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Oskarshamn site investigation

Field investigation of selected lineaments and minor deformation zones in the Laxemar area

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This report concerns a study which was conducted for SKB. The conclusions and viewpoints presented in the report are those of the authors and do not necessarily coincide with those of the client.

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Abstract

A large number of lineaments have been interpreted in the Laxemar area, primarily in the length scale > 100 metres. In this activity these are complemented in selected areas with shorter lineaments, down to less than 10 metres. Lineaments in all scales are believed to be the location of deformed and fractured rock, which also has been shown to be the case at several places. Only few direct observations of rock conditions at the surface along lineaments are at hand in Laxemar, however. This document reports an activity that aims to detect and expose Minor Deformation Zones in two selected areas with the help of both existing lineaments and lineaments interpreted on a DTM, based on LIDAR data (laser scanning).

Over 40 lineaments where identified in the LIDAR data. These, together with existing lineament interpretations and also nearby outcrops in the study area, were examined in the field. At four chosen sites the rock was fully uncovered across three identified zones of brittle deformation and one suspected such zone.

At one excavation, close to borehole KLX09, a detailed high-resolution photo was taken and transformed to an orthophoto. The excavated rock at this site was mapped along two scan-lines across the deformed zone. The excavation exposes deformation that show the north end of what may be classified as a Minor Deformation Zone.

At another excavation close to borehole KLX10 one scan-line mapping was performed. The excavation at this site was two metres deep and exposed a few fractures and somewhat oxidised rock, but no actual deformation zone.

Examples on how the characterization and documentation may be done are presented. The methodology presented in the report is in part used in a second stage of this work in SW Laxemar; a work performed as a separate activity.

Sammanfattning

Ett stort antal lineament har tidigare tolkats i Laxemarorådet, primärt med längder över 100 meter. I denna aktivitet kompletteras dessa i utvalda områden med lineament kortare än 100 meter, i enstaka fall kortare än 10 meter. Lineament i alla skalor tros indikera läget för deformationszoner i berggrunden av olika slag, vilket delvis också har belagts. Bara enstaka direkta observationer av bergets egenskaper på bergöverytan utmed dessa lineament har dock skett i Laxemarområdet. Detta dokument rapporterar en aktivitet som syftar till att identifiera och exponera Mindre Deformationszoner, både med hjälp av existerande lineament och av lineamentstolkningar gjorda inom ramen för denna aktivitet på en DTM baserad på LIDAR data (laserskannad data).

De över 40 lineament som identifierades i LIDAR data undersöktes i fält tillsammans med äldre existerande lineament, samt närliggande hällar. Fyra lokaler där deformationszoner identifierades eller misstänktes finnas valdes ut och berggrunden blottlades.

En av dessa blottläggningar, nära borrhålet KLX09, fotograferades med hög upplösning och fotot gjordes om till ett ortofoto. Kartering av bergarter och sprickor genomfördes här längs två linjer, tvärs den deformerade berggrunden. Den blottade berggrunden uppvisar vad som kan tolkas som det norra slutet på en Mindre Deformationszon.

En annan blottläggning av berggrunden skedde över ett ost-västligt lineament nära borrhål KLX10. Djup till berg var här två meter. Linjekartering som genomfördes här visade på enstaka sprickor och något oxiderad berggrund, men ingen egentlig deformationszon.

Exempel presenteras på hur karaktärisering och dokumentation av blottlagt berg kan ske. Metoderna som presenteras i rapporten är delvis använda i en andra fas av arbetet i sydvästra Laxemar, vilket utförts som en separat aktivitet.

Contents

1 Introduction

1.1 Local Minor Deformation Zones

SKB conducts site investigations for a future deep repository for spent nuclear fuel in Oskarshamn. The execution of the investigations is basically controlled through a general programme /1/ a site specific programme for the initial site investigation in Oskarshamn /2/, and a site specific for the complete site investigation in Oskarshamn /3/.

The present investigation concerns Local Minor Deformation Zones (MDZ), defined by SKB as deformation zones in the scale range 10 m–1 km length /1/. The investigation also comprises lineaments in this scale range, since these at first normally are the available indications that a deformation zone might be present. There are a large number of lineaments interpreted in the Laxemar area in the scale range >100 m /4/ and there would be a lot more if shorter lineaments were considered /5/. To what extent these lineaments represent deformation zones or other geological structures related to fractured rock is of interest for the site investigation, as well as the character of the zones and structures.

This activity is conducted as a methodology test on how to locate, expose and document MDZ. It is focussed into two areas in central Laxemar, adjacent to drill sites KLX09 and KLX10. The methodology used in the present activity for identification and documentation of selected MDZ's and lineaments is later, in a second stage, partly utilized in southern and western parts of Laxemar. Since this second stage is a separate activity (AP 400-06-053) it is reported separately /6/. The investigation areas for the first and second stages are shown in Figure 1-1. The final choice of the areas for the second stage in the southern and western part of Laxemar is made when the results from the ground geophysical survey are available.

This document reports the results gained from the first stage of this activity, which is performed as part of the site investigation at Oskarshamn. The work was carried out in accordance with activity plan AP PS 400-05-096. In Table 1-1 controlling documents for performing this activity are listed. Both activity plan and method descriptions are SKB's internal controlling documents.

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

Activity plan	Number	Version
Karaktärisering av mindre defonationszoner på delområde Laxemar	AP PS 400-05-096	1.0
Method descriptions	**Number**	**Version**
Detaljerad sprickundersökning på berghällar	SKB MD 132.003	1.0
Metodbeskrivning för lineamentstolkning baserad på topografiska data	SKB MD 120.001	1.0

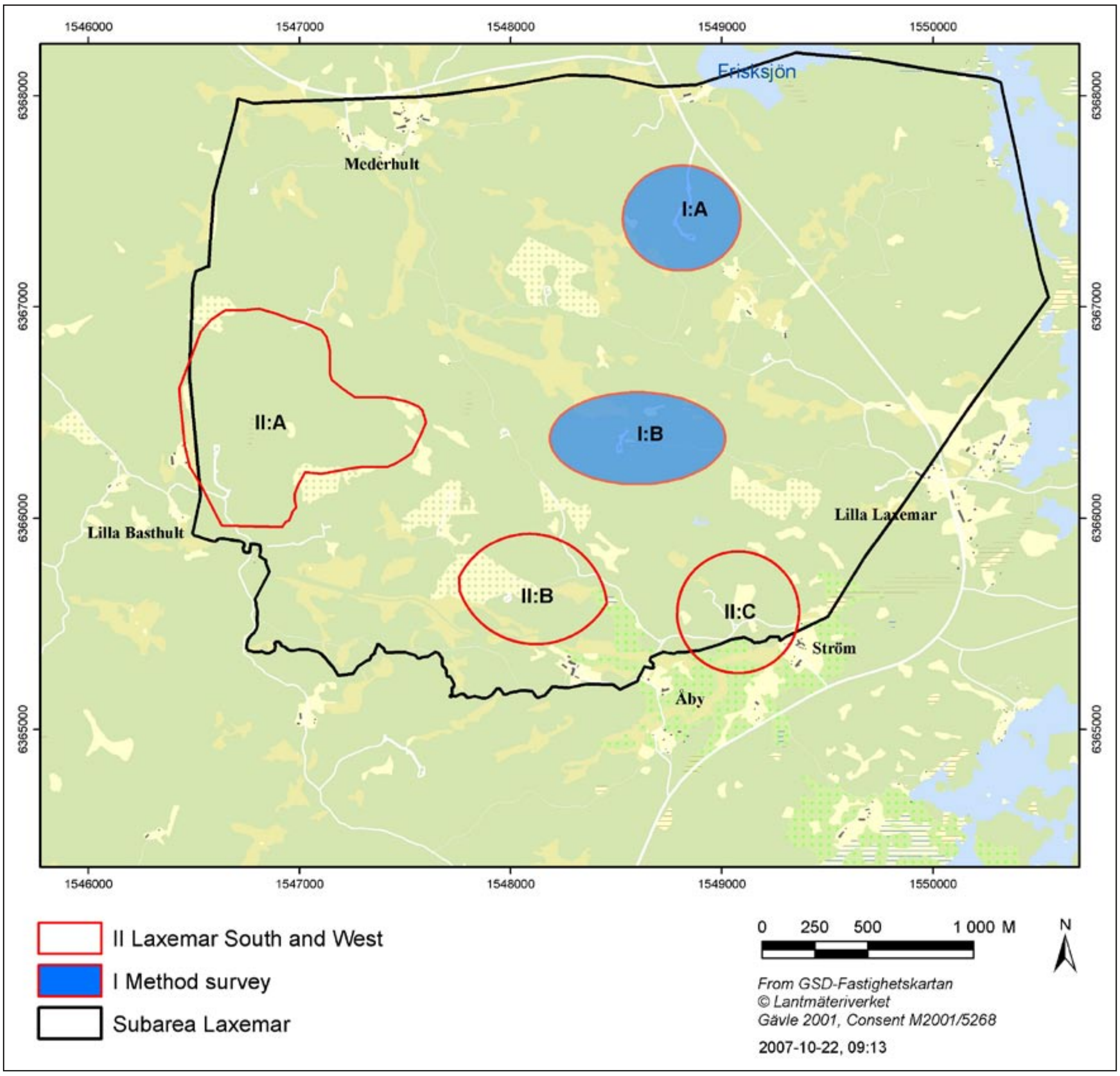

Figure 1-1. *Investigation areas for the first stage of the activity (I:A and I:B) and preliminary areas for the investigationsin the second stage (activityplan AP PS 400-06-053) in S and W Laxemar (II:A–C).*

1.2 Development of methodology

Starting with the work related to the so-called FIL-study /7/ a methodology was developed during the autumn and winter 2005/2006.

The basic principals in this methodology involve the following steps:

1. Lineament interpretation on images from LIDAR data /8/ with correlation to aerial orthophotos. Focus on lineaments in the approximate length scale range 5–200 m and on lineaments not covered by existing lineament interpretations /4/.
2. Field reconnaissance for a brief characterization of identified lineaments from 1. and existing lineaments in the scale range > ca 5 m in well expose areas in order to identify minor deformation zones at the rock surface.
3. Excavation and cleaning of the rock surface over selected identified zones and suspected zones.
4. Documentation of geology on excavated surfaces.

2 Objective and scope

The objective of this activity is to identify lineaments representing potential MDZ's and to locate and expose selected ones in the field. Another objective is to document the methodology used doing so. Examples of how characterization of the zones may be done is also given and documented. The methodology will then be utilized in southern and western Laxemar /6/.

Lineaments identified in this activity are from the LIDAR data and visited in the field are assigned a few attributes attached to the GIS layer. However, only a brief field investigation is made on each lineament and geological information in the attributes is only given when it is considered probable (with high confidence) that observed geology actually is genetically related to the lineament in question. The same reasoning yields for the measure of magnetic susceptibility.

The field investigation includes both lineaments interpreted from ground geophysics and larger scale topography /4/ as well as interpretation from aerial orthophotos and detailed digital terrain models (LIDAR data, the present activity). It also comprises a selection of zones for excavation and a brief geological characterization of selected excavated rock.

During the progress of this activity, the previously interpreted lineaments in topographic data and geophysical data /9, 10/ have been re-evaluated by Geovista AB, Luleå /4/, when the LIDAR data and new ground geophysical data became available and permitted a higher resolution in the interpretations.

3 Execution

3.1 Lineament detection

A method has been developed in order to automatically extract the outlines of the geomorphological domains in reference to small-scale topography. In the literature this normally is referred to as the terrain skeleton or the break lines of the terrain /11, 12/.

The fundamental theory behind this process is that the terrain skeleton as the network of ridges and valleys is an important expression of the structural geology of the landscape.

It expose watersheds, show drainage networks, ridge lines, breaks in slope, etc.

To automatically, and thus objectively, outline the terrain skeleton has been considered important in order to secure that all present linear features take part in the analysis. For interpretation purposes, the skeletal lines may be combined with other display methods such as contour lines or shading on order to improve the visual interpretation of the topographic shape.

The primary input to the skeletonizing procedure is the digital elevation model (DEM). The DEM is a surface representation where heights can be presented either as a colour grid layer (e.g. a greyscale colour ramp) or elevation contours, a relief can be analytically shaded, etc (Figure 3-1).

The results of the analytical hillshade depend on the incidence angle of the light source – the resulting value equals the cosine of the angle between the normal vector to the surface and the vector in the direction of the light source. The analytical hill shade is controlled by the azimuth (the direction of the light regarding the north), and the zenith distance (the angle above the horizontal plane). A shade effect is more expressive, when zenith distance is large (over 70°).

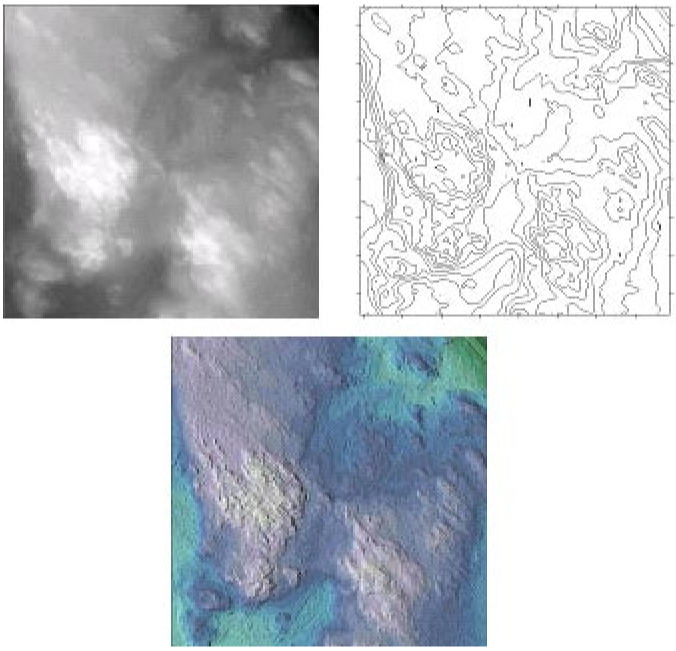

Figure 3-1. *Digital elevation model (DEM) presented as greyscale grid, elevation contours and as an analytical shaded relief.*

It is also necessary to perform the analytical hill shade from different azimuths (Figure 3-2), because only the features that are approximately perpendicular to the direction of light source are clearly detected.

Terrain skeleton features are characteristic lines (ridges, ravines) and points (peaks, sinks and saddles). The most important parameters, which define a terrain skeleton feature, are sudden changes of heights, which lead to either aspect changes or slope changes.

For the extraction of local minima (i.e. ravines, sinks etc) a method originally developed for hydrological analysis have been used /13/. The method calculates the "runoff" by reducing the effects of local minima thus ensuring that the accumulated runoff units reach the boundaries of the surface.

Using low-pass filters /14/ the terrain model can be filtered to derive the valley structures at certain scales. In Figure 3-3 the structural components at full resolution without using a cut-off frequency at certain scale is visualised.

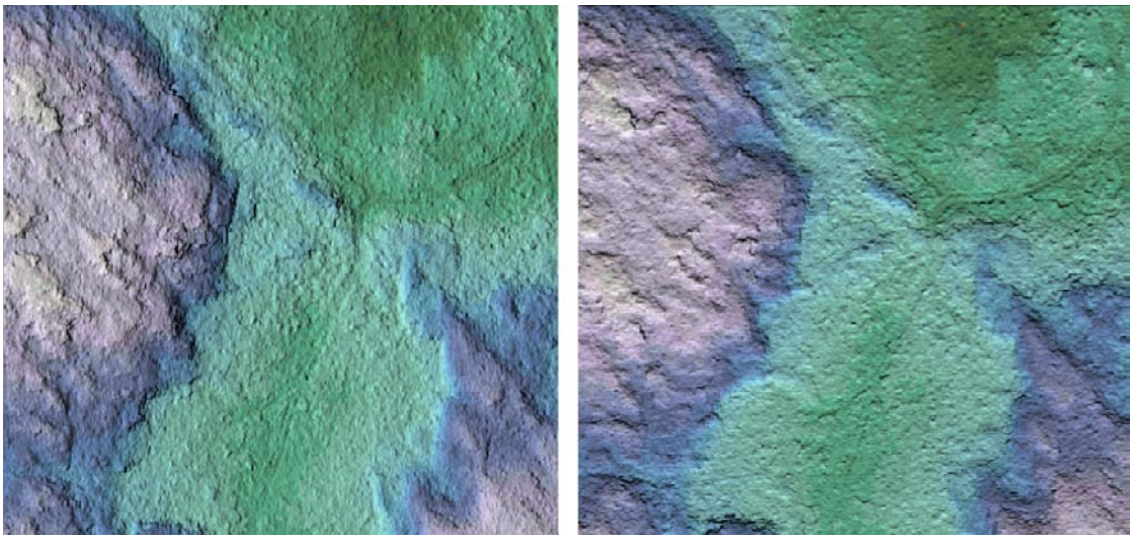

Figure 3-2. *Analytically shaded DEM (zenith distance 45°, azimuth 270° and 180°) in the area of 150 by 150 metres.*

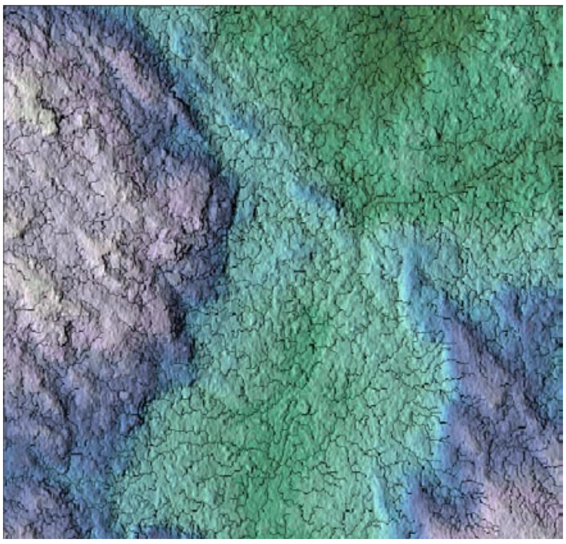

Figure 3-3. *Example of extracted valleys without using a cut-off frequency (the area is 150 by 150 metres). The image in the background is the shaded relief.*

To extract valley structures at a scale suitable to the focus of this study, a low-pass filter of 61×61 grid elements /15/ have been found relevant (15 metres when the cut-off is expressed in metres).

The lines associated to escarpments are extracted from a shaded DEM using an edge detection technique. Every shaded layer has to be filtered using a Sobel filter /15/ in order to detect edges (Figure 3-4). Furthermore, an overly, which extracts the maximum edge value for every input cell of all the filtered layers, has to be done. Resulting raster layer carries information about the potential for terrain skeleton features associated to escarpments.

The selection of lineaments to include in the fieldwork is a somewhat intuitive work, based on perceptive empiric experience from previous similar work in the area /7/. The techniques described in the previous text and the maps derived from this are used as an aid in order to be as consistent as possible. Some guidelines for the selections are given here.

The lineaments that are interpreted in this activity and to be examined in the fieldwork are distinct linear features, whereas undulating, bent or curved features are separated into shorter linear segments or omitted. Very short linear features (~ 5 metres) are included only if they represent a significant topographic relief. Features with a small topographic relief (less than 0.5–1 metre) are included as lineaments only if they are fairly long and straight and thus apparent in the images.

The lineament interpretation will still be somewhat biased by a subjective judgment of what should be included or not.

3.2 Field investigation around KLX09 and KLX10

During the fieldwork a handheld computer is used, containing raster and vector data from the lineament interpretation. The data is shown graphically on the computer screen together with the present position (GPS with ± 5 m at good condition). Although the uncertainty and fluctuation of the GPS positioning is rather large in the forest, the practical uncertainty of the positioning can normally be held within a radius of less than 1–2 metres with help from the high resolution analytical shaded relief image. A geological hammer and a magnetic susceptibility meter (GF Instruments SM-20) are used as an aid to characterise geological features.

Basically all outcropping bedrock in the investigated areas (Figure 3-5) is scrutinized for geological structures, not only the interpreted lineaments. Locally, relevant linear geological structures can be found even though they do not show up as a lineament on the LIDAR data

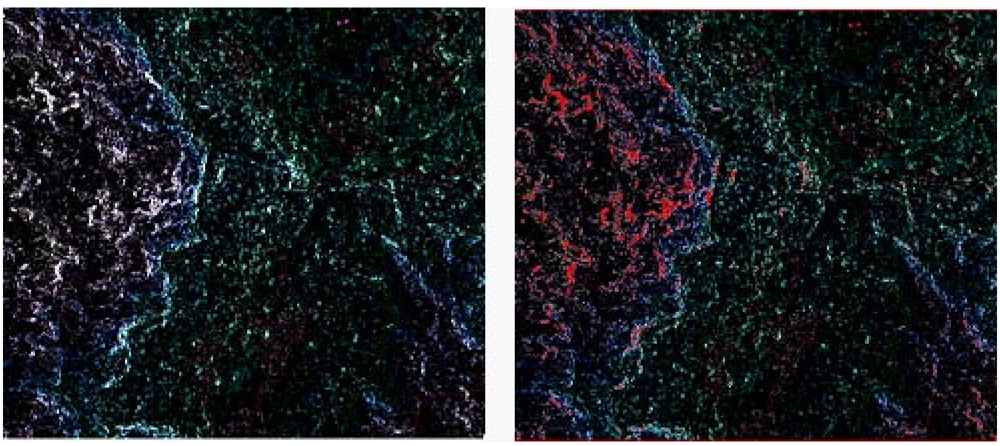

***Figure 3-4.** Results of edge detection from analytically shaded DEM (azimuth 270°; red presents edges), overlaid (maximum edge value) layers and layer of binary classified edges in the area of 150 by 150 metres.*

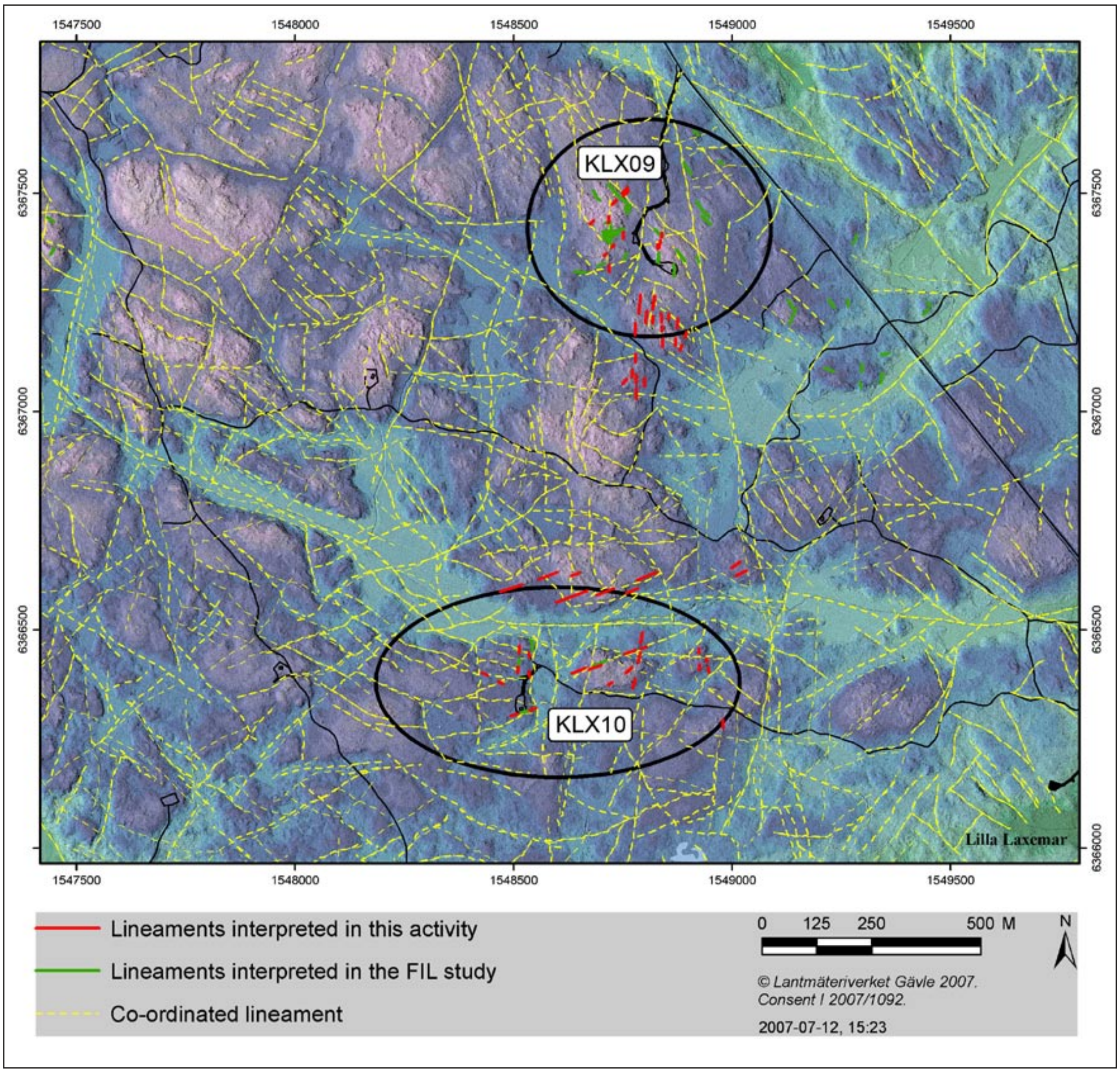

Figure 3-5. *The two general areas selected for this study are encircled in black together with lineaments in the areas. Green lines represent lineaments interpreted in the FIL study /7/. Dashed yellow lines are co-ordinated lineaments available at the start of this activity /4/. Red lines mark lineaments interpreted in this activity, or rather the extension of lineaments in order not to hide their visual expression in the image. The background is the analytical shaded relief.*

(or in geophysical data). Relevant structures in this respect are fault-rock related in one way or another. This include ductile shear zones, brittle-ductile shear zones, brittle fault zones and even single fractures or clusters of a few parallel fractures. Other rocks or structures that can be correlated with interpreted lineaments, such as dykes and rock boundaries, were also looked for during the fieldwork. In this way a brief characterization of the lineaments were done.

3.3 Excavation of selected rock

Three deformation zones were selected for excavation close to KLX09, based on the findings during the fieldwork. Two of them can be related to lineaments identified in magnetic data and all three are to some degree related to lineaments that can be detected in the LIDAR data. At the scale they are viewed in the field they may all qualify as Local Minor Deformation Zones, but since at least the magnetic lineaments related to two of them are long they may possibly also qualify within other categories of deformation zones. It is, however, out of the scope of this activity to decide which category they finally should be related to.

One of the zones around KLX09 was excavated and cleaned more utterly (see Figure 3-6a), with both pressurised air and water. The zone is named MDZNS019A. The excavation was mapped along two scan-lines, in accordance with SKB MD 132.003. The length of the fractures was, however, not measured. Also the magnetic susceptibility was measured along these two lines. With the distance of approximately one metre along the line, 8 measurements were conducted, in order to get an average value that may be regarded as more representative than just a single measurement.

Just one area was selected for excavation around KLX10. Few indications of deformation zones were found in the LIDAR and during the field investigation. Instead interest was placed on the frequent east-west trending magnetic lineaments in the area. One such lineament is located in a narrow trough (see Figure 3-6b), with an expected shallow depth to the rock surface. This site was chosen for excavation and a scan-line mapping and measurement of the magnetic susceptibility was performed in the same way as described above for the excavation close to KLX09.

The areas to excavate were initially chosen in order to expose the full width of the zones along a distance of ca 5–10 times its width. Local environmental matters were, however, also considered in order to minimize the damage on vegetation.

The result of the lineament interpretation and consecutive field survey is documented in the GIS layers with assigned attributes to lineaments that are related to geological features in the field, as described in Table 3-1.

The values used in the geology field are abbreviated. Used abbreviations are explained in Table 3-2.

3.4 Documentation of excavated rock

This document gives information regarding the scope, execution and documentation of the work.

The measurements and other new data produced in this activity is delivered to SKB as GIS (Arcview) or in protocols designed by SKB for SICADA input.

The new, excavated rock exposures are generally documented by digital photos, without geometric information. Line mapping of rock types and fractures were conducted along two profiles

Table 3-1. List of parameters assigned to lineaments in this activity.

Name of attribute	Values	Comment
ID	n.a.	Identities have not been assigned to the individual lineaments
Lenght	Length in metre of interpreted lineament	Measured in metre with 1 decimal
Orientation	Orientation of lineament	0–180°, RT90, 2.5 Gon west
Geology	Geological structure indicated in the field	0–360°
Strike/dip	Strike end dip of structure, measured in the field	0–360/0–90, right hand rule
Suscept_in	Approximate average measured in the structure	
Suscept_out	Approximate average measured outside the structure	

Table 3-2. Abbreviations used in the parameterisation.

Abbreviation	Meaning
fg granite	Fine grained granite
bdsz	Brittle ductile shear zone
frac. zone	Fractured zone

across the zone MDZNS019A and along the excavated trench close to KLX10. In each rock type along these profiles the magnetic susceptibility was measured at eight spots, in order to get an indication of the representative value.

A large part of the excavated area at MDZNS019A was documented with high-resolution photos, from which a close-range orthophoto was produced (See Chapter 4). A selected part of this photo was also converted to a detailed digital terrain model. The photo and terrain model is delivered to SKB as digital images, as GIS layers and as Microstation design files (dgn-format).

With the digital terrain model, orthophoto and field notes as a basis a brief geological map and fracture map was produced (See Chapter 4).

3.5 Supplementary investigations

Three cored boreholes were drilled through two of the excavated zones close to KLX09. They are located according to Figure 3-6a. The drillings are part of separate activities and the mapping (Boremap) are thus reported elsewhere /16, 17/. Close to KLX10 two boreholes (KLX10B and KLX10C) where drilled towards lineaments, as shown in Figure 3-6b. The results from the mapping of KLX10B and KLX10C are also reported elsewhere /16/.

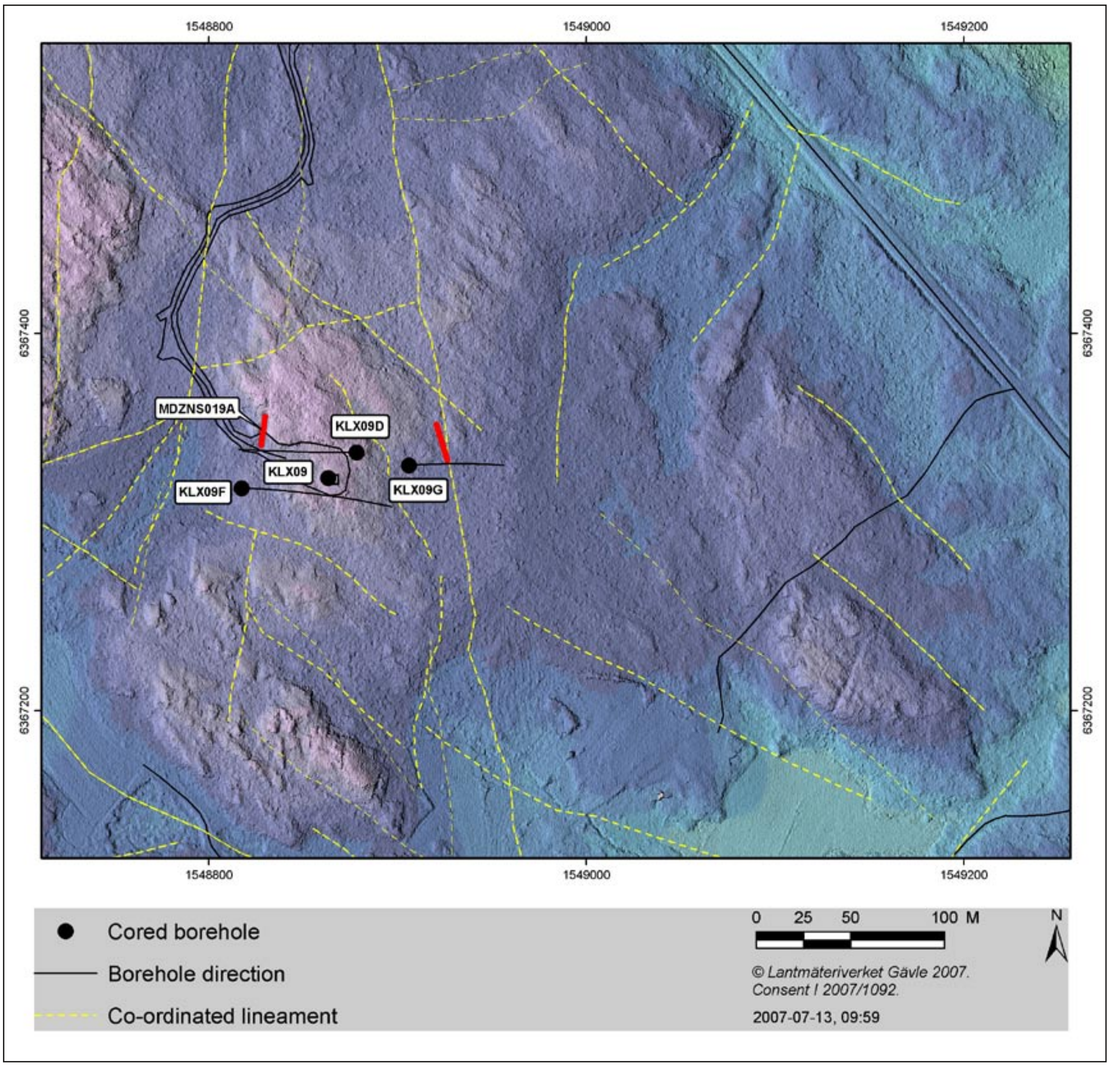

Figure 3-6a. *Background: shaded relief created from LIDAR data. The boreholes KLX09D and KLX09F penetrate the zone MDZNS019A. A red line marks excavated part of the zone. KLX09G was drilled towards another, longer north-south deformation zone (excavated part marked with red line).*

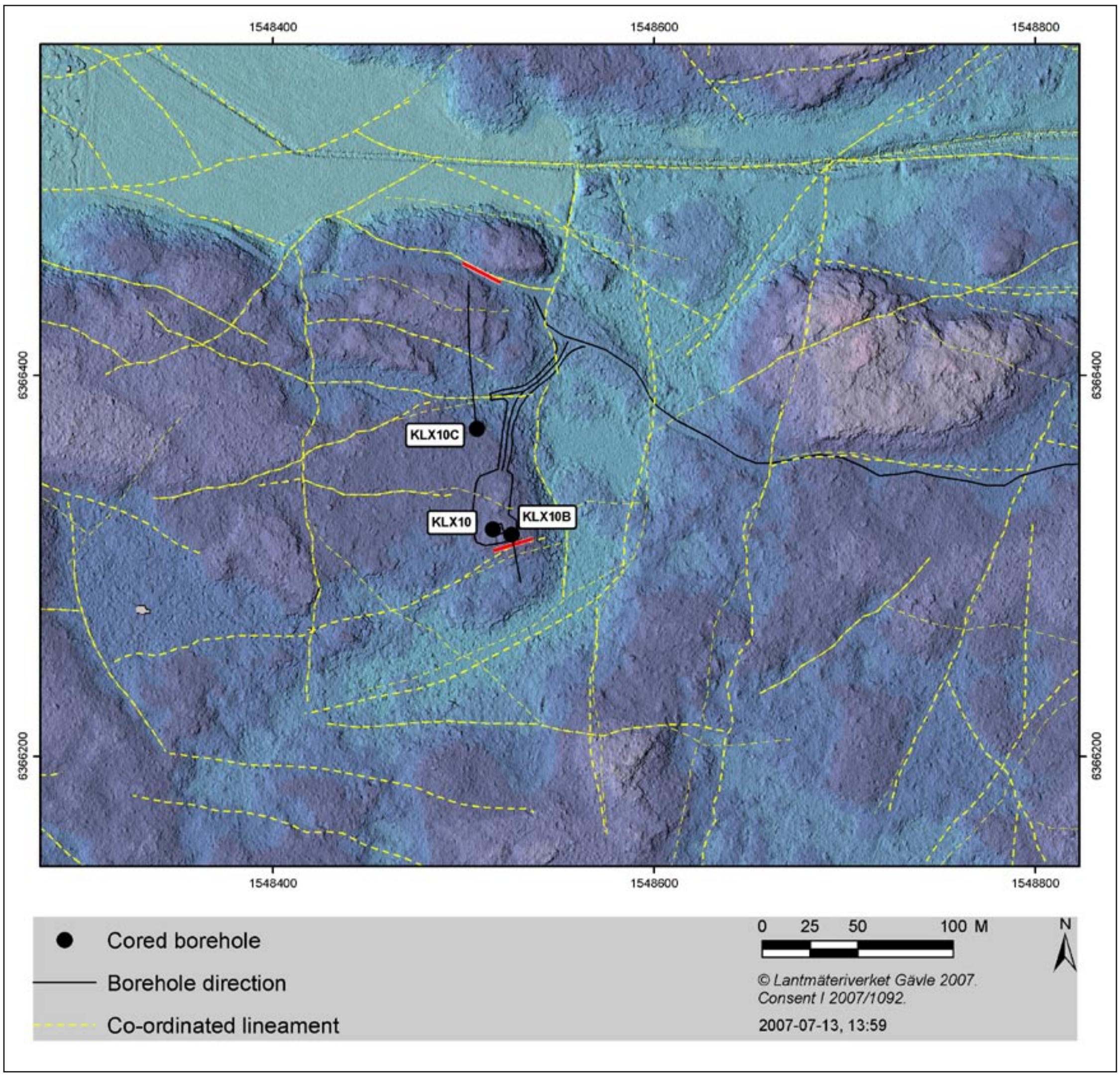

Figure 3-6b. *Background: shaded relief created from LIDAR data. The borehole KLX10B was drilled towards a NE-SW striking lineament just south of KLX10. The rock in this area, which outcrops along the red line, is a fine-grained granite. The borehole KLX10C crosses several lineaments and was also aimed to penetrate a south-dipping structure located in the excavated part of an E-W lineament north of the borehole (marked with red line).*

4 Results

Results from the lineament interpretation and the successive fieldwork are presented in this chapter. Interpreted lineaments can also be found as GIS material, where assigned attributes to the lineaments, if present, are found in the GIS database.

4.1 Lineament interpretation and field survey

42 new lineaments have been included from the interpretation of LIDAR data and are marked with red lines in Figure 4-1a and 4-1b. Assigned attributes to the lineaments are found in Appendix 1 and described in Table 3-1. For most lineaments, however, there is just a brief information regarding kind of geological structure. The lineaments have not been given an explicit identity, so the relation between attribute and lineament can only be found in the GIS. During

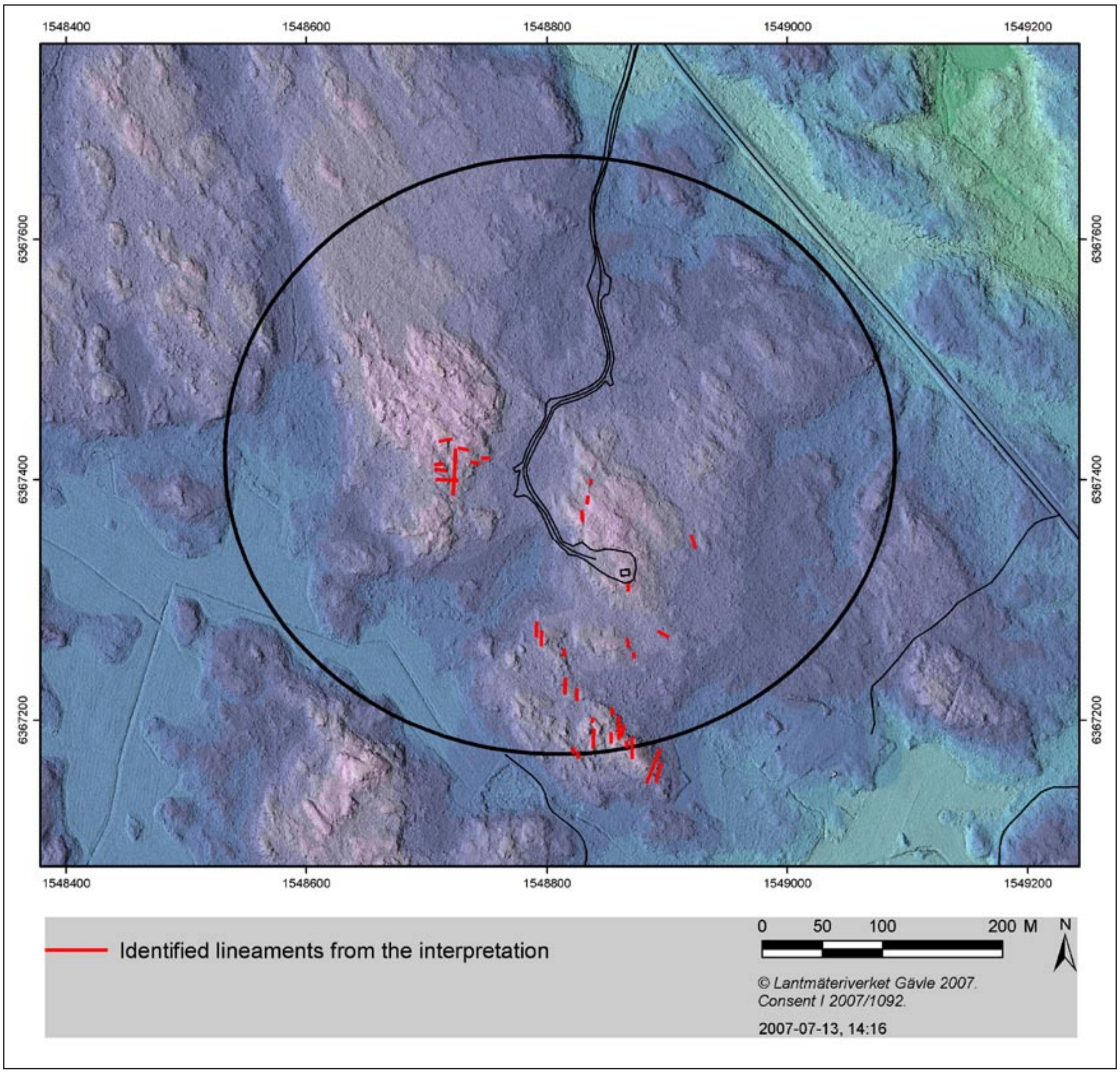

Figure 4-1a. *Background: shaded relief created from LIDAR data. Area around KLX09. The red lines represent new identified lineaments in this activity, checked in the field.*

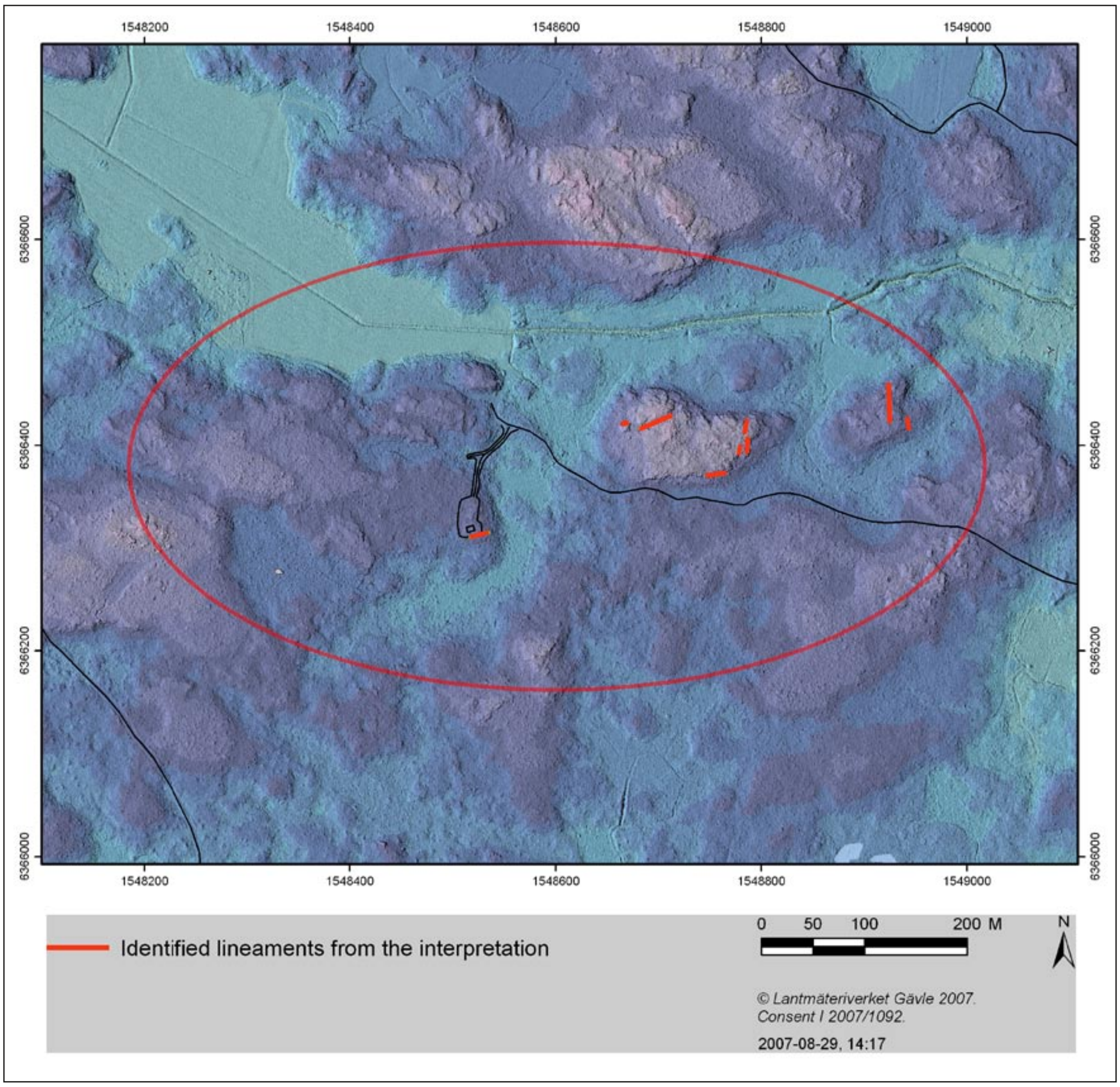

Figure 4-1b. *Background: shaded relief created from LIDAR data. Area around KLX10. The red lines represent new lineaments in this activity, checked in the field.*

this activity we have used an early version of the lineaments presented in /4/, since that activity was contemporaneous with the present. For this reason some of the lineaments in the illustrated in the figures below may not be exactly the same as those found in /4/.

In Figures 4-2 and 4-3 the lineaments detected in this work have been colour coded to separate between different geological features.

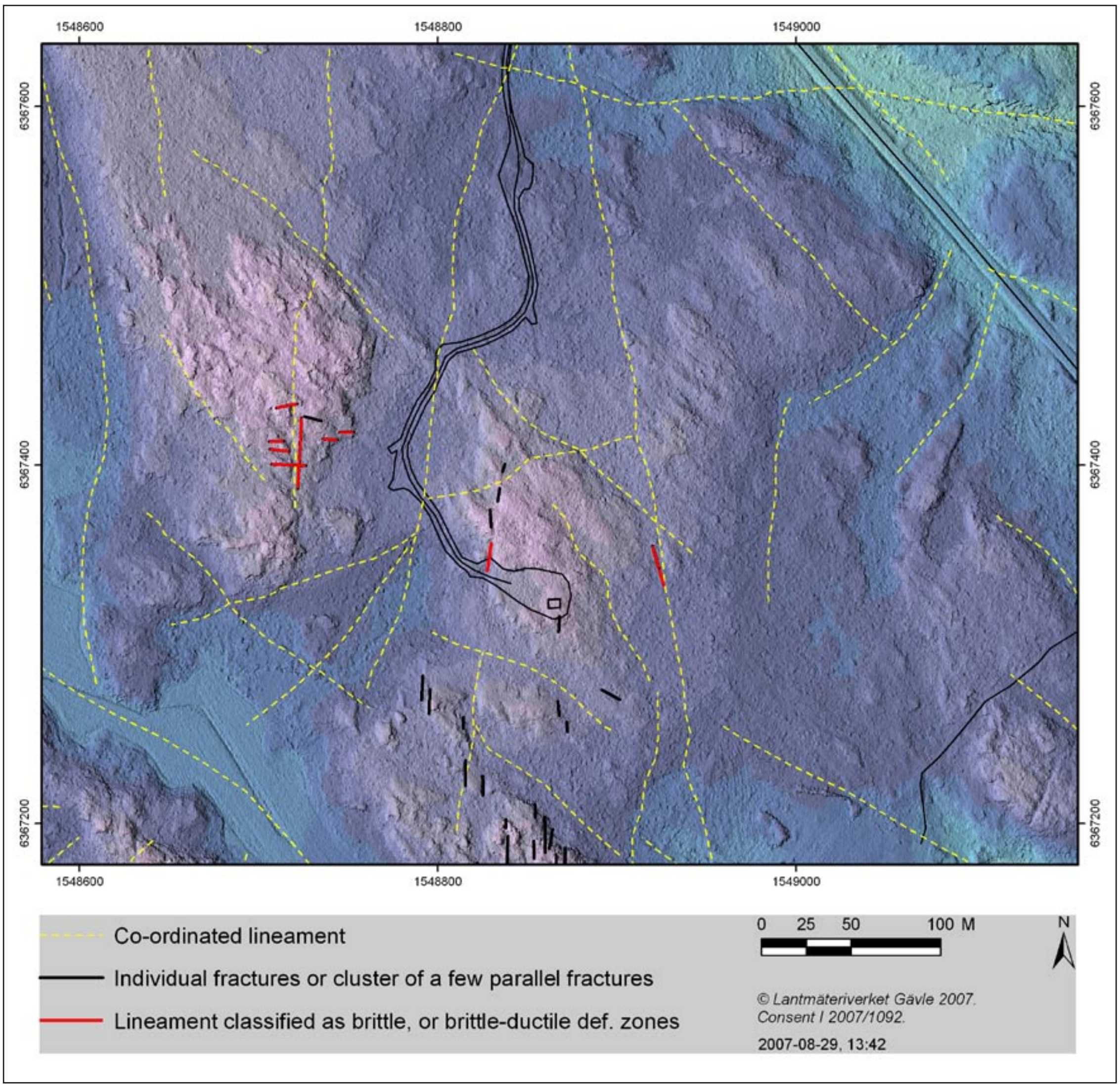

Figure 4-2. *Background: shaded relief created from LIDAR data. Area around KLX09 with colour coded lineaments. Black lines represent lineaments classified in the field as individual fractures or a cluster of a few parallel fractures and red lines represent lineaments classified as brittle, or brittle-ductile deformation zones. Dashed yellow lines are co-ordinated lineaments available at the start of this activity.*

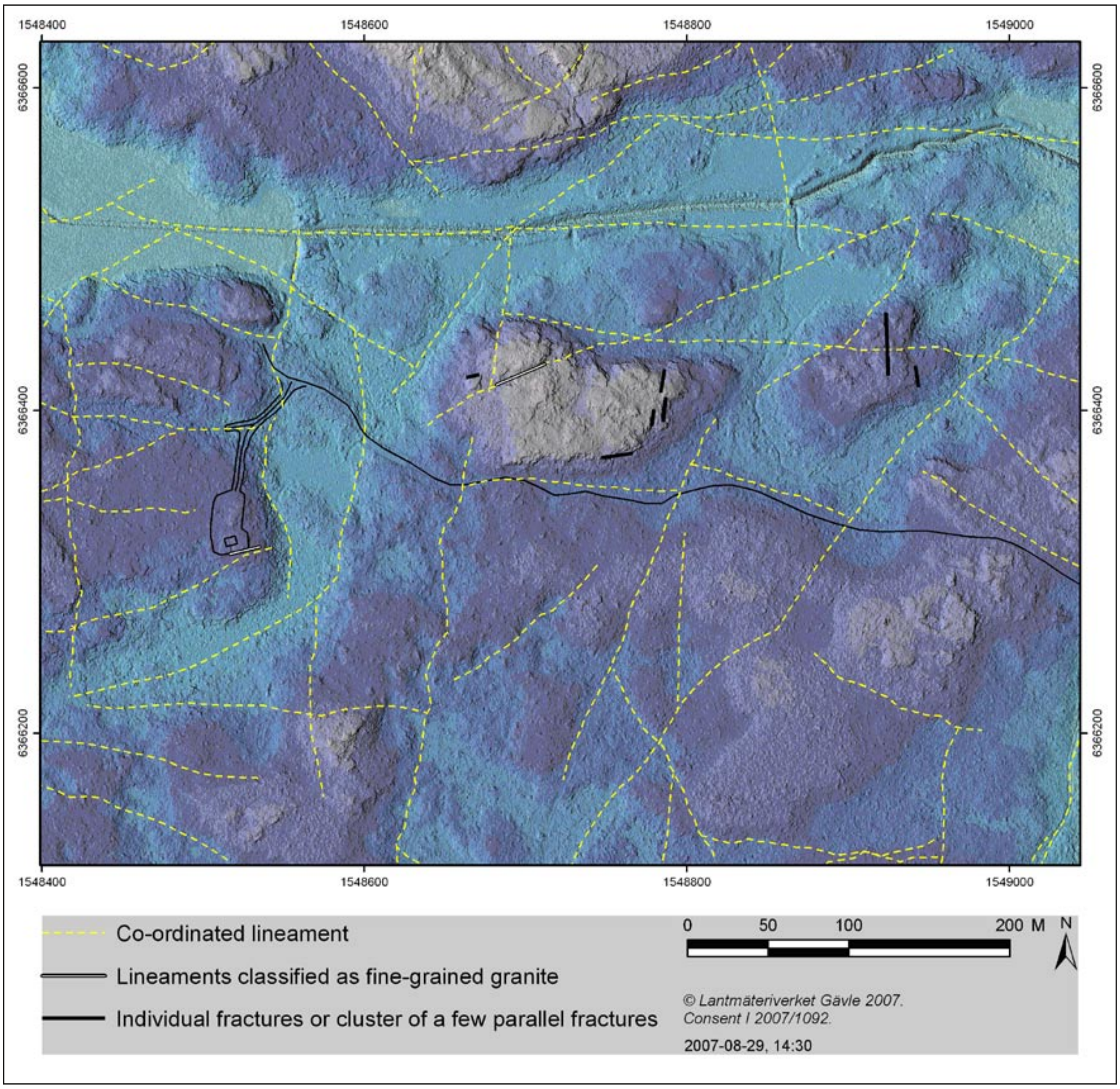

Figure 4-3. *Background: shaded relief created from LIDAR data. Area around KLX10 with colour coded lineaments. Black lines represent lineaments classified in the field as individual fractures or a cluster of a few parallel fractures and white lines represent lineaments classified as fine-grained granite. Dashed yellow lines are co-ordinated lineaments available at the start of this activity.*

4.2 Excavations

The result from the two scan-line mappings (LSM000581 and LSM000582) from excavation close to KLX09 and the scan-line mapping from the excavation close to KLX10 (LSM000583) are appended as tables (Appendix 2) and illustrated in Figures 4-6 to 4-11. The orientations of measured fractures and magnetic susceptibility are graphically illustrated in Figures 4-8 and 4-9.

The two easterly-excavated zones in Figure 4-4 have also been drilled upon. The zone closest to KLX09 (central black arrow in Figure 4-4, MDZNS019A) is penetrated close to the surface by two cored boreholes (KLX09D and KLX09F) just south of the excavation. The boreholes were

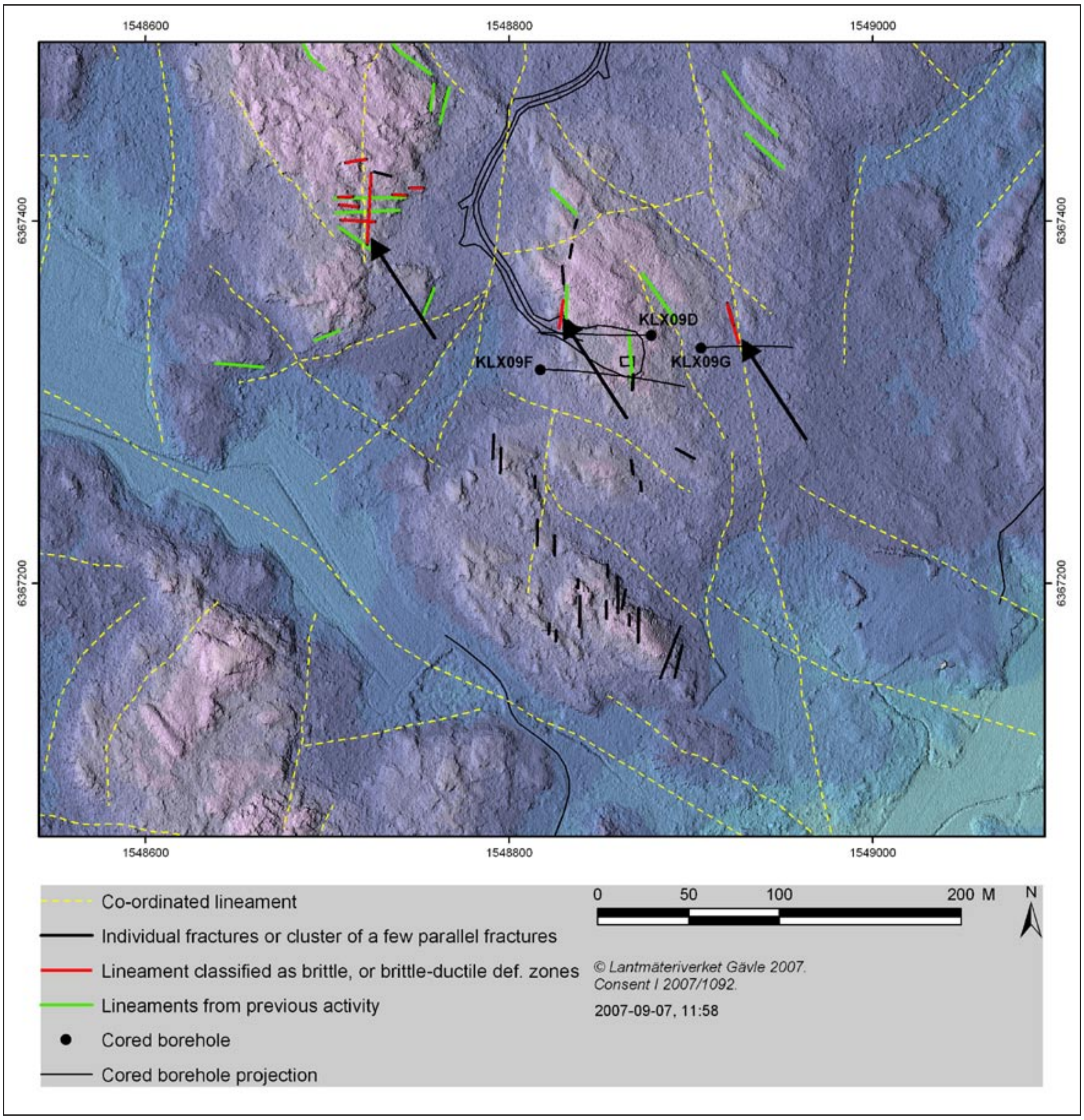

Figure 4-4. *Background: shaded relief created from LIDAR data. The area around KLX09. The black arrows are pointing at the locations of excavated areas. Red and black lines represent lineaments interpreted and examined in the field in this activity, whereas green lines are lineaments from a previous activity /4/. Dashed yellow lines are co-ordinated lineaments available at the start of this activity.*

mapped in Boremap as part of the regular site investigation activities, but an overview mapping was also made within the present activity of the two passages across the deformation zone in the drill-cores. The latter mappings are appended as WellCad plots (Appendix 3).

The lineament just south of KLX10 coincides in this area with a dyke of fine-grained granite, approximately 4 metres wide. The cored borehole KLX10B is inclined towards the south and penetrates this dyke. The cored borehole KLX10C, between KLX10 and the black arrow in Figure 4-5 is inclined towards the north, in order to penetrate possible deformation zones along the east-west trending lineaments in this area (yellow dashed lines).

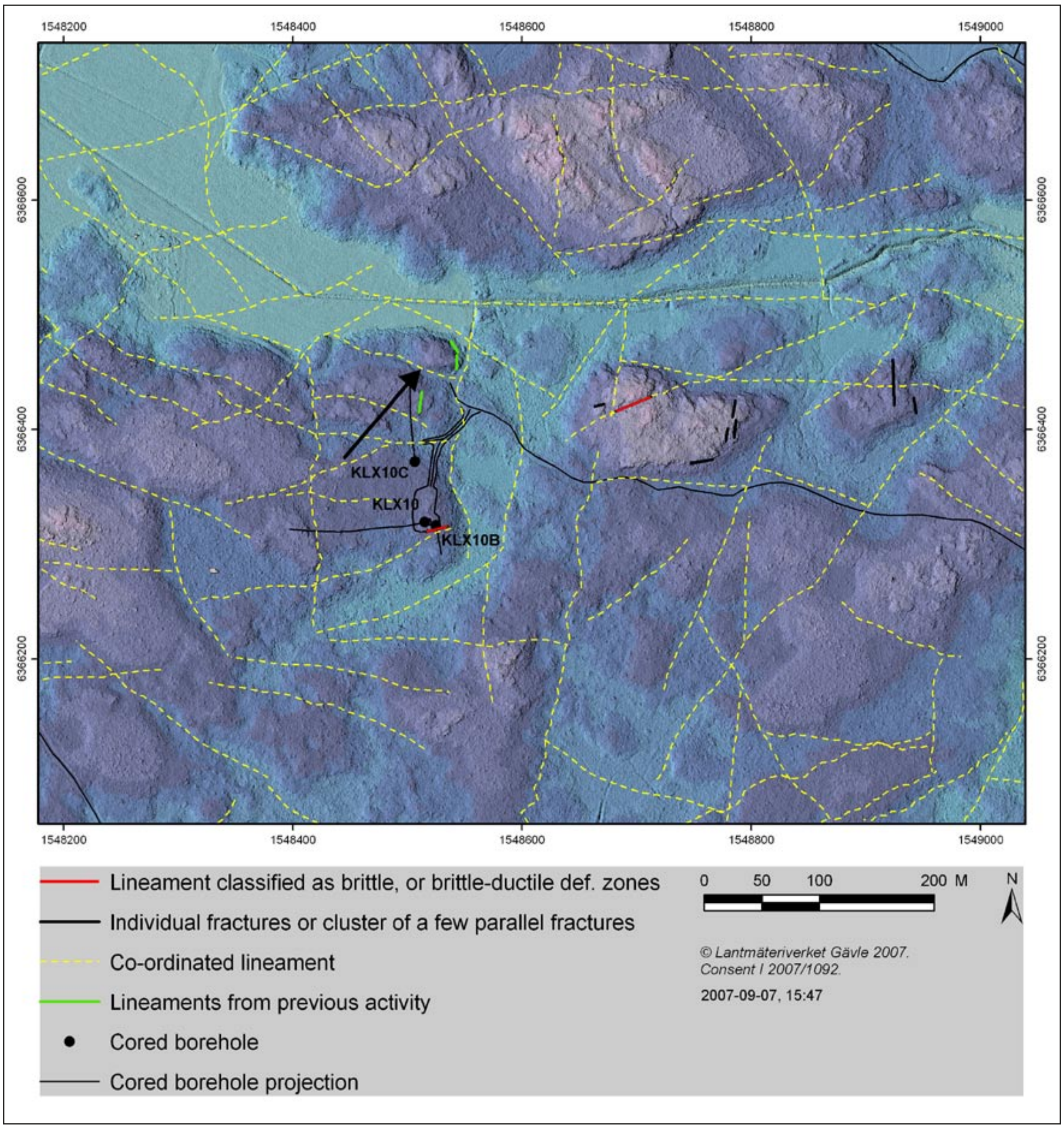

Figure 4-5. *Background: shaded relief created from LIDAR data. The area around KLX10. The black arrow is pointing at the location of the excavated area (cf. Figure 4-13). Red and black lines represent lineaments interpreted and examined in the field in this activity, whereas green lines are lineaments from a previous activity /4/. Dashed yellow lines are co-ordinated lineaments available at the start of this activity.*

4.3 Examples on zone characterization and documentation

In the following some examples are given on how documentation may be done of exposed geology. See also Appendices 2 and 3. In order to get a good geological characterization of each specific section across a deformation zone, however, a detailed geological mapping, including lithological, mineralogical, geochemical and kinematic studies should be done. Such detailed investigations are not within the scope of the present activity.

First, examples from an excavated outcrop close to KLX09 are shown (zone MDZNS019A, Figures 4-6 to 4-11), followed by examples from an excavated outcrop close to KLX10 (Figures 4-12 and 4-13). See figure captions for details.

The deformation zone (MDZNS019A) has not been strictly defined on the outcrop or in the boreholes penetrating it and there are no clear-cut boundaries between deformation zone and undeformed rock. For this reason thee are no exact levels for the deformation zone in the boreholes, but examples on what the deformation of the rock look like at the approximate levels where the zone is penetrated can be seen in Figures 4-10 and 4-11. In KLX09D deformation along the zone is found between core length 81 and 90 metres (Figure 4-10). In KLX09F it is located between 8 and 18 metres core length (Figure 4-11).

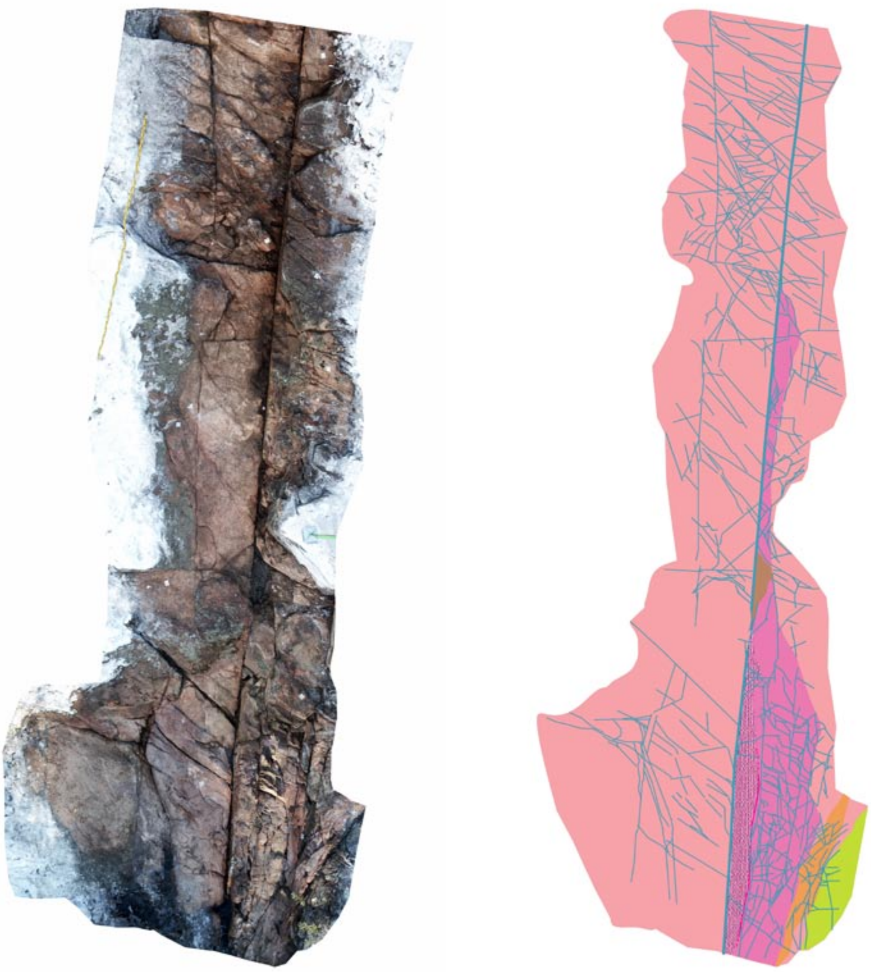

Figure 4-6. *Example of documentation from the excavated zone MDZNS019A (North is upwards in the figure and the width of the outcrop is approximately 4 metres). On the left a high-resolution photographic image, that has been transformed to a close-range orthophoto. To the right a geologic map (schematic) showing fractures as blue lines and the rock types in different colours (pink = Ävrö granite, purple = fine-grained granite, orange = pegmatite, green = gabbro, brown = soil covered). A more intensely fractured part of the fine-grained granite is marked by a hatch pattern, bounded to the east by a fine-grained cataclastic rock (2 cm wide, dark purple in the figure).*

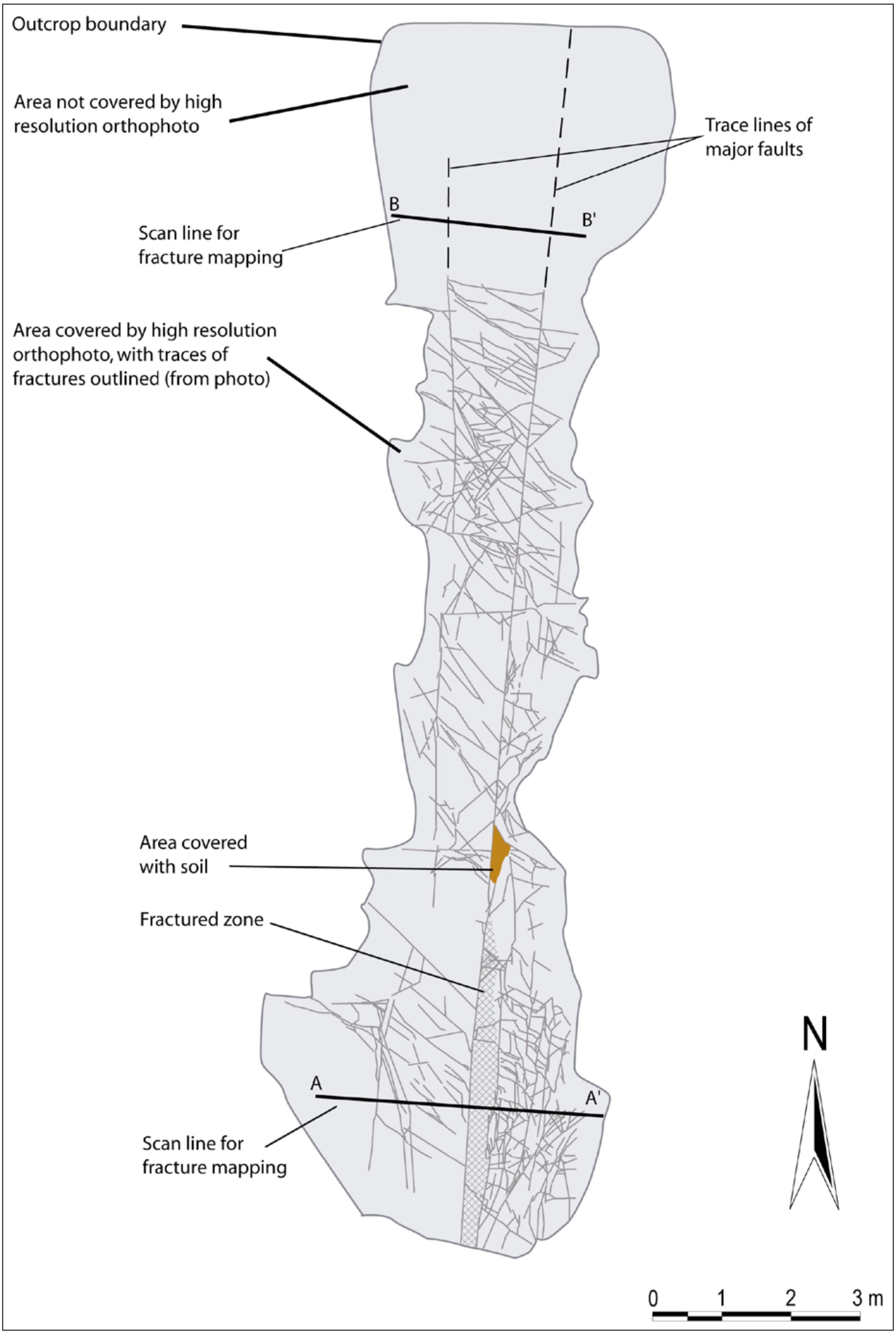

Figure 4-7. *Excavated area (same as in Figure 4-6) with location of mapped scan-lines.*

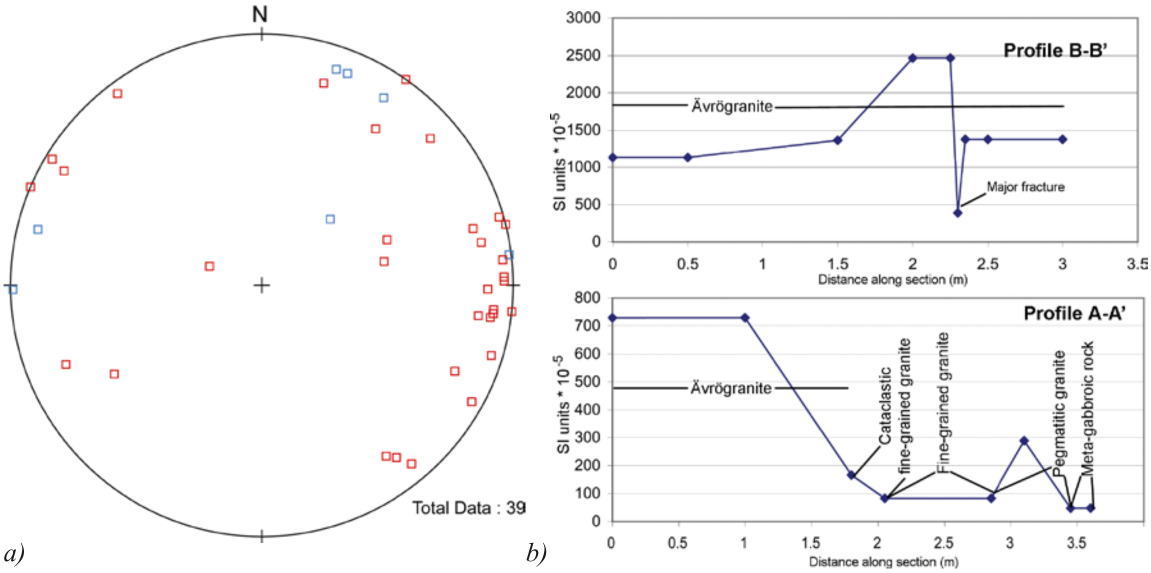

Figure 4-8. *a) Stereographic plot of measured fractures along the two scan-lines across the deformation zone shown in Figure 4-7. Red symbols are from line A-A' and blue from B-B'. Plots represents pole to planes, right-hand rule, lower hemisphere, equal area. b) Magnetic susceptibility along the two profiles shown in Figure 4-7.*

Figure 4-9. *Photos of excavated rock around fracture zone MDZNS019A taken from north (left) and south (right), respectively.*

Figure 4-10. *Deformation, ductile and brittle, as it appear at the probable location of the deformation zone MDZNS019A as it appears in KLX09D (left: c 85.5 metres and right: ca 88 metres core length).*

Figure 4-11. *Cataclastic deformation from probable location of the deformation zone MDZNS019A as it appears in KLX09F (ca 9 metres core length).*

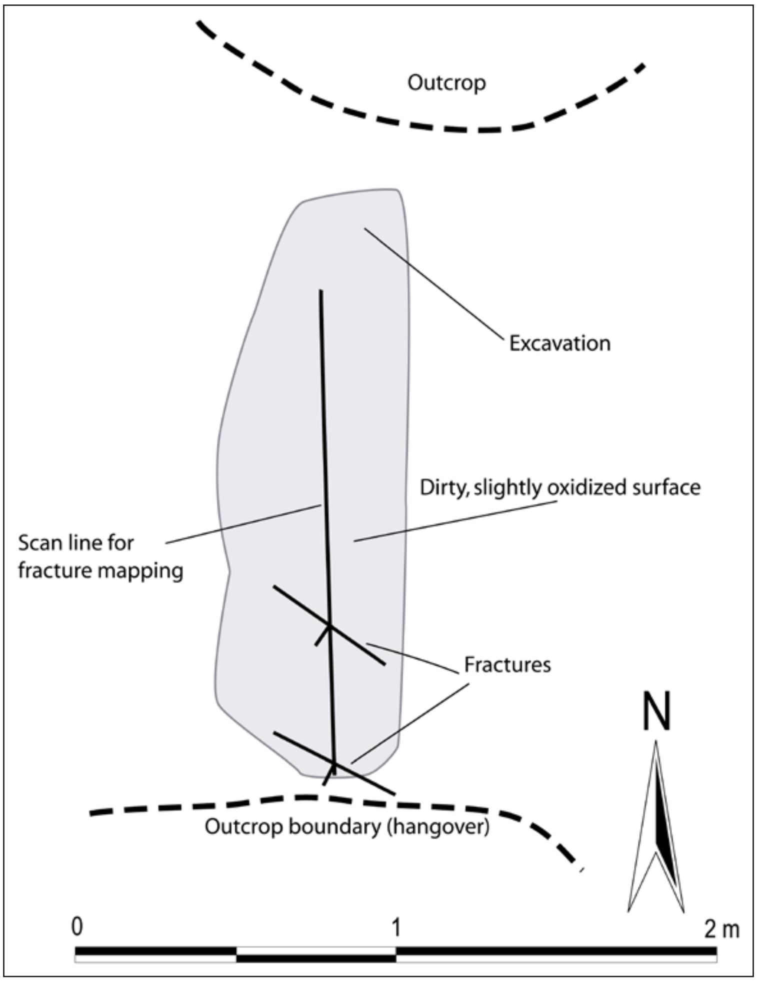

Figure 4-12. *Excavated area (same as in Figure 4-11) with location of mapped scan-lines.*

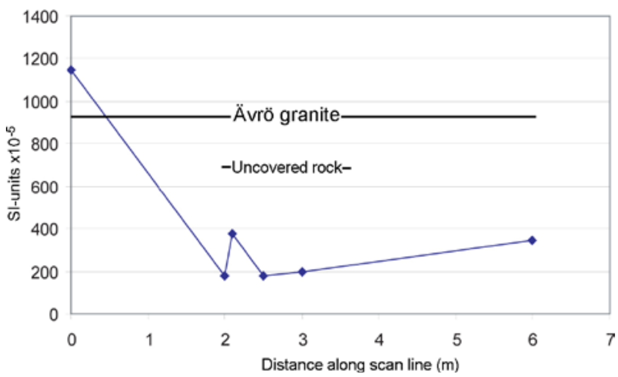

Figure 4-13. *Photo from the scan-lines close to KLX10 (left). There are only two fractures here, both dipping gently to the south. Magnetic susceptibilty along the scan-line (right) shown in Figure 4-10.*

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Appendix 1

Lineaments attribute table

Id	Length	Orientation	Geology	Strike/dip	Suscept_in	Suscept_out
n.a.	33.7	69	fg granite		30	400
n.a.	8.2	77	fracture/frac.zone	260/85	0	0
n.a.	16.3	178	fracture/frac.zone	10/85	0	0
n.a.	14.6	9	fracture zone	15/90	50	200
n.a.	19.8	79	fracture/frac.zone	80/80	0	0
n.a.	10.6	9	fracture/frac.zone	10/90	0	0
n.a.	39.4	178	fracture/frac.zone	350/85	0	0
n.a.	18.9	76	fg granite		45	1,200
n.a.	12.5	163	bdsz		0	0
n.a.	8.1	94	fracture/frac.zone		0	0
n.a.	7.9	90	fracture/frac.zone		0	0
n.a.	9.6	103	fracture/frac.zone		0	0
n.a.	11.7	80	fracture/frac.zone		0	0
n.a.	39.1	3	fracture/frac.zone		0	0
n.a.	19.1	93	fracture/frac.zone		0	0
n.a.	10.6	97	fracture/frac.zone		0	0
n.a.	7.7	89	fracture/frac.zone		0	0
n.a.	9.7	176	fracture		0	0
n.a.	7.6	9	fracture		0	0
n.a.	4.4	16	fracture		0	0
n.a.	8.7	3	fracture		0	0
n.a.	8.0	171	fracture		0	0
n.a.	5.5	174	fracture		0	0
n.a.	11.3	119	fracture		0	0
n.a.	30.8	21	fracture		0	0
n.a.	18.0	13	fracture		0	0
n.a.	18.8	1	fracture		0	0
n.a.	9.5	180	fracture		0	0
n.a.	6.9	178	fracture		0	0
n.a.	19.7	180	fracture		0	0
n.a.	10.8	11	fracture		0	0
n.a.	6.4	179	fracture		0	0
n.a.	16.9	2	fracture		0	0
n.a.	4.7	2	fracture		0	0
n.a.	6.1	1	fracture		0	0
n.a.	5.9	3	fracture		0	0
n.a.	10.8	179	fracture		0	0
n.a.	14.2	1	fracture		0	0
n.a.	6.4	0	fracture		0	0
n.a.	13.6	2	fracture		0	0
n.a.	13.4	3	fracture		0	0
n.a.	13.3	171	fracture/frac.zone	165/90	0	0

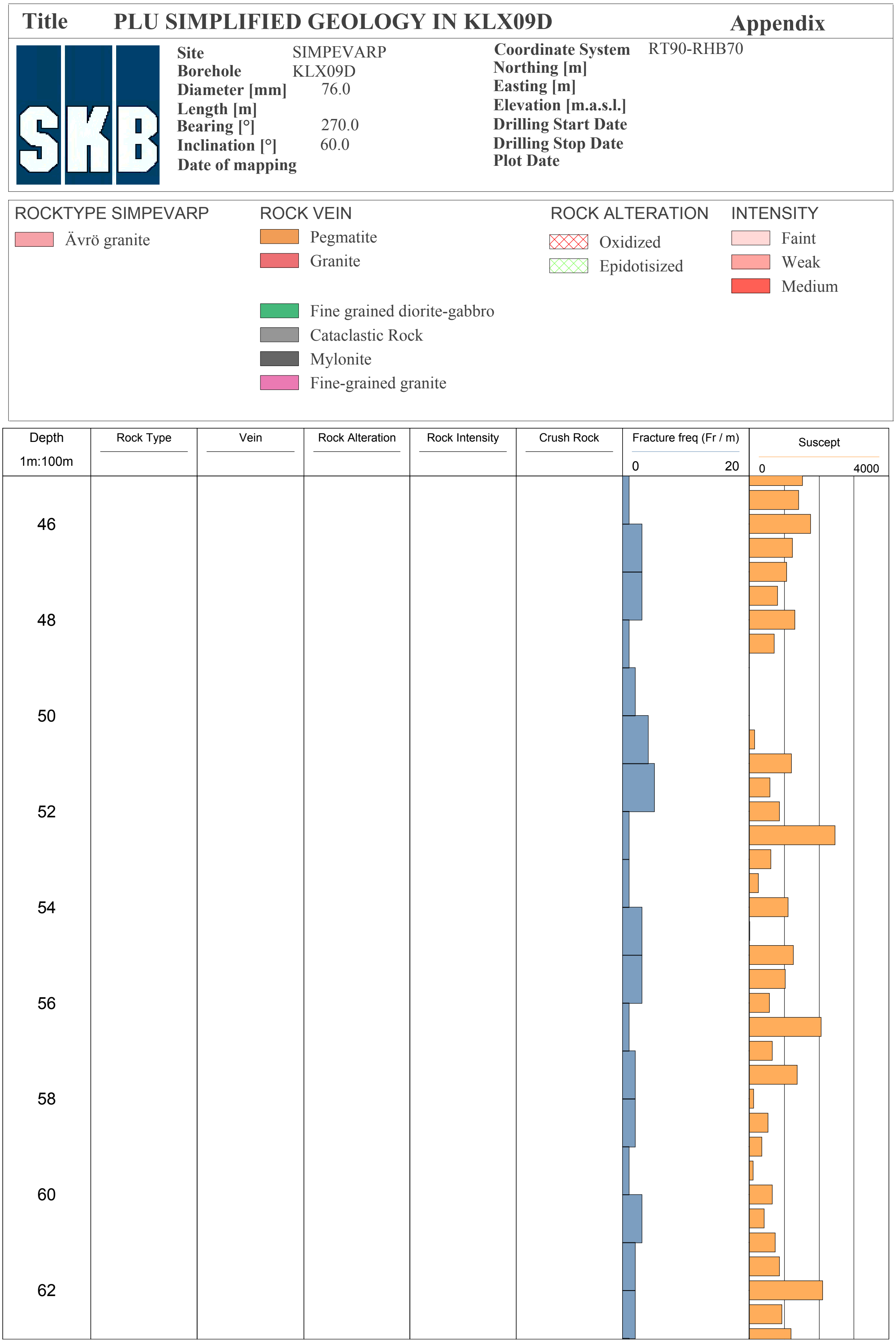
Appendix 2

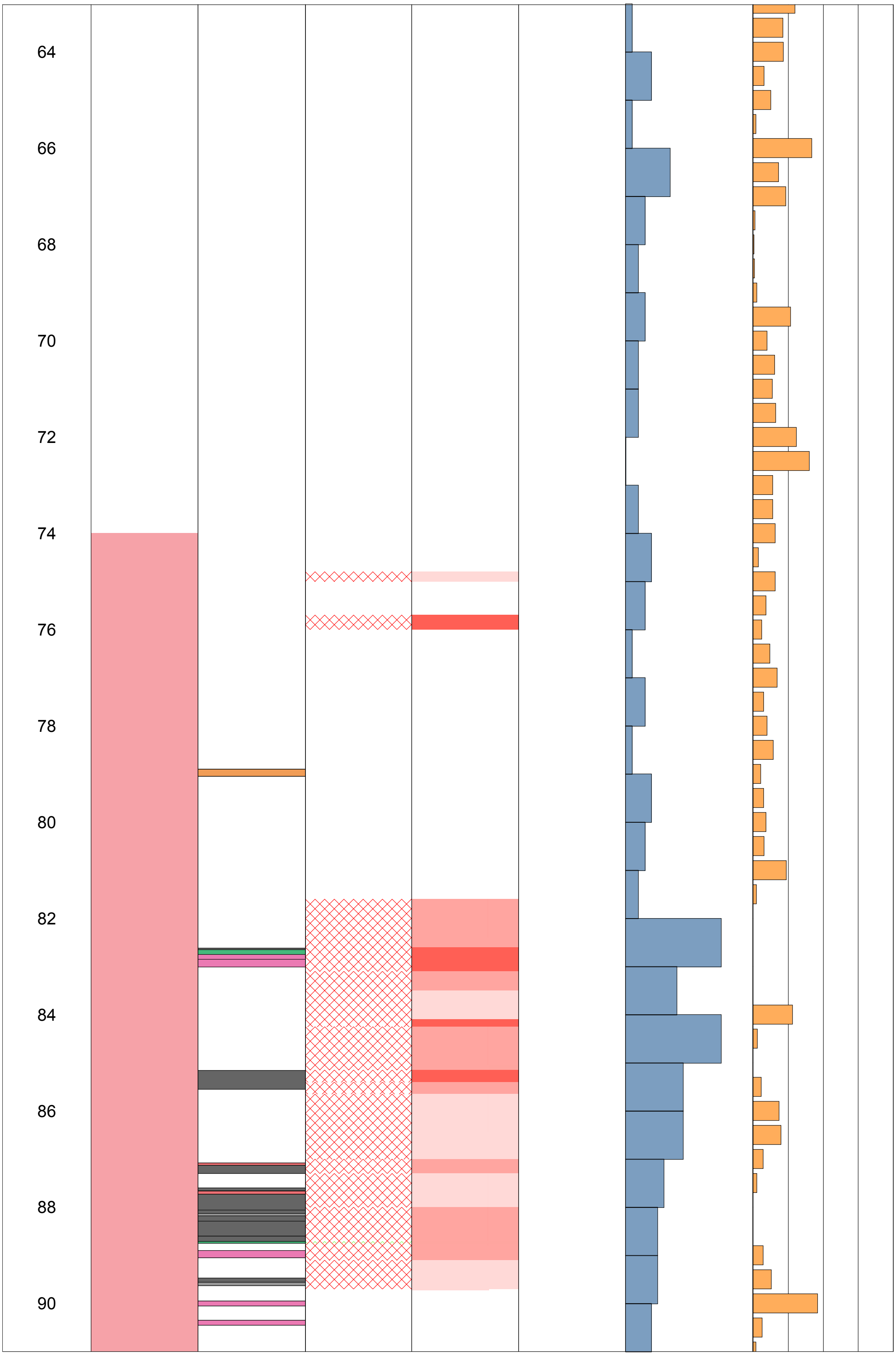
Scan-line mapping

fracture_no	length_ along_ line	strike	dip	fracture_ ends	fracture_ ends2	comment
LSM0005811	0.50	136	31	p	t	
LSM0005812	0.94	173	89	t	o	
LSM0005813	1.13	14	81	t	t	
LSM0005814	1.15	123	78	t	t	
LSM0005815	1.80	112	80	t	t	
LSM0005816	1.86	109	80	p	p	
LSM0005817	2.30	359	89	o	o	
LSM0005818	3.00					End of line
LSM0005821	0.08	197	85	p	p	
LSM0005822	0.10	53	85	p	o	
LSM0005823	0.16	139	78	p	p	En échelon
LSM0005824	0.97	186	90	t	o	
LSM0005825	1.15	126	66	t	t	
LSM0005826	1.26	160	44	t	t	1 cm wide cataclastic rock
LSM0005827	1.30	169	41	t	t	
LSM0005828	1.41	20	18	t	o	
LSM0005829	1.75	178	86	o	o	Soil covered, 3 cm wide
LSM00058210	1.85	125	90	t	t	gouge, 3 mm wide
LSM00058211	1.88	209	85	t	t	gouge, 1 mm wide
LSM00058212	1.94	164	88	t	t	gouge+epidote, 2 mm wide
LSM00058213	1.96	188	76	t	t	gouge, 3–5 mm wide
LSM00058214	2.04	187	82	p	p	
LSM00058215	2.11	188	81	p	t	
LSM00058216	2.20	107	73	t	t	En échelon
LSM00058217	2.26	165	76	p	p	
LSM00058218	2.34	179	86	p	t	
LSM00058219	2.39	174	86	p	p	
LSM00058220	2.55	169	78	p	p	
LSM00058221	2.65	186	82	p	t	
LSM00058222	2.90	181	79	p	p	
LSM00058223	3.00	204	73	p	t	
LSM00058224	3.20	166	90	p	t	
LSM00058225	3.40	31	87	o	o	Contact to pegmatite
LSM00058226	3.41	23	90	t	t	
LSM00058227	3.44	329	58	p	t	
LSM00058228	3.48	338	73	t	o	
LSM00058229	3.60	232	76	t	t	
LSM00058230	3.64	234	73	t	o	
LSM00058231	3.80	230	82	p	t	
LSM00058232	3.97	30	80	o	o	Contact to metabasite
LSM00058233	4.10					End of line
LSM0005831	0.11	125	40	o	o	
LSM0005832	0.71	117	37	o	o	
LSM0005833	1.55					End of line

Appendix 3

WellCad plots of mapping across the deformation zone (MDZNS019A) in KLX09D and KLX09F

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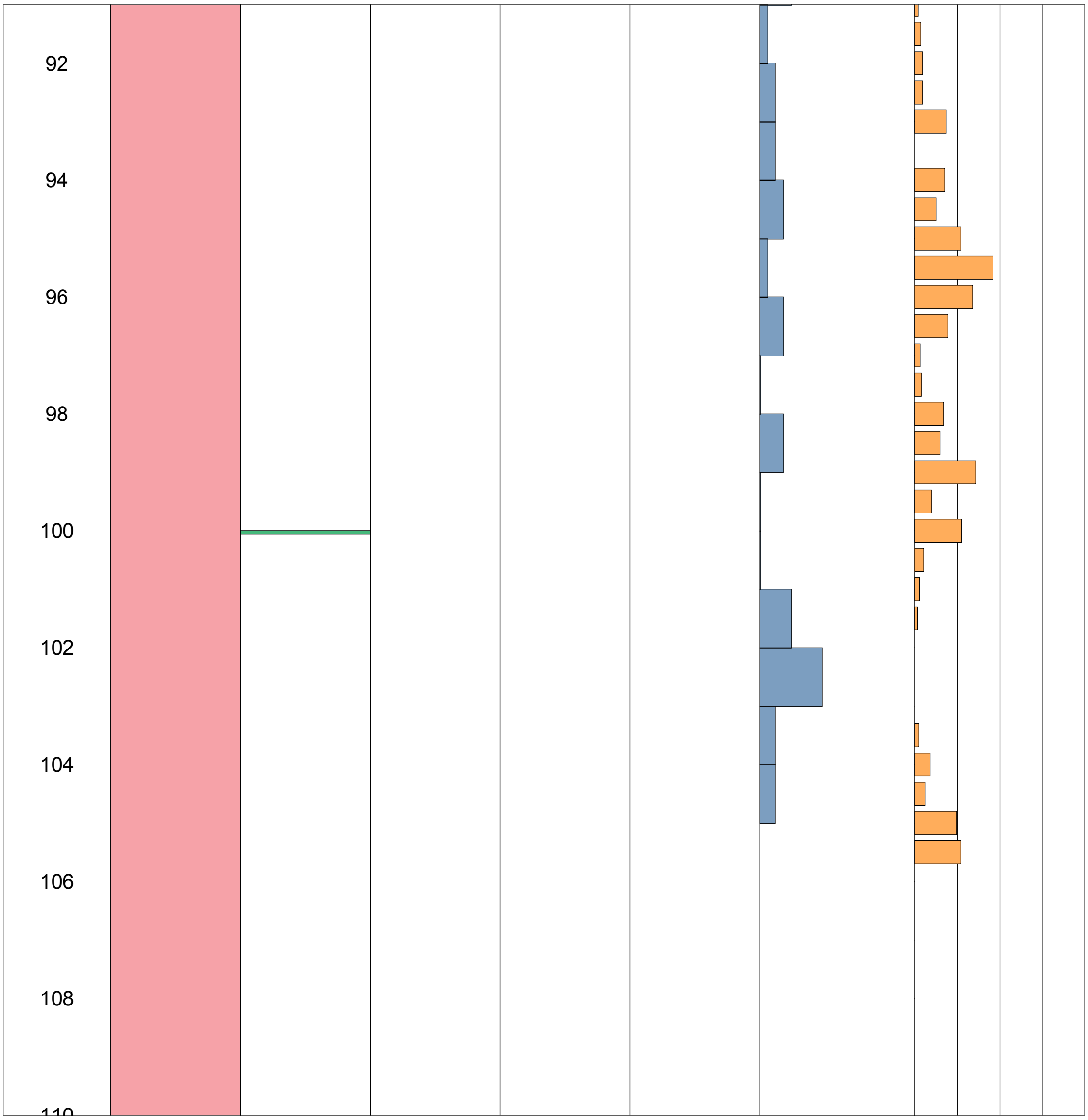
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Title	PLU SIMPLIFIED GEOLOGY IN KLX09F	Appendix

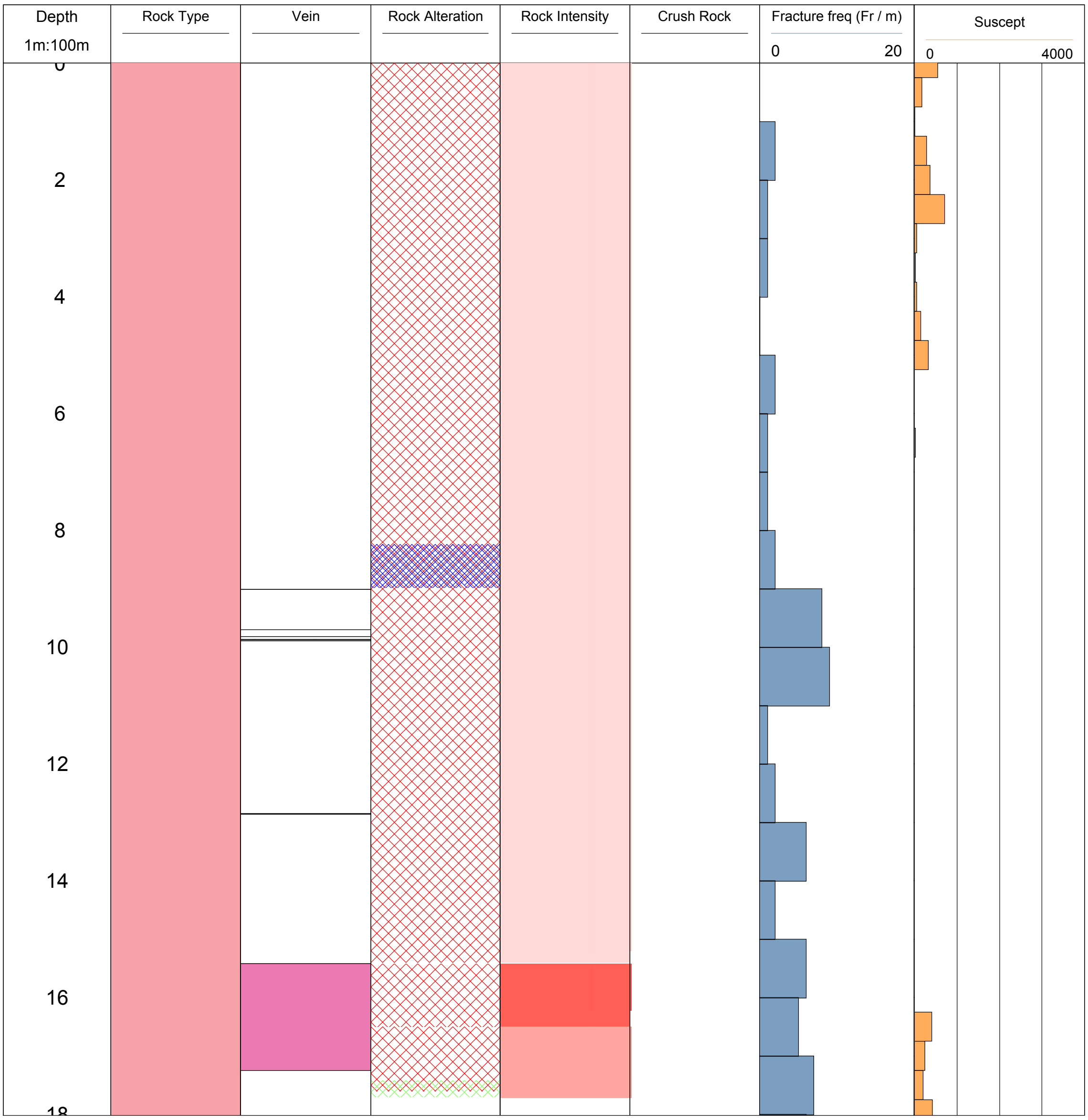
Site	SIMPEVARP	**Coordinate System**	RT90-RHB70
Borehole	KLX09F	**Northing [m]**	
Diameter [mm]	76.0	**Easting [m]**	
Length [m]		**Elevation [m.a.s.l.]**	
Bearing [°]	90.0	**Drilling Start Date**	
Inclination [°]	60.0	**Drilling Stop Date**	
Date of mapping		**Plot Date**	

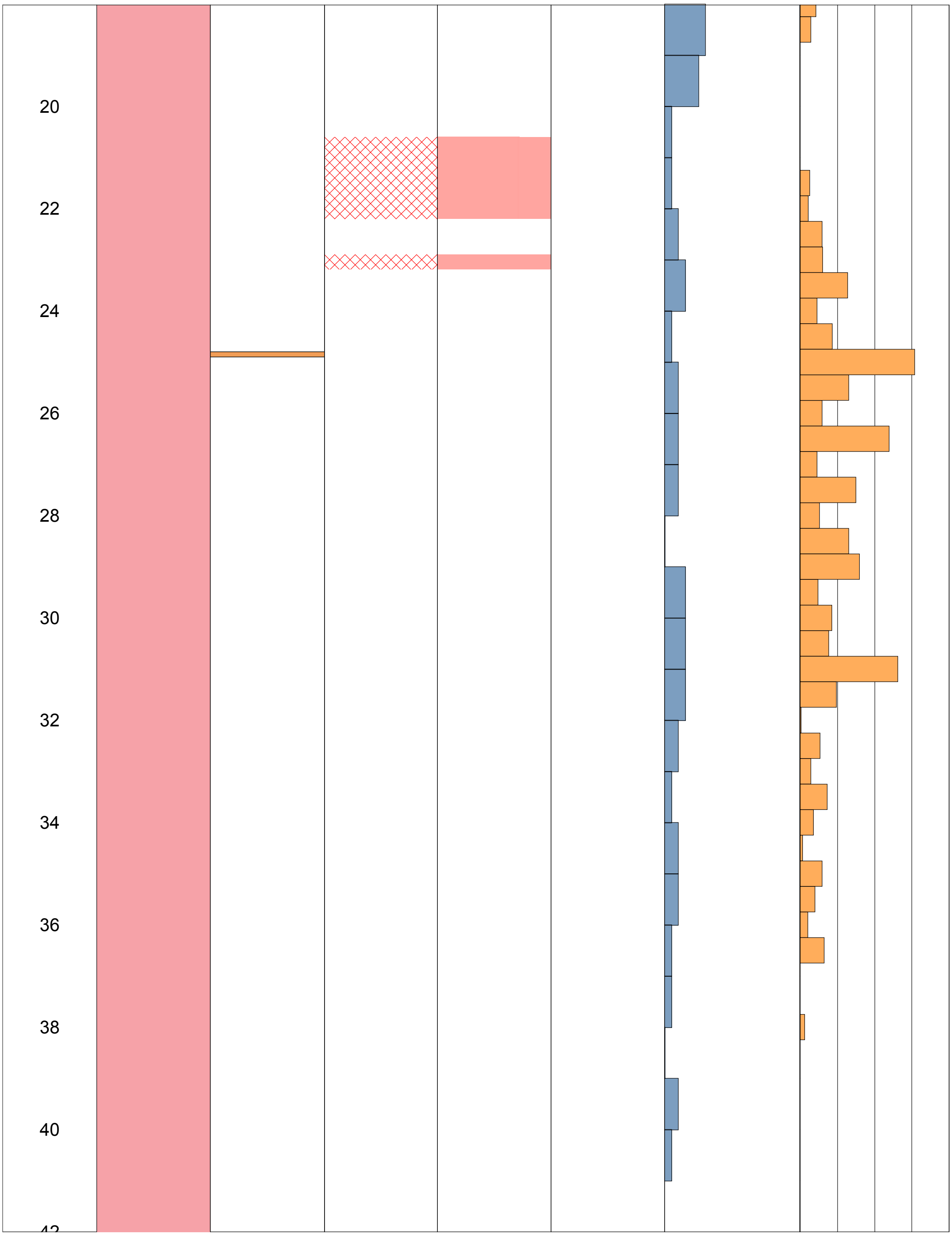
ROCKTYPE SIMPEVARP
- Ävrö granite

ROCK VEIN
- Pegmatite
- Cataclastic Rock
- Breccia
- Fine-grained granite

ROCK ALTERATION
- Oxidized
- Epidotisized
- Saussuritization

INTENSITY
- Faint
- Weak
- Medium

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