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Oskarshamn site investigation

Detailed ground geophysics at Laxemar, spring 2007

Magnetic total field

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August 2007

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Keywords: Laxemar, Ground geophysics, Magnetic measurements, Magnetic total field, Magnetisation, Lineament, Deformation zones.

Abstract

Detailed geophysical measurements have been performed in the Laxemar area during March to May, 2007. A total of approximately 2.2 km^2 were covered with measurements of the total magnetic field. The survey area borders to previous magnetometry surveys performed at Laxemar in 2005 and 2006, and a mosaic map of the survey results has been produced.

The aim of the study was to identify and locate possible deformation of the bedrock indicated by regional deformation zones, local major deformation zones, local minor deformation zones and also general fracturing. Furthermore, interpretation of lithological inhomogeneity of the bedrock was performed.

The measurements of the magnetic total field were carried out along profiles directed in north-south, with a profile spacing of 10 m and a station separation of 5 m. A number of low-magnetic semi-linear features appear in the results. The most prominent of these correspond to known deformation zones like e.g. NW042 and NS059, of which some have been modelled to reflect the dip and geometric complexity of the source.

More than 1,000 lineaments have been identified in the magnetic total field data from 2007. A majority of the lineaments are oriented in NE-SW direction (from NNE-SSW to ENE-WSW). A number of new short lineaments have been possible to identify in the presented data and some of the lineaments identified in earlier activities have been re-evaluated.

The magnetic modelling of the possible deformation zone NW042 indicates subvertical or steeply south plunging dip and large variations in width along the deformation zone. The possible deformation zone NS059 is indicated having steep dip plunging westward, which correlates well with previously presented magnetic models. The magnetic data indicate dominant occurrences of highly magnetized areas (possibly related to diorite/gabbro or fine-grained dioritoid) along the southern boundary of the quartz monzodiorite, with the highest concentration in the western part of the measured area.

Sammanfattning

Detaljerade geofysiska mätningar har utförts i Laxemarområdet under perioden mars–maj, 2007. Totalt cirka 2,2 km^2 har undersökts med mätning av magnetiskt totalfält. Undersökningsområdet gränsar till tidigare mätområden för magnetometri från 2005 och 2006 i Laxemar och en mosaik av undersökningarna har sammanställts.

Målet med undersökningen var att identifiera och lokalisera deformation i berggrunden indikerad av regionala deformationszoner, lokala större deformationszoner, lokala mindre deformationszoner samt områden med generellt uppsprucket berg. Områden som är litologiskt inhomogena har också identifierats.

Mätningarna av magnetiskt totalfält har utförts längs nord-sydliga profiler separerade med 10 meter och med ett mätpunktsavstånd av 5 meter. Ett antal lågmagnetiska semi-linjära strukturer kan ses i resultaten. De mest signifikanta av dessa motsvaras av kända deformationszoner som t ex NW042 och NS059. Några av dessa möjliga deformationszoner har modellerats för att belysa källans stupning och geometriska komplexitet.

Mer än 1 000 lineament har identifierats i den nya datamängden från 2007. Ett antal nya kortare lineament har varit möjliga att identifiera i data och några lineament som identifierats i tidigare tolkningar har omvärderats. En majoritet av lineamenten har en NO-SV orientering (varierande från NNO-SSV till ONO-VSV).

Den magnetiska modelleringen av den möjliga deformationszonen NW042 indikerar subvertikal till brant sydlig stupning och stora variationer i bredd längs med deformationszonens sträckning. Den möjliga deformationszonen NS059 indikeras ha en brant stupning mot väster, vilket överensstämmer väl med tidigare utförda magnetiska modelleringar. Magnetiska totalfältsdata uppvisar kraftigt förhöjd magnetisering (trolig förekomst av diorit/gabbro eller finkornig dioritoid) längs stora delar av den södra kontakten mellan kvartsmonzodiorit och Ävrögranit, med en tydlig koncentration i den västra delen av mätområdet.

Contents

1 Introduction

This document reports the results gained from the ground geophysical measurements of the magnetic total field at Laxemar, spring 2007, which is one of the activities performed within the site investigation at Oskarshamn. The work was carried out in accordance with the activity plan AP PS 400-07-018. In Table 1-1 controlling documents for performing this activity are listed. Both activity plan and method descriptions are SKB's internal controlling documents.

The ground geophysical measurements were carried out by GeoVista AB during March 2007 to May 2007 at Laxemar in an area covering around 2.2 km^2, Figure 1-1. The survey included measurements of the magnetic total field. The processing and interpretation of the data was performed by GeoVista AB during May-August 2007.

The original results of the survey are stored in the primary data bases (SICADA and GIS) and they are traceable by the activity plan number AP PS 400-07-018.

The grid system over the area was prepared by GeoVista AB.

Table 1-1. Controlling documents for the performance of the activity.

Activity plan	**Number**	**Version**
Detaljerade markgeofysiska mätningar i Laxemar under våren 2007	AP PS 400-07-018	1.0
Method descriptions	**Number**	**Version**
Metodbeskrivning för markbaserad magnetometri	SKB MD 212.004	1.0
Metodbeskrivning för lineamentstolkning baserad på topografiska data.	SKB MD 120.001	1.0

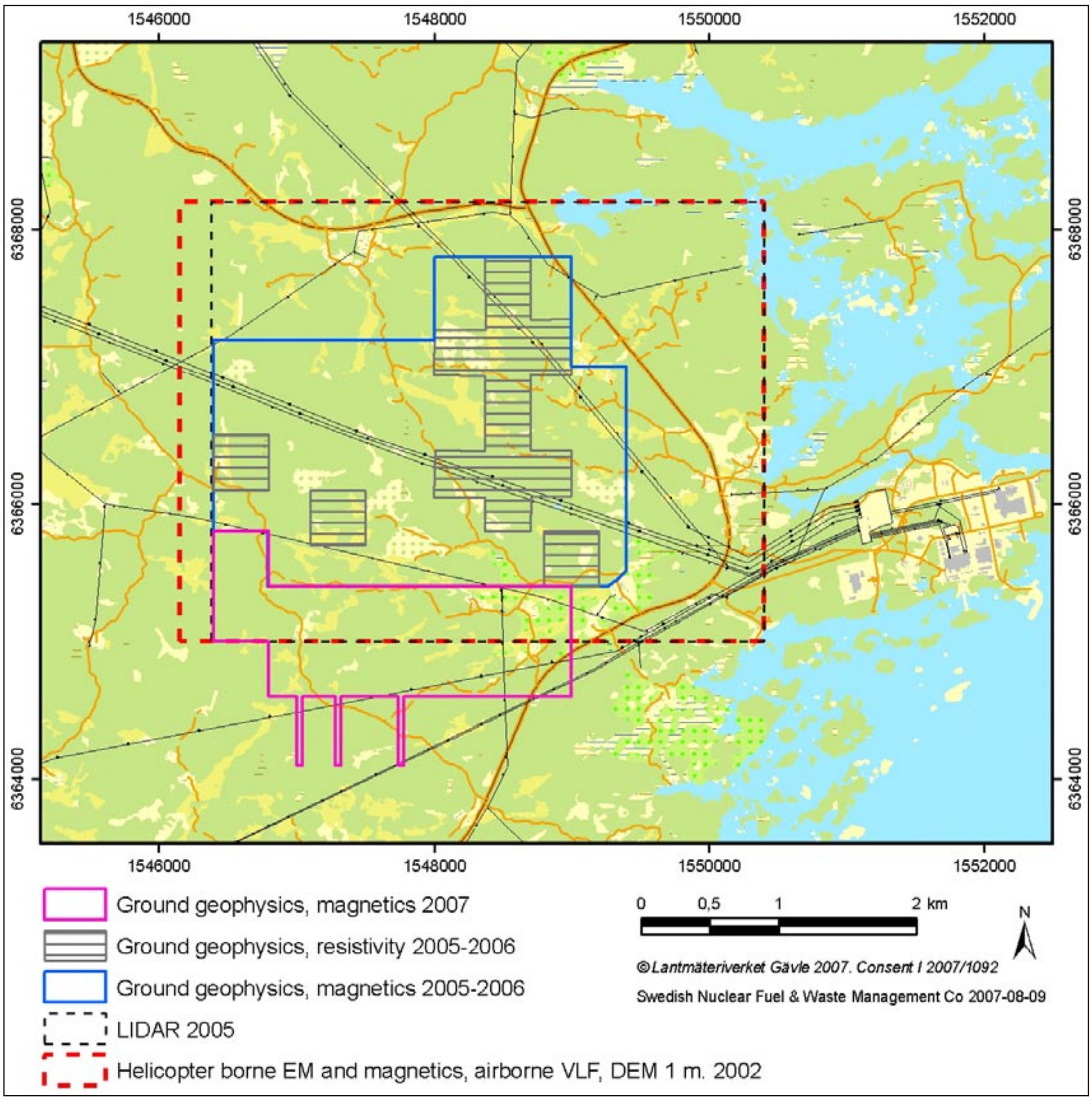

Figure 1-1. *Location of the area at Laxemar where the detailed measurements of the total magnetic field were carried out (pink polygon). The location of the area where detailed measurements of the total magnetic field were carried out in 2005 and 2006 is shown with a blue polygon /1/ and /2/.*

2 Objective and scope

The results of the detailed ground geophysical survey at Laxemar were expected to support the future site investigations at Laxemar by reflecting the:

- Deformation of the bedrock by possible regional deformation zones, local major deformation zones, local minor deformation zones and general fracturing.
- Lithological inhomogeneity of the bedrock.

This was done by processing and interpretation of the collected data of the magnetic total field. The magnetic total field reflects the magnetisation of the ground. The magnetisation in the Laxemar area is dependent on the rock type and the alteration and deformation of the rock, which is shown by thorough investigations of the magnetic properties of the area /3, 4, 5, 6, 7/.

3 Equipment

3.1 Description of equipment/interpretation tools

The measurements of the magnetic field were performed with magnetometers Gem Systems GSM-19 of which one was used as a diurnal base station.

The magnetometers used were calibrated at the factory and a quality controlled performance of them was assured by following method descriptions and the internal quality plan of the activity as presented to SKB before the survey started.

The processing, interpretation and reporting included the use of the following software:

Grapher v6 (Golden Software).

Oasis Montaj 5.0 (Geosoft Inc).

ModelVision Pro 6.0 (Encom Technology).

Profile Analyst 6.0 (Encom Technology).

Mag3D (UBC GIF).

MapInfo Professional 8.0 (MapInfo Corporation).

Discover 7.1 (Encom Technology).

ArcView (Environmental Systems Research Institute Inc.).

Microsoft Excel (Microsoft Corp.).

Microsoft Word (Microsoft Corp.).

Adobe Acrobat and Adobe Distiller (Adobe Systems Inc.).

4 Measurements, processing and interpretation

4.1 General

The detailed geophysical survey at Laxemar consisted of the following main sub-activities:

- Preparation of a grid system.
- Measurements of the magnetic total field.
- Processing, interpretation and reporting.

4.2 Preparation of a grid system

By the use of a high resolution GPS (accuracy better than 0.5 m in general) east-west lines were staked all over the area to be measured. Normally the distance between these lines was 100 m though less in some areas. Along these lines, a mark was positioned in the terrain every 20th metre.

The distance along the profile for magnetic measurement stations was established with the use of a 1.67 m long stick which was laid out three times to give 5 m advance to a new station. The orientation along the profile was controlled with a compass and the marks every 100 m (see above).

4.3 Measurements of the magnetic total field

The magnetic total field survey was conducted with several Gem Systems GSM-19 magnetometers of which one was used as a diurnal base station. One reading at the base station was registered every 10 seconds and was used to make a diurnal correction of the data collected with the mobile magnetometer.

The magnetometers were time synchronized every morning before starting the survey.

Magnetic readings were taken along profiles with a station interval of 5 m; the profile separation was 10 m. The profiles were directed in north-south.

Base station position was the same as position no. 3 in the previous survey /2/.

The measurements of the magnetic total field were carried out according to the method description (Metodbeskrivning för markbaserad magnetometri, SKB MD 212.004, version 1.0, SKB internal document).

4.4 Processing and interpretation of magnetic total field data

The processing performed on the magnetic data was the removal of diurnal variations recorded by the base magnetometer. A regular grid with a node spacing of 2.5 metres was interpolated to form the base for different map products. The magnetometers were affected by noise close to the major power lines. Corridors around these power lines were therefore blanked out from the grid file.

Based on the grid file, filtering has been carried out in order to produce different types of maps used for the identification of in-homogeneous rock and lineaments. Filtering has included reduction to the pole, vertical derivatives, upward continuation, and horizontal gradients.

Forward modelling has been performed over selected magnetic features. The bodies in the models have been assigned magnetic susceptibility values that are compatible with petrophysical data /3, 4, 5/. Model Vision has been used as a modelling tool.

The interpretation of magnetic data has included identification of areas with high magnetization that could indicate the presence of diorite/gabbro or fine-grained dioritoid. In a selection process with the aim to isolate such areas a comparison has been made of the magnetic susceptibility measurements on outcrops, the mapping of diorite/gabbro or fine-grained dioritoids, and the total magnetic field as measured in the detailed ground magnetic survey. The selection of areas with high magnetisation with potential presence of diorite/gabbro or fine-grained dioritoid was based on the following criteria:

- A pronounced magnetic high anomaly is selected if no observations of a magnetic susceptibility in either Ävrö-granite or in the quartz monzodiorite higher than $1,500 \cdot 10^{-5}$ SI, is found on or very near the anomaly.

The highly magnetized areas have then been compared with the geological map (version 1.2).

An identification of lineaments in magnetic data was also carried out. As explained above the processing of magnetic data by various filters resulted in different types of images of the magnetic field. From such images lineaments were identified. Based on the clearness of the lineament the attribute named "Uncertainty" was given a number of 1, 2 or 3. A low value (1) means that the lineament is clearly identifiable while a high number (3) means that it is less clear.

The identification of lineaments is easier in areas with high magnetic relief. In areas with low and almost uniform magnetisation it is however more difficult to both identify and delineate a lineament. Some of the areas of low magnetisation in the Laxemar area represent parts of local major deformation zones. In such areas it is very difficult to draw a single line that represents the lineament in an appropriate way. If such an extensive area with low magnetisation is found at the crossing with another low magnetic zone with another strike direction, probably representing another possible deformation zone, it becomes even more difficult to draw representative lines. It is problematic in the same product to present, both short lineaments with high degree of spatial significance, together with long lineaments bearing the problem with low spatial significance as described above. The interpreter must concentrate on either. In the present work the focus is on the Laxemar area where spatial significance of the shorter lineaments is honoured. Instead the extensive areas of low magnetisation, which may represent regional deformation zones, are presented explicitly as delineated areas. These areas, together with the lineaments identified, form two complementary sets of information.

4.5 Co-ordination and linking of lineaments

4.5.1 Co-ordination of lineaments

The *method-specific lineaments* that were identified in the magnetic total field data were one of the input elements into the co-ordination process. Other data sources where lineaments had been identified in earlier activities were helicopter-borne magnetics and EM, fixed-wing borne VLF /8/ and /9/, the digital elevation model (DEM) /10/ from the airborne photogrammetric survey of 2002 and ground geophysics from 2005/2006 (magnetics and resistivity) /1/ and /2/.

What is then the process of co-ordinating lineaments? If several more or less coinciding *method-specific lineaments* are supposed to indicate one unique lineament, all of them can instead be represented by one single lineament. This single lineament is called a *co-ordinated lineament*. In the process of co-ordinating lineaments the first step is to construct such *co-ordinated* *lineaments* and then to assign attributes to the lineament. The attributes indicates in what kind of data the co-ordinated lineament was visible, the judged level of uncertainty in the visibility etc. The list of parameters describing every co-ordinated lineament is given in Table 4-1.

Table 4-1. List of parameters assigned to every co-ordinated lineament.

Name of attribute	Values in this activity	Comment
ID_T	n.a.	Identities have not been assigned to the individual lineaments.
ORIGIN_T	method specific lineaments, older co-ordinated lineaments and maps	Data sets.
CLASS_T	n.a.	The individual co-ordinated lineaments have not been classified.
METHOD_T	hcp geophysics, ground geophysics, LIDAR, Coarse DEM	
EV_N	0 or 1	Visible in data reflecting the resistivity or conductivity (resistivity and/or EM). 0 if not detected, 1 if detected.
M_N	0 or 1	Visible in data reflecting the magnetization. 0 if not detected, 1 if detected.
T_N	0 or 1	Visible in data reflecting the morphology (Topography/DEM). 0 if not detected, 1 if detected.
PROPERTY_N	1, 2 or 3	Number of properties (EV_N-resistivity/conductivity, M_N-magnetization, T_N-morphology) where the lineament has been identified.
WEIGHT_N	1, 2, 3, 4, 5	According to a weighting function involving number of properties (np) and level of uncertainty (lu). np = 3, lu = 1 eq. weight = 5 np = 3, lu = 2 eq. weight = 4 np = 3, lu = 3 eq. weight = 3 np = 2, lu = 1 eq. weight = 4 np = 2, lu = 2 eq. weight = 3 np = 2, lu = 3 eq. weight = 2 np = 1, lu = 1 eq. weight = 3 np = 1, lu = 2 eq. weight = 2 np = 1, lu = 3 eq. weight = 1
CHAR_T	Co-ordinated lineament	
UNCERT_N	1, 2, 3	Level of uncertainty in visibility 1 = low, 2 = medium, 3 = high.
COMMENT_T		Free text.
PROCESS_T	Image analysis	
DATE_D	20051030	Date when the last change was made in the individual co-ordinated lineament.
SCALE_T	10,000	Typical scale in which the identification of a lineament has been carried out.
PLATFORM_T	hcp geophysics, ground geophysics, LIDAR, Coarse DEM	Data sets.
WIDTH_N	0	Has not been specified.
PRECIS_N	0	Has not been specified.
SIGN_T	Carl-Axel Triumf/Geo-Vista AB	Name of the interpreter.
DIRECT_N	0–360	Calculated average orientation of the lineament.
LENGTH_N	In metre	Calculated length in m.
COUNT_N	1	By default = 1.

The parameter T_N indicates if the co-ordinated lineament has been detected in topographical data. In this case such data is either the digital elevation model (DEM) prepared from the photogrammetric airborne survey of 2002 /10/, or the LIDAR survey /11/. The parameter M_N informs if the co-ordinated lineament has been detected in magnetic total field data, either measured from helicopter or on ground. The parameter EV_N indicates if the co-ordinated lineament has been detected in electromagnetic data (helicopter-borne multi-frequency EM of 2002) /8/ or in ground resistivity measurements /1/ and /2/. The parameter UNCERT_N reflects the level of uncertainty in the detection and/or delineation of the co-ordinated lineament. It is the result of personal weighting done by the interpreter based on how the lineament occurs in the different data sets.

The main difficulty in the co-ordination process has been to overcome the difference in spatial resolution between the different data sets. As an example the resolution in LIDAR data is higher than in ground magnetics. In areas where ground magnetics are missing and only helicopter-borne magnetics are available, the resolution contrast with LIDAR data is even more severe. Due to this it may be difficult to judge whether a lineament identified in LIDAR data is also visible in magnetic data. The area where the "LIDAR"-lineament is observed may have an overall low magnetic field due to a general fracturing or alteration of the rock; in such an area individual lineaments in the magnetic field are more difficult to observe with the same resolution as is possible in LIDAR data. The assignment of parameters to the lineaments has been carried out so that if a lineament was identified in for example LIDAR data, and the lineament is located in an area where the magnetic field is generally low, it is judged to have been observed also in magnetic data.

4.5.2 Linking of lineaments

The linking of lineaments means linking of several co-ordinated lineaments, which are interpreted to form a geometrically continuous structure along its strike, to one single continuous linked lineament. It is also possible that a linked lineament is only formed by one co-ordinated lineament.

The physical appearance of a linked lineament may vary along its strike. As an example part of it may be easily recognised in magnetic total field data while less pronounced in a DEM while yet another length section is only visible in a DEM. To express these variations in visibility, together with other characters of the lineament, several parameters were set to each linked lineament. The list of parameters is displayed in Table 4-2.

4.6 Nonconformities

The major power lines in the area have disturbed the magnetic measurements. Data of the magnetic total field could not be used near the power lines. The affected areas are easily recognised in the maps of the magnetic total field as blanked areas. A few small areas close to houses could not be measured.

Table 4-2. List of parameters assigned to every linked lineament.

Name of attribute	Values in this activity	Comment
ID_T	n.a.	Identities have not been assigned to the individual lineaments.
ORIGIN_T	Co-ordinated lineaments	
CLASS_T	n.a.	The individual co-ordinated lineaments have not been classified.
METHOD_T	hcp geophysics, ground geophysics, LIDAR, Coarse DEM	Data sets.
EV_N	0–1	Visible in data reflecting the resistivity or conductivity (resistivity and/or EM). According to a linear weighting function related to the length of each individual co-ordinated lineament building the linked lineament.
M_N	0–1	Visible in data reflecting the magnetization. According to a linear weighting function related to the length of each individual co-ordinated lineament building the linked lineament.
T_N	0–1	Visible in data reflecting the morphology (Topography/DEM). According to a linear weighting function related to the length of each individual co-ordinated lineament building the linked lineament.
PROPERTY_N	1–3	Number of properties (EV_N-resistivity/conductivity, M_N-magnetization, T_N-morphology) where the lineament has been identified. According to a linear weighting function related to the length of each individual co-ordinated lineament building the linked lineament.
WEIGHT_N	1–5	According to a linear weighting function related to the length of each individual co-ordinated lineament building the linked lineament.
CHAR_T	Linked lineament	
UNCERT_N	1–3	Level of uncertainty in visibility. According to a linear weighting function related to the length of each individual co-ordinated lineament building the linked lineament.
COMMENT_T		Free text.
PROCESS_T	Image analysis	
DATE_D	20070630	Date when the last change was made in the individual linked lineament.
SCALE_T	10,000	Typical scale in which the identification of a lineament has been carried out.
PLATFORM_T	hcp geophysics, ground geophysics, LIDAR, Coarse DEM	Data sets.
WIDTH_N	0	Has not been specified.
PRECIS_N	0	Has not been specified.
SIGN_T	Carl-Axel Triumf/ GeoVista AB	Name of the interpreter.
DIRECT_N	0–360	Calculated average orientation of the lineament.
LENGTH_N	In metre	Calculated length in m.
COUNT_N	1–several	By default = 1.

5 Results

The results are stored in the primary data bases (SICADA and/or GIS). The data is traceable in SICADA and GIS by the activity plan number (AP PS 400-07-018).

5.1 The magnetic total field

A map showing a mosaic of the presented ground magnetic survey together with the magnetic surveys from the spring 2005 /1/ and the autumn/winter 2005-2006 /2/ is presented in Figure 5-1. The magnetic total field from the helicopter-borne survey /8/ and / 9/ is shown in the background. The data sets are displayed with different colour scales.

Two maps displaying the new data from 2007 are presented below. The vertical derivative of the magnetic total field is shown as a coloured image in Figure 5-2 and the magnetic total field is shown as a shaded relief image, enhancing the appearance of narrow features, in Figure 5-3.

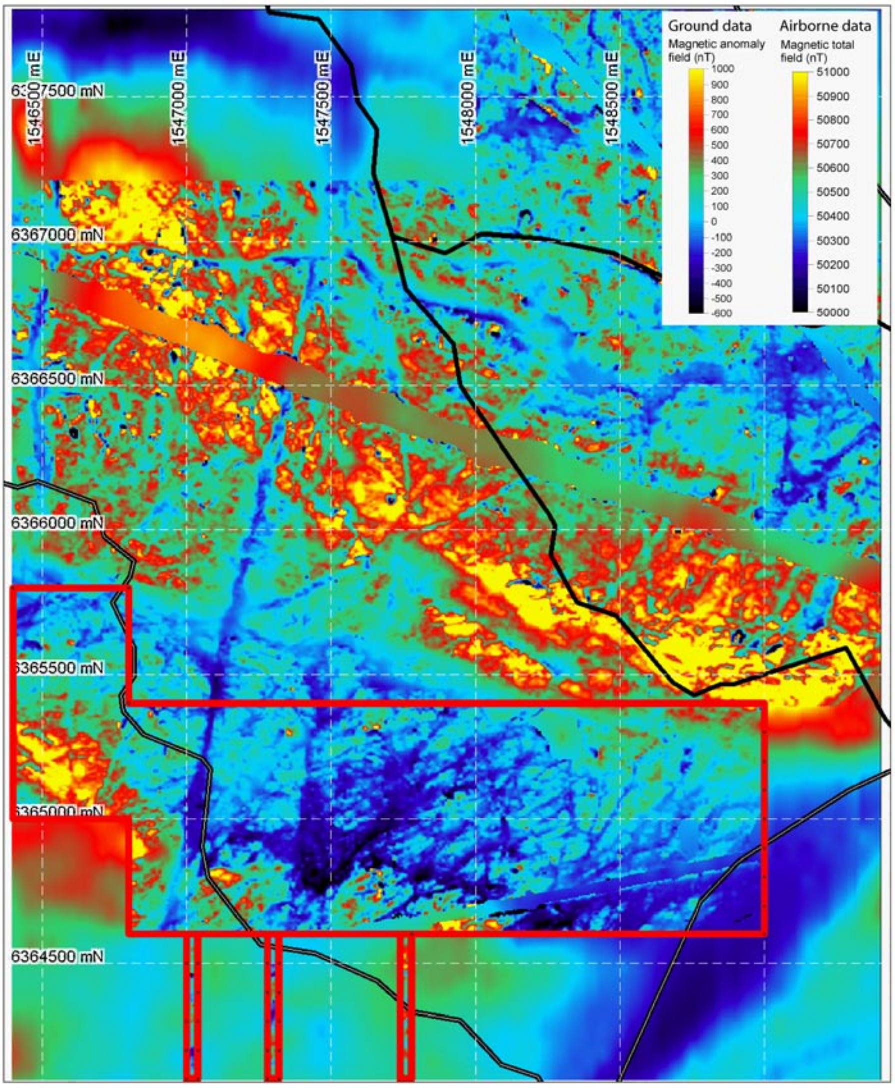

Figure 5-1. *The magnetic total field from the detailed ground geophysical surveys of 2007 (new data, area indicated by red line) and of 2005 and 2006 /1/ and /2/ displayed on the magnetic total field from the helicopter-borne survey of 2002 /8/ and / 9/. Different colour scales have been applied.*

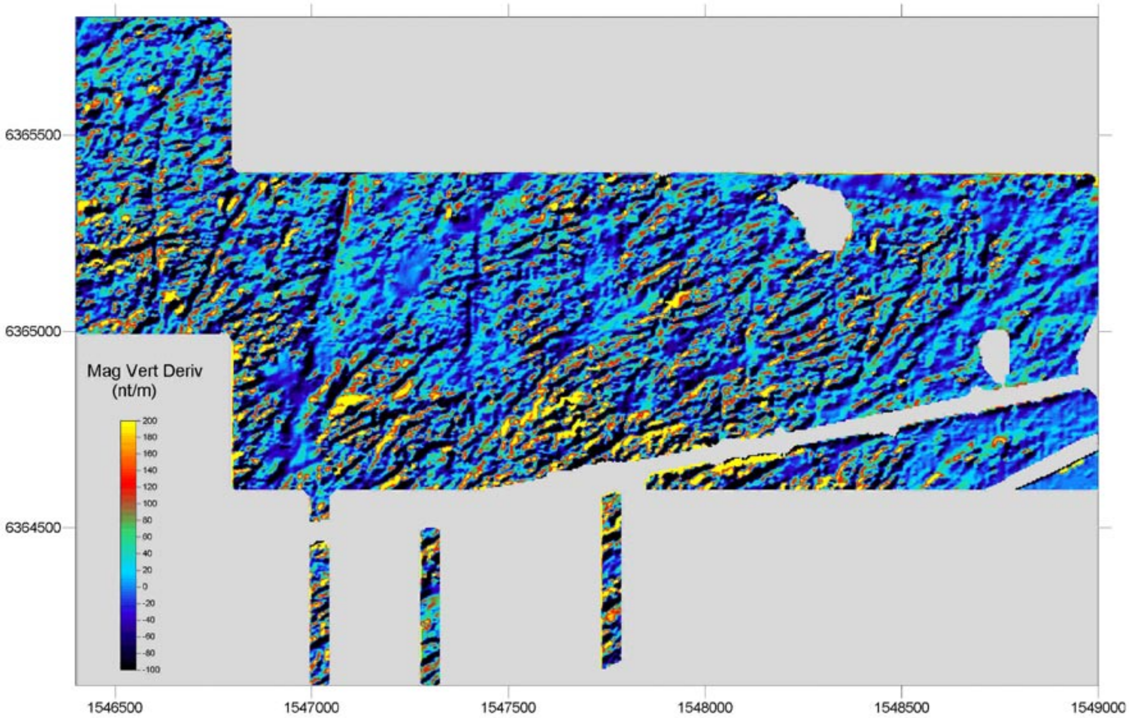

Figure 5-2. Vertical derivative of magnetic total field from the detailed ground survey in 2007 shown as a coloured image.

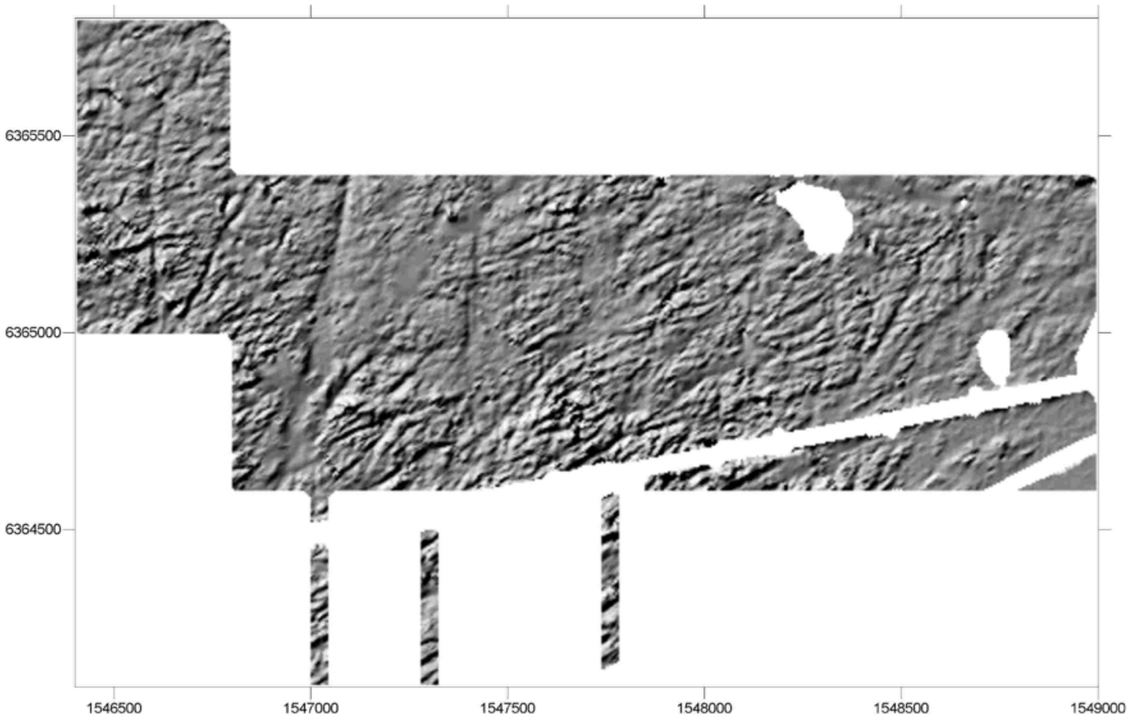

Figure 5-3. Magnetic total field from the detailed ground survey in 2007 shown as shaded relief image. Illumination is from north-west.

5.2 Identification of lineaments

5.2.1 Lineaments identified in magnetic total field data

Lineaments have been identified in data of the magnetic total field. Furthermore, extensive areas with locally comparatively low relief in the magnetic total field have been delineated in the southern part of the Laxemar area where the new magnetic data presented in this report are available. During the procedure of lineament identification also lineaments earlier presented were re-evaluated /1, 2, 12, 13, 14, 15/. The reason is that the new measurements have increased the area covered by dense measurements of the magnetic total field where the view of a large area favours identification of subtle anomaly patterns.

Lineaments identified in the magnetic total field from all the ground magnetic measurements, including the latest, are shown in Figure 5-4. More than 3,000 lineaments are identified. The parameter "Uncertainty" has been classified and its variation is displayed in Figure 5-5 together with the extensive areas of low magnetic relief from the southern-most part.

5.2.2 Co-ordinated lineaments

The process of co-ordination is described above in section 4.5.1. The map of all the resulting 1,854 co-ordinated lineaments longer than 100 m is shown in Figure 5-6. The co-ordinated lineaments cover a larger area than the method-specific lineaments from the ground magnetic survey described above, because the co-ordinated lineaments are supposed to cover the entire Local model area of Laxemar. Outside the ground magnetic survey area are lineaments available identified in data from the helicopter-borne survey and LIDAR survey; these lineaments have also been used in the co-ordination process. Some of the co-ordinated lineaments continue outside of the Local model area of Laxemar, version 2.1, which is of purpose for a statistical length analysis. These co-ordinated lineaments are partly the same as presented earlier /12/, however also new lineaments are introduced in the southern part of the Laxemar area due to the new measurements of the magnetic total field. Some of the earlier presented co-ordinated lineaments have been changed due to information from the new magnetic data.

5.2.3 Linked lineaments

The linking of the 1,854 co-ordinated lineaments have resulted in 1,434 linked lineaments in the length interval 100–1,000 m, and 18 longer than 1,000 m (Figure 5-7).

A majority of the linked lineaments are to more than half of their length visible in both magnetic and topographic data, which is displayed in Figure 5-8. In areas where detailed ground magnetic data are missing the proportion of these lineaments is lower due to less detailed information about the magnetisation in the bedrock. When studying the spatial variations in the character of the linked lineaments it is important to consider the data coverage (see Figure 1-1).

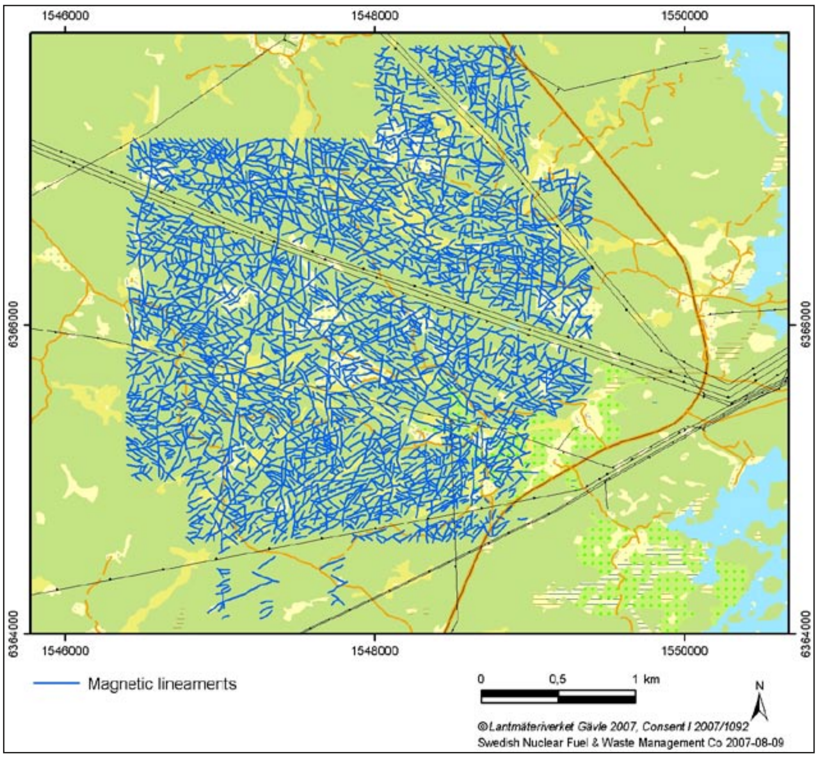

Figure 5-4. *The lineaments identified in magnetic total field data from all detailed ground surveys of the magnetic total field.*

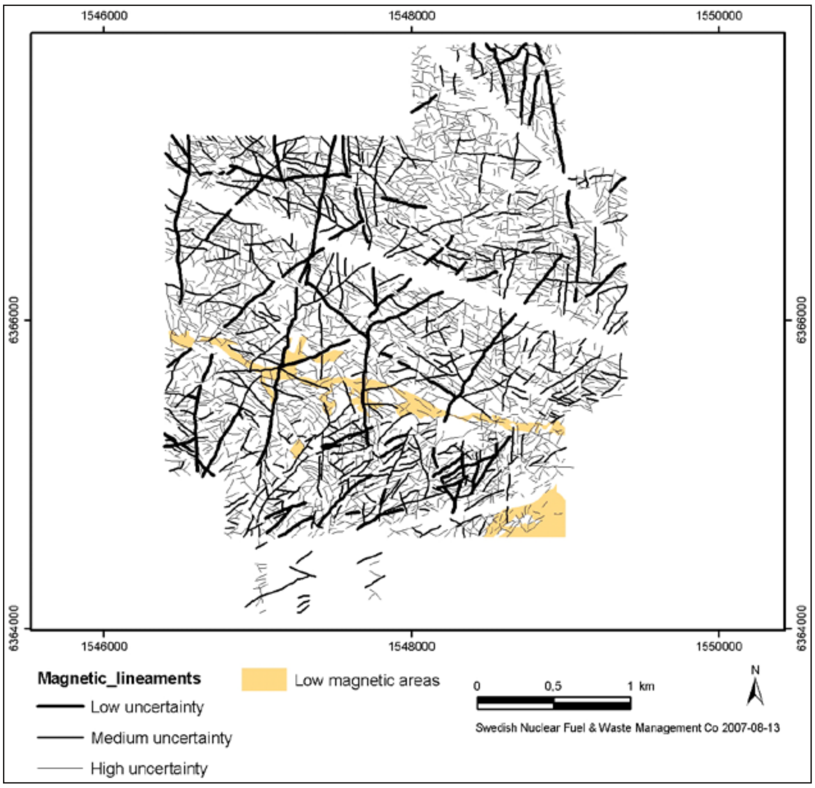

Figure 5-5. *The lineaments identified in magnetic total field data with the parameter Uncertainty displayed. Thick lines show the lineaments with the lowest uncertainty (1), medium thickness medium uncertainty (2) and thin lines high uncertainty (3). Extensive areas with low magnetisation in the southern-most part of the Laxemar area are also shown (light brownish areas).*

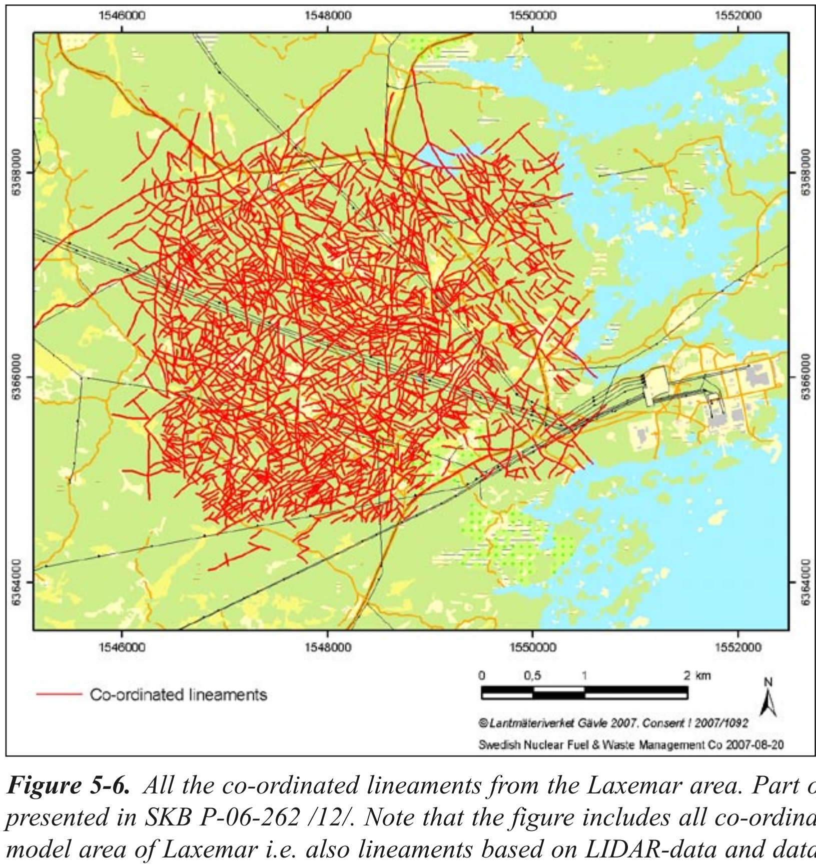

Figure 5-6. *All the co-ordinated lineaments from the Laxemar area. Part of these lineaments has been presented in SKB P-06-262 /12/. Note that the figure includes all co-ordinated lineaments in the Local model area of Laxemar i.e. also lineaments based on LIDAR-data and data from the helicopter-borne survey outside the ground magnetics area. This result in a larger area of interpretation compared to the figures 5-4 and 5-5 with magnetic lineaments only.*

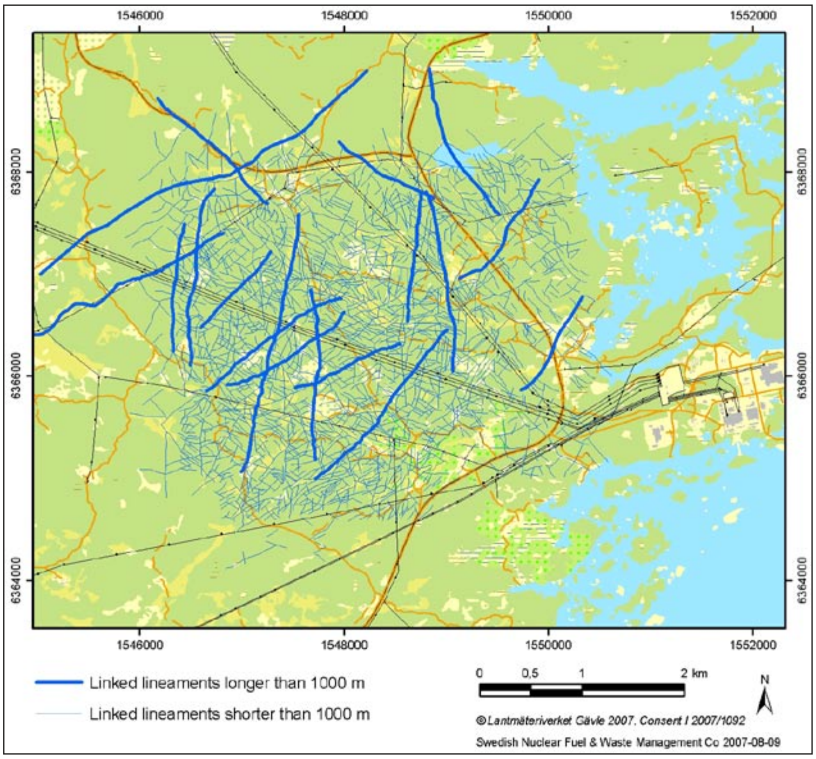

***Figure 5-7.** The linked lineaments from the Laxemar area are in total 1,452 of which 18 are longer than 1,000 m (thicker blue).*

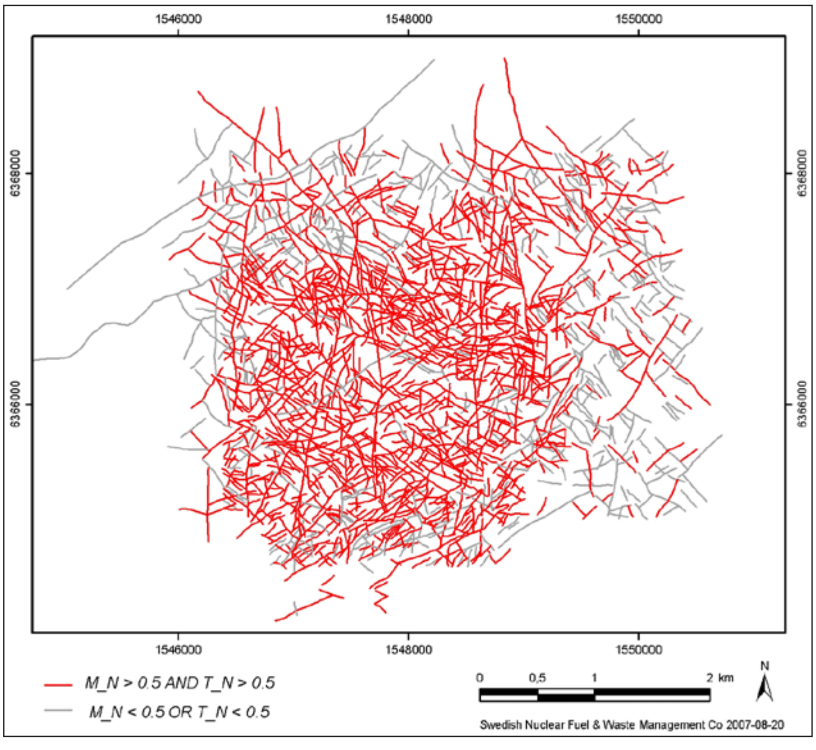

***Figure 5-8.** The linked lineaments from the Laxemar area, displaying in red all lineaments detected to more than half of their length in both magnetic and topographic data. In grey other linked lineaments. The spatial distribution of the variation in the characters partly reflects the data distribution.*

5.3 Numerical forward magnetic modelling of possible deformation zones

Forward modelling of the several structures (for example NW042 and NS059) have yielded indications of the geometric complexity and dip. The modelling was carried out on nine profiles; see Figure 5-9 for modelled profile locations. The profiles 1, 2 and 3 crosscut the NW042 structure. The profile 5 transects a number of ENE-WSW oriented low magnetic lineaments and profile 8 crosscuts a major ENE-WSW low magnetic lineament. The profiles 4 and 6 crosscut NE-SW oriented low magnetic lineaments. The profile 7 traverses the NS059 structure and the profile 9 transects the crossing between two ENE-WSW oriented and WNW-ESE oriented lineaments.

The forward modelling of magnetic data has many degrees of freedom and a fairly large part of the fit to measured data is achieved by adjusting the near-surface part of the model bodies. The deeper parts of the bodies are not as well constrained. This means that the interpreted dips might reflect near-surface geometry even though the models extend to depths of several hundred metres.

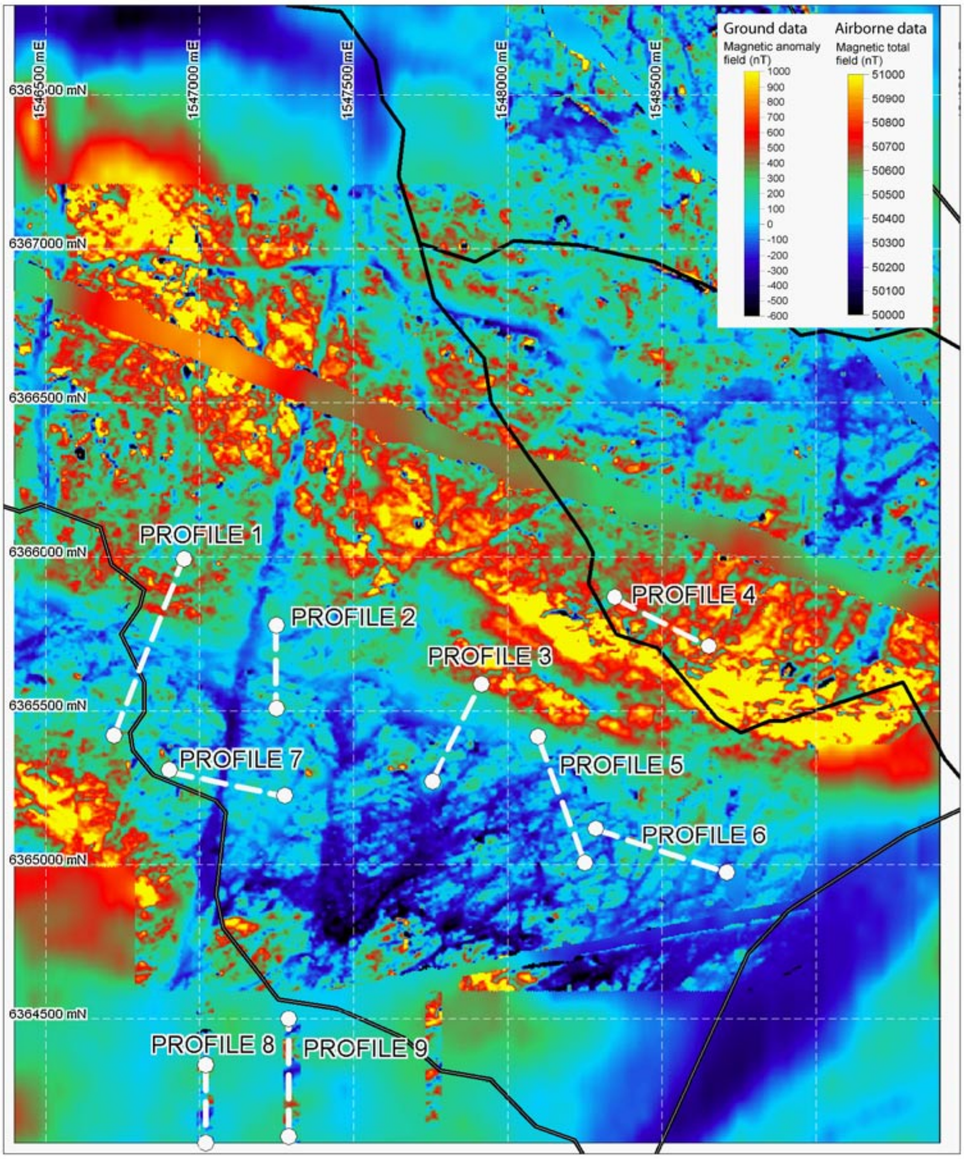

Figure 5-9. Location of profiles with forward modelling of magnetic total field data. The results are displayed in Figures 5-10 to 5-18.

The results are almost self-explaining and can be viewed in Figures 5-10 to 5-18. The background magnetic susceptibility is chosen to represent an average value of the modelled area. Modelled bodies therefore indicate explanations to positive and negative anomalies along the trajectory. Pink colours indicate increased susceptibility (most likely indicating fresh rock with increased content of magnetite). Light blue colour indicates decreased magnetic susceptibility (generally in the order of 10^{-3} SI) and dark blue colour indicates significantly decreased magnetic susceptibility (generally in the order of 10^{-4} SI).

The modelling results of the NW042 structure indicate sub-vertical or steeply south plunging dip of the low magnetic source body (bodies) (Figures 5-10, 5-11 and 5-12).

The modelling results of a NE-SW oriented lineament located in an area of increased magnetic total field intensity are shown in profile 4. The structure (at profile length c 200 m) indicates steeply northwest plunging dip of the low magnetic source body crosscutting the lithological units (Figures 5-13).

In Figure 5-14 the modelling result of several ENE-WSW oriented lineaments (profile 5) is presented. The structures indicate steeply north plunging dips of the low magnetic source bodies as well as all other modelled units.

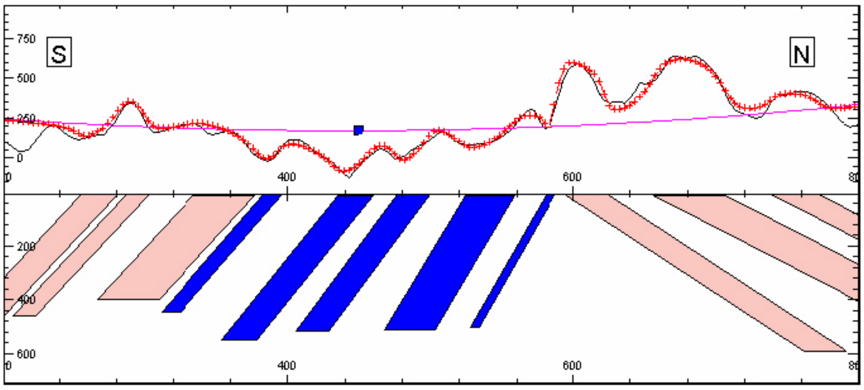

Figure 5-10. *Profile 1. Forward modelling of magnetic total field data over the NW042 structure. Black line corresponds to measured data and red line to modelled data. Pink colours of modelled bodies indicate increased susceptibility, light blue colour indicates decreased magnetic susceptibility (generally in the order of 10^{-3} SI) and dark blue colour indicates significantly decreased magnetic susceptibility (generally in the order of 10^{-4} SI).*

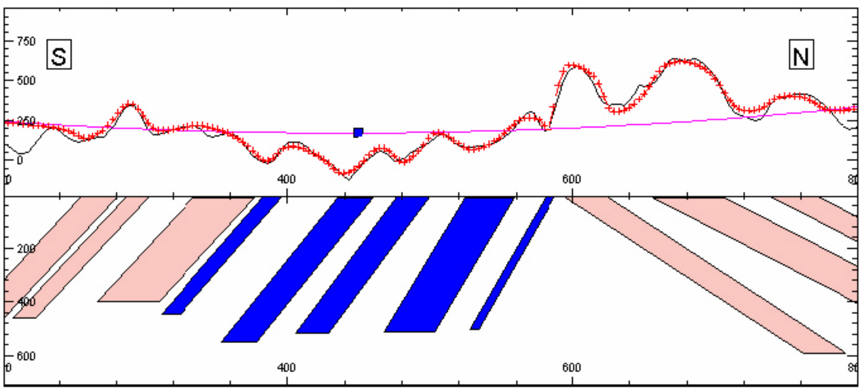

Figure 5-11. *Profile 2. Forward modelling of magnetic total field data over the NW042 structure. Black line corresponds to measured data and red line to modelled data. Pink colours of modelled bodies indicate increased susceptibility, light blue colour indicates decreased magnetic susceptibility (generally in the order of 10^{-3} SI) and dark blue colour indicates significantly decreased magnetic susceptibility (generally in the order of 10^{-4} SI).*

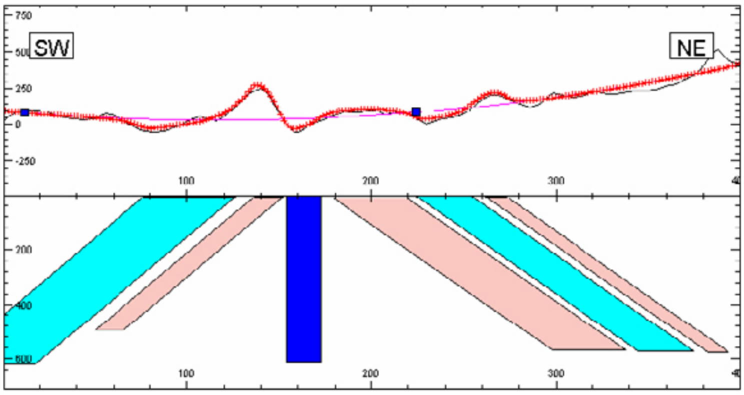

Figure 5-12. *Profile 3. Forward modelling of magnetic total field data over the NW042 structure. Black line corresponds to measured data and red line to modelled data. Pink colours of modelled bodies indicate increased susceptibility, light blue colour indicates decreased magnetic susceptibility (generally in the order of 10^{-3} SI) and dark blue colour indicates significantly decreased magnetic susceptibility (generally in the order of 10^{-4} SI).*

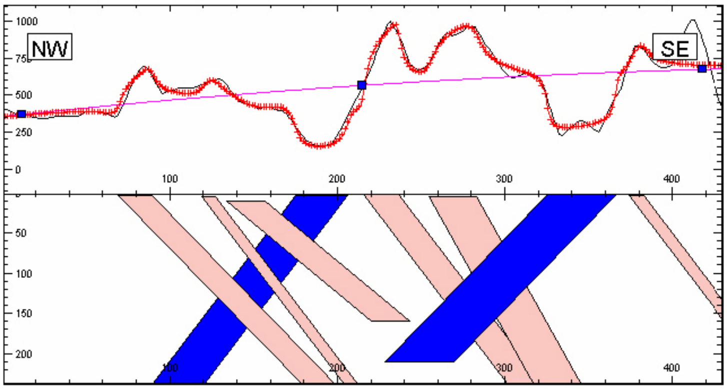

Figure 5-13. *Profile 4. Forward modelling of magnetic total field data across NE-SW oriented low magnetic lineament. Black line corresponds to measured data and red line to modelled data. Pink colours of modelled bodies indicate increased susceptibility, light blue colour indicates decreased magnetic susceptibility (generally in the order of 10^{-3} SI) and dark blue colour indicates significantly decreased magnetic susceptibility (generally in the order of 10^{-4} SI).*

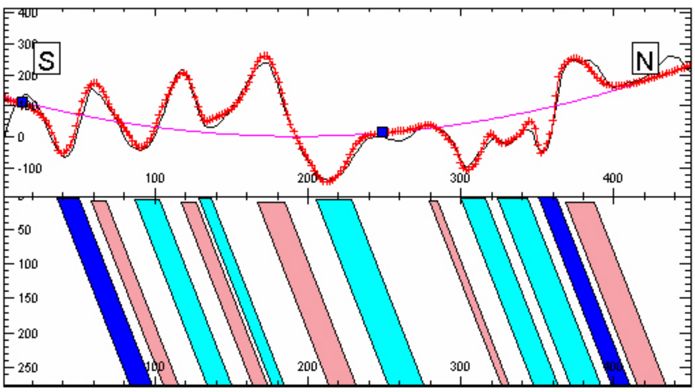

Figure 5-14. *Profile 5. Forward modelling of magnetic total field data across several ENE-WSW oriented low magnetic lineaments. Black line corresponds to measured data and red line to modelled data. Pink colours of modelled bodies indicate increased susceptibility, light blue colour indicates decreased magnetic susceptibility (generally in the order of 10^{-3} SI) and dark blue colour indicates significantly decreased magnetic susceptibility (generally in the order of 10^{-4} SI).*

In Figure 5-15 the modelling result of several NNE-SSW oriented lineaments (profile 6) is presented. The structures indicate sub-vertical dips of the low magnetic source bodies.

Profile 7 crosscuts the NS059 structure (Figure 5-16). The model result indicates a steep dip towards the west of the low magnetic source body.

In Figure 5-17 the modelling result of a major ENE-WSW oriented lineament (profile 8) is presented. The structure indicates steep south plunging dip of the low magnetic source body.

Profile 9 transects the crossing between two ENE-WSW oriented and WNW-ESE oriented lineaments (Figure 5-18). The model results indicate steep north plunging dips of the source bodies.

A 3D perspective view plot showing the geographical distribution of all nine magnetic models and a colour image of the total magnetic field data is displayed in Figure 5-19 below. The numbers denote each of the profile numbers.

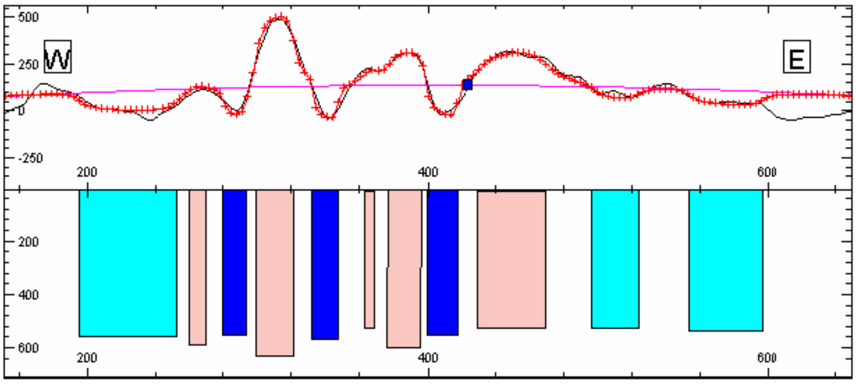

Figure 5-15. *Profile 6. Forward modelling of magnetic total field data across several NNE-SSW oriented low magnetic lineaments. Black line corresponds to measured data and red line to modelled data. Pink colours of modelled bodies indicate increased susceptibility, light blue colour indicates decreased magnetic susceptibility (generally in the order of 10^{-3} SI) and dark blue colour indicates significantly decreased magnetic susceptibility (generally in the order of 10^{-4} SI).*

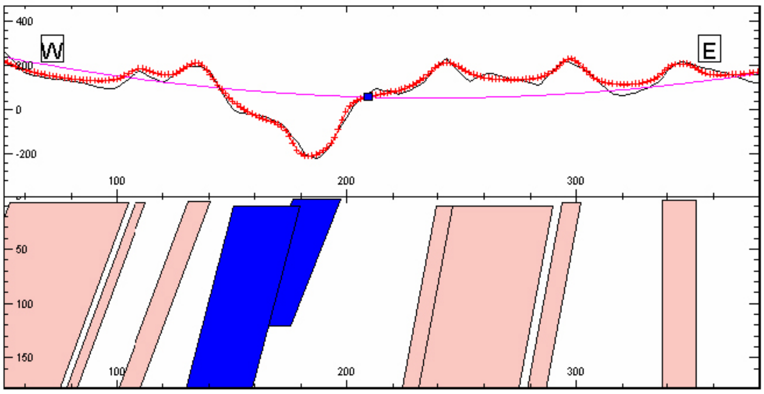

Figure 5-16. *Profile 7. Forward modelling of magnetic total field data across the NS059 structure. Black line corresponds to measured data and red line to modelled data. Pink colours of modelled bodies indicate increased susceptibility, light blue colour indicates decreased magnetic susceptibility (generally in the order of 10^{-3} SI) and dark blue colour indicates significantly decreased magnetic susceptibility (generally in the order of 10^{-4} SI).*

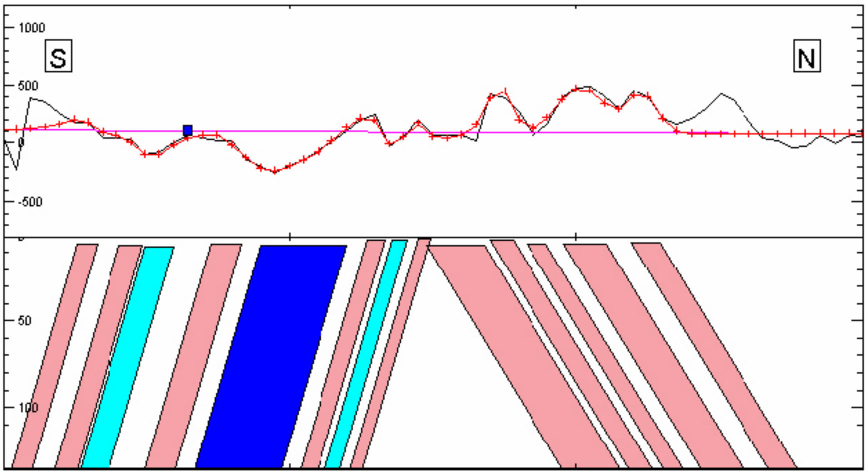

Figure 5-17. *Profile 8. Forward modelling of magnetic total field data across major ENE-WSW oriented low magnetic lineament. Black line corresponds to measured data and red line to modelled data. Pink colours of modelled bodies indicate increased susceptibility, light blue colour indicates decreased magnetic susceptibility (generally in the order of 10^{-3} SI) and dark blue colour indicates significantly decreased magnetic susceptibility (generally in the order of 10^{-4} SI).*

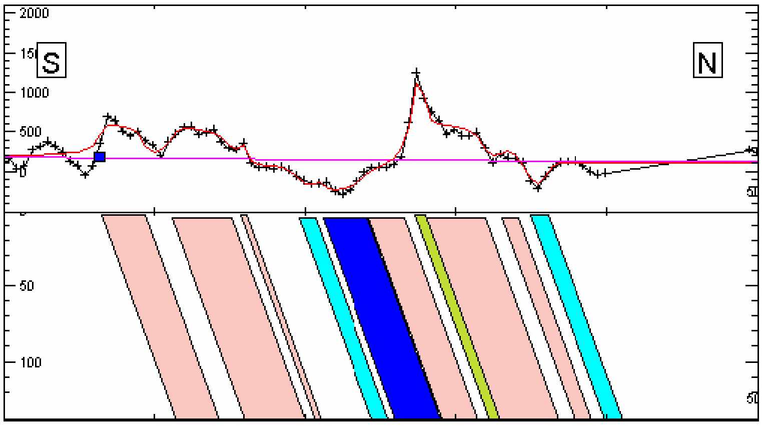

Figure 5-18. *Profile 9. Forward modelling of magnetic total field data across major ENE-WSW oriented low magnetic lineament. Black line corresponds to measured data and red line to modelled data. Pink colours of modelled bodies indicate increased susceptibility, light blue colour indicates decreased magnetic susceptibility (generally in the order of 10^{-3} SI) and dark blue colour indicates significantly decreased magnetic susceptibility (generally in the order of 10^{-4} SI).*

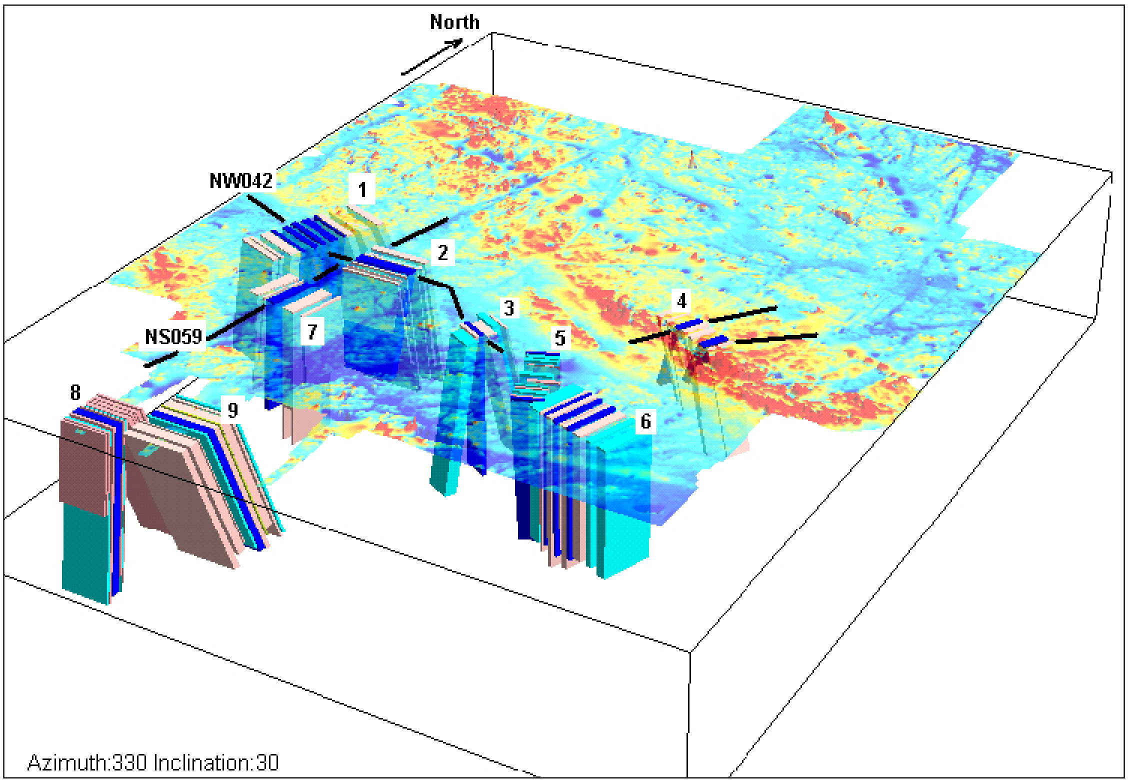

Figure 5-19. *3D perspective view of the nine magnetic models with reference to the magnetic total field map from the measurements in 2005, 2006 and 2007. Pink colours of modelled bodies indicate increased susceptibility, light blue colour indicates decreased magnetic susceptibility (generally in the order of* 10^{-3} *SI) and dark blue colour indicates significantly decreased magnetic susceptibility (generally in the order of* 10^{-4} *SI).*

5.4 Magnetic in-homogeneities related to lithology

According to petrophysical studies /3, 4 and 5/ the magnetisation of the diorite/gabbro is often higher compared to the Ävrö-granite and to the quartz monzodiorite. The fine-grained dioritoid has a very broad distribution in the frequency diagram of the magnetic susceptibility where some measurements show very high magnetic susceptibilities. In areas with high magnetisation levels it could thus be expected that diorite/gabbro, or the high susceptibility forms of the fine-grained dioritoid, would more often be observed as compared to areas with a normal magnetisation. In a selection process with the aim to isolate such areas a comparison has been made of the magnetic susceptibility measurements on outcrops, the mapping of diorite/gabbro or fine-grained dioritoids, and the total magnetic field as measured in the detailed ground magnetic survey. The selection of areas with high magnetisation with potential presence of diorite/gabbro or fine-grained dioritoid was based on the following criteria:

- A pronounced magnetic high anomaly is selected if no observations of a magnetic susceptibility in either Ävrö-granite or to the quartz monzodiorite higher than $1,500 \cdot 10^{-5}$ SI is found on or very near the anomaly.

The highly magnetized areas have been compared with the Site Descriptive Model (version 1.2) /16/. In Figure 5-20 all indications of highly magnetized rock outside areas marked as diorite/gabbro or fine-grained dioritoids are presented with yellow dots.

The distribution of the yellow dots clearly indicates dominant occurrences of highly magnetized areas along the southern boundary of the quartz monzodiorite, with the highest concentration in the western part of the measured area.

Large parts of the central and south eastern measurement area show significantly decreased magnetic total field intensity, which is related to decreased magnetic susceptibility of the rock (dominant rock type is quartz monzodiorite). The decreased magnetic susceptibility is clearly seen in the in situ magnetic susceptibility measurements performed during the bedrock mapping, compiled and presented in the petrophysical report by Mattsson et al. 2003 /3/. Decreased magnetic susceptibility can often be related to alteration and deformation.

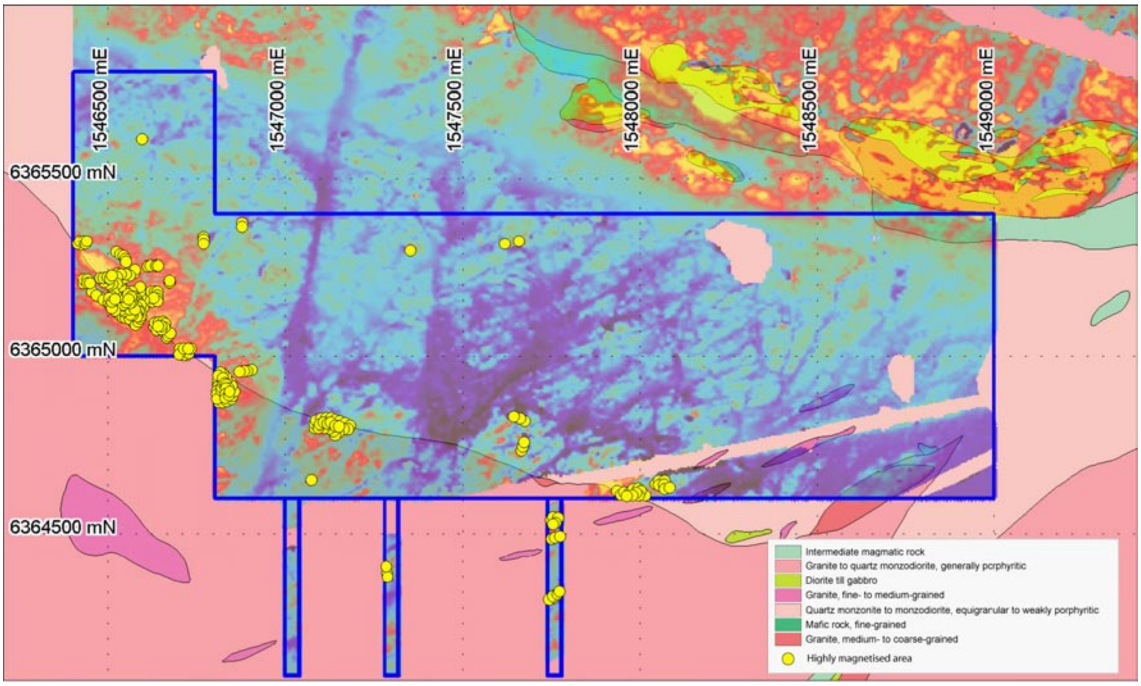

Figure 5-20. *Areas with possible high magnetic lithological inhomogeneities, such as diorite/gabbro or fine-grained dioritoid, are shown by yellow dots. In the background there is a transparent version of the magnetic total field data on top of the geological map from the Site Descriptive Model (version 1.2) over the Laxemar area /16/.*

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