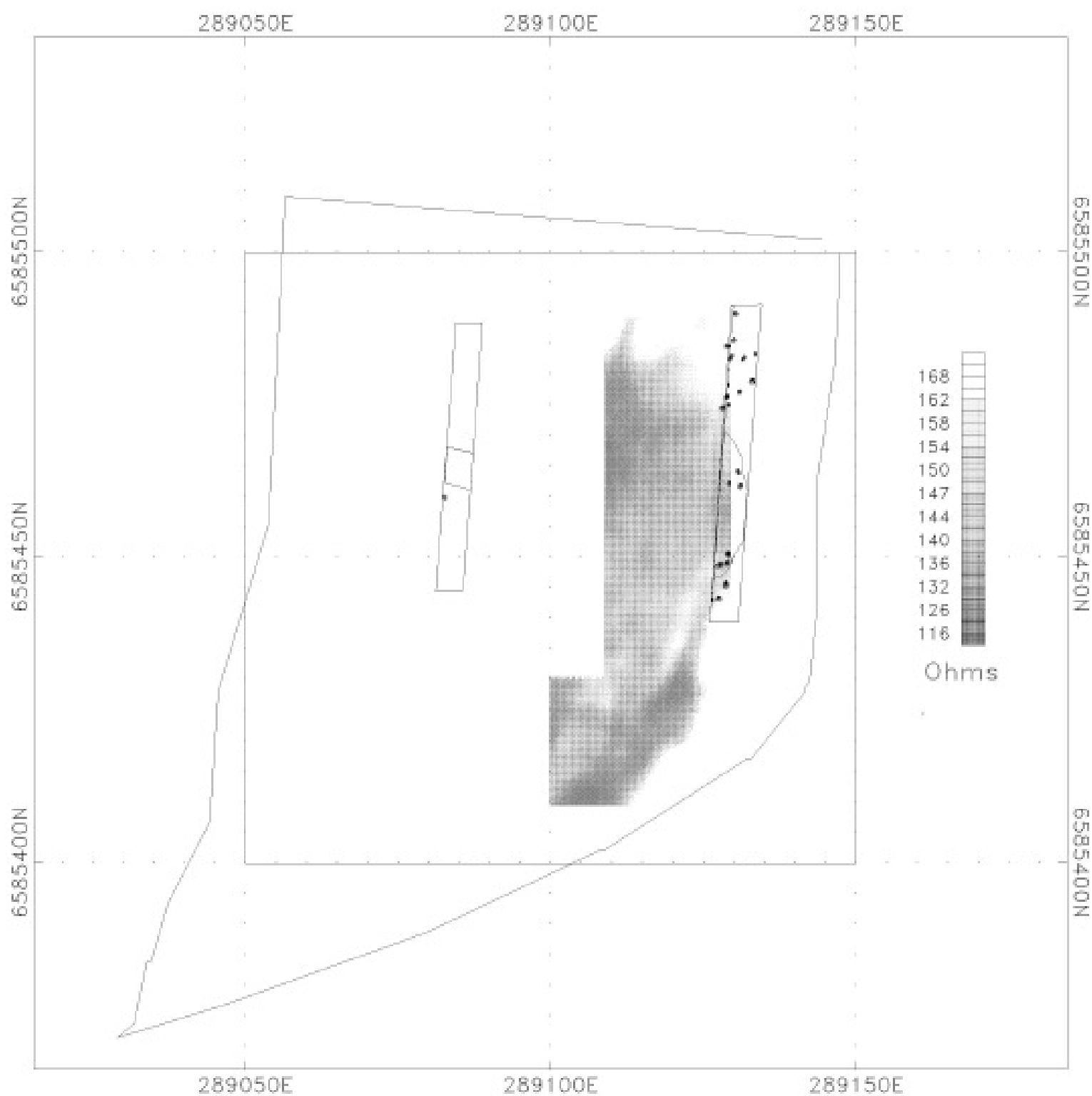


**Fig 16 : Avaldsnes Geophysical Survey – Area 2**  
**Earth Resistance Survey**  
**Kevin Barton, NTNU/EA, August 2009**

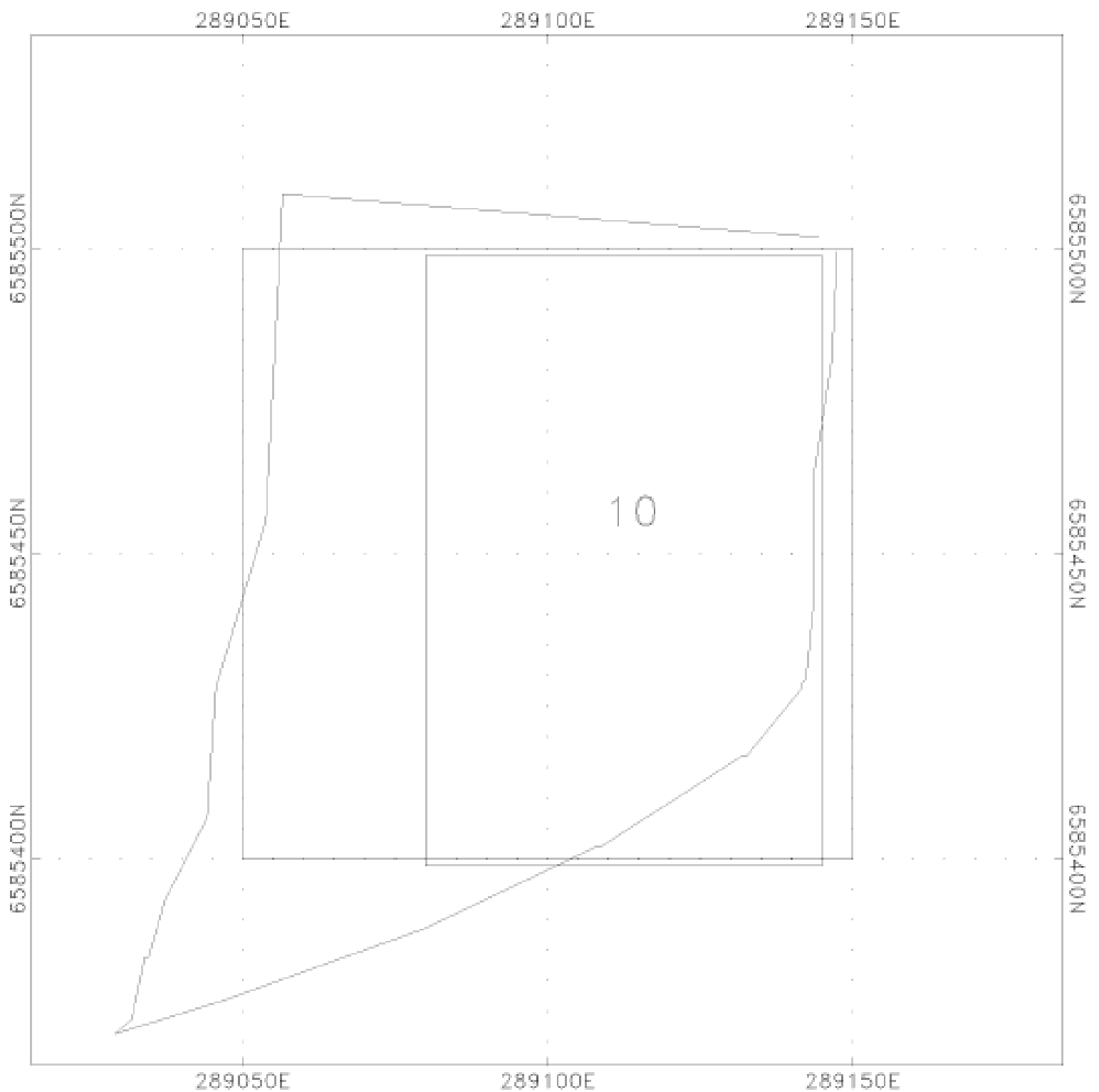




**Fig 16.1 : Avaldsnes Geophysical Survey – Area 2**  
**Earth Resistance Survey – Trenches**  
**Kevin Barton, NTNU/EA, November 2009**



**Fig 16.2 : Avaldsnes Geophysical Survey – Area 2**  
**Earth Resistance Survey – Features**  
**Kevin Barton, NTNU/EA, November 2009**



**Fig 17 : Avaldsnes Geophysical Survey – Area 2**  
**Ground Penetrating Radar – Grid Location Map**  
**Kevin Barton, NTNU/EA, August 2009**



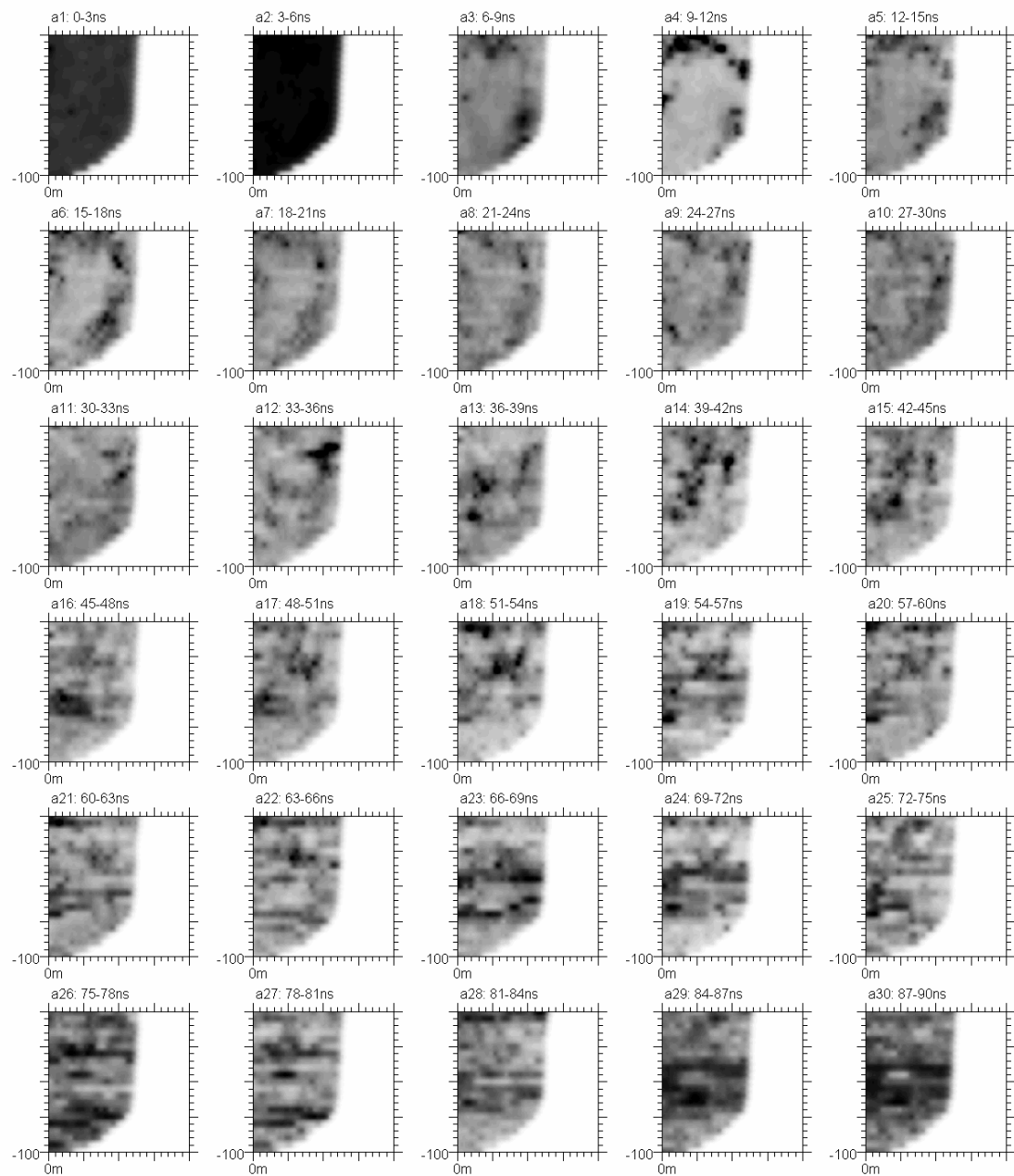
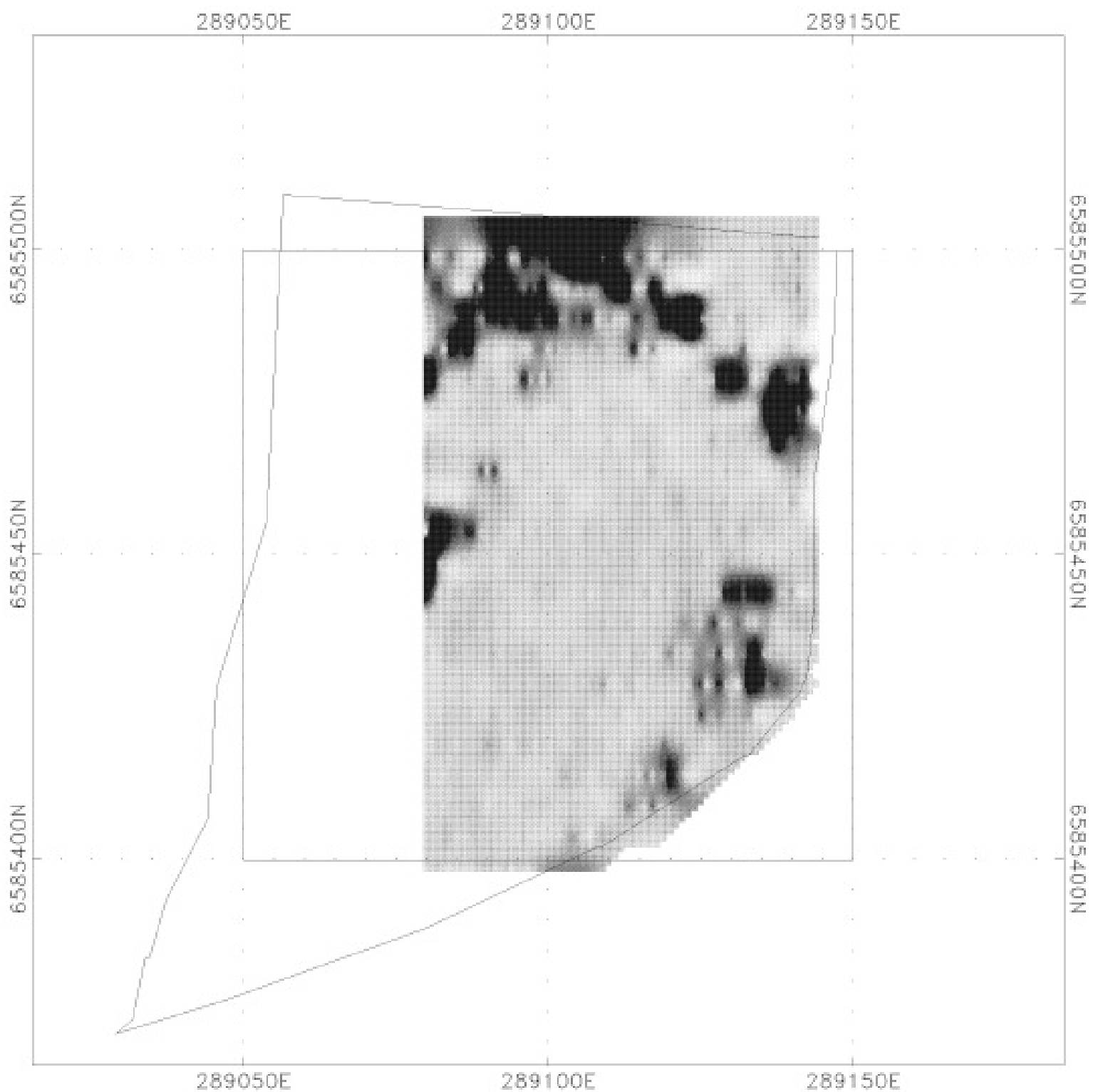
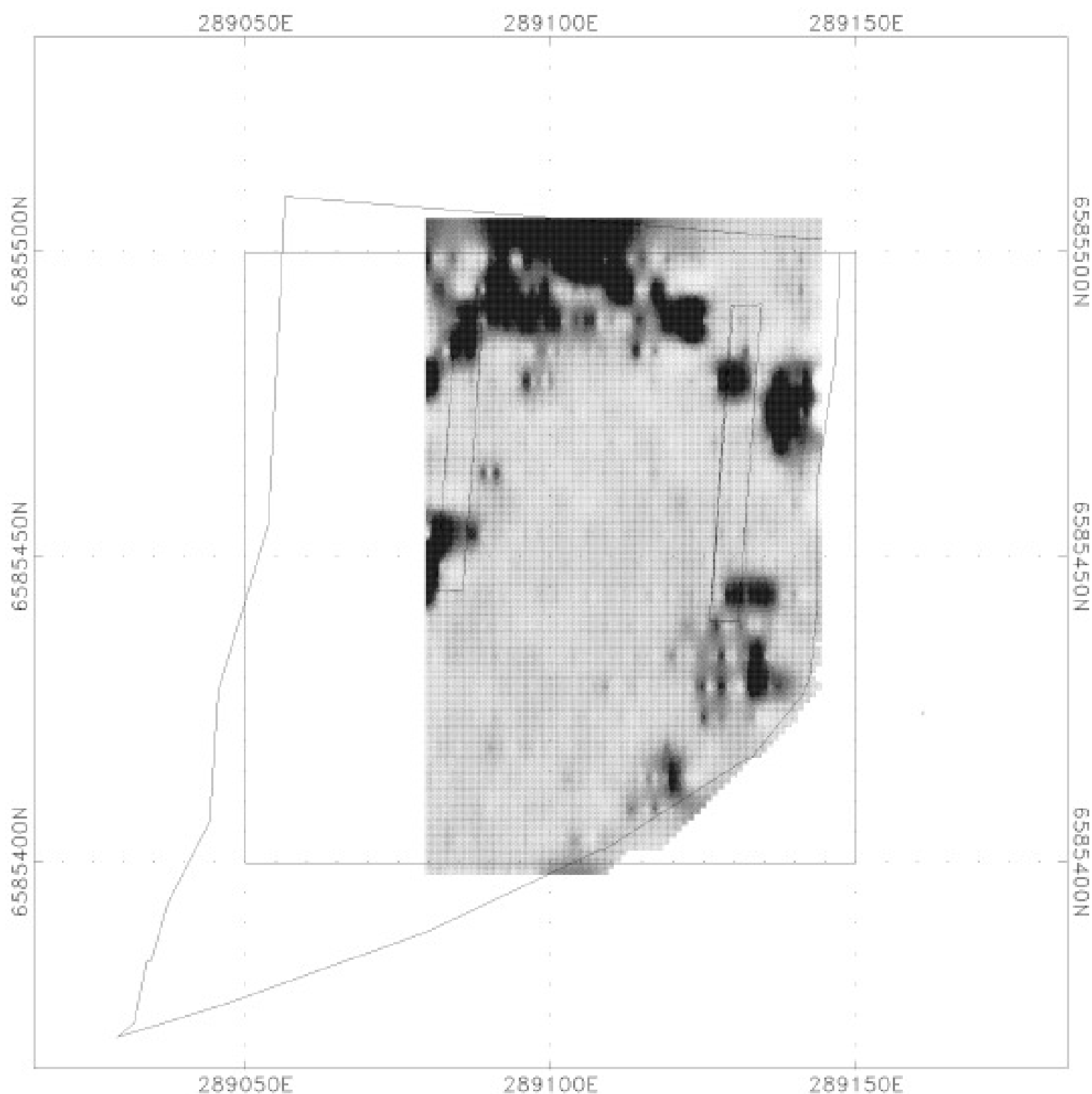


Fig 17.1 : Avaldsnes Geophysical Survey; Area 2  
Grid 10 - GPR Horizontal Slices

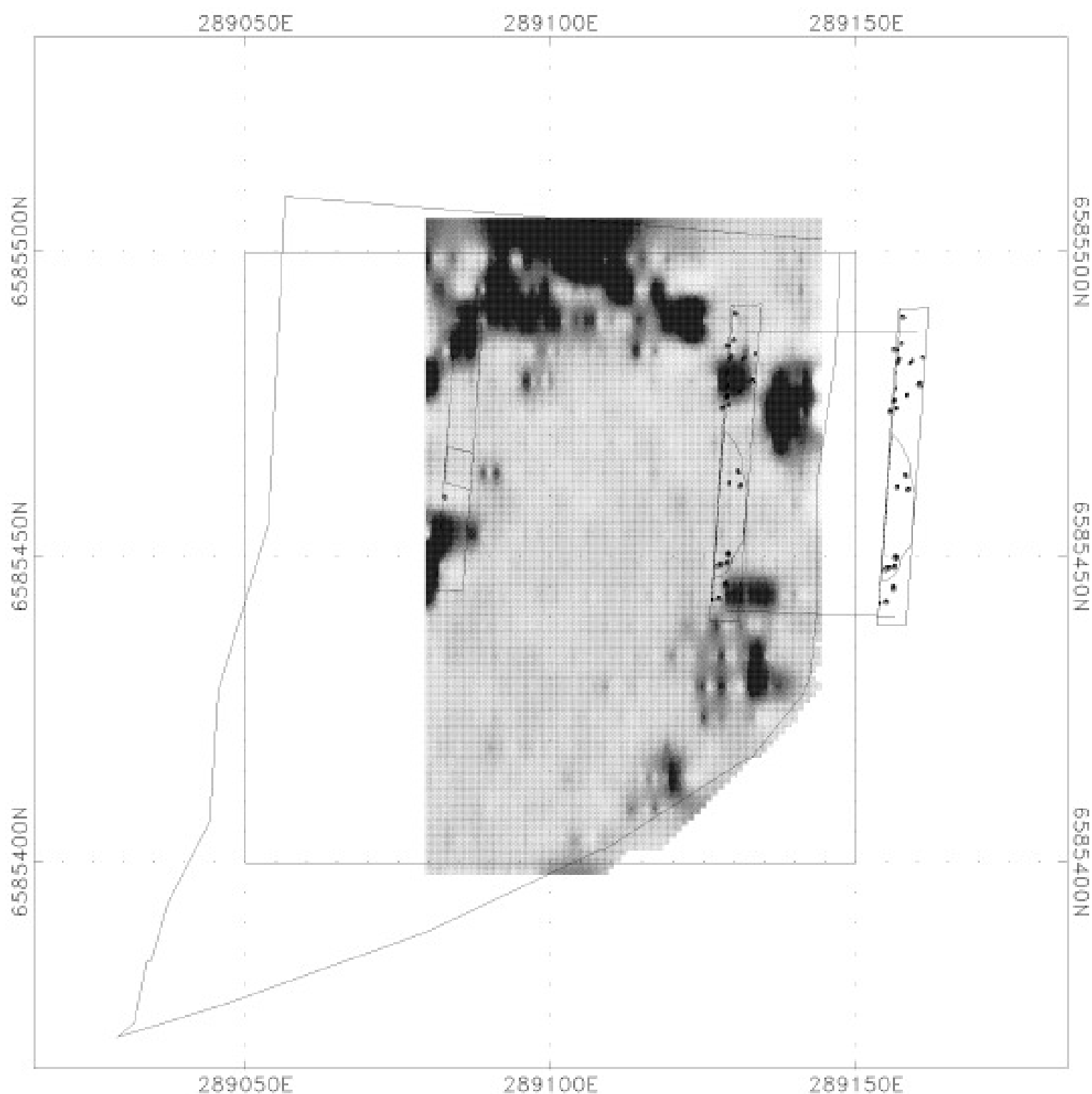


**Fig 17.2 Avaldsnes Geophysical Survey – Area 2**  
**Ground Penetrating Radar – Slice 4, 9 – 12 ns**  
**Kevin Barton, NTNU/EA, September 2009**



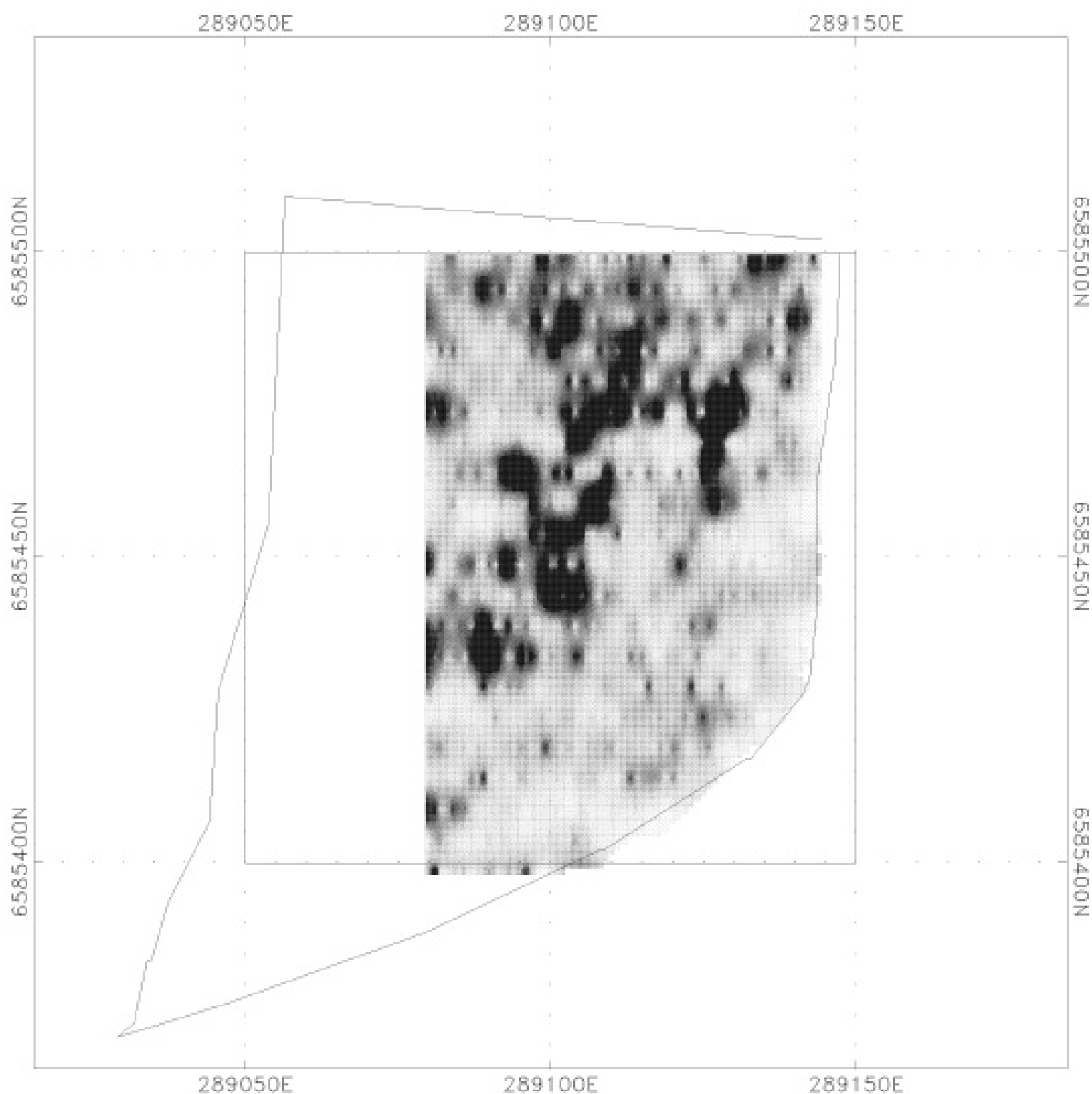
**Fig 17.2.1 : Avaldsnes Geophysical Survey – Area 2**  
**Ground Penetrating Radar – Slice 4 – Trenches**  
**Kevin Barton, NTNU/EA, November 2009**

10 0 10 20 30  
(metres)



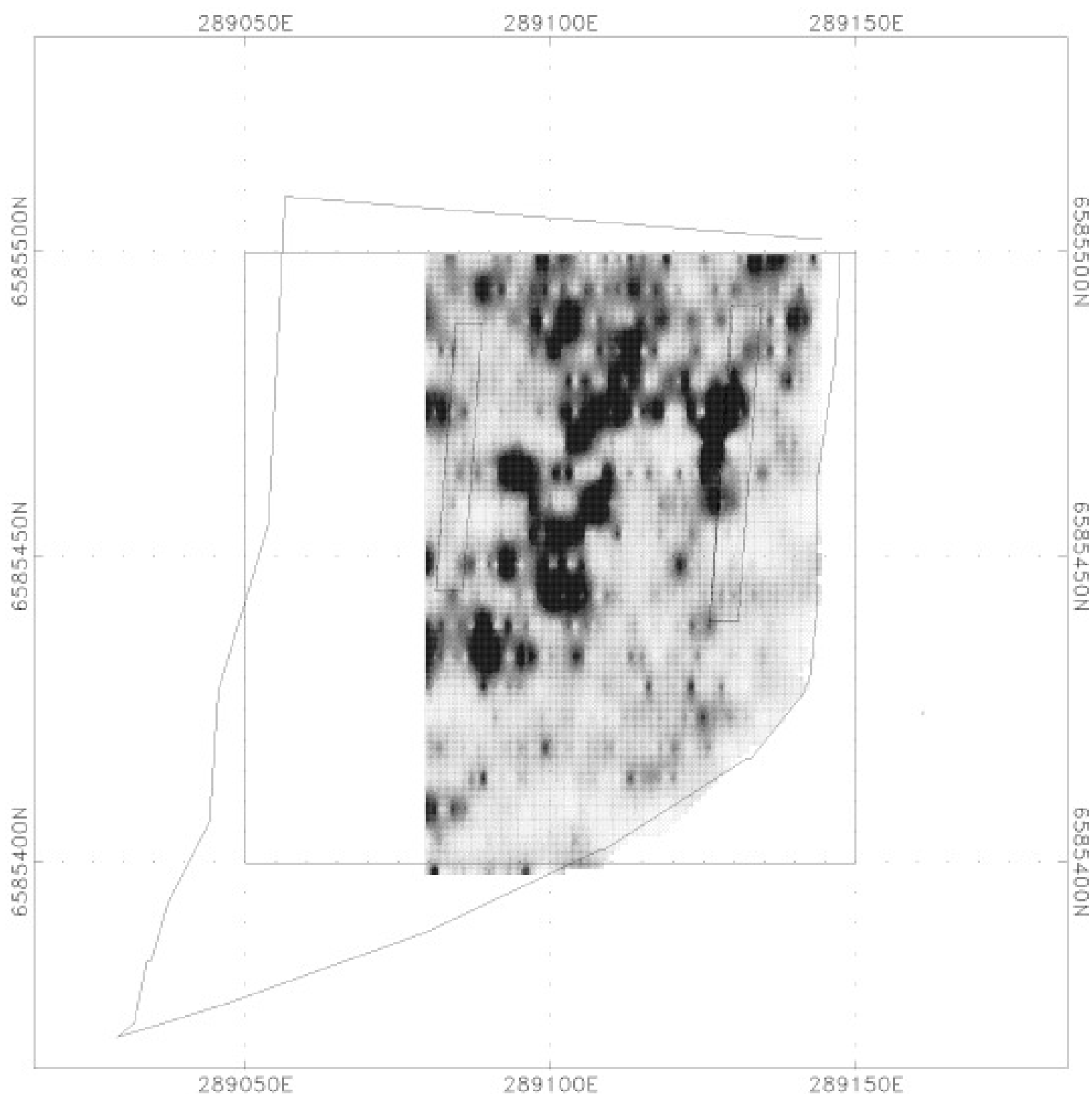
**Fig 17.2.2 : Avaldsnes Geophysical Survey – Area 2**  
**Ground Penetrating Radar – Slice 4 – Features**  
**Kevin Barton, NTNU/EA, November 2009**

10 0 10 20 30  
 (metres)



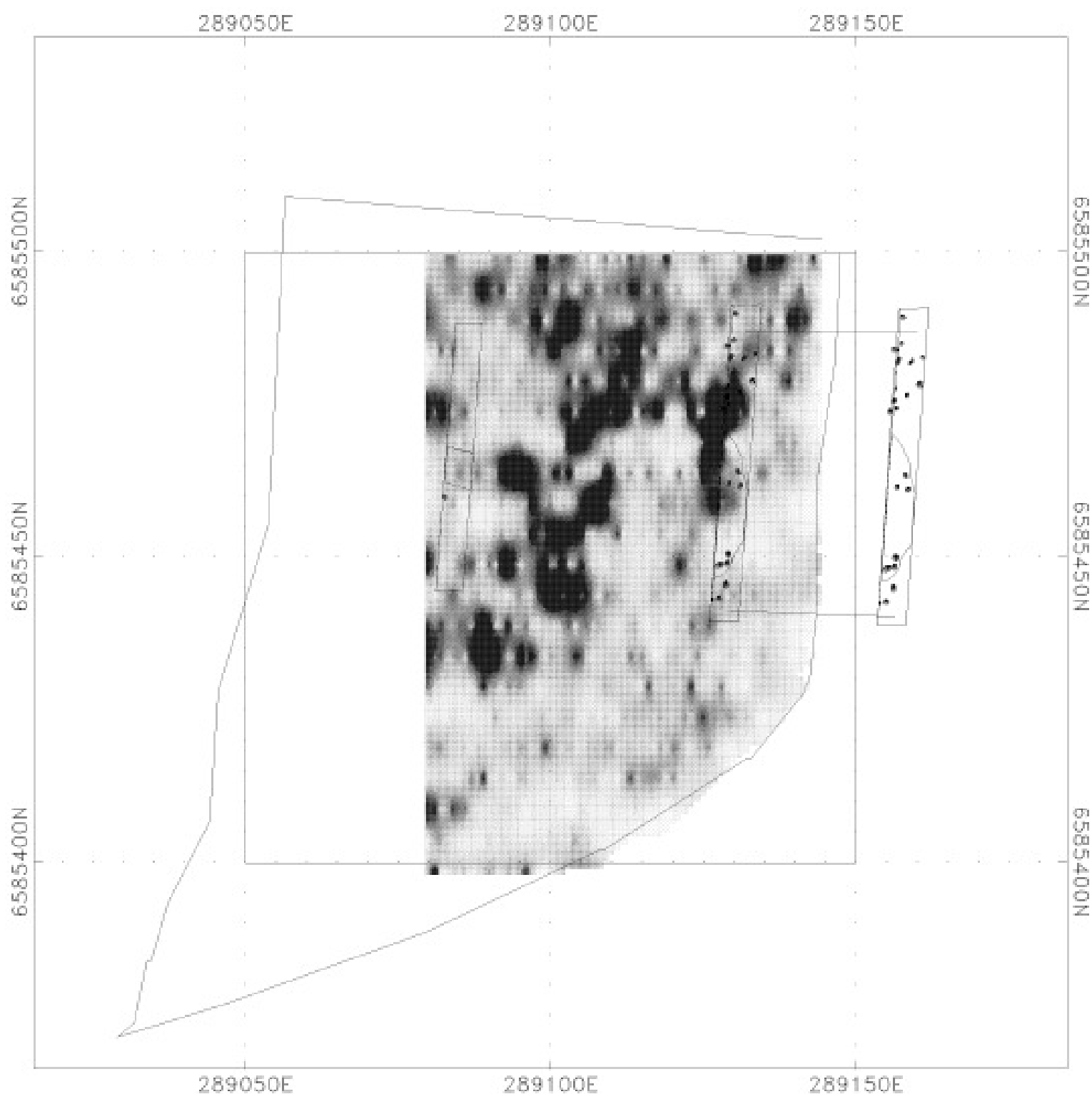
**Fig 17.3 Avaldsnes Geophysical Survey – Area 2**  
**Ground Penetrating Radar – Slice 14, 39 – 42 ns**  
**Kevin Barton, NTNU/EA, September 2009**

10 0 10 20 30  
(metres)



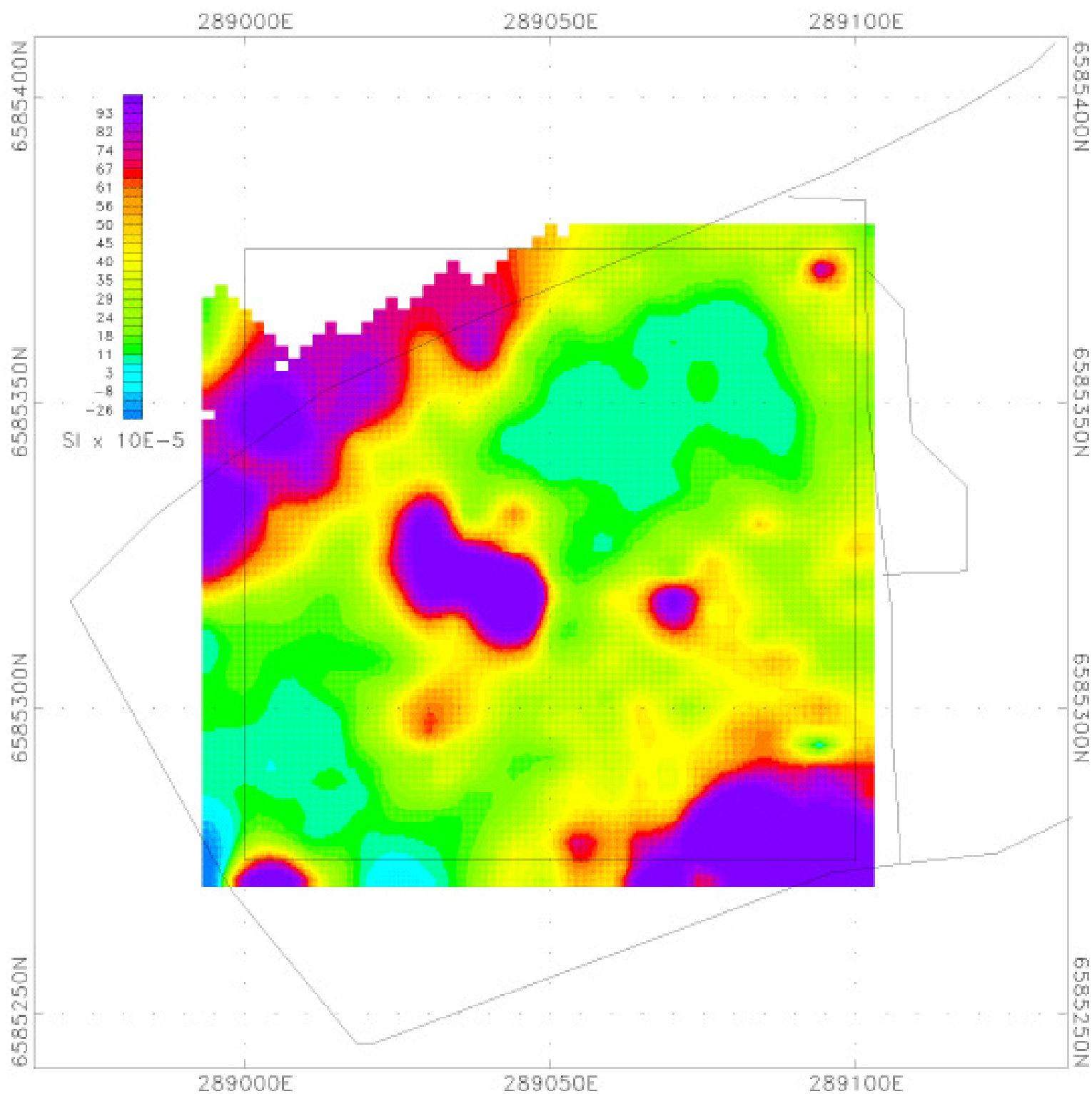
**Fig 17.3.1 : Avaldsnes Geophysical Survey – Area 2**  
**Ground Penetrating Radar – Slice 14 – Trenches**  
**Kevin Barton, NTNU/EA, November 2009**



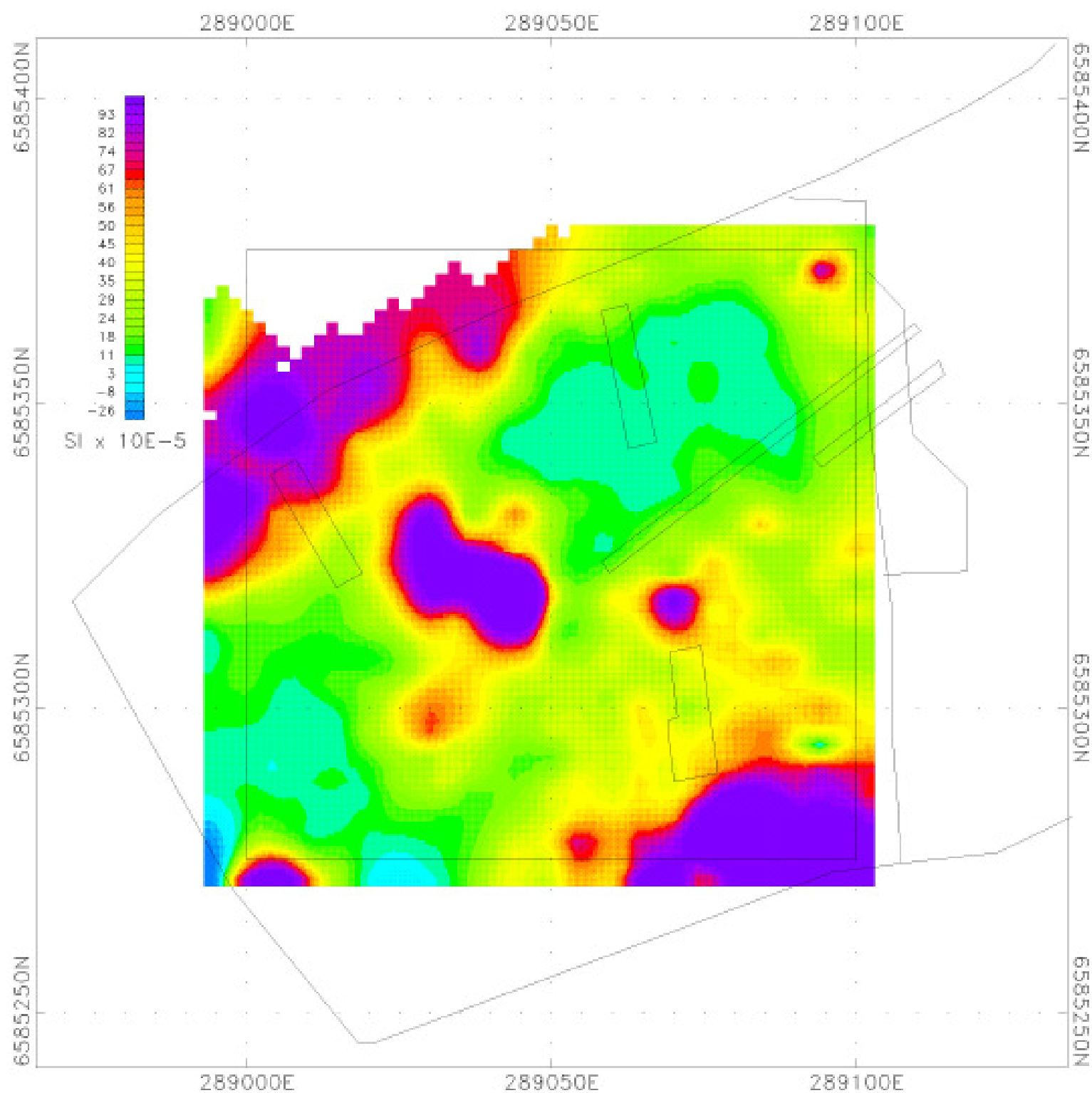


**Fig 17.3.2 : Avaldsnes Geophysical Survey – Area 2**  
**Ground Penetrating Radar – Slice 14 – Features**  
**Kevin Barton, NTNU/EA, November 2009**

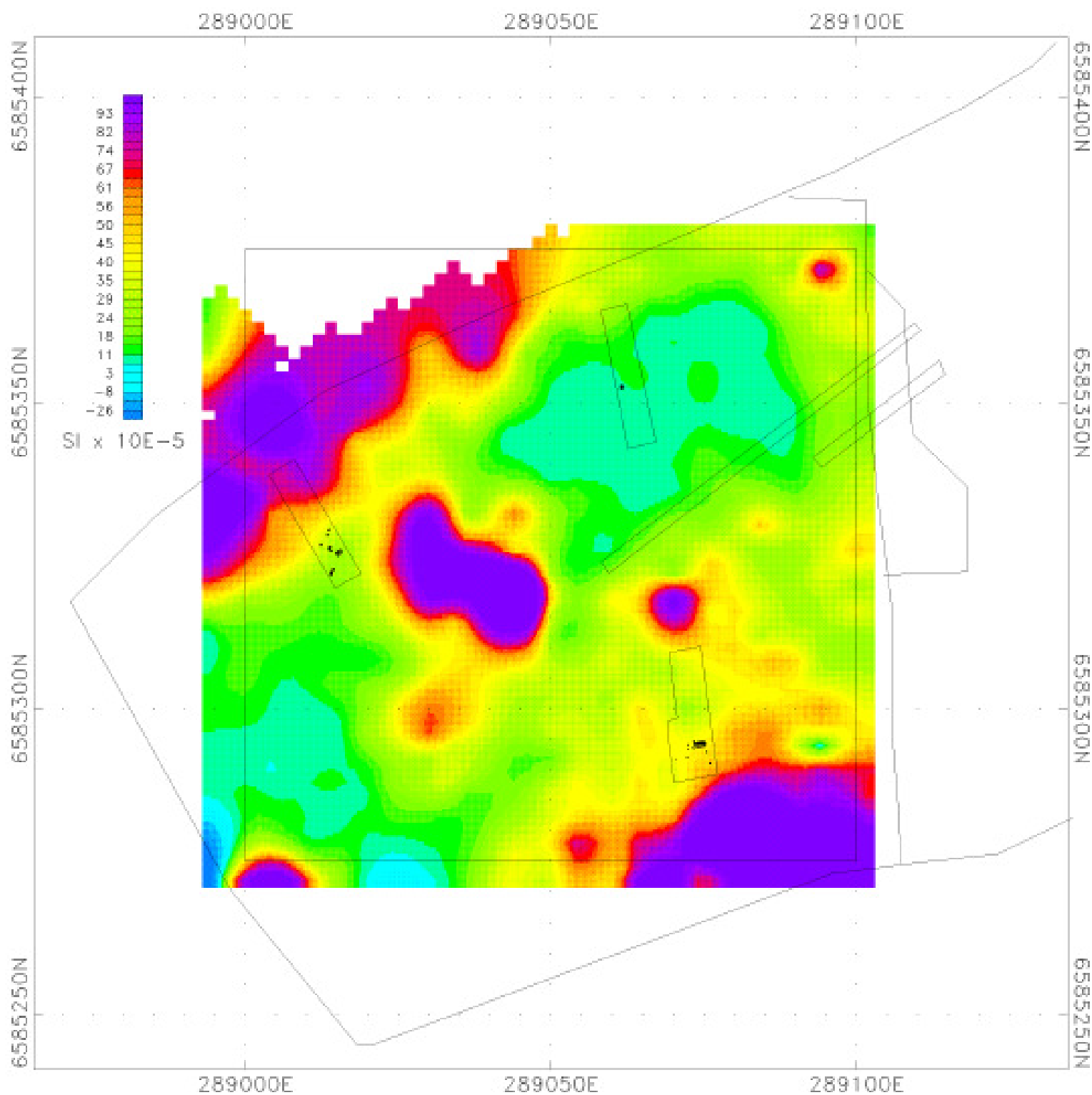




**Fig 18 : Avaldsnes Geophysical Survey – Area 3**  
**Reconnaissance Magnetic Suceptibility Survey**  
**Kevin Barton, NTNU/EA, August 2009**

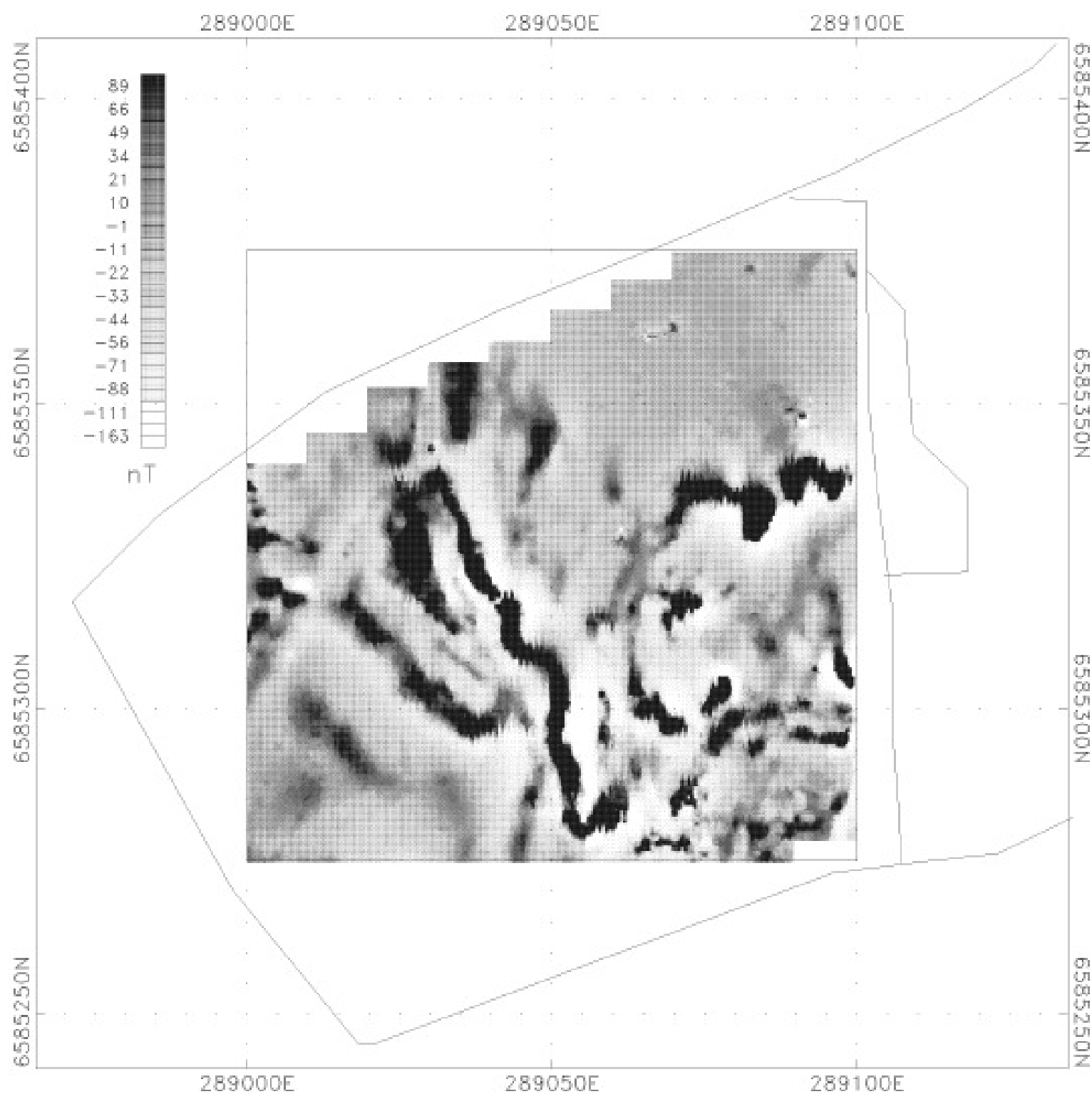


**Fig 18.1 : Avaldsnes Geophysical Survey – Area 3**  
**Reconnaissance Magnetic Suceptibility Survey–Trenches**  
**Kevin Barton, NTNU/EA, November 2009**



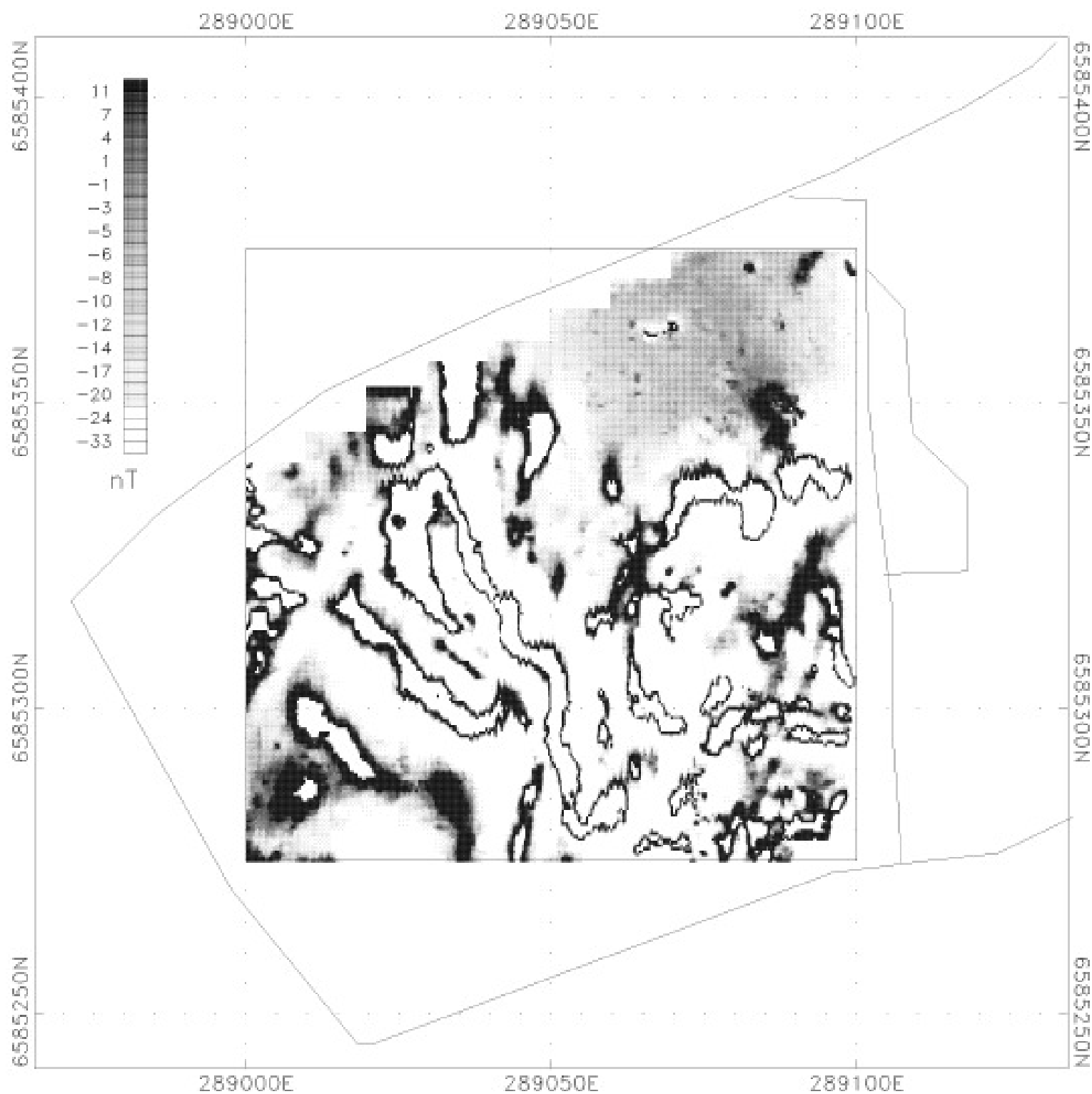
**Fig 18.2 : Avaldsnes Geophysical Survey – Area 3**  
**Reconnaissance Magnetic Suceptibility Survey–Features**  
**Kevin Barton, NTNU/EA, November 2009**





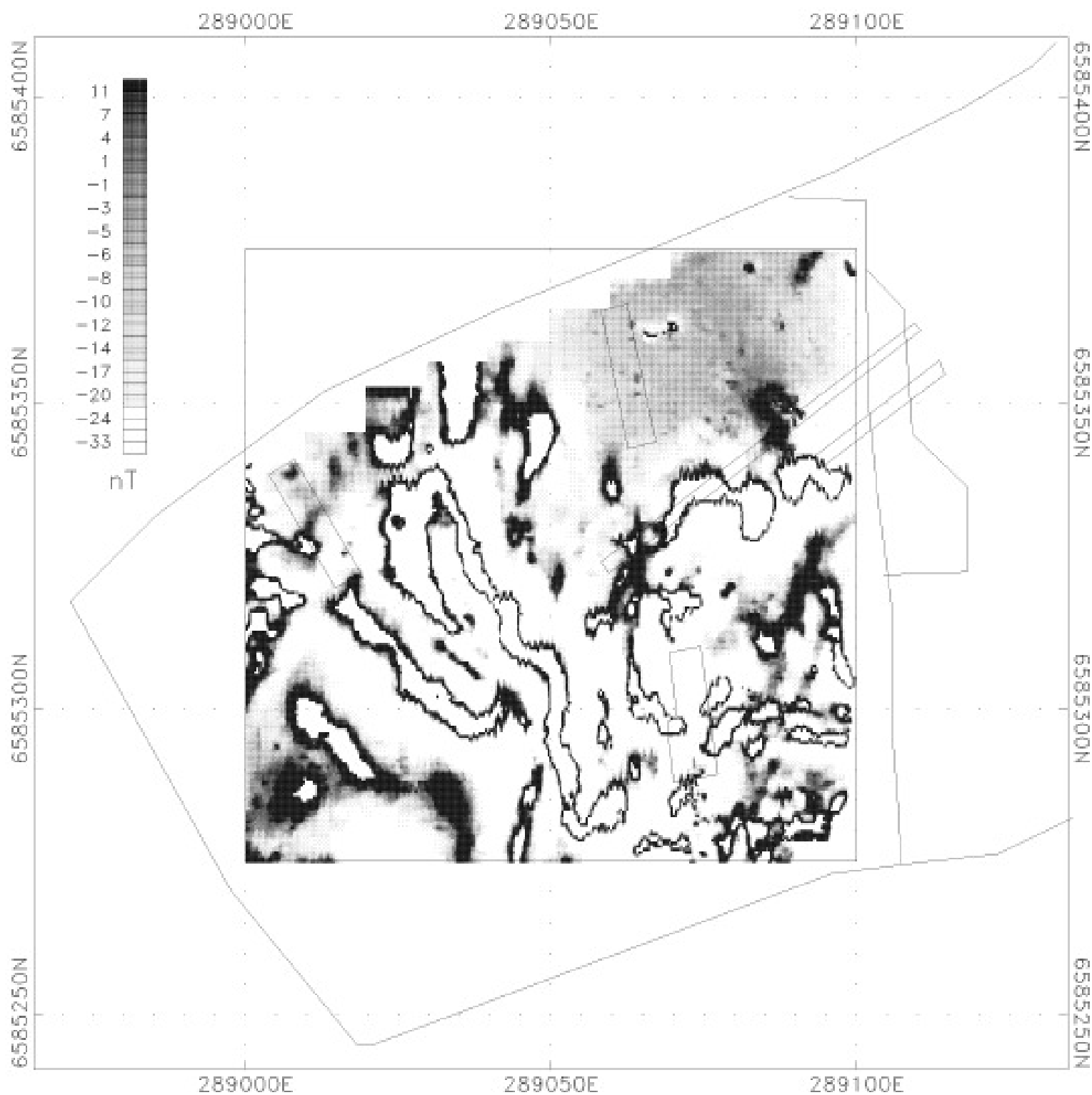
**Fig 19 : Avaldsnes Geophysical Survey – Area 3**  
**Magnetic Gradiometry Survey**  
**Kevin Barton, NTNU/EA, August 2009**

10 0 10 20 30  
(metres)



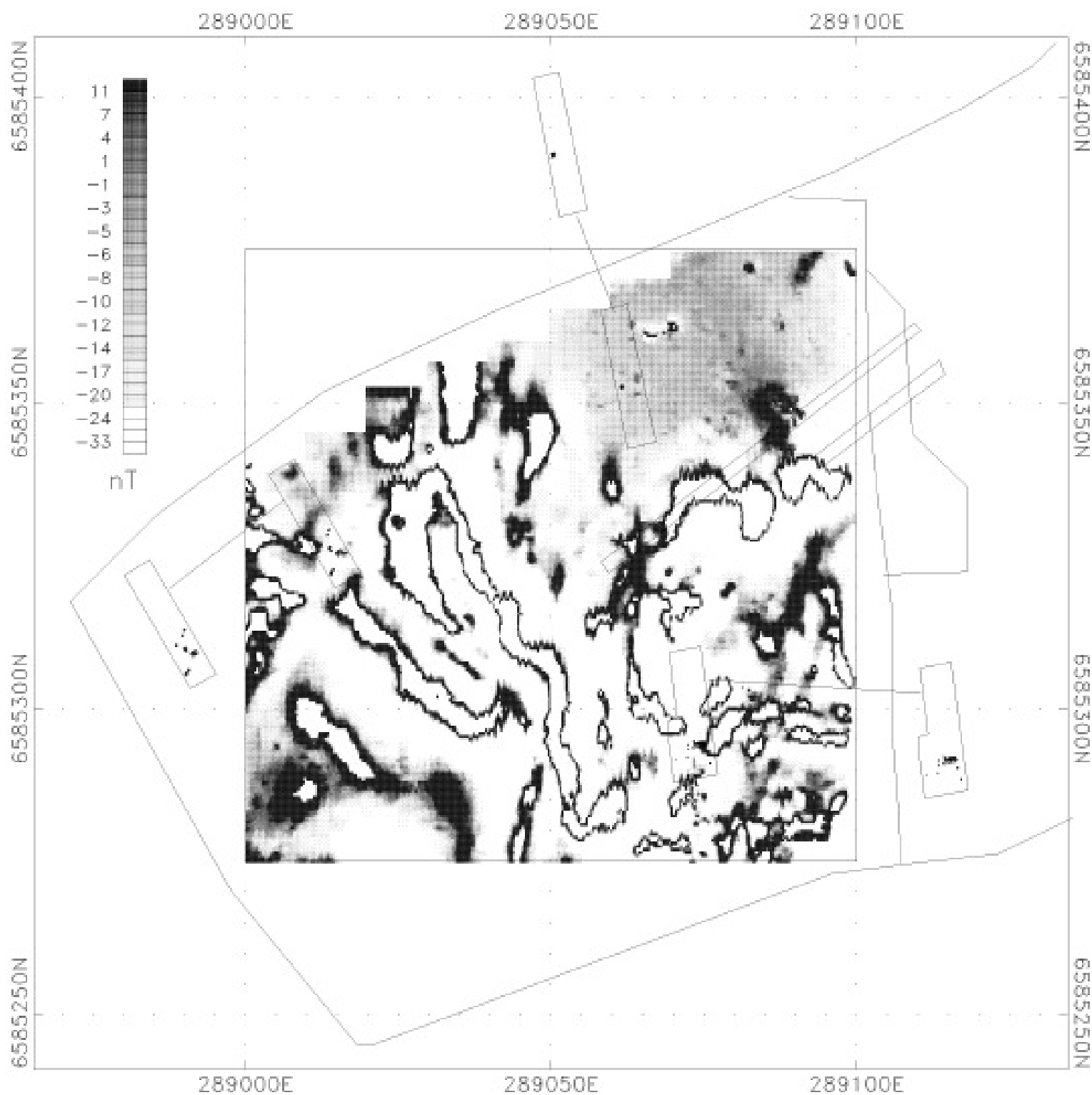
**Fig 19.1 : Avaldsnes Geophysical Survey – Area 3**  
**Magnetic Gradiometry Survey – Clipped 40 nT**  
**Kevin Barton, NTNU/EA, August 2009**

10 0 10 20 30  
(metres)



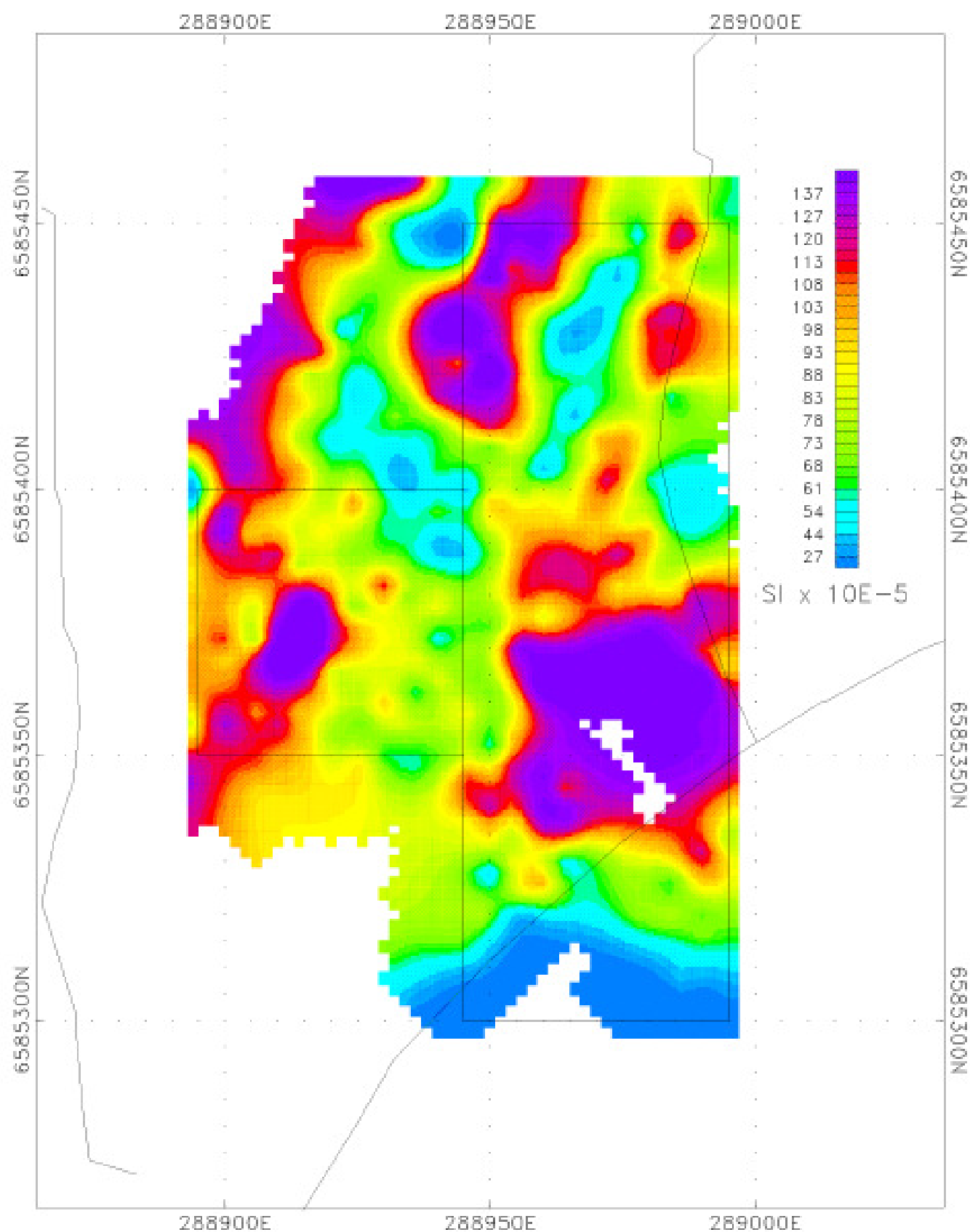
**Fig 19.2 : Avaldsnes Geophysical Survey – Area 3**  
**Magnetic Gradiometry Survey – Trenches**  
**Kevin Barton, NTNU/EA, November 2009**

10 0 10 20 30  
(metres)



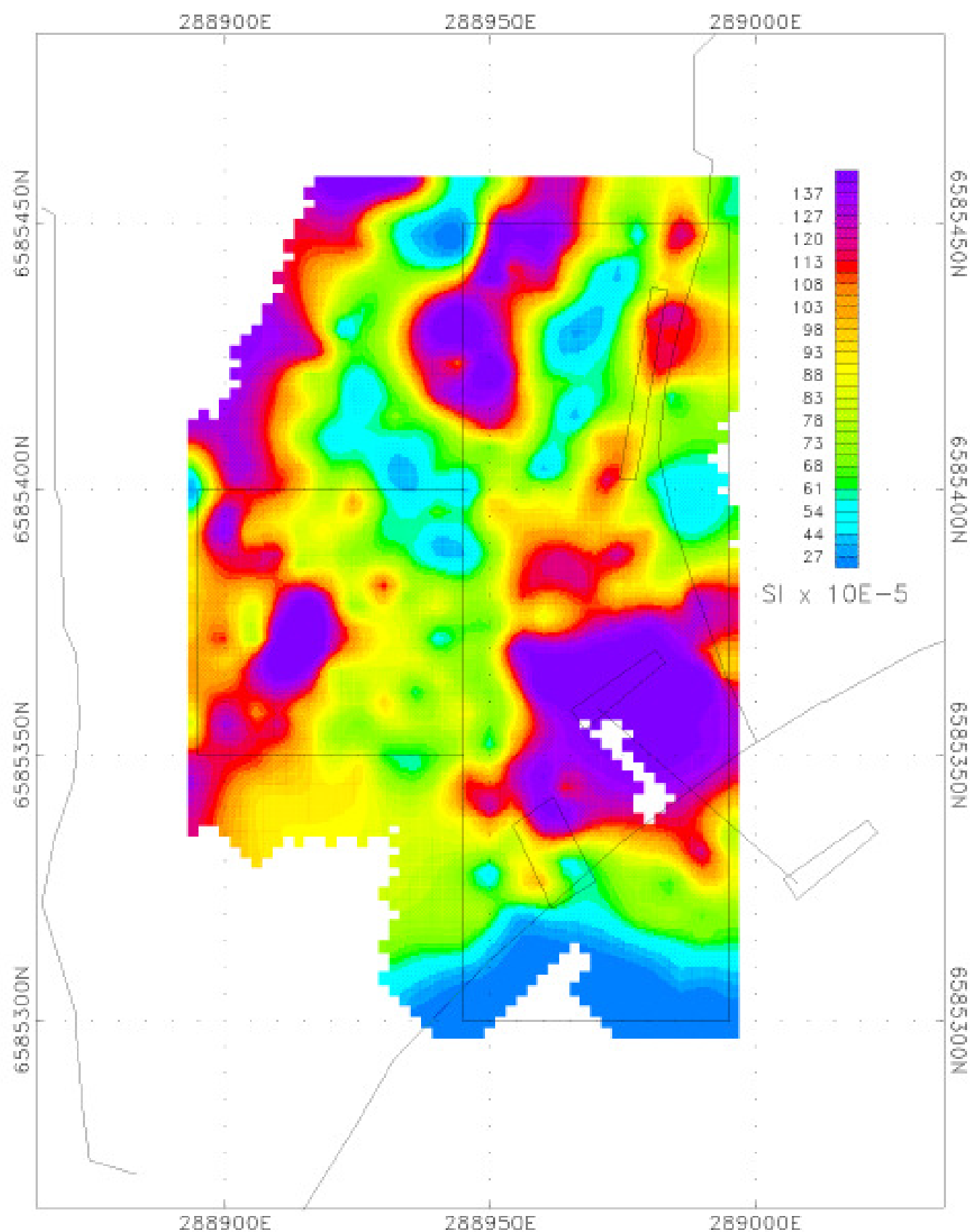
**Fig 19.3 : Avaldsnes Geophysical Survey – Area 3**  
**Magnetic Gradiometry Survey – Features**  
 Kevin Barton, NTNU/EA, November 2009

10 0 10 20 30  
 (metres)



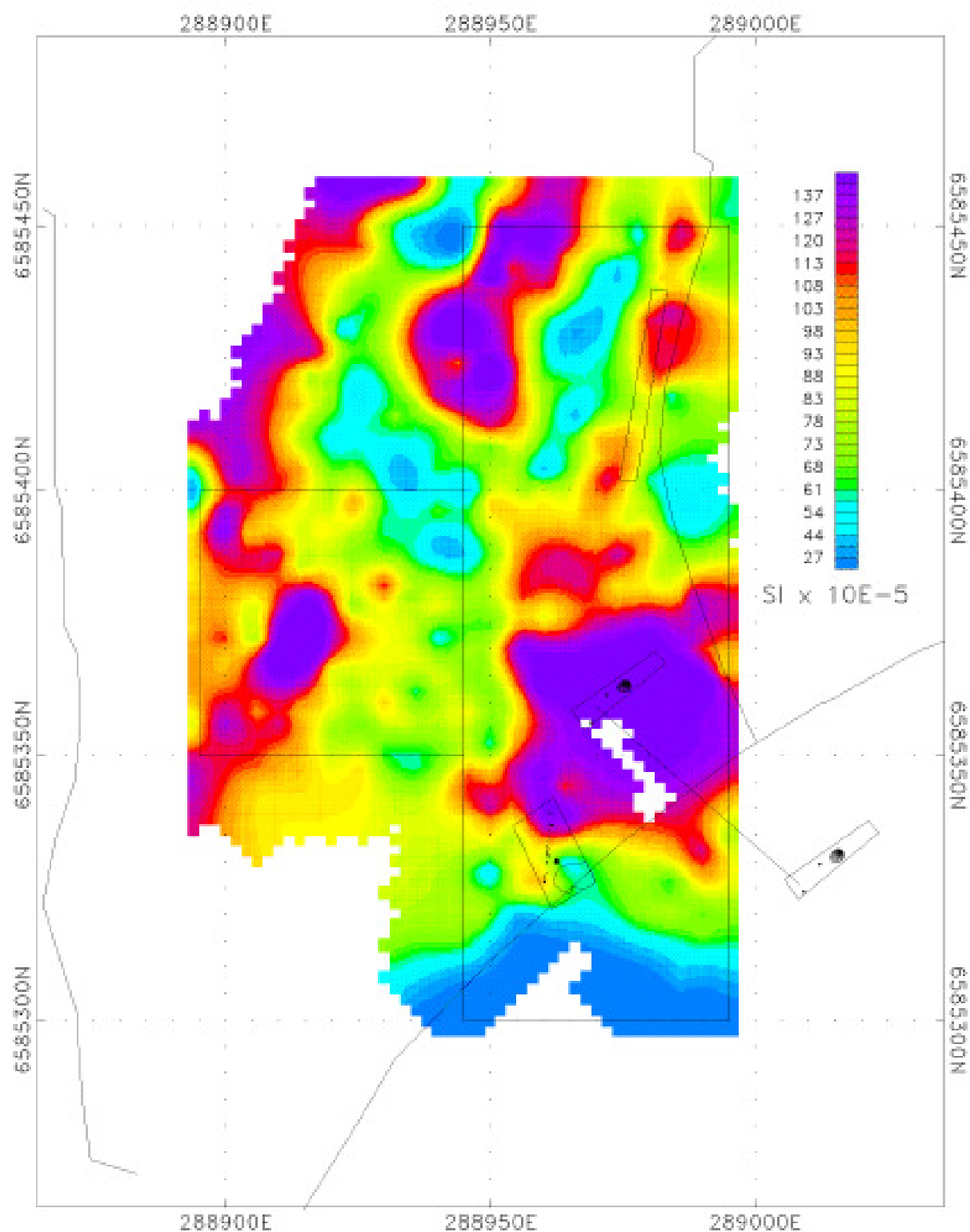
**Fig 20 : Avaldsnes Geophysical Survey – Area 4**  
**Reconnaissance Magnetic Suceptibility Survey**  
**Kevin Barton, NTNU/EA, August 2009**

25 0 25  
(metres)

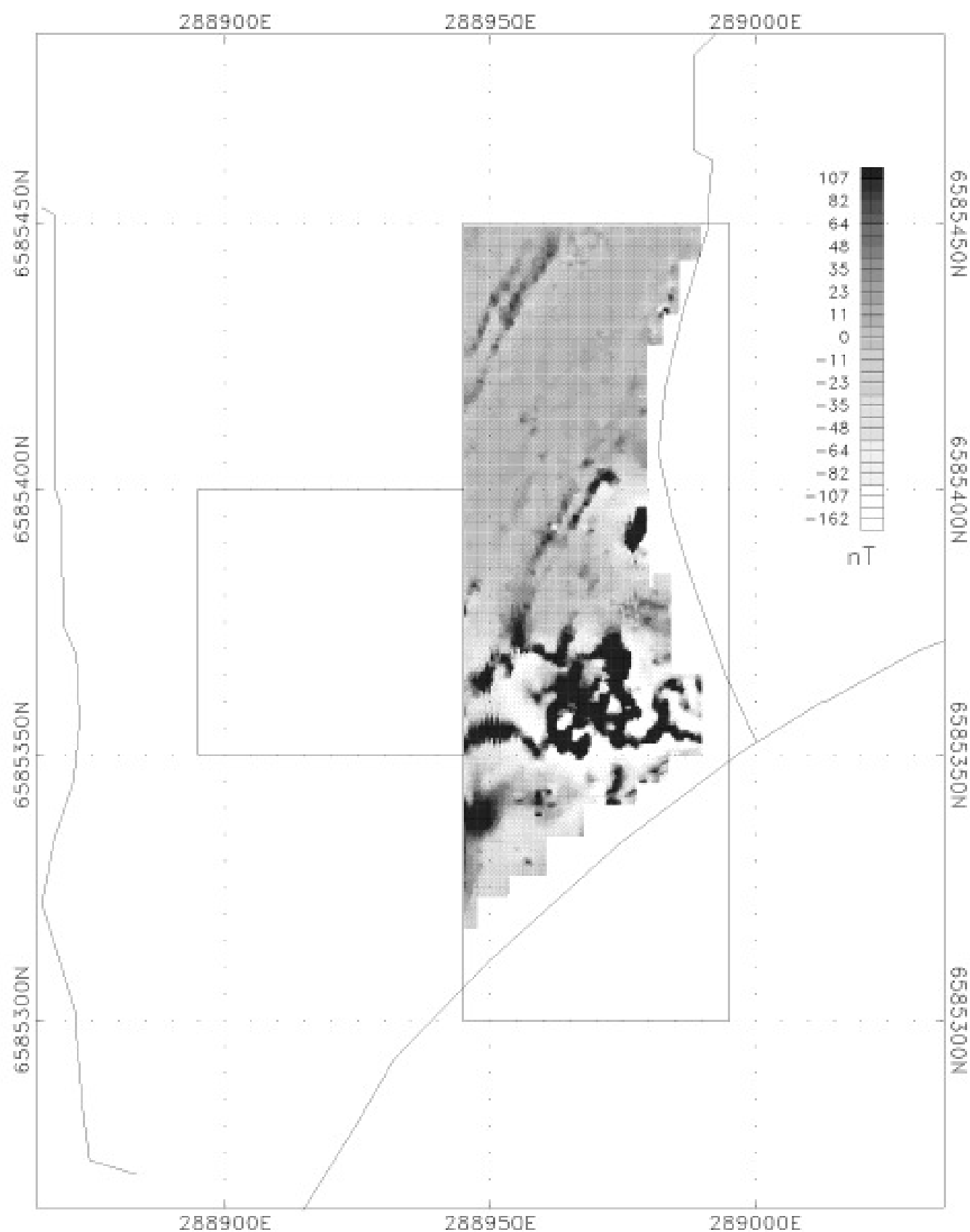


**Fig 20.1 : Avaldsnes Geophysical Survey – Area 4**  
**Reconnaissance Magnetic Suceptibility Survey–Trenches**  
 Kevin Barton, NTNU/EA, November 2009

25 0 25  
 (metres)

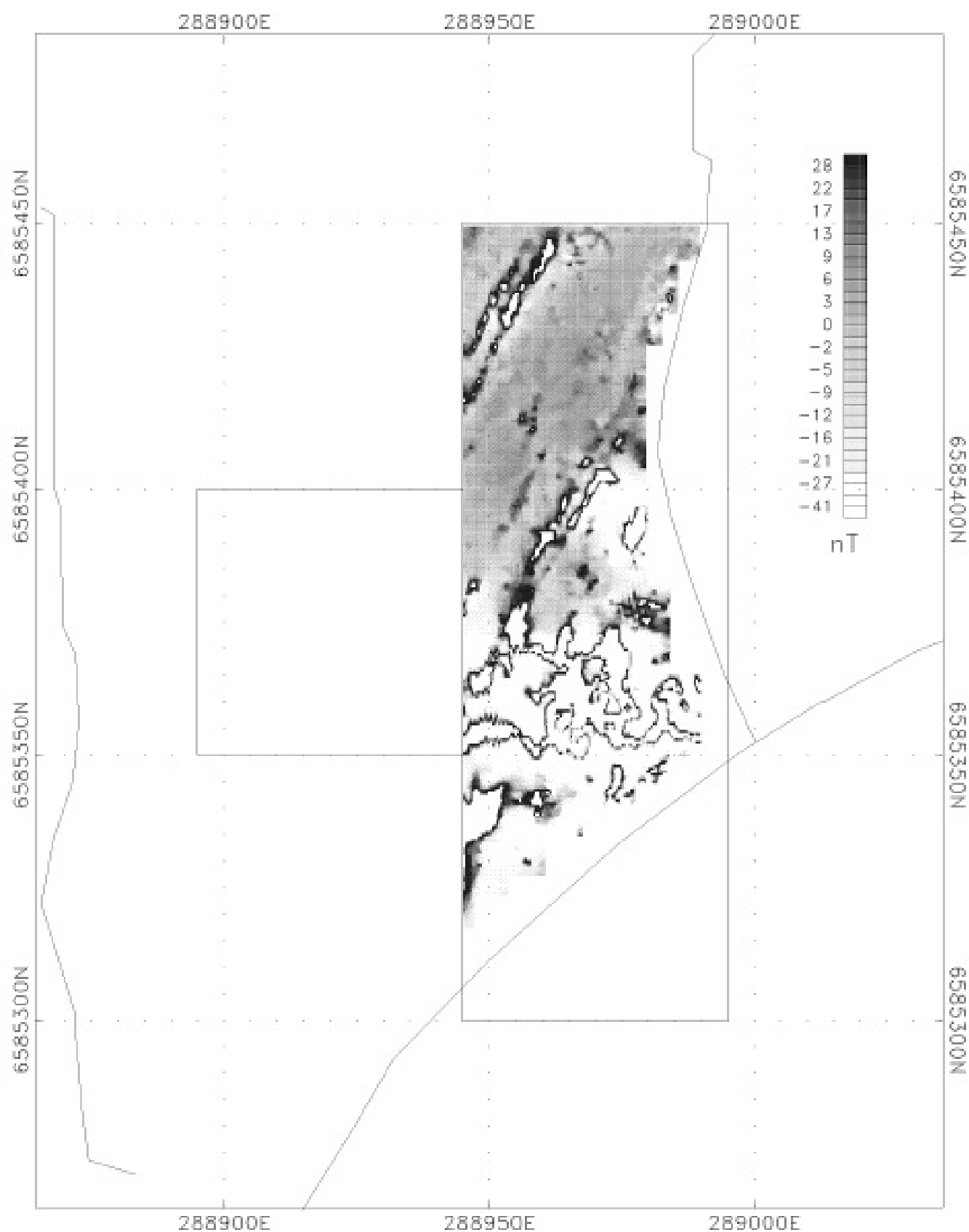


**Fig 20.2 : Avaldsnes Geophysical Survey – Area 4**  
**Reconnaissance Magnetic Suceptibility Survey–Features**  
 Kevin Barton, NTNU/EA, November 2009



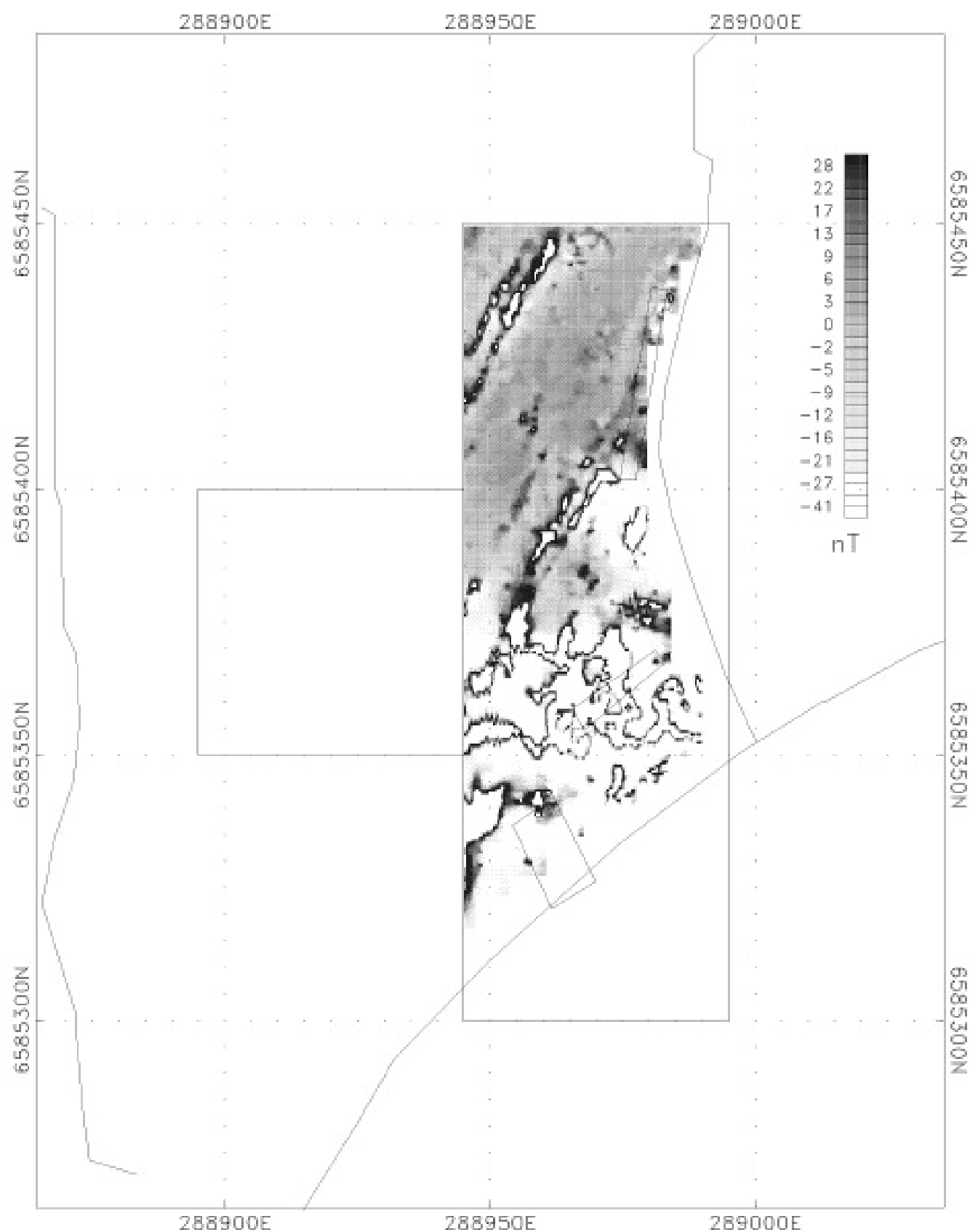
**Fig 21 : Avaldsnes Geophysical Survey – Area 4**  
**Magnetic Gradiometry Survey**  
**Kevin Barton, NTNU/EA, August 2009**

25 0 25  
(metres)



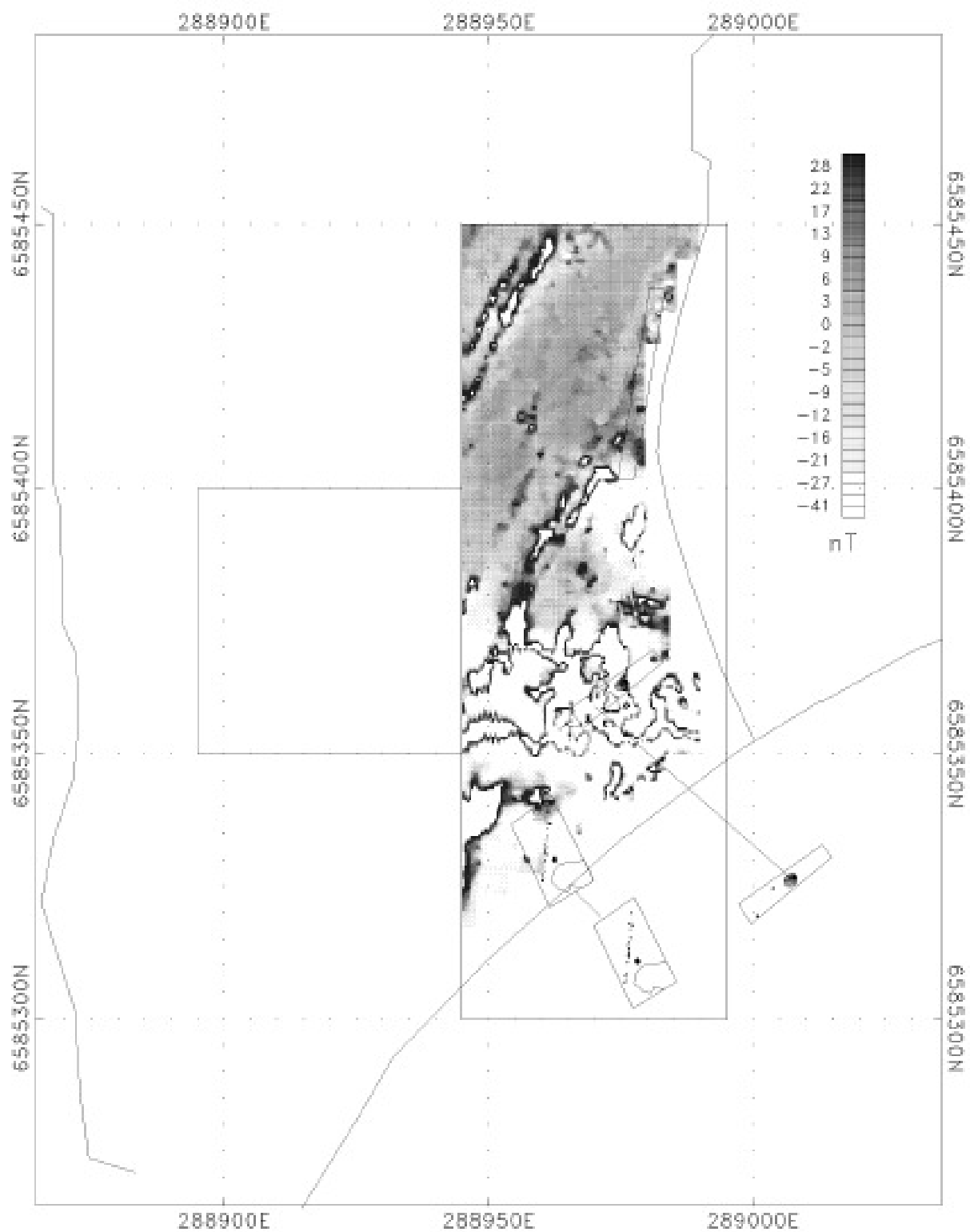
**Fig 21.1 : Avaldsnes Geophysical Survey – Area 4**  
**Magnetic Gradiometry Survey – Clipped 40 nT**  
**Kevin Barton, NTNU/EA, August 2009**

25 0 25  
(metres)



**Fig 21.2 : Avaldsnes Geophysical Survey – Area 4**  
**Magnetic Gradiometry Survey – Trenches**  
 Kevin Barton, NTNU/EA, November 2009

25 0 25  
 (metres)



**Fig 21.3 : Avaldsnes Geophysical Survey – Area 4**  
**Magnetic Gradiometry Survey – Features**  
 Kevin Barton, NTNU/EA, November 2009

25 0 25  
 (metres)

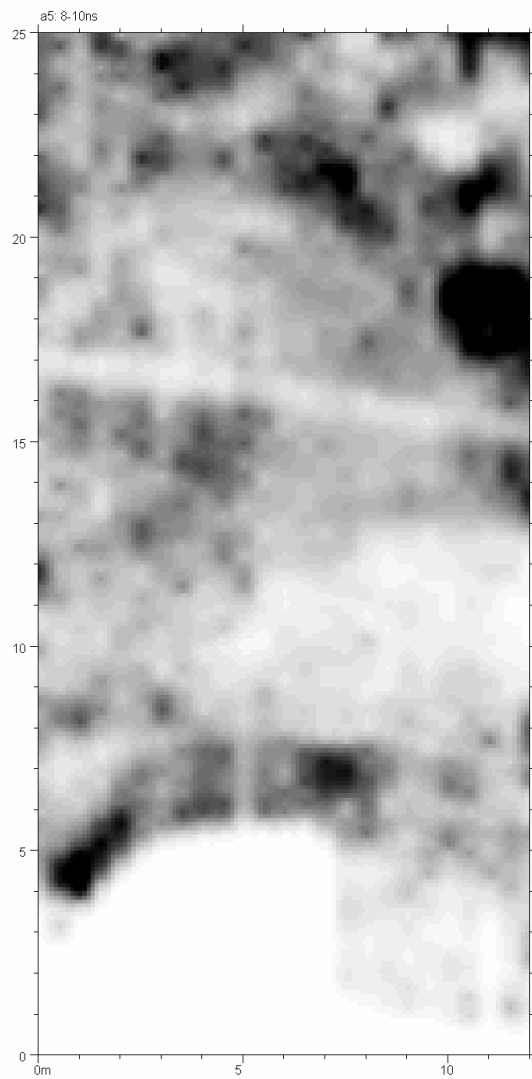


Fig A12.1.1 : Avaldsnes Geophysical Survey ; Area 1  
Grid 1 – GPR Horizontal Slice 5

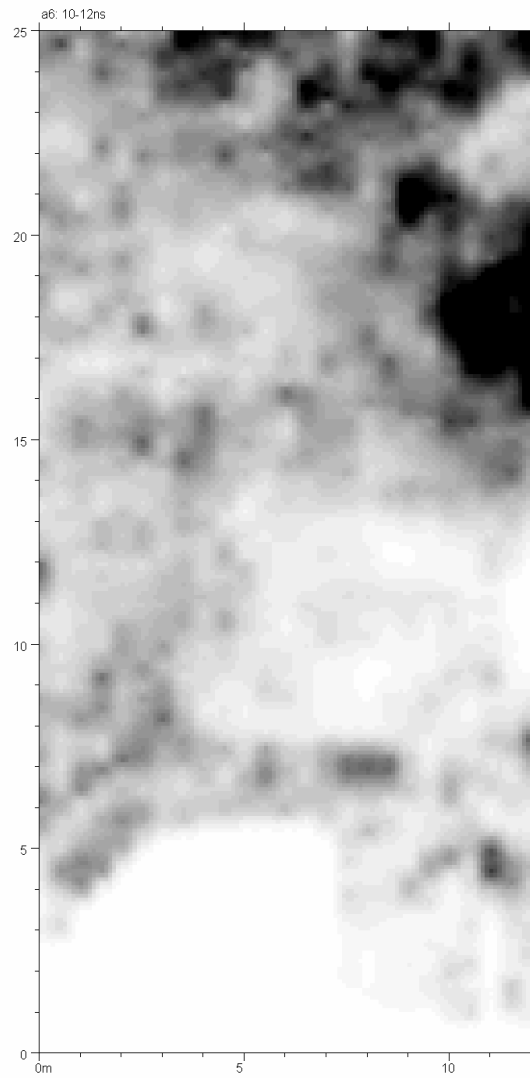


Fig A12.1.2 : Avaldsnes Geophysical Survey – Area 1  
Grid 1 – GPR Horizontal Slice 6

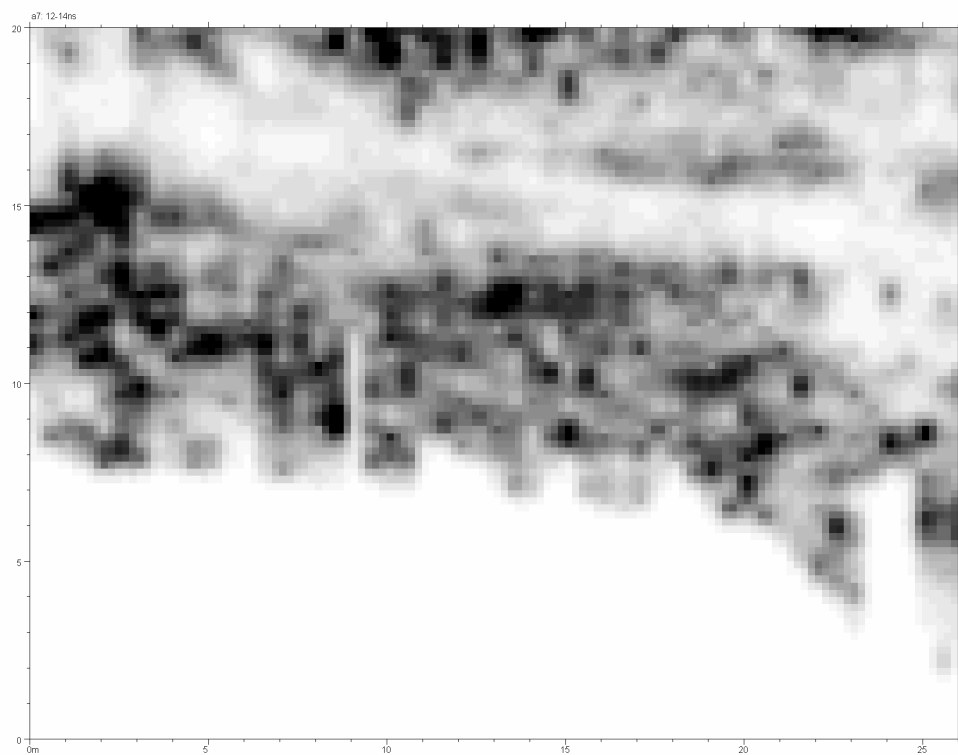


Fig A12.2.1 : Avaldsnes Geophysical Survey ; Area 1  
Grid 2 – GPR Horizontal Slice 7

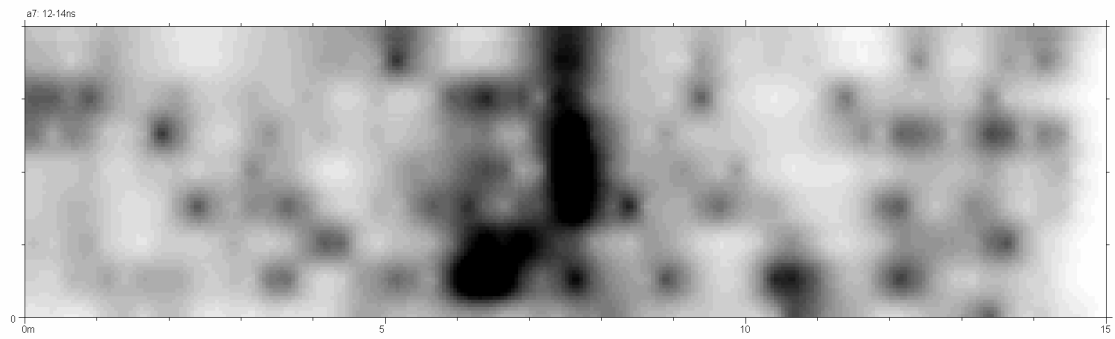


Fig A12.3.1 : Avaldsnes Geophysical Survey ; Area 1  
Grid 3 – GPR Horizontal Slice 7

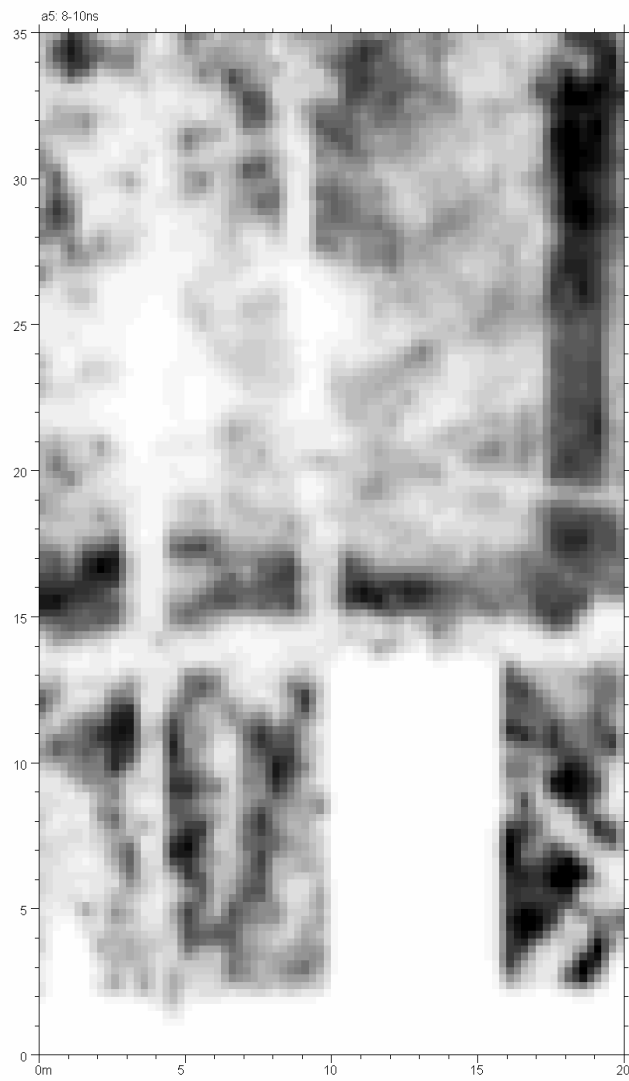


Fig A12.4.1 : Avaldsnes Geophysical Survey ; Area 1  
Grid 4 – GPR Horizontal Slice 5

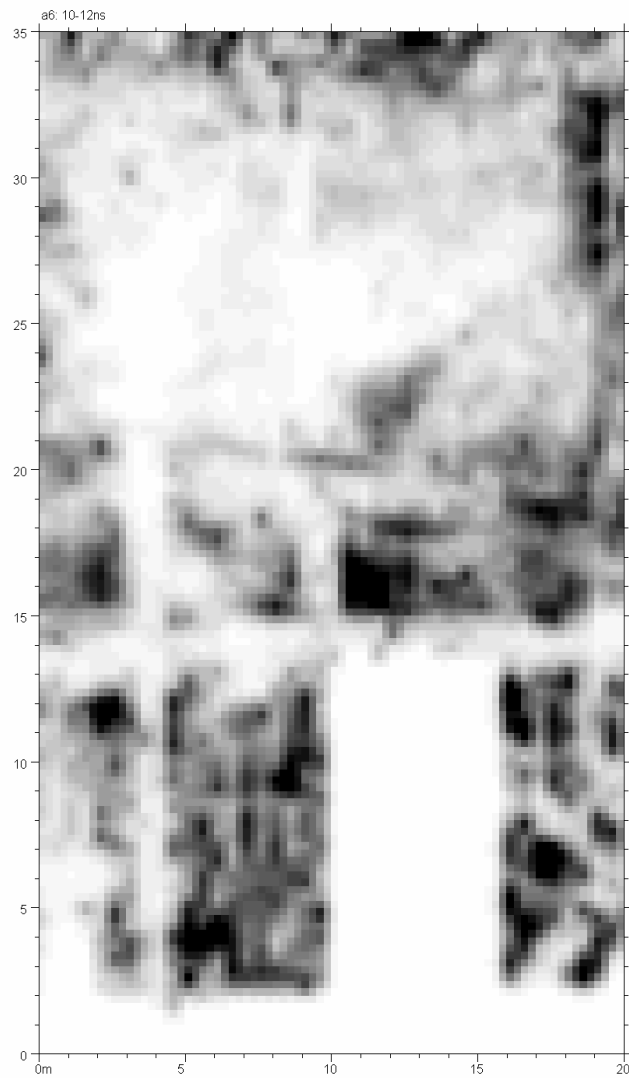


Fig A12.4.2 : Avaldsnes Geophysical Survey ; Area 1  
Grid 4 – GPR Horizontal Slice 6

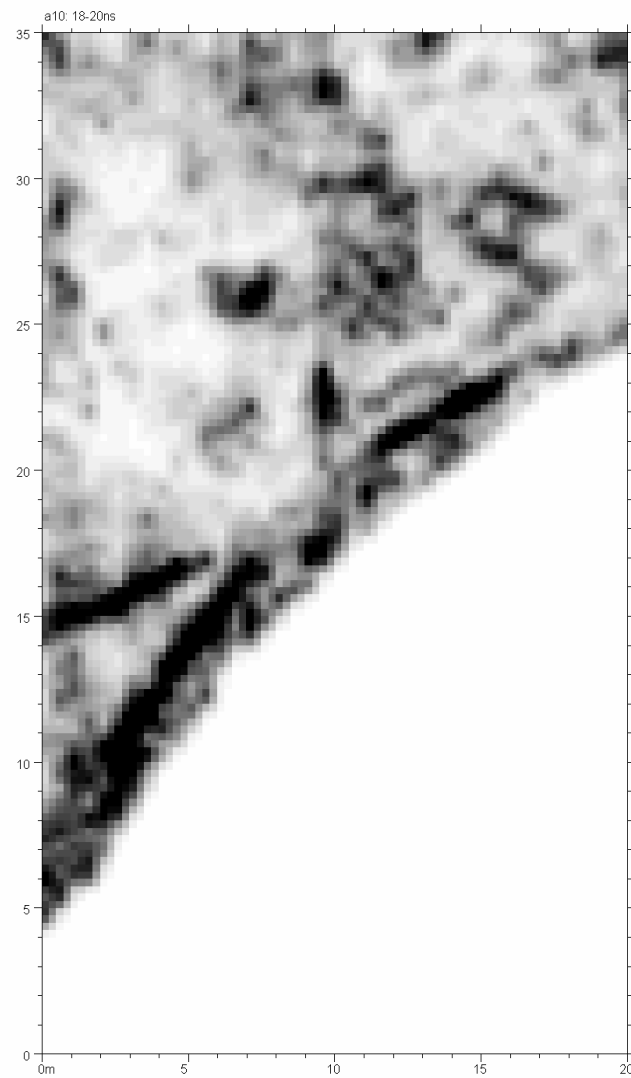


Fig A12.5.1 : Avaldsnes Geophysical Survey ; Area 1  
Grid 5 – GPR Horizontal Slice 10

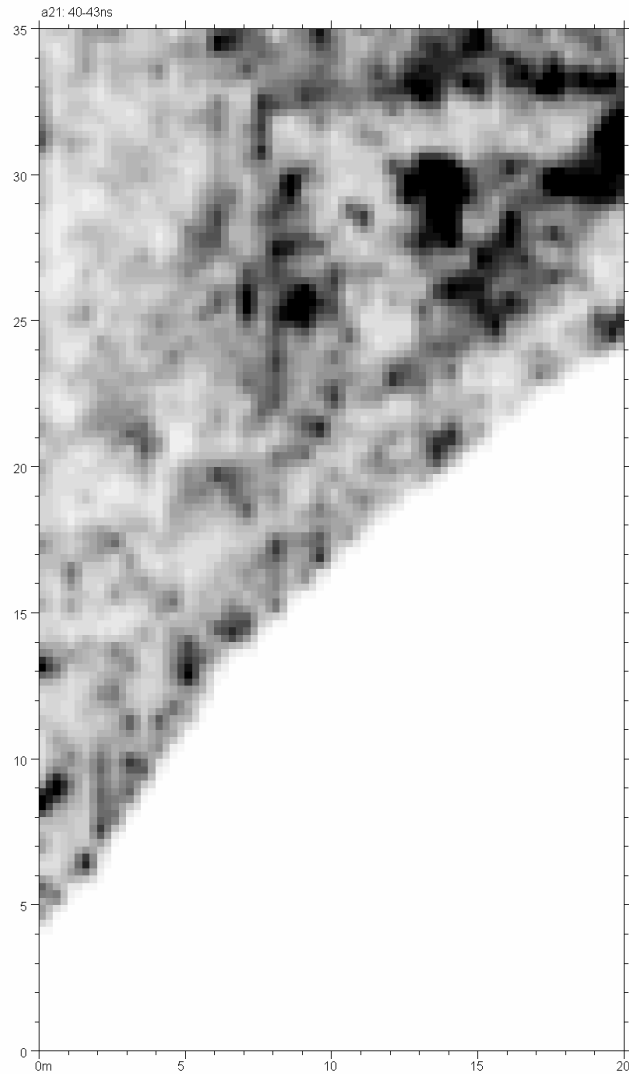


Fig A12.5.2 : Avaldsnes Geophysical Survey ; Area 1  
Grid 5 – GPR Horizontal Slice 21

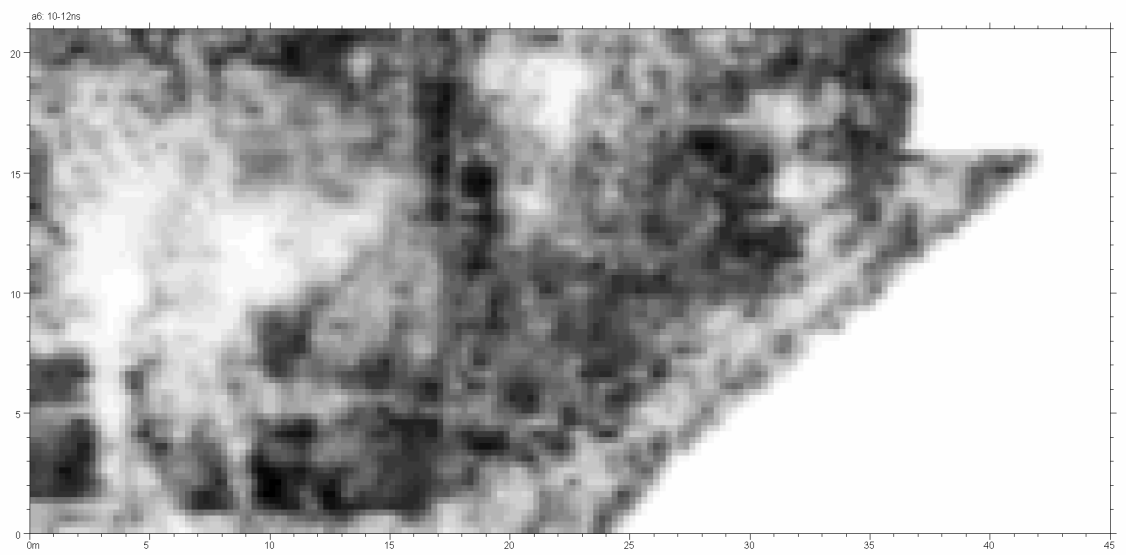


Fig A12.6.1 : Avaldsnes Geophysical Survey ; Area 1  
Grid 6 – GPR Horizontal Slice 6

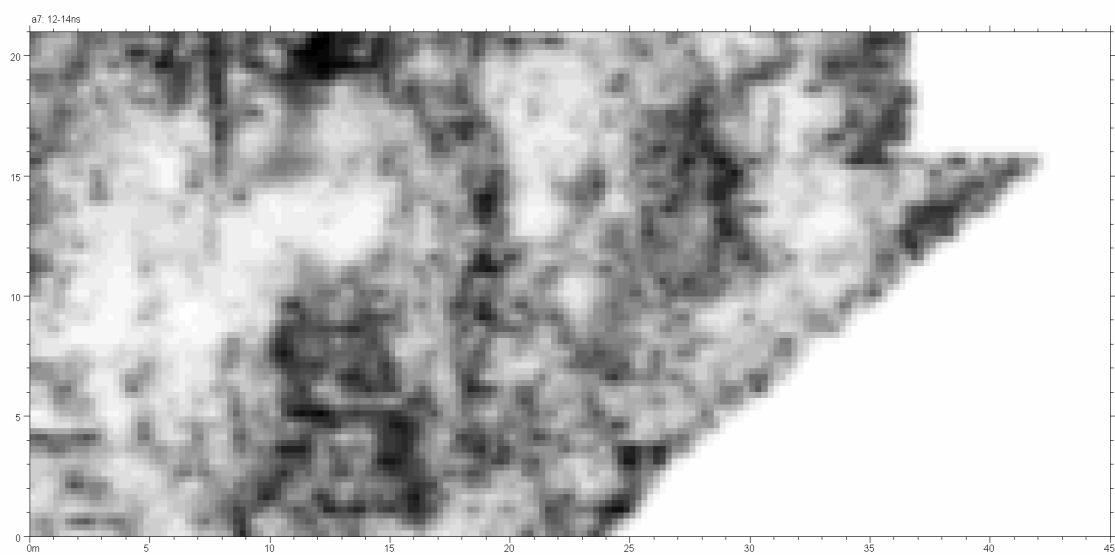


Fig A12.6.2 : Avaldsnes Geophysical Survey ; Area 1  
Grid 6 – GPR Horizontal Slice 7

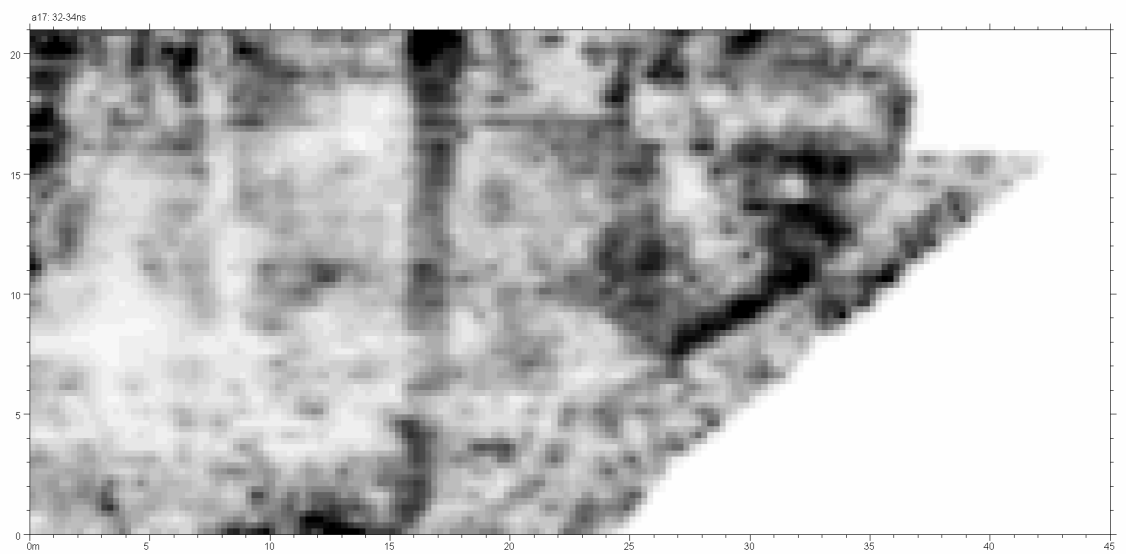


Fig A12.6.3 : Avaldsnes Geophysical Survey ; Area 1  
Grid 6 – GPR Horizontal Slice 17

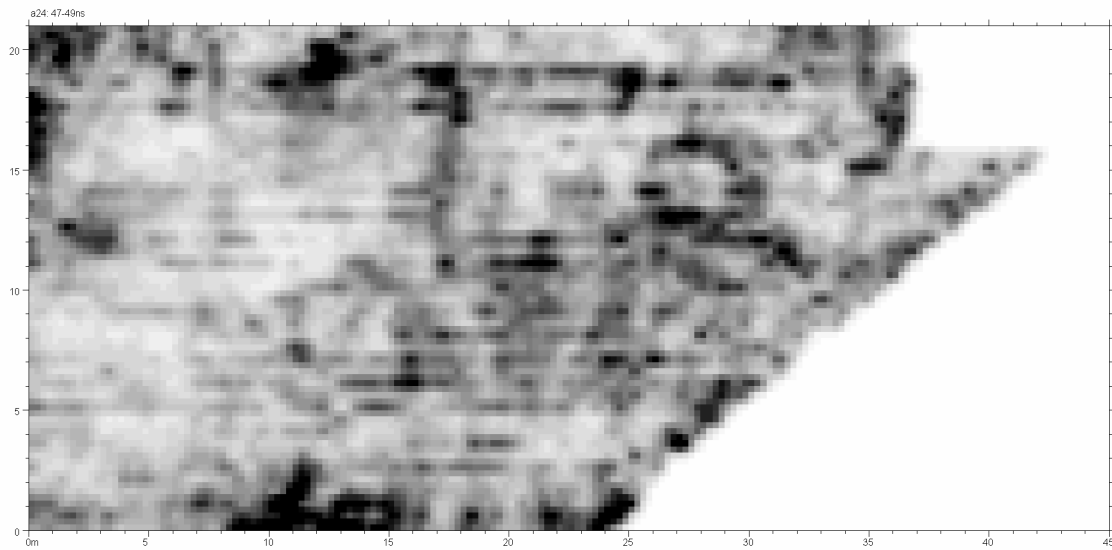


Fig A12.6.4 : Avaldsnes Geophysical Survey ; Area 1  
Grid 6 – GPR Horizontal Slice 24

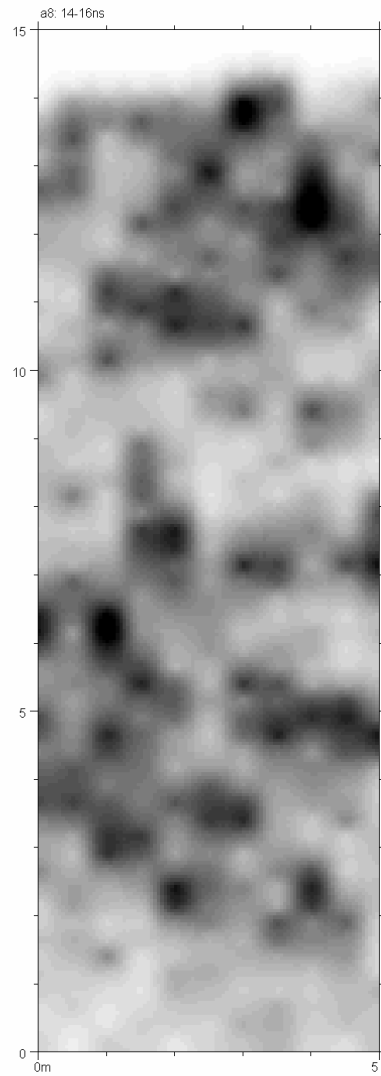


Fig A12.7.1 : Avaldsnes Geophysical Survey ; Area 1  
Grid 7 – GPR Horizontal Slice 8

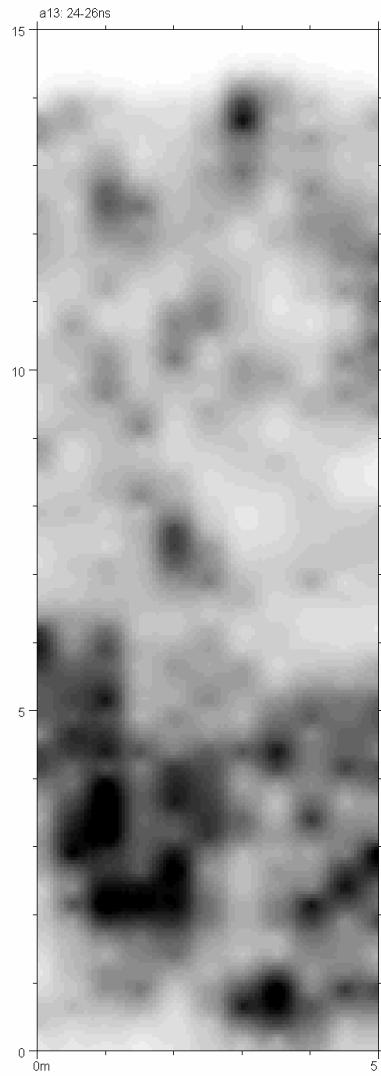


Fig A12.7.2 : Avaldsnes Geophysical Survey ; Area 1  
Grid 7 – GPR Horizontal Slice 13

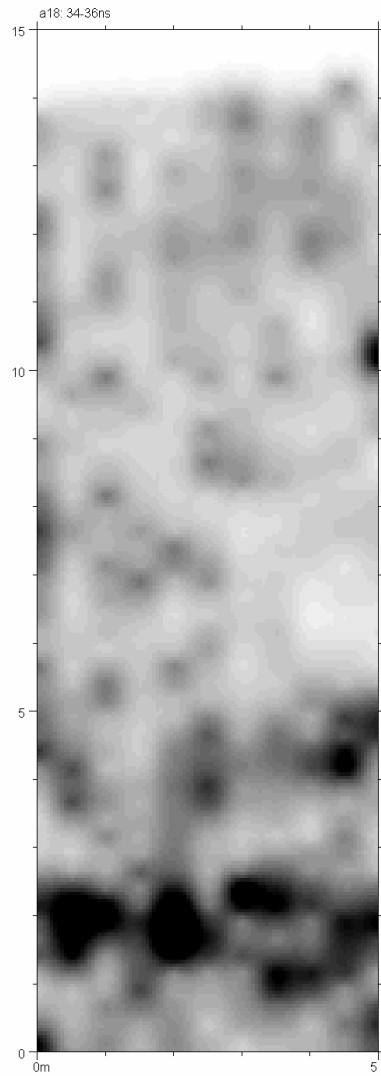


Fig A12.7.3 : Avaldsnes Geophysical Survey ; Area 1  
Grid 7 – GPR Horizontal Slice 18

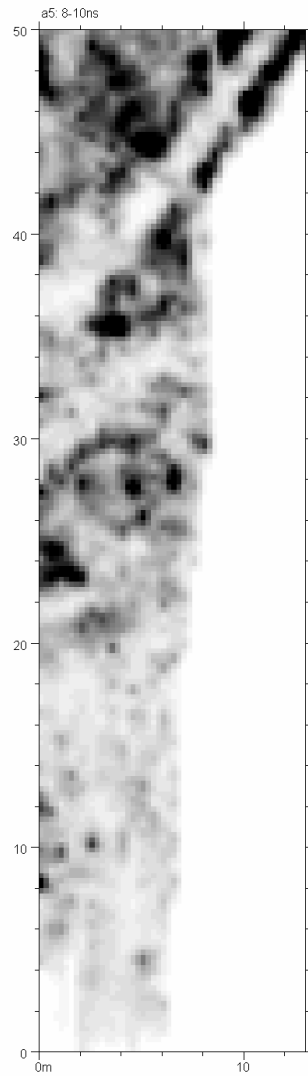


Fig A12.8.1 : Avaldsnes Geophysical Survey ; Area 1  
Grid 8 – GPR Horizontal Slice 5

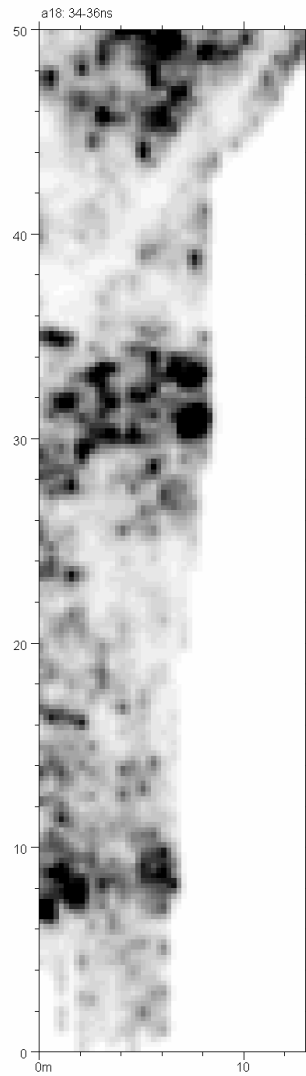


Fig A12.8.2 : Avaldsnes Geophysical Survey ; Area 1  
Grid 8 – GPR Horizontal Slice 18

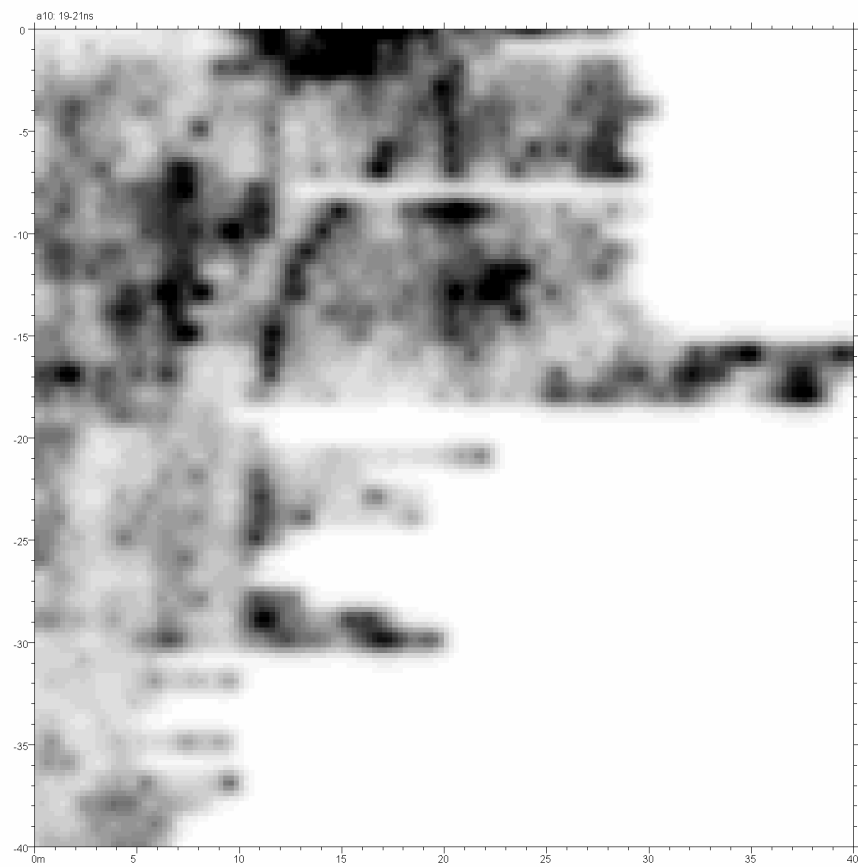


Fig A12.9.1 : Avaldsnes Geophysical Survey ; Area 1  
Grid 9 – GPR Horizontal Slice 10