P-06-262

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Identification of lineaments from LIDAR data and co-ordination with lineaments in other topographical and geophysical data

Carl-Axel Triumf, Hans Thunehed, GeoVista AB

May 2007

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Abstract

Previous work done in the Laxemar and Simpevarp areas shows linked lineaments with a cut-off length of 1 km. This comparatively large dimension adapts to the needs for a regional model of deformation zones and the linked lineaments have thus been evaluated and partly implemented into the deformation zone model version 1.2 of the Laxemar area.

The information density in the Laxemar area has increased since the linked lineaments were produced. With the introduction of dense ground geophysical surveys and an elevation model based on LIDAR data, there is now a potential to identify lineaments with lengths considerably less than 100 m.

In the present activity, lineaments have been identified in LIDAR data and co-ordinated with previously identified lineaments from other data sets. The action has resulted in 1399 co-ordinated lineaments longer than 100 m, everyone with parameters that describe their character. The study area covers the Local model area of Laxemar, version 2.1 which is approximately 13.6 km^2.

From the co-ordinated lineaments of the present activity it is possible to identify signs of bedrock deformation in the scale interval between fractures mapped in outcrops, and regional fracture zones. The increased details in the current lineaments, as compared to previous work, show that the geometry of fracture zones can be more complex than expected.

In short the co-ordinated lineaments support the site investigations by:

- reflecting deformation of the bedrock, the focus in this work is on the scale between local fractures and regional deformation zones,
- increasing the knowledge of the geometry of deformed rock within larger deformation zones.

The new co-ordinated lineaments should be viewed as a complementary set of lineaments to the pre-existing linked lineaments due to differences in working scales and base data resolution.

Sammanfattning

Tidigare arbeten med lineamentstolkningar har resulterat i s k linked lineaments med längder över 1 km vilka har utgjort ett av de huvudsakliga underlagen till möjliga deformationszoner i den platsspecifika modellen (version 1.2) i Laxemarområdet.

Sedan de första lineamentstolkningarna har nya data tillkommit med högre upplösning. De utgörs av täta markgeofysiska undersökningar och laser skanning från flygfarkost, s k LIDAR-mätning. Dessa nya data har gjort det möjligt att identifiera tecken på deformation i berggrunden vars längd kan vara betydligt under 100 m. I den föreliggande aktiviteten identifieras lineament i digitala höjdmodeller. Dessa lineament koordineras sedan med lineament som tidigare identifierats i andra datamängder, t ex markgeofysiska mätningar. Resultatet består av 1 399 koordinerade lineament som är längre än 100 m där varje enskilt lineaments karaktär framgår av dess parametrar. Arbetet med lineamenten täcker den yta (ca 13,6 km^2) som motsvarar det lokala modellområdet för Laxemar version 2.1.

De koordinerade lineament, längre än 100 m, som utgör resultatet av föreliggande aktivitet kan användas i platsundersökningen som ett stöd för deformationszonsmodeller. Lineamenten förväntas belysa möjlig deformation i berggrunden i en skala som ligger mellan de tidigare identifierade lineamenten, längre än 1 km, och den information som detaljerad sprickkartering ger. Lineamenten belyser också komplexiteten i geometri i de möjliga större deformationszonerna i Laxemarområdet.

De nya koordinerade lineamenten (längre än 100 m) kan ses som ett komplement till de lineament som identifierats i tidigare arbeten.

Contents

1 Introduction

This document reports the results gained from the identification of lineaments in LIDAR data (Light Detection and Ranging) and the co-ordination of these lineaments with pre-existing lineaments /1, 2/ in helicopter-borne geophysics /3/, conventional digital elevation models /4/, and ground-geophysical data /5, 6/.

The identification and co-ordination of lineaments described in this report is one of the activities performed within the site investigation at Oskarshamn. The work was carried out in accordance with the activity plan *"Plan of activities for the establishment of geological models, version 2.1, Laxemar subarea"*. In Table 1-1 the controlling documents for performing this activity are listed. Both the activity plan and the method description are SKB's internal controlling documents.

Carl-Axel Triumf, GeoVista AB carried out the identification and co-ordination of the lineaments during October 2005 to May 2006. The work covered an area at Laxemar of 3,200×4,250 m which is the Local Model area Laxemar version 2.1 (Figure 1-1).

Before the identification and co-ordination of lineaments could start, the LIDAR data were processed and implemented into a GIS by Hans Thunehed, GeoVista AB during October 2005.

The results, i.e. the co-ordinated lineaments, are expected to support the future site investigations at Oskarshamn by indicating the distribution and character of possible fracture zones in the Laxemar area.

The original results of the work are stored in the primary data bases (SICADA and GIS) and they are traceable by the activity plan name *"Plan of activities for the establishment of geological models, version 2.1, Laxemar subarea"*.

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

Activity plan	**Number**	**Version**
Plan of activities for the establishment of geological models, version 2.1, Laxemar subarea.	No number	1.0
Method descriptions	**Number**	**Version**
Metodbeskrivning för lineamentstolkning baserad på topografiska data	SKB MD 120.001	1.0

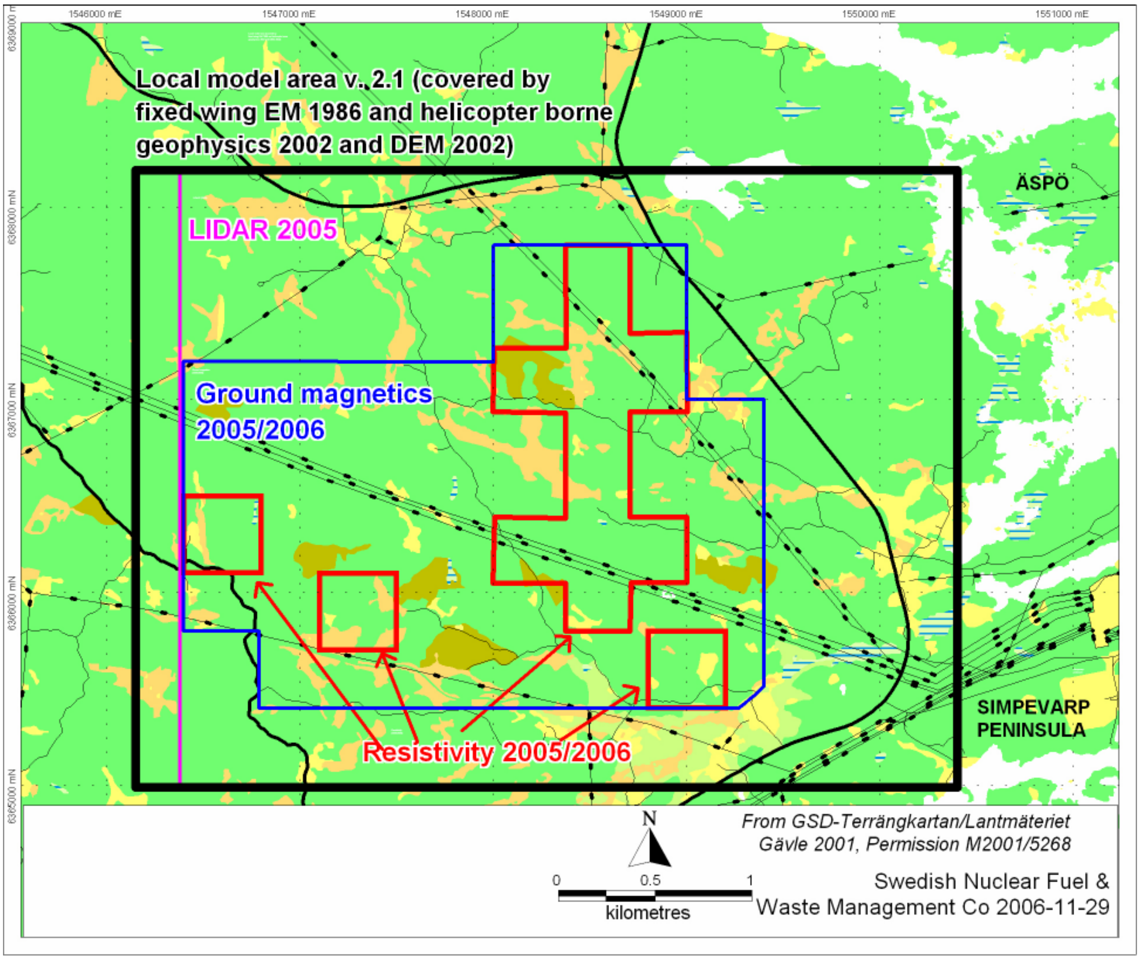

Figure 1-1. *The lineaments were identified and co-ordinated so that the entire Local Model area Laxemar version 2.1 (3,200×4,250 m) was covered. The work was carried out in October 2005 to May 2006 by GeoVista AB. The coverage of the different data sets in the Local Model area is shown.*

2 Objective and scope

In the present activity we identify lineaments in LIDAR data and co-ordinate them with previously identified lineaments from other data sets /1, 2, 3, 4, 5, 6/. The activity results in co-ordinated lineaments longer than 100 m within the Local model area, Laxemar, v2.1. They are expected to support the site investigations by:

- Reflecting the deformation of the bedrock with focus on the scale between local fractures and large deformation zones
- Increasing the knowledge of the geometry within larger deformation zones

The new co-ordinated lineaments should be viewed as a complementary set of lineaments to the pre-existing linked lineaments /2/ due to differences in working scales and base data resolution.

3 Equipment

3.1 Tools for processing, identification, co-ordination and reporting

The processing, identification, co-ordination and reporting is a purely desk-top based, with the use of computers with appropriate software. The software used included:

Grapher v 6.0 (Golden Software)

Surfer v 8.0 (Golden Software)

Oasis Montaj v 5.0 (Geosoft Inc)

MapInfo Professional v 7.5 (MapInfo Corporation)

Discover v 7.0 (Encom Technology)

R2V v 5.5 (Able Software)

ArcView (Environmental Systems Research Institute Inc.)

Microsoft Excel (Microsoft Corp.)

Microsoft Word (Microsoft Corp.)

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

4 Processing of LIDAR data, identification and co-ordination of lineaments

4.1 Definitions

A *lineament* is a linear anomaly on the Earth's surface, straight or gently curved, which has been interpreted on the basis of a 2-dimensional data set, such as a topographic map, a digital elevation model (DEM) and/or a map over the magnetic total field /7/.

A *method specific lineament* is a technical term meaning a lineament defined from a single and specific type of data set. The data set comes from one type of an investigation method such as a photogrammetric survey for a digital elevation model, airborne magnetics or airborne EM or ground geophysical measurements; see also Figure 4-1.

A *co-ordinated lineament* is a technical term meaning a single lineament that represents all method specific lineaments that are supposed to indicate the same length section of the actual source structure, see also Figure 4-1.

Method specific and *co-ordinated lineaments* are all supposed to represent a *lineament* according to the general definition explained above. The prefix is used only due to reasons of communication and quality assurance where the names are supposed to associate the reader to a specific interval in the process of defining and describing lineaments.

A *linked lineament* is a technical term meaning a lineament that is composed of one or several co-ordinated lineaments i.e. the co-ordinated lineaments have been joined along the strike into one linked lineament. Linking has not been carried out in the current activity.

4.2 General

The current activity consisted of the following main sub-activities:

- Processing and preparation of grids from LIDAR data.
- Implementation of grids into a GIS.
- Identification of lineaments in LIDAR data.
- Co-ordination of lineaments from LIDAR data with previously identified lineaments and parameterisation of the co-ordinated lineaments.
- Reporting.

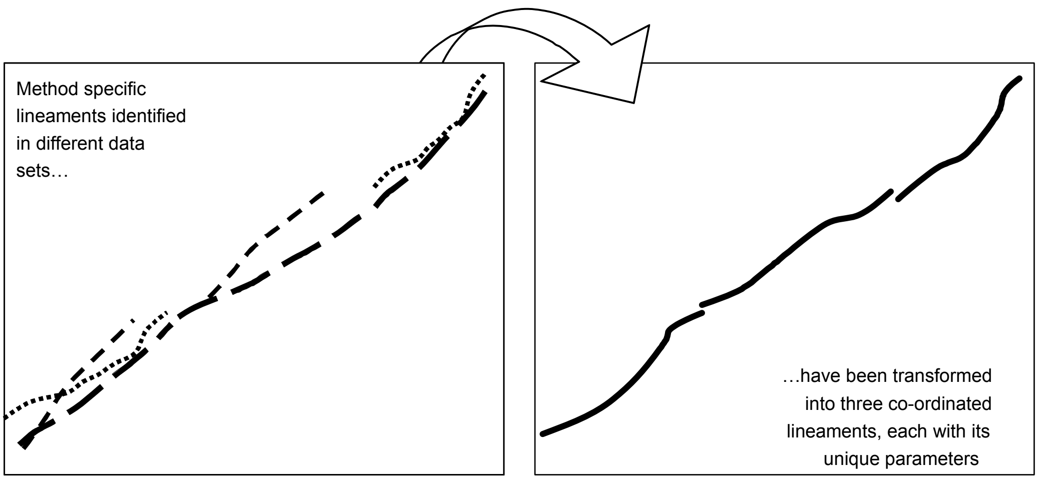

Figure 4-1. *Condensed explanation of the identification and co-ordination of lineaments.*

4.3 Processing and preparation of LIDAR data

LIDAR data were extracted from the SKB file archive as a set of XYZ text-files. Each file covers an area of roughly 600 by 600 metres. LIDAR reflections from e.g. vegetation had been filtered out from the data which means that the data density varied slightly within the area but a typical number would be around 5 samples per m^2.

4.3.1 Grid interpolation and filtering

The data from each sub-area were interpolated into a regular grid with a node spacing of 0.6 m using inverse distance weighting and a search radius of 3 metres. The choice of interpolation method is not critical due to the high density of data. A mosaic of all grids was then made. The node spacing in the mosaic was 1 metre.

The LIDAR terrain model contains information about local morphology as well as regional trends in elevation. Digital filters were applied to the data in order to enhance the appearance of local features. The following filters were applied:

- High-pass filter with cut-off wave-length of 125 metres.
- Residual of "upward continuation" to 20 and 70 metres respectively (exponential attenuation of long wave-lengths).

Colour images of the above grids were produced with shading from a vertical light source. Examples can be seen in section 5 of this report.

4.3.2 Segmentation

An attempt was made to automatically and objectively extract information about dominating directions of morphological features in the LIDAR data. A curvature filter was applied to the data and a grey-scale image with high contrast was produced. Very small features were removed by median filtering and the remaining image was converted to vectors. The length and direction of each vector was calculated and all vectors with a length shorter than 3 metres were rejected.

4.3.3 Implementation into a GIS and integration with other data

The images of filtered data were implemented into a GIS. Images showing the results from the helicopter borne geophysics /3, 8/, the digital elevation model based on the airborne photogrammetry of 2002 /9/, and the ground geophysics /5, 6/ were also implemented into the GIS. All images were used in the work with the lineaments.

The coverage of the different data sets is shown in Figure 1-1. The digital elevation model from the airborne photogrammetric survey of 2002, the helicopter borne and fixed-wing borne geophysics covers the entire area. The elevation model based on LIDAR data covers almost the entire area; only a few hundred metres are missing in west. The dense ground geophysical survey with magnetics covers 5.75 km^2 while resistivity covers one larger area of approx. 1.13 km^2 together with three smaller areas, 0.4×0.4 km each.

4.4 Identification of lineaments in LIDAR data

Method-specific lineaments have been identified in an elevation model based on LIDAR data. The *method-specific lineaments* were however not delivered explicitly to SKB as a separate product; instead they were inherited by the next step in the process i.e. the co-ordination, which is explained in section 4.5 below.

4.5 Co-ordination of lineaments from LIDAR data with previously identified lineaments

4.5.1 Co-ordination

The *method-specific lineaments* that were identified in the LIDAR elevation model 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, the digital elevation model (DEM) from the airborne photogrammetric survey of 2002 and ground geophysics from 2005/2006 (magnetics and resistivity).

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.

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, or the LIDAR survey. Ortophotos have not been used. 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 or the VLF survey of 1986) or in ground resistivity measurements. 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.

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	
CLASS_T	n.a.	The individual co-ordinated lineaments have not been classified
METHOD_T	see PLATFORM_T below	
EV_N	0 or 1	Visible in data reflecting the resistivity or conductivity (resistivity and/or EM and/or VLF). 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

Name of attribute	Values in this activity	Comment
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	Airborne photogrammetry, helicopter-borne geophysics, fixed-wing borne geophysics, ground geophysics, topography/DEM	Different combinations of available data sets depending on where the lineament is located
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	270–360 or 0–90	Calculated average orientation of the lineament, within 270–360 or 0–90 degrees
LENGTH_N	In meter	Calculated length in m
COUNT_N	1	By default = 1

The main difficulty in the co-ordination process has been to overcome the difference in spatial resolution between the different data sets (see also Chapter 6). As an example is the resolution in LIDAR data 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 Comparison with previous lineaments

The co-ordinated lineaments from the present activity have been compared with pre-existing linked lineaments /2/. This was done because the differences in base data resolution will affect the result of lineament identification. The base data resolution has increased since the pre-existing lineaments were delineated. The differences in resolution might cause difficulties in the co-ordination process, with possible conflicting results.

In the present activity, the focus has been on lineaments longer than 100 m, as compared with earlier activities where lineaments longer than 1 km were of main interest. This change to a shorter cut-off length also will affect the interpreters' threshold level for accepting a lineament. High detail in base data means high threshold – in such data it is easier to find obstacles preventing a lineament to be drawn. The choice to focus on shorter lineaments is expected to give detailed information about the local geometry of possible deformation zones. However becomes the overview deteriorated and it is thus more difficult to draw a single line that uniquely represents a regional lineament. Due to this earlier versions of lineaments are complementary to the current version of co-ordinated lineaments. Both are available for usage by adaptation to the appropriate scale for the problem to analyse.

4.6 Nonconformities

The method specific lineaments from the interpretation of the LIDAR elevation model have not been made a unique product and were thus not delivered to SKB. Instead they were transferred into the process of co-ordination and come out implicitly as part of the co-ordinated lineaments.

5 Results

The results are stored in the primary data bases (SICADA and/or GIS). The data are traceable in SICADA and GIS by the Activity Plan name *"Plan of activities for the establishment of geological models, version 2.1, Laxemar subarea"*.

5.1 Co-ordinated lineaments

The processing of LIDAR data has resulted in different products displaying the information content of the digital elevation model in different modes. Two examples are shown in Figures 5-1 and 5-2, in Figure 5-1 the elevation model is only enhanced by shading from a vertical light source, in Figure 5-2 the residual is shown after an "upward continuation" to a height of 20 m. The latter is a type of high-pass filtered elevation model where local structural information is enhanced and regional variations attenuated.

The map of all 1,399 co-ordinated lineaments is shown in Figure 5-3. Some of the lineaments continue outside of the Local model area of Laxemar, version 2.1, which is for purposes of length calculations.

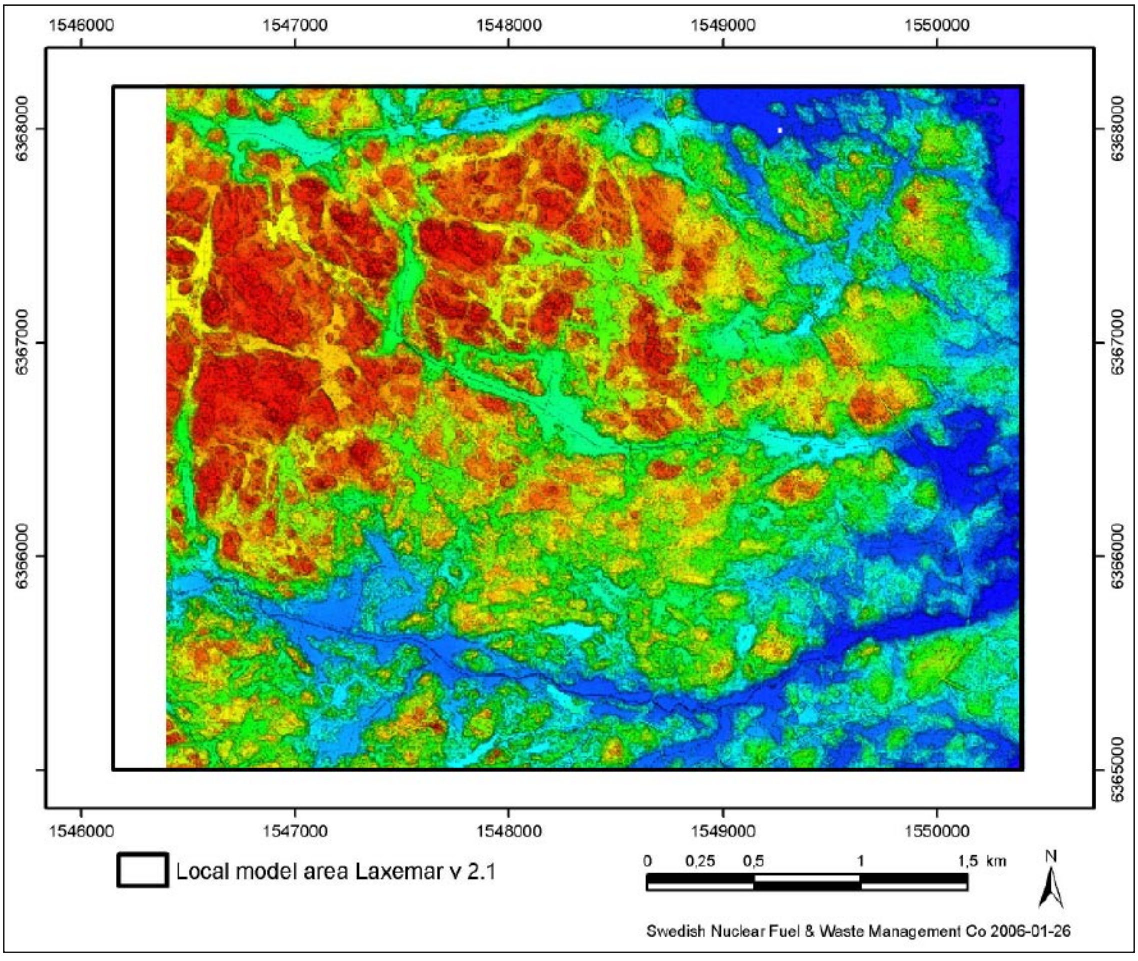

Figure 5-1. *Elevation model prepared from LIDAR data. Vertical light applied. The local model area is shown.*

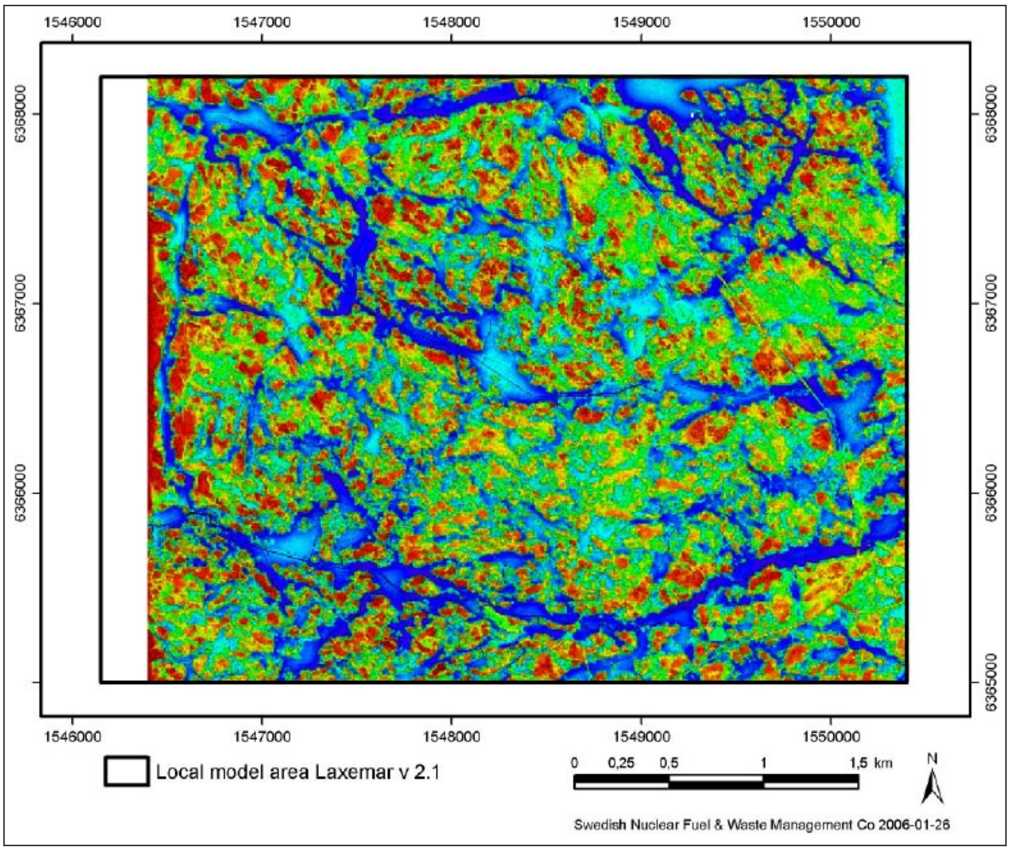

Figure 5-2. Elevation model prepared from LIDAR data. Residual from "upward continuation" to 20 m. Vertical light applied. The local model area is shown.

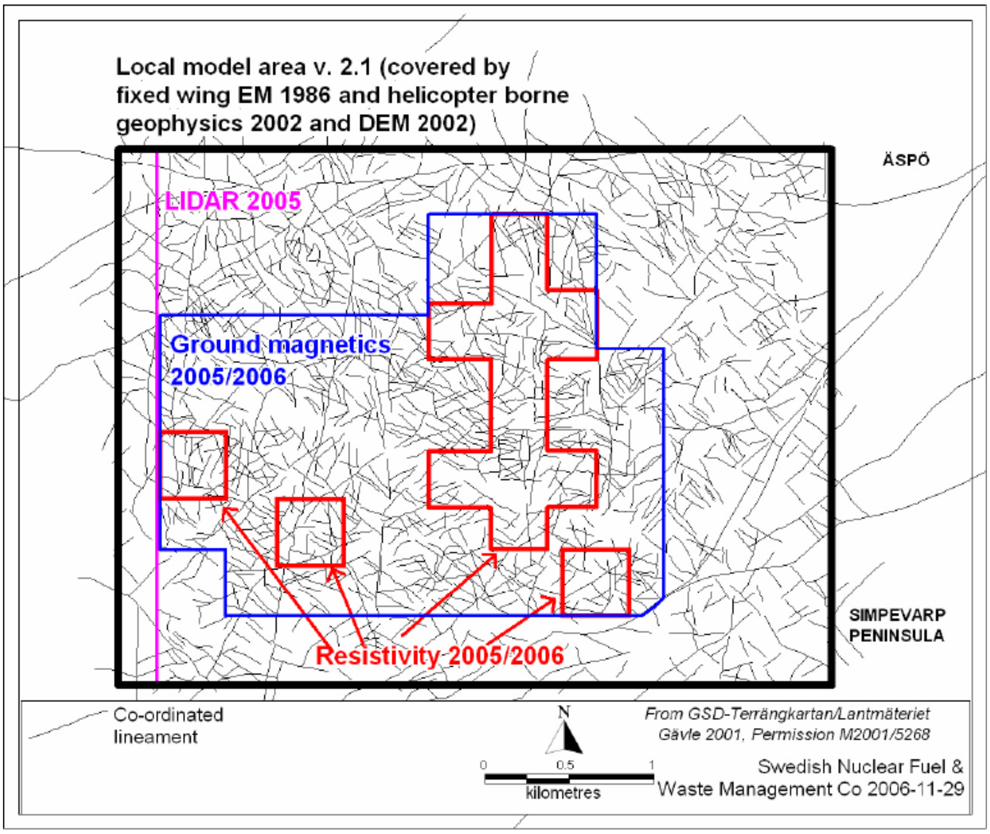

Figure 5-3. Co-ordinated lineaments (> 100 m) in the Local model area, Laxemar, version 2.1. The coverage of different data is displayed.

The parameterisation made of every co-ordinated lineament makes it possible to display the lineaments based on their individual character. Two examples are shown in Figures 5-4 and 5-5. In Figure 5-4 the different colours indicate in what base data the lineaments were observed (T_N, M_N, EV_N). In Figure 5-5 the parameter Weight_N is expressed in terms of line thickness.

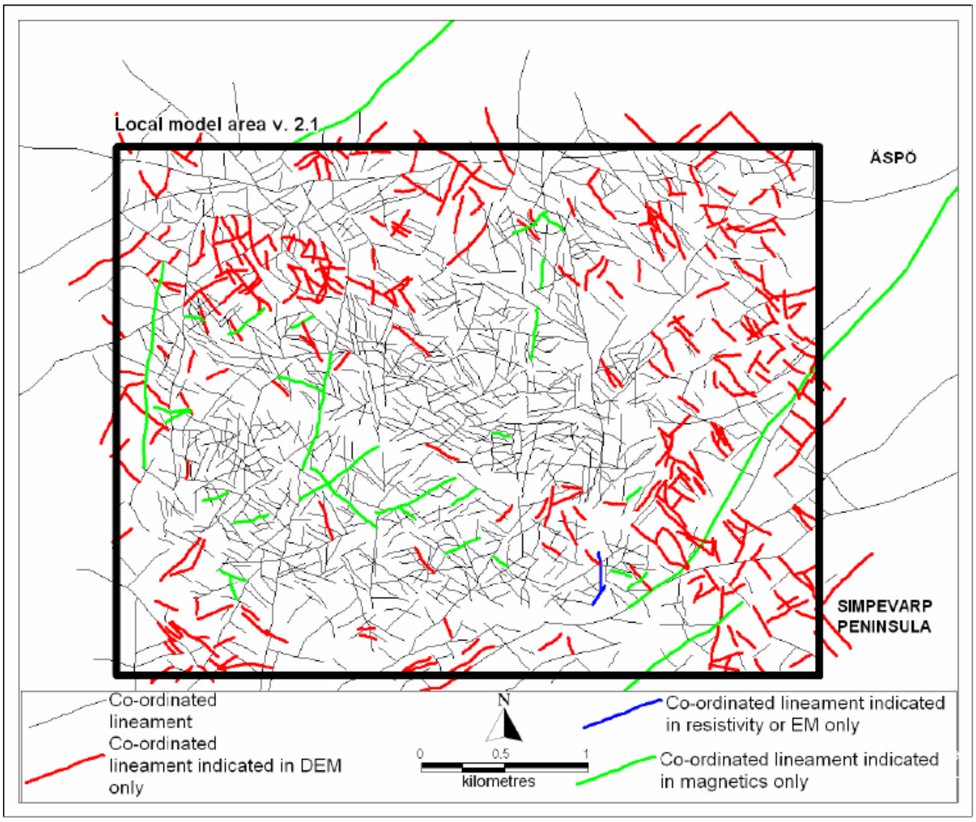

Figure 5-4. *Co-ordinated lineaments (> 100 m) in the Local model area, Laxemar, version 2.1. The parameters T_N, M_N, and EV_N are displayed according to: Blue colour = lineament indicated in resistivity and/or EM only, red colour = lineament is indicated in elevation model only, green colour = lineament is indicated in magnetics only, grey colour = other combinations.*

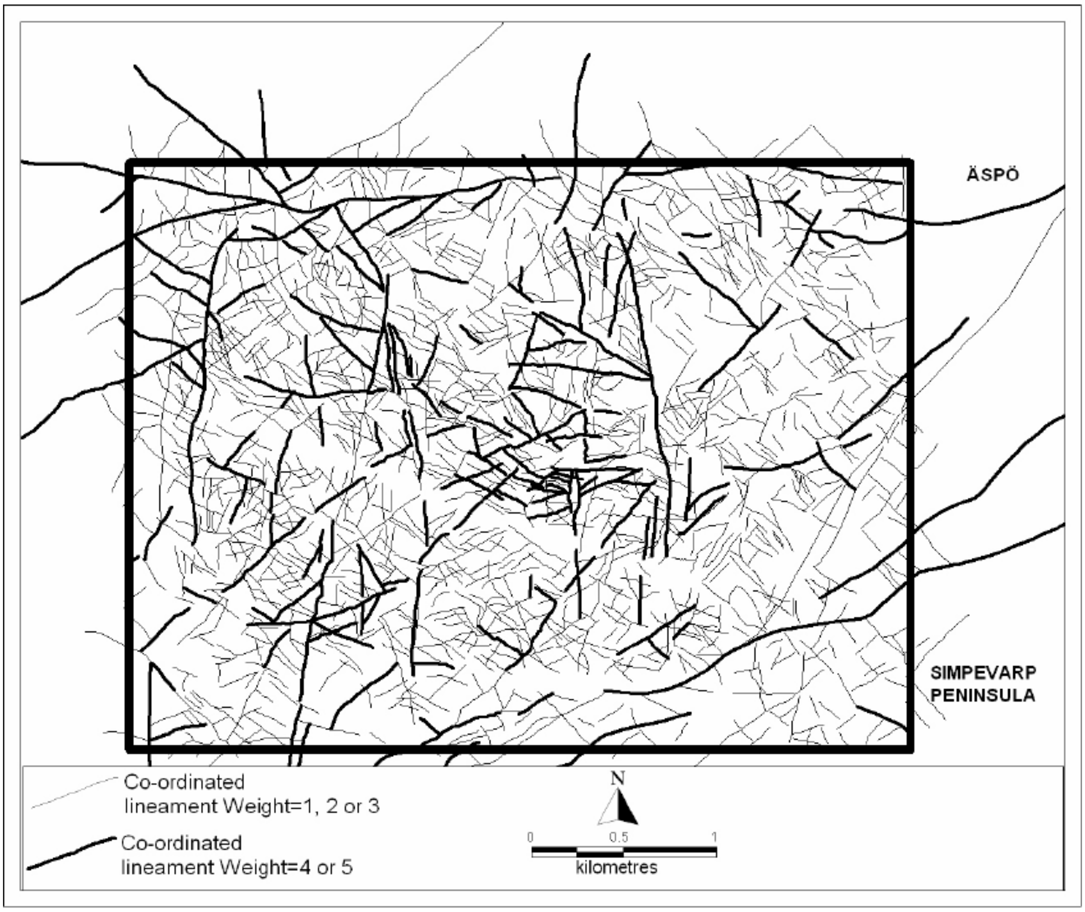

Figure 5-5. *Co-ordinated lineaments (> 100 m) in the Local model area, Laxemar, version 2.1. The parameter Weight_N is displayed as thickness (Weight=5 and 4 thick line, 3–1 thin line).*

In Figure 5-6 is shown all lineaments together with areas of low magnetic relief and areas where ground magnetics were disturbed by power lines.

A majority (> 72%) of the co-ordinated lineaments have lengths in the interval of 100–200 metres (Figure 5-7).

The distribution of orientations among the co-ordinated lineaments from the current activity shows a broad peak around 40° to 70° and one more pronounced at 300° to 310° (Figure 5-8). The distribution reflects the lineament orientations over a large area covering more than 13 km^2. Only some hundreds of square metres are covered in the detailed fracture mapping of outcrops, /10/. Outcrop ASM000209 is located at the southern central part of the Laxemar area. The fracture orientation data at ASM000209 has the major distributional peak around 330° which is a bit off-set as compared to one of the peaks among the co-ordinated lineaments (300–310°). The second largest frequency peak at ASM000209 is found around 10° which partly coincides with the peak from the current activity located between 350°–10°. Outcrop ASM000208 is located in the northern central part of the Laxemar area. At ASM000208 the distributional peak is located around 65°, which coincides well with one of the frequency peaks among the co-ordinated lineaments from the current activity.

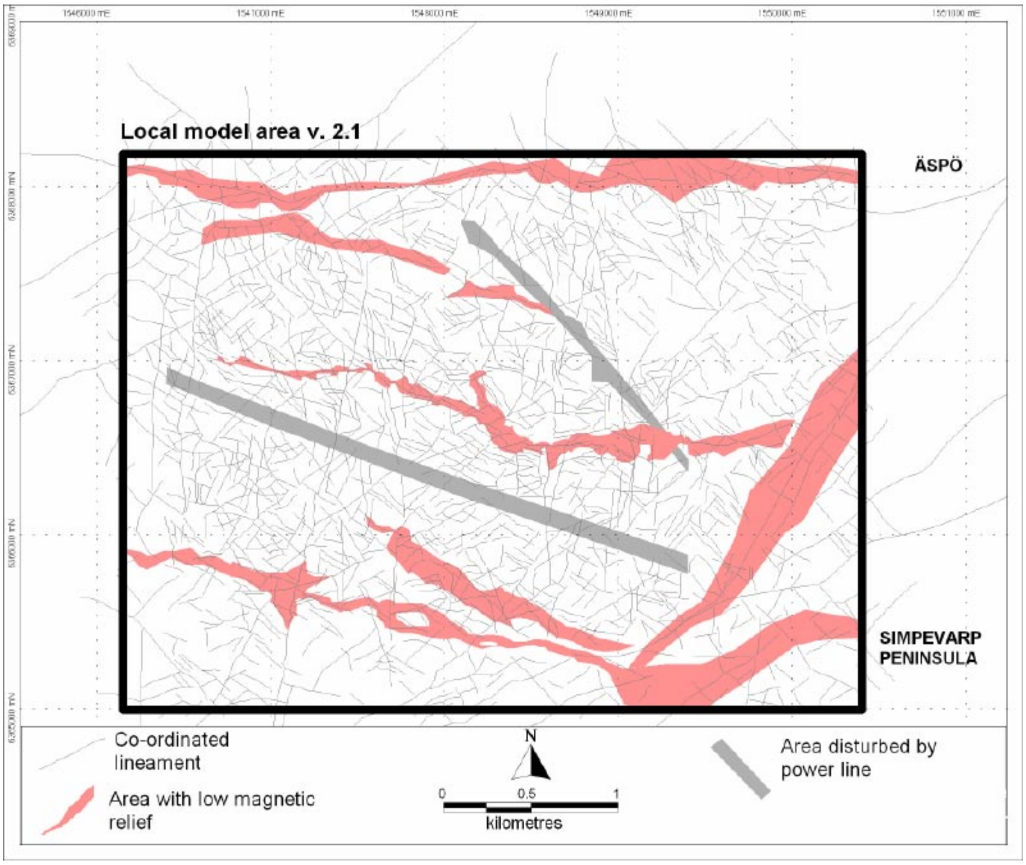

Figure 5-6. *The figure shows the 1,399 co-ordinated lineaments (> 100 m) in the Local model area, Laxemar, version 2.1. Areas with low magnetic relief (pink) and areas where power lines have disturbed especially ground magnetics (grey) are also shown.*

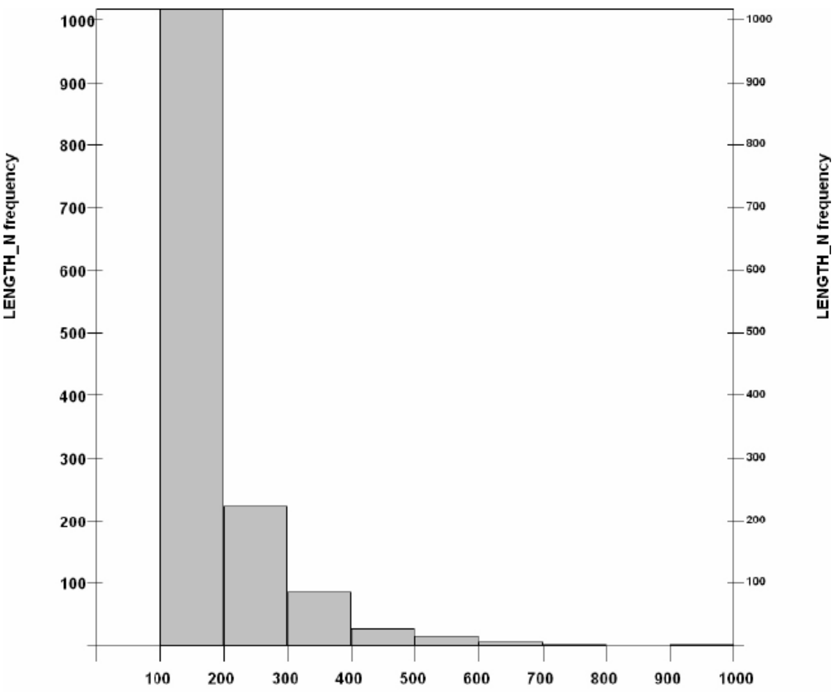

Figure 5-7. *Frequency diagram showing the distribution of lengths among co-ordinated lineaments longer than 100 m in the Local model area, Laxemar version 2.1.*

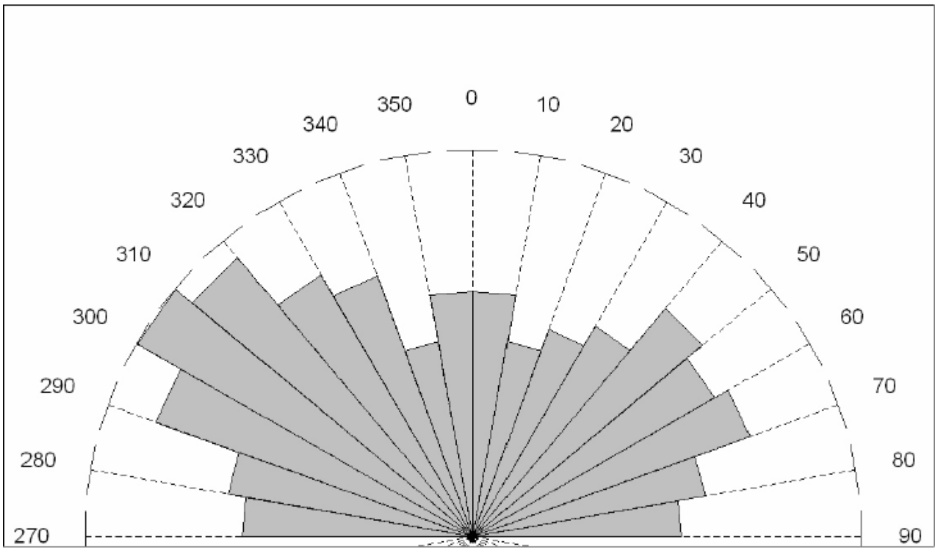

Figure 5-8. Rose diagram showing the distribution of orientations among co-ordinated lineaments longer than 100 m in the Local model area, Laxemar version 2.1.

The orientations of morphological features from the segmentation as described in section 4.3.2. may be compared to the orientation analysis based on co-ordinated lineaments above. An example of the curvature filtered image and the resulting vectors can be seen in Figure 5-9. A rose diagram showing the total length of vectors in different directions can be seen in Figure 5-10. Two dominating directions can be identified, one being a bit fuzzy in NNW to NW and the other being in E to ENE. It should be pointed out that not all vectors in this type of analysis are related to lineaments. Some of them are due to roads, ditches and other man-made features and some are too curved to be considered to be part of any lineament.

The most dominating direction in the co-ordinated lineaments corresponds well with the dominating direction of vectors from the segmentation. However, the frequent NE-trending lineaments do not have any correspondence in the segmentation vectors. This might partly be due to a systematic difference in how these lineaments are expressed in surface morphology and partly due to a difference in observation scale. A comparison between the lineaments and the segmentation vectors showed that most NE-trending lineaments actually were represented by series of short vectors in the same direction, but apparently not to the same degree as NW-trending lineaments. The results of the segmentation should therefore be used with some caution.

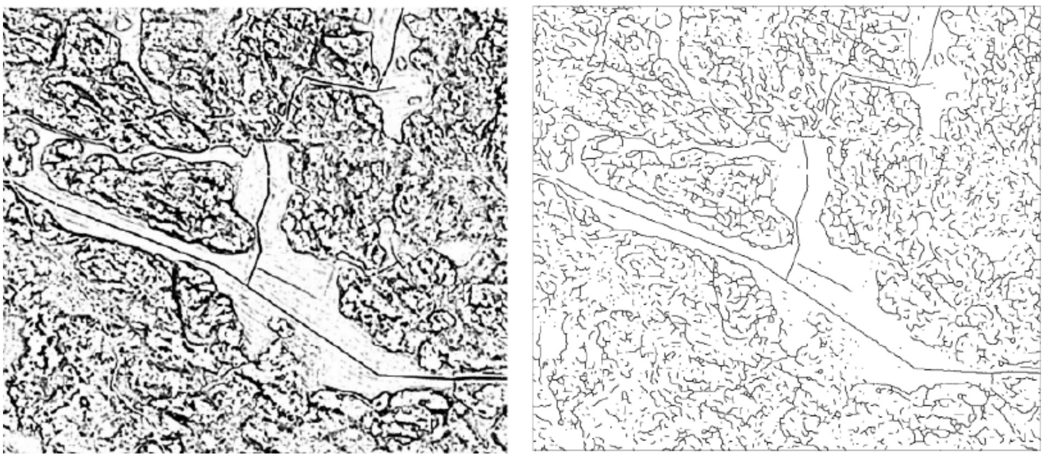

***Figure 5-9.** Example of segmentation of LIDAR data, central Laxemar area around ZSMEW007. Left: Curvature filtered image of LIDAR elevation data where dark tones correspond to strong negative curvature. Right: Vectors produced by segmentation of the image to the left.*

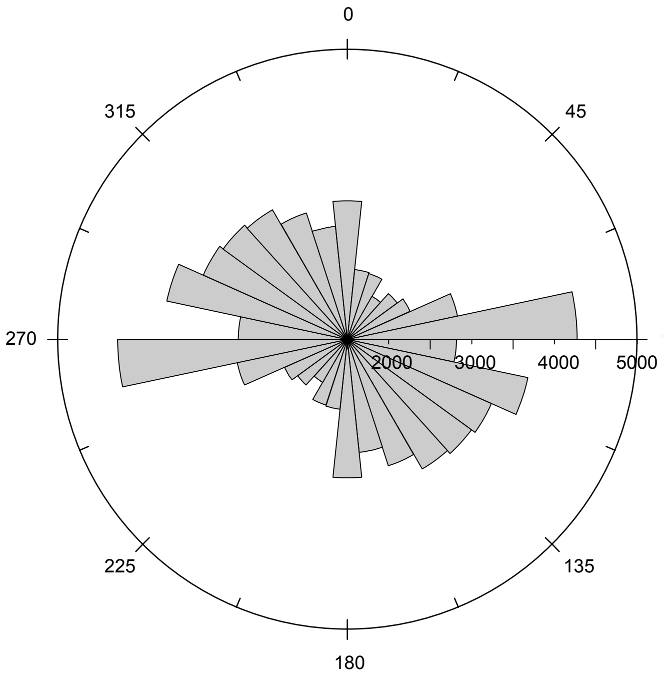

Figure 5-10. *Rose diagram showing the direction of vectors from the segmentation process of LIDAR data for the whole study area. The radius axis shows total length of vectors per aerial unit (m/km²).*

5.2 Comparison with the current Site Descriptive Model version 1.2

The structural part of the Site descriptive model version 1.2 of the Laxemar area is shown together with the co-ordinated lineaments of the current activity in Figure 5-11. In spite of the differences in base data resolutions between the current and former activities, most of the major features in the model are more or less well represented among the co-ordinated lineaments. Some of the major discrepancies that appear have been chosen for comments:

1 – ZSMNS059A. At this northern part near the Mederhult zone the continuity of the deformation zone is difficult to follow in the detailed topography and partly also in the helicopter borne magnetics. A broad electromagnetic indication however supports its existence.

2 – ZSMNW932A. The major problem with the lineament is whether to connect it to ordinary variations in magnetite content due to bedrock lithology or to a decrease in magnetic susceptibility emanating from fracturing or alteration.

3 – ZSMNS054A. It appears very discontinuous when crossing ZSMNW929A. Probably there are two different features north and south of ZSMNW929A.

4 & 5 – ZSMNE138A. This lineament appears very discontinuous. At 5 it violates the magnetic anomalies from the ground survey. It could probably be divided into two different lineaments north and south of EW007; furthermore the geometry of the northern part is strongly debatable.

6 – ZSMEW039A. This lineament is visible in the helicopter borne magnetics and the old low resolution DEM. It is however difficult to find support for it in the new high resolution DEM.

7 – ZSMNS046A. At the southern part of this lineament/deformation zone the continuity is debatable.

8 & 9 – Several lineaments enter these areas. The areas have fairly broad low magnetic zones. The topography is very complicated, several possibilities exist.

10 – ZSMNW051A. The southern continuation of the lineament is difficult to follow in the high resolution DEM. It is only weakly indicated in the helicopter borne magnetics, and sub-parallel to the survey direction.

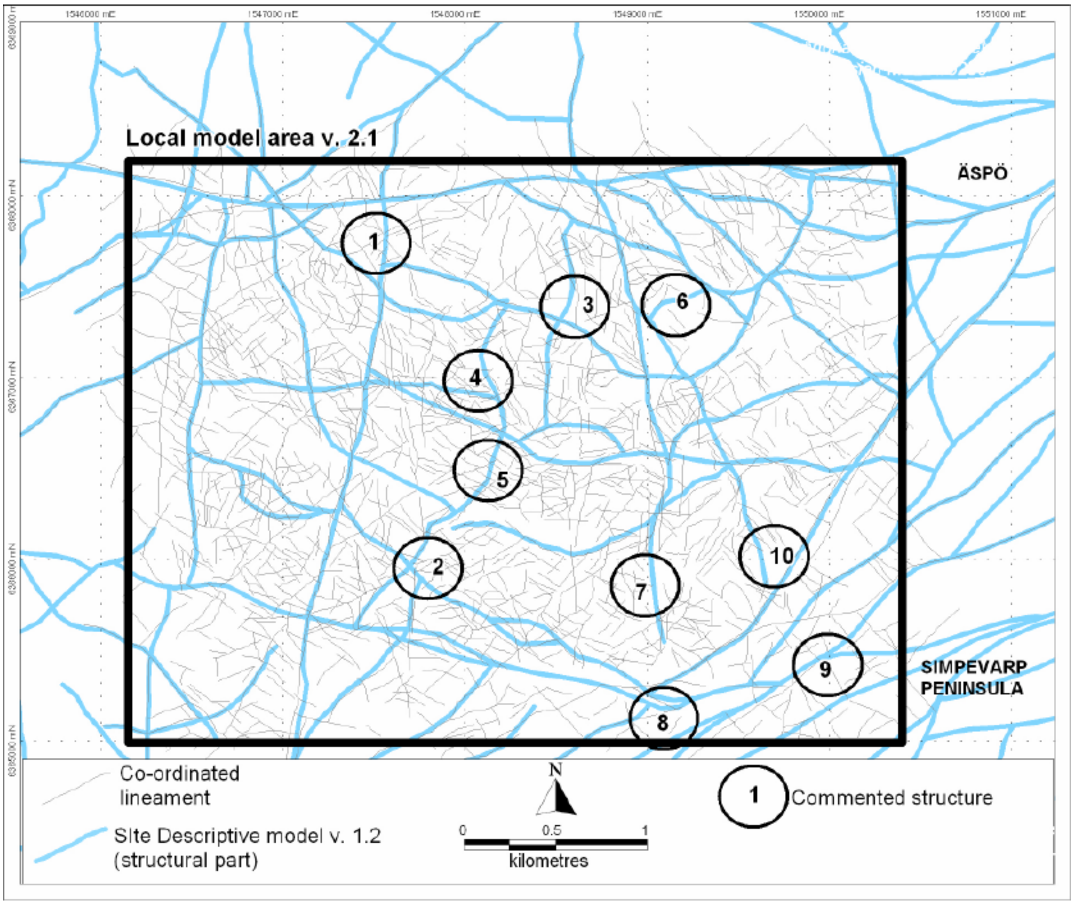

Figure 5-11. *Comparison of the structural part of the Site Descriptive model version 1.2 (coarse blue) and the present co-ordinated lineaments longer than 100 m (thin grey). Circles with numbers refer to comments in text.*

6 Discussion

The data coverage of the different data sets will affect the result when identifying lineaments and co-ordinating them. The high resolution DEM based on LIDAR data is available for almost the entire area, only a few hundred metres in the west are missing. Dense ground geophysical measurements are however not available over the entire local model area. This will lead to fewer short lineaments detected compared to a case where the entire area would have been covered with a dense ground geophysical survey.

The focus in the current activity has been on lineaments longer than 100 m, as compared to earlier activities where lineaments longer than 1 km were of main interest. This change to a shorter cut-off length also affects the interpreters' threshold level for accepting a lineament. High detail in data will lead to a high threshold for accepting a lineament – it is easier to find obstacles preventing a lineament to be drawn in detailed data. The co-ordinated lineaments from the present activity could thus differ from the earlier ones quite substantially in some areas. The most important reason is found in the base data resolution, which has increased since the pre-existing lineaments were delineated (see Figure 6-1).

The differences in resolution might cause difficulties in the co-ordination process, with possible conflicting results in some areas. One example below (Figures 6-2 to 6-3) illustrates how the previously identified linked lineaments were based on data that gave a good overview and served well to delineate the general regional structural setting of the Laxemar area with surroundings. As data were viewed in regional scale the indications emanating from regional lineaments were enhanced, and the interpreter could grasp the general character and extension of the structure. In regional scale it was furthermore quite easy to represent the structure or lineament by a single thin line. The example indicates how the high resolution may obscure some of the general character and extension of a lineament as the details may confuse the observer/interpreter.

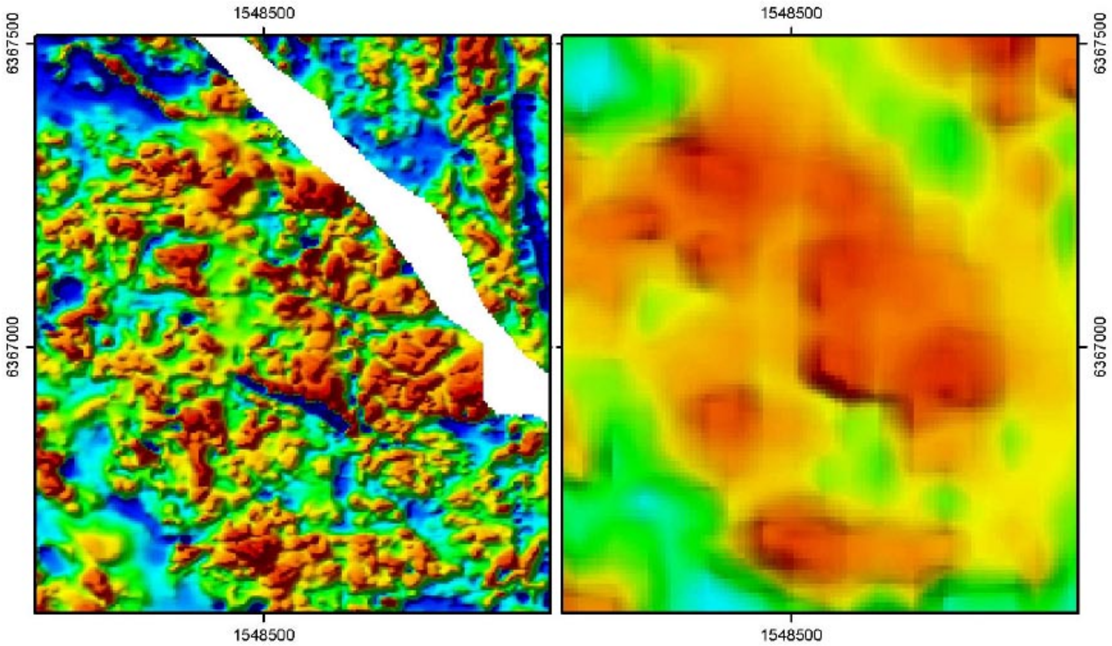

Figure 6-1. *Comparison of the resolution in ground magnetics (left) and helicopter borne magnetics (right). These differences in resolution will affect the detail with which a lineament is drawn, but the threshold for accepting a lineament will also be raised as the resolution increases.*

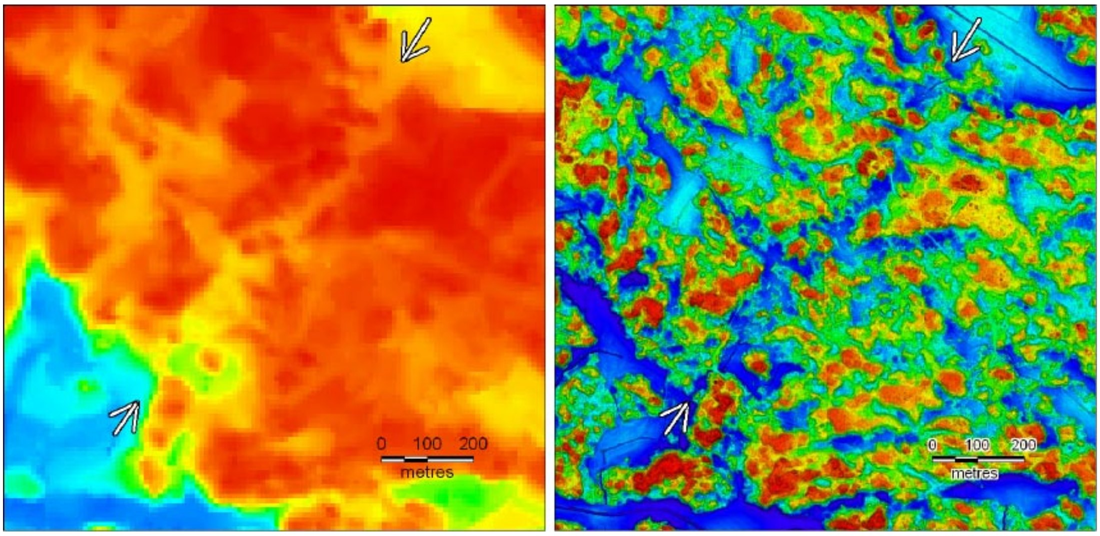

Figure 6-2. At left: Detail of the pre-LIDAR DEM over the central part of Laxemar area, south of EW007. To the right: Detail of the enhanced DEM from LIDAR over the same area. Arrows mark a possible NE-SW trending semi-regional lineament that appears very discontinuous in the high resolution DEM.

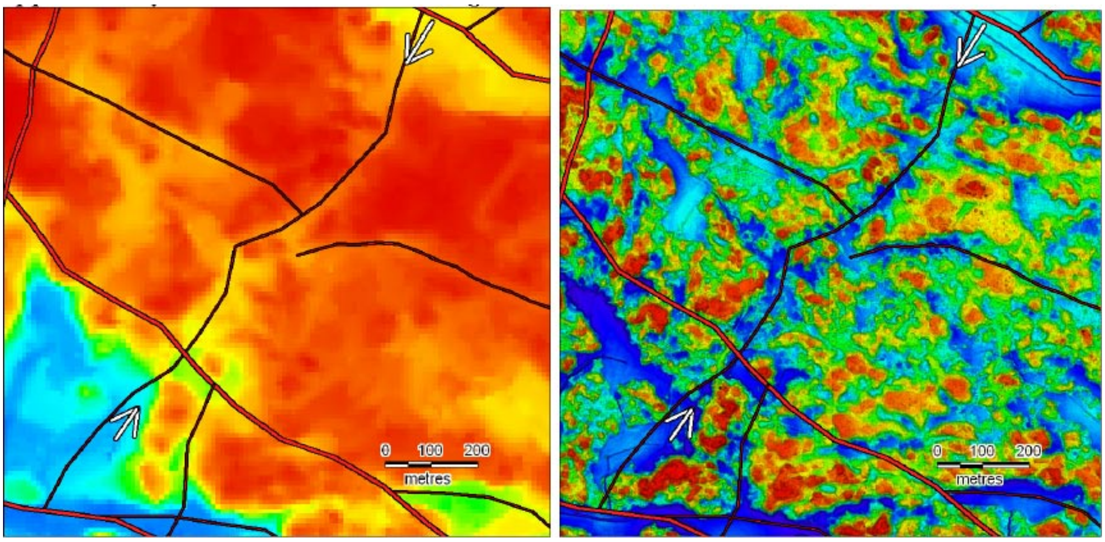

Figure 6-3. At left: Detail of the pre-LIDAR DEM over the central part of Laxemar area, south of EW007. To the right: Detail of the enhanced DEM from LIDAR over the same area. The structural part of the Site Descriptive Model version 1.2 is also shown as lines.

Figure 6-4 shows a principal sketch of how the previous linked lineaments and the co-ordinated lineaments of the present activity may represent potential bedrock deformation in a tentative area. In base data of comparatively lower resolution (coarse DEM and airborne geophysics), a linked lineament (cut-off 1 km) may be a good representation of a possible deformation zone. In high resolution base data the same possible deformation zone may be less clear; however more detail of its geometry is revealed. Earlier versions of lineaments are thus partly complementary to the current version of co-ordinated lineaments and should be used with adaptation to the appropriate scale for the problem to analyse.

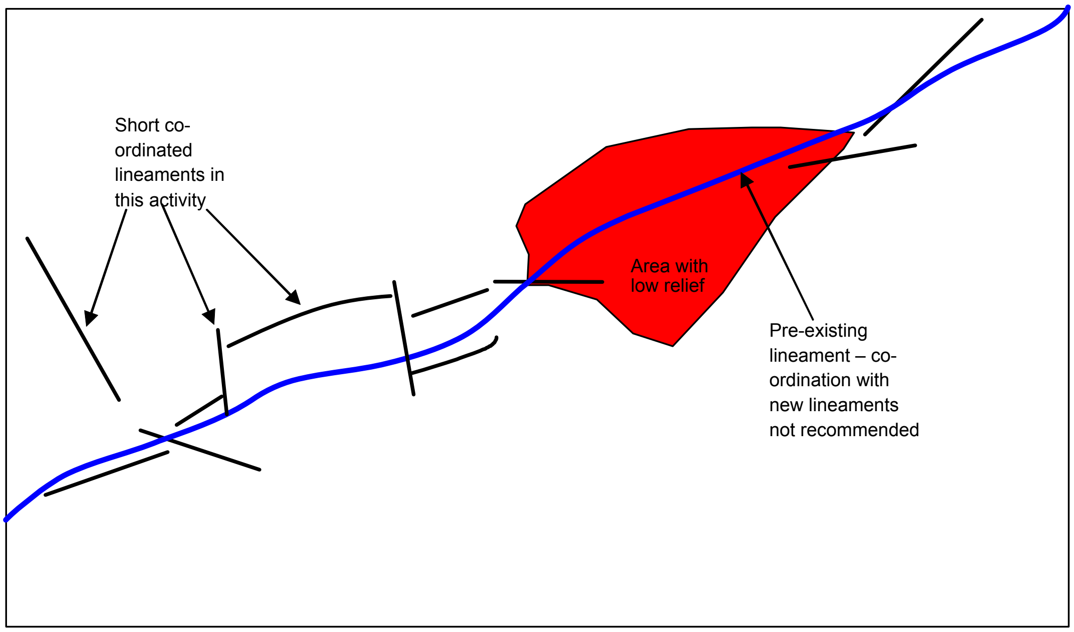

Figure 6-4. *Principal sketch where a possible deformation zone is represented by a lineament defined in previous activities concentrating on regional scale and compared to the co-ordinated shorter and more detailed lineaments from the current activity.*

Some of the époques in the tectonic history may be more evident in one data set as compared to another. Such an example from the Laxemar area is the Äspö shear zone, which manifests itself clearly in data of the magnetic total field, whilst it is only partly visible in topographic data. This fact must be taken into consideration when making lineament identifications and co-ordinations in order not to introduce unnecessary errors. An example of such an erroneous action would be to force two nearby method specific lineaments into one co-ordinated lineament though in the reality both method specific lineaments are representing different tectonic processes and different features. The correct behaviour in such a case would be to maintain the two individual method specific lineaments and transfer them into two separate co-ordinated lineaments. These judgements are however very difficult and certainly such errors may have been introduced during the process. If follow-up work on lineaments will result in ambiguous results, the best action will be to control the method specific lineaments in the specific area of interest, and compare them with the base data sets.

Deformation of the rock in the Laxemar area is investigated in many scales, from regional deformation based on helicopter-borne geophysics to very detailed scales in the dimension of one single fracture. The present activity fills the gap between the two by introducing co-ordinated lineaments typically in a length interval of 100 to 500 metres.

Finally it is important to note that the lineament map only presents linear objects on the map, and they are not to be regarded as deformation zones. The co-ordinated lineaments resulting from the interpretation will be further evaluated in order to control whether they represent deformation zones, some of them with geological field control and some by means of geophysics and drilling.

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