P-05-260

Oskarshamn site investigation

Detailed outcrop mapping at the drill site of KLX09 in Laxemar

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Golder Associates AB

December 2005

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ISSN 1651-4416
SKB P-05-260

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Keywords: Outcrop, Fracture, Lithology, KLX09, Scanline.

Abstract

SKB performs site investigations in Forsmark and Oskarshamn for location of a deep repository for high radioactive waste. This document reports the data gained during detailed fracture and bedrock mapping of an outcrop at the Laxemar area in Oskarshamn.

The aim of the activity is to collect fracture samples for discrete fracture network modelling and other statistical analyses.

The fracture mapping of the outcrop ASM100234 follows the SKB MD 132.003. The fracture location and geometry was surveyed with a totals station. A varying number of points along the fracture traces were recorded. Fracture orientation and other geologic characteristics were mapped in the field. For each fracture; fracture termination, roughness, form, relation to lithology, filling and host rock alteration etc were described. All fractures with a trace length longer than 50 cm were mapped.

An additional focused study was made on a distinct deformation zone on the outcrop. The same methodology of mapping and surveying was applied but with a lower truncation limit. Within the studied part of the zone all fractures longer than 20 cm were mapped.

Line mapping was conducted along two 10 m lines in a north-south/east-west oriented cross. The truncation limit was 20 cm.

A detailed mapping of outcrop lithology was conducted according to SKB MD 132.001.

The outcrop ASM100234 contained 1,128 fractures longer than 50 cm, which represents approximately 2.4 fractures per m^2. In the deformation zone however the frequency was higher. Counting fractures in the focus area within the zone gave 29 fractures and 6.6 fractures per m^2 with a 50 cm truncation limit. With the lower truncation limit of 20 cm 75 fractures where counted within the focus area, giving a frequency of 16.9 fractures per m^2.

The fracture frequency along the north-south and the east-west trending lines were 3.1 and 3.0 factures per meter respectively, using a truncation limit of 20 cm.

Four rock types are present in the mapped area of the outcrop – Ävrö granite (granite to quartz monzodiorite, generally porphyric), fine- to medium-grained granite, pegmatite and fine-grained mafic rock. The Ävrö granite is predominant on the outcrop.

Sammanfattning

SKB utför platsundersökningar i Forsmark och Oskarshamn för att finna en plats att djupförvara använt kärnbränsle. Följande rapport beskriver en detaljkartering av sprickor och bergarter på en berghäll i Laxemarsområdet norr om Oskarshamn.

Ändamålet för insamlande av sprickdata är att samla data för diskret sprickmodellering och statistisk sprickanalys.

Sprickornas geometri har karterats med en totalstation, där ett antal punkter uppmätts längs sprickspåret i hällen. Om sprickan är rak och hällens topografi jämn, har endast de två ändpunkterna uppmätts. Om sprickan är undulerande eller om topografin varierar har mät-punkter etablerats på lämpliga ställen utmed sprickspåret. Samtliga sprickor med sprickspår längre än 0,5 m har karterats.

Denna hällkartering avviker från tidigare utförda karteringar i och med att även en detaljkartering av en sprickzon utförts lokalt på hällen med lägre trunkeringsgräns (0,2 m) än på den resterande hällen.

På hällen utfördes även linjekartering längs med två ca 10 m långa linjer i nord-sydlig respektive öst-västlig riktning, där samtliga sprickor med sprickspårslängd längre än 0,2 m har karterats. Alla inmätta geometriska data har konverterats till RT90-systemet.

Sprickornas strykning, stupning och övriga geologiska egenskaper har karterats för hand. För varje spricka beskrivs sprickavslut, relation till bergartsgränser, vidd, form, strävhet, rörelseindikationer, sprickmineral och vittring i enlighet med vad som beskrivs i metod-beskrivning SKB MD 132.003. En detaljerad bergartskartering utfördes även på hällen enligt SKB MD 132.001.

Primäranalys från hällen ger en sprickfrekvens på 2,36 sprickor per m^2. Hällen har totalt en yta på 600,75 m^2 varav 478,63 m^2 karterats i detalj. Sammanlagt identifierades och karterades 1 128 sprickor över trunkeringslängden 0,5 m.

4,43 m^2 av en markant deformationszon har karterats med en lägre trunkeringsnivå. Vid zonkarteringen har totalt 93 sprickor identifierats räknat med trunkeringslängd 0,2 m. 18 stycken av dessa sprickor berör dock endast zonens avgränsningssprickor och går sedan utåt, de ligger alltså inte i zonen. Frekvensen i zonen blir sålunda 16,9 sprickor per m^2. 29 sprickor i zonen var längre än 0,5 m. Den med resten av hällen jämförbara frekvensen var sålunda 6,6 sprickor per m^2.

Contents

1 Introduction

SKB performs site investigations in Forsmark and Oskarshamn for location of a deep repository for high radioactive waste. This document reports the data gained during detailed fracture and bedrock mapping of an outcrops at the Laxemar area in Oskarshamn. The outcrop, ASM100234, was mapped in early july 2005.

The detailed fracture mapping was conducted according to the activity plan AP PS 400-04-049 and the method description SKB MD 132-003 (SKB internal controlling document).

The locations of the investigated outcrop can be seen in Figure 1-1. The outcrop has been exposed and cleaned from the soil cover prior to mapping. The total horizontal area of the outcrop is 600.75 m^2 and the mapped area is 478.63 m^2.

4.43 m^2 of a distinct deformations zone has been mapped with a lower truncation limit for fracture length.

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**
Detaljerad sprickkartering av borrplats klx09	AP PS 400-05-049	1.0
Method descriptions	**Number**	**Version**
Detaljerad sprickundersökning på berghällar	SKB MD 132.003	1.0
Metod för berggrundskartering	SKB MD 132.001	1.0

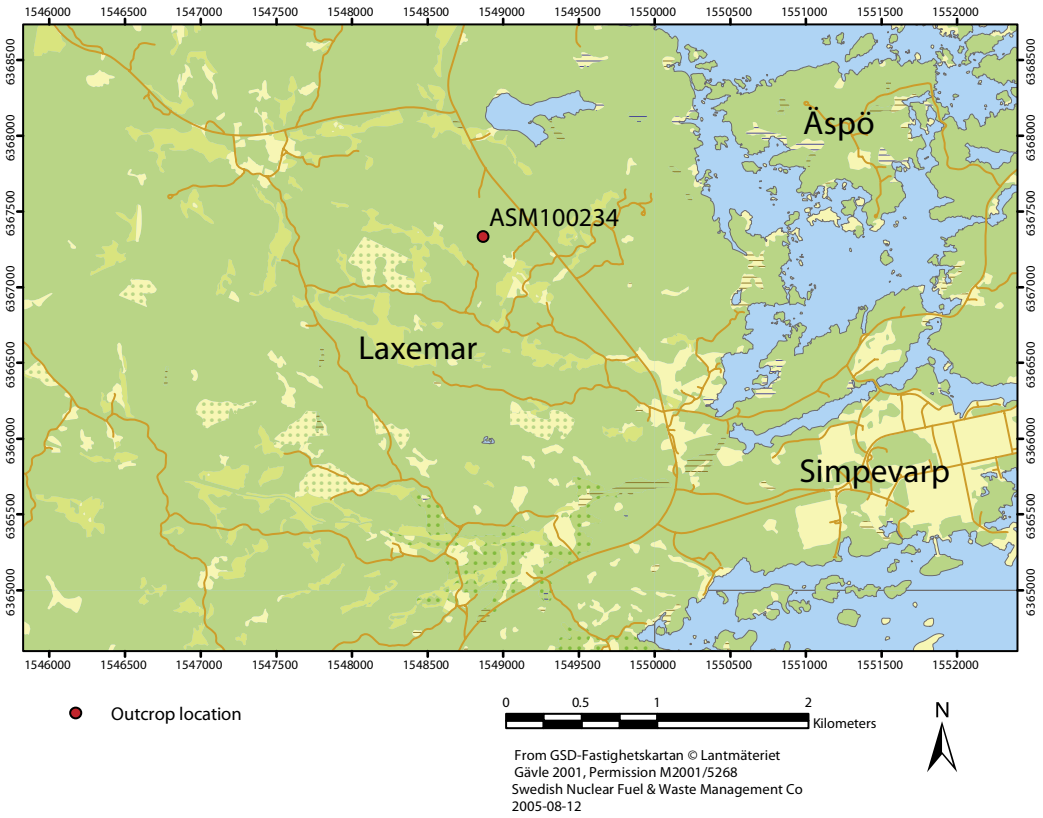

Figure 1-1. *Locations of the outcrop.*

2 Objective and scope

The activity aimed at collecting detailed fracture data at allocation within the focused site investigation area in Laxemar. The data will be used in discrete fracture analysis and discrete fracture modelling in the site investigation. The area mapping is expected to indicate the geometric properties for open and sealed fractures in the trace length interval between 0.5 m to approximately 10 m at the sites. The results are indicative of the properties of the local fracture network. The variability and properties of the fractures may also depend on type of bedrock and its structures which is presented in appendix.

The line mapping aims at giving information about the truncation effect since it has a lower truncation limit of 0.2 m.

The extra detailed study of the minor deformation zone on the outcrop aims at giving information about deformation zone features. The internal structure of such zones has showed to be of interest in the site investigation programme.

3 Equipment

3.1 Description of equipment

The fracture trace geometry and contacts between rock types were measured with a Geodimeter 640S Total Station. In theory, the survey instrument gives an error of the position (x, y and z) of less than 3 mm. However, this accuracy is based on the assumption that the measuring lath is held in a perfectly vertical position. Since this is not always possible to achieve in typical field conditions the error is larger. Each measurement is therefore estimated to be performed with an x, y accuracy better than 1 cm. The elevation error is estimated to be less than 0.5 cm.

The number of points measured along each fracture trace varies. The minimum is 2 points but more is needed as the complexity of the trace and rock surface increases. The number of points along a contact between rock types varies between a few up to a hundred. More measurements results in a better definition of the extent of the fracture trace or contacts between rock types. However, an increasing number of measurements slow down the survey substantially. The work was performed such that there was a balance between mapping speed and degree of detail of the mapped fracture traces.

The orientation and most of the other fracture parameters were mapped by hand in field. Fracture length and fracture host rock was computed in excel and ArcView after the field trip, based on the geodetic data from the bedrock and the fracture survey.

4 Execution

4.1 General

The mapping was performed using standard protocols following the methods described in the method descriptions for detailed fracture mapping at outcrops (SKB MD 132.003) and for bedrock mapping (SKB MD 132.001) respectively.

4.2 Preparations

The survey instrument was positioned outside the outcrop and was calibrated against four fix points located around the outcrop. The fix points where positioned by SKB prior to the fracture mapping. The fix points are listed in Table 4-1. The survey instrument was calibrated against the fix points after at the beginning and at the end of each fieldwork session. The survey results are presented in the RT90 system.

Table 4-1. Fix points for the outcrop ASM100234. in RT90 2.5 gon V 0:–15.

Pnr	Northing	Easting	Elevation
AKLX09	6367349.175	1548824.383	21.214
BKLX09	6367342.148	1548863.849	23.736
CKLX09	6367316.896	1548849.569	22.632
DKLX09	6367312.178	1548871.682	23.096

4.3 Execution of work

4.3.1 Field work

Site establishment involved the following activities

1. The SKB activity leader introduced the staff to the outcrop, and the fix points around the outcrop. The minor deformation zone cutting trough the outcrop was delineated, and it was agreed which part of it that should be studied in extra detail.
2. The survey instrument was calibrated against known and appointed fix points in the vicinity to the outcrop (Table 4-1).
3. A grid of approximately 5×5 m squares of plastic tape was applied over the outcrop as a help to subdivide the outcrop in smaller sub domains during the mapping. (The area within this grid has been completely mapped i.e. every fracture on the outcrop that have any part inside the grid system has been registered). The grid has no imprint on the collected data.
4. The coordinates of the grid nodes were measured with the total station.
5. The complete extent of the cleaned outcrop was measured with the total station.

The methodology of the lithologic mapping follows the SKB controlling document SKB MD 132.001. Specifically the work was carried out as follows:

6. The lithologic boundaries of the outcrop was identified and marked with crayons.
7. The lithologic boundaries where registered with a required number of measurements with the survey instrument.
8. The survey data was extracted and digitally conversed to RT90–RHB70 coordinates. The measurements where opened in a CAD software and a lithologic draft map was printed.
9. The draft map was controlled on the outcrop and complementary notes and corrections where marked on the map or measured with the survey instrument.

The methodology for mapping fractures follows the method presented in SKB MD 132.003 (SKB internal controlling document). The work process was conducted as follows:

10. Each fracture trace was marked with a metal marker at its startpoint (A) and end-point (B) on the outcrop to keep track of measured fractures. The used truncation length for mapping fracture traces was 0.5 m. The direction from start to end was defined according to the right hand rule.
11. A fracture characterisation start meeting was conducted. The aim was to achieve a common judgement of the more general fracture characteristics on the outcrop. This was especially important since the alteration in the fracture host rock had some special features on this outcrop. One result of the meeting was an updated version of the alteration code table (Table 5-2).
12. Each fracture location and length was measured with two or more points with the survey instrument. The number of measured points on each fracture was dependent of the complexity of the structure. At the end of each day the data was extracted from the survey instrument. A digital conversion of survey instrument data to RT90–RHB70 coordinate data was conducted and the measurements of the day where opened in a CAD software. The reasonability of the traces was checked.
13. Each fracture was mapped with respect to the given geological parameters outlined in SKB MD 132-003, also given in Tables 5-1 and 5-2.
14. The agreed part of the minor deformation zone was mapped with a lower truncation length (0.2 m). The same parameters as for the surface mapping were collected. The detailed mapping was performed in a layer fashion, where all fractures longer than 0.5 m was mapped in the regular mapping, and all fractures between 0.5 and 0.2 m was mapped separately. Even fractures starting on the zone border and going out was counted to the zone at this stage.
15. Scan line measurements were performed along two 10 m long, approximately orthogonal scan lines put in a NS and EW orientation on a representative part of the outcrop. The truncation length was 0.2 m. The same parameters as for the surface mapping were collected.

16. Cross mapping was conducted. The two persons, who had carried out the main part of the fracture description activity, mapped 10 randomly chosen fractures that had been mapped by the other person. This resulted in 20 fractures that where double mapped. These where used in order to indicate any systematic deviations in fracture characterisation between the mappers and is part of the quality assurance programme.
17. The outcrop was cleared from markers, nails and plastic tape.

4.3.2 Post processing

Off field activities conducted:

18. Construction of ArcMap shape files of fracture traces, lithologic features, outcrop grid and boundary.
19. Calculation of fracture lengths from the fracture survey data.
20. Spatial calculation of fracture host rock from the fracture survey and the lithology survey data.
21. Calculation of the compass declination by comparing a bearing taken in field with the corresponding survey data.
22. Quality control of the survey data and a consistency check between calculated orientations from the survey data with the orientations registered on the mapping protocols. Analysis of the cross mapping.
23. Report production.

4.4 Data handling and deliveries.

A complete registry of the delivered documents are given in the following tables.

Table 4-2. Field notes.

Description	Name	Format
Field mapping protocols	Blanket sprickkartering	Hard copy
Calibration notes	Compass declination	.xls
Start meeting protocol	SE-P1_05_RL0_StartmötePåHäll.doc	.doc
Activity daily log	Aktivitetsdagbok V2.0.1	Hard copy

Table 4-3. Primary data.

Folders	Files	Description	Gis format
ASM100234_Bedrock_ GIS	ASM100234_bedrock.shp	Bedrock lithology	Polygon
	ASM100234_StructOrient.shp	Structure orientation in bedrock	Point
	ASM100234_FractureMove. shp	Fractures along which movement has occurred	Line
	ASM100234_Bedrock Description.jpg/pdf	Map displaying the GIS-layers	
ASM100234_Fractures_ GIS	ASM100234_Fractures.shp	Fracture traces. Contains all fractures having any part within the mapped area.	Line
	ASM100234_FracturesDZ.shp	Fracture traces. Contains all fractures having any part within the mapped part of the zone.	Line
	LSM000545&6 _ FracturesLineM	The traces from the line mapping. Contains all fractures that intersects the lines.	Line
	ASM100234_Fractures.emf	Map displaying the fracture layers	
ASM100234_Site_GIS	ASM100234_Grid.shp	The grid established on the outcrop	Line
	ASM100234_MappedArea.shp	Mapped extent of the outcrop	Polygon
	ASM100234_OutcropArea.shp	Complete extent of the outcrop	Polygon
	ASM100234_DefZone.shp	The outlining of the fracture zone	Line
	ASM100234_DefZone_ mapped.shp	Mapped extent of the deformation zone	Polygon
	LSM000545&6 _Scanlines.shp	The lines along which the line mapping was executed.	Line
	ASM100234_Site	Description.emf	Map displaying the outcrop descriptive layers
Each shape file is a combination of several file;, such as a database file, different binary files, sometimes a layout (lyr) file and an xls -metadata file.			
ASM100234_CAD	ASM100234_OutcropArea.dgn	The boundary of the washed outcrop.	
	ASM100234_Grid.dgn	The grid established on the outcrop.	
	LSM000545&6 _ FracturesLineM.dgn	The lines along which the line mapping was executed. And the mapped fractures. The line mapping file only contains the fractures between the truncation limit limits of 0.5 and 0.2 m.	
	ASM100234_fractures.dgn	The mapped fracture traces from the outcrop in cad format.	
	ASM100234_fracturesDZ.dgn	The mapped fracture traces from the focused mapping in the deformation zone.	
	ASM100234_Topography.dgn	Extra topographic points needed to sample the 3D form of the outcrop.	
	ASM100234_Suscept.dgn	Susceptibility measurements.	
ASM100234_pictures			
	jpg-files as listed in:		
	ASM100234 _Photo_texts.xls		
	AFM100234_#.jpg (# ; 1 – 14)		
ASM100234_SICADA	EG165 – ASM100234_ OutcropArea_surveying.xls	Coordinates of a mapped extent of the outcrop in a SICADA template.	

Folders	Files	Description	Gis format
	EG170 – LSM000545&6 Surveying.xls	Coordinates of the scanlines in a SICADA template	
	GE075 – LSM000545&6 _LineMapping.xls	Parameters of the mapped fractures along the scanlines, contains every fracture that at any part intersects the scanlines and is longer than the truncation length of 0.2 m.	
	GE076 – ASM100234_ Fractures.xls	Parameters of the mapped fractures on the outcrop. Contains each fracture that has any part within the area limitation and is longer than the truncation length of 0.5 m.	
	GE076 – ASM100234_ FracturesDZ.xls	Parameters of the mapped fractures in the deformation zone. Contains each fracture that has any part within the area limitation and is longer than the truncation length of 0.2 m.	

Table 4-4. Documentation.

Description	File name
Report	Report-Detailedoutcropmapping On Drillsite KLX09.Doc
File list	Fillista.doc
QA-protocol	Granskning&kvalitet.doc

5 Results

5.1 Detailed fracture mapping

The results of the outcrop mapping include data tables, Cad files and ArcMap shape files of:

- Outcrop lithology and shape
- Area fracture mapping.
- Focused Area fracture mapping of the minor deformation zone.
- Scan line fracture mapping.

The compass declination on the outcrop was controlled and was found to be approximately 4° east. This was in line with information from SGU that predicted a declination of the magnetic north of 3.5–4° towards the east (www.sgu.se). Four degrees have therefore been added to the compass measured fracture strike values during the post processing.

Based on experience from work in crystalline basement outcrops, it was prior to the field investigation estimated that there would be approximately two fractures (over the truncation trace length of 0.5 m) in each m^2 of the outcrop. ASM100234 contained 1,128 fractures which represent approximately 2.4 fractures per m^2, which is close to the expectation.

In the deformation zone however the frequency was higher. Counting fractures within the zone focus area with the normal truncation limit, gave 29 fractures and 6.6 fractures per m^2. With the lower truncation limit of 0.2 meters 75 fractures where counted within the focus area, giving a frequency of 16.9. fractures per m^2. 18 of the fractures spotted with the lower truncation limit was beginning on the zone border and pointing out, these where not included in the zone frequency.

The scan line mapping was performed along two 10 m long lines of the outcrop, one along North and one along West in a perpendicular cross. The truncation length for fracture traces in the scan line survey was 0.2 m. The fracture frequency along the North trending line and the West trending line for ASM100234 was 3.1 and 3.0 factures per meter respectively.

Table 5-1 and Table 5-2 present the mapped geological parameters on each fracture trace. The parameters have been coded according to a specified system that is appropriate for retrieving from SICADA, the SKB data base for the site investigations.

Figure 5-1 shows the outcrop survey pattern at site ASM100234 and Figure 5-2 and Figure 5-3, the actual trace maps of the outcrops.

Table 5-1. Bedrock codes and description. SKB code system has been used to describe rock, structure, grain size and color.

Code	**Rock type** (two first digits relate to the Simpevarp site)
501044	Ävrö granite (Småland-Ävrö granite)
505102	Mafic rock, fine-grained
511058	Fine-grained granite
101061	Pegmatite
Code	**Structure**
45	Lineation
20	Gneissic
98	Metamorphic, unspecified
12	Discordance
52	Veined
53	Banded
Code	**Appearance**
31	Vein
Code	**Grain-size of matrix**
2	Fine-grained
3	Fine-medium-grained
6	Fine- to medium-grained
8	Medium- to coarse-grained
9	Medium-grained
4	Coarse-grained
Code	**Colour**
3	Red
28	Reddish grey
58	Greenish grey
18	Reddish grey
4	Grey
6	Dark grey
13	Black
	Orientation (terminology applied on all structures in bedrock).
	Strike/dip (used for all planar structures).
	Bearing/plunge (used for all linear structures).

Table 5-2. Code table for fracture characterization.

Parameter	Codes	
Fracture termination (See figure A2-1)	o	The fracture termination is not visible.
	p	The fracture is terminated in a point, but not against any discontinuity in the rock.
	t	The fracture terminates against another fracture.
	y	The fracture ends independently on the rock but in several splays. Some of these splays could connect to other fractures.
	x	The fracture terminates against a lithologic boundary.
Relation to lithology	a	No lithologic boundary is crossed.
	b	One lithologic boundary is crossed.
	c	More than one lithologic boundary is crossed.
	d	The fracture coincides with a lithologic boundary.
Fracture type	o	Open fracture. This needs to be open at depth. Many fractures give the impression of being open due to increased erosion at surface.
	c	Closed fracture, c is considered default, i.e. write c if the aperture cannot be seen or detected.
Fracture shape /Waviness (See figure A2-2)	t	The fracture is stepped if it is composed of several segments with a lateral offset, and the segments are connected with smaller perpendicular or close to perpendicular segments. If the offset is great or no connecting fracture is found, the segments should be mapped separately.
	u	The fracture is undulating (wavy).
	p	The fracture is planar or close to planar. A planar fracture with a bend or splay in the end is still considered planar.
Roughness /unevenness (See figure A2-2)	r	The fracture plane is rough. This is the normal case when movement has not taken place along a fracture. r can be considered default value, i.e. write r if the fracture walls cannot be seen.
	s	The fracture plane is smooth, either due to a mineral filling or due to grinding activity between the fracture walls.
	h	Slickenside (Harnesk). Grinding has taken place in a visible direction.
Indication of movement	0	There are indications that no movement has taken place.
	s	Sinistral; Standing on one side of the fracture facing the other, the opposite side should have moved relatively to the left.
	d	Dextral. Standing on one side of the fracture facing the other, the opposite side should have moved relatively to the right.
	1	The fracture has indications of movement but direction cannot be determined.
	–	Nothing can be said about the movement.
Alteration	0	No alteration (equivalent to ISRM** weathering class I).
	1	change of colour in the host rock, other than red (ISRM weathering class II).
	2	Change of mineral composition in host rock. The mineral durability is reduced. (ISRM weathering class III).
	3	Change of mineral composition in host rock. The mineral durability is increased.
	r or rr	The host rock around the fracture is red or strongly red coloured. This can be combined with the above digit codes 2 and 3.
	–	Nothing can be said about alteration due to soil infill etc.
Fracture filling	0	No fracture filling.
	text	Give code according to SKB standard or other definition decided among the crew. If more than one mineral is present, write them in order of magnitude.
	–	Nothing can be said about fracture filling due to soil infill etc.

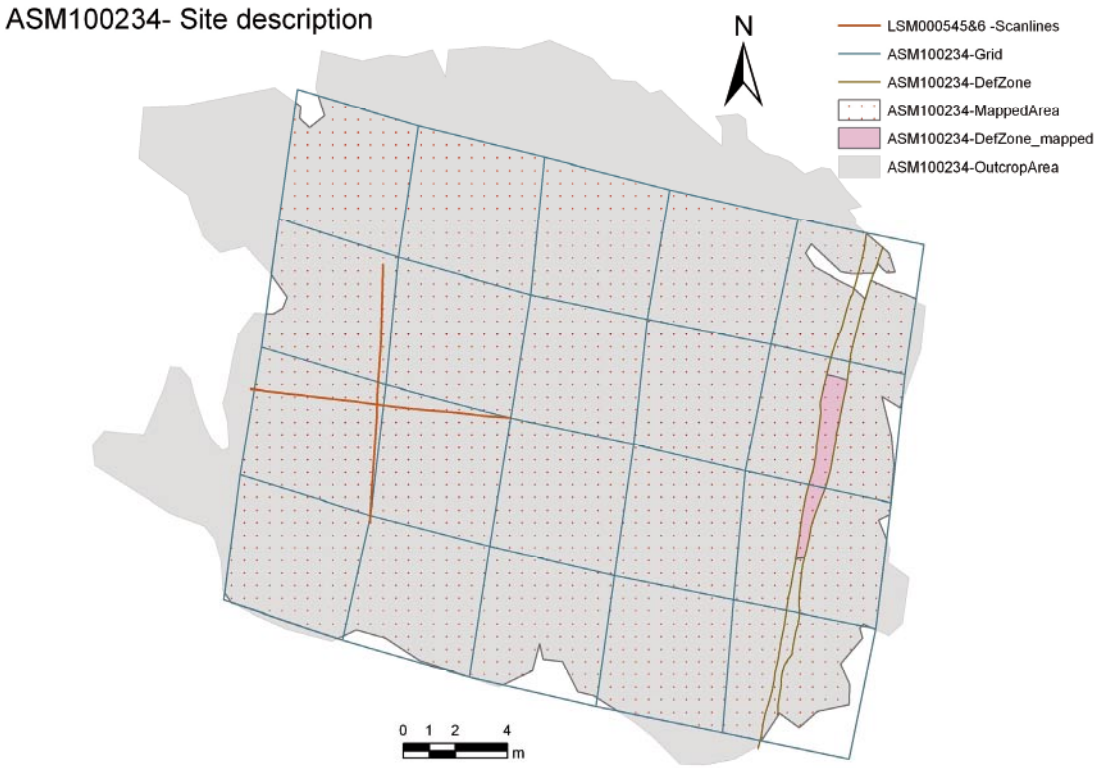

Figure 5-1. *Outcrop ASM100234. The measuring grid and the different mapping areas displayed. Each grid cell is approximately 5×5 m.*

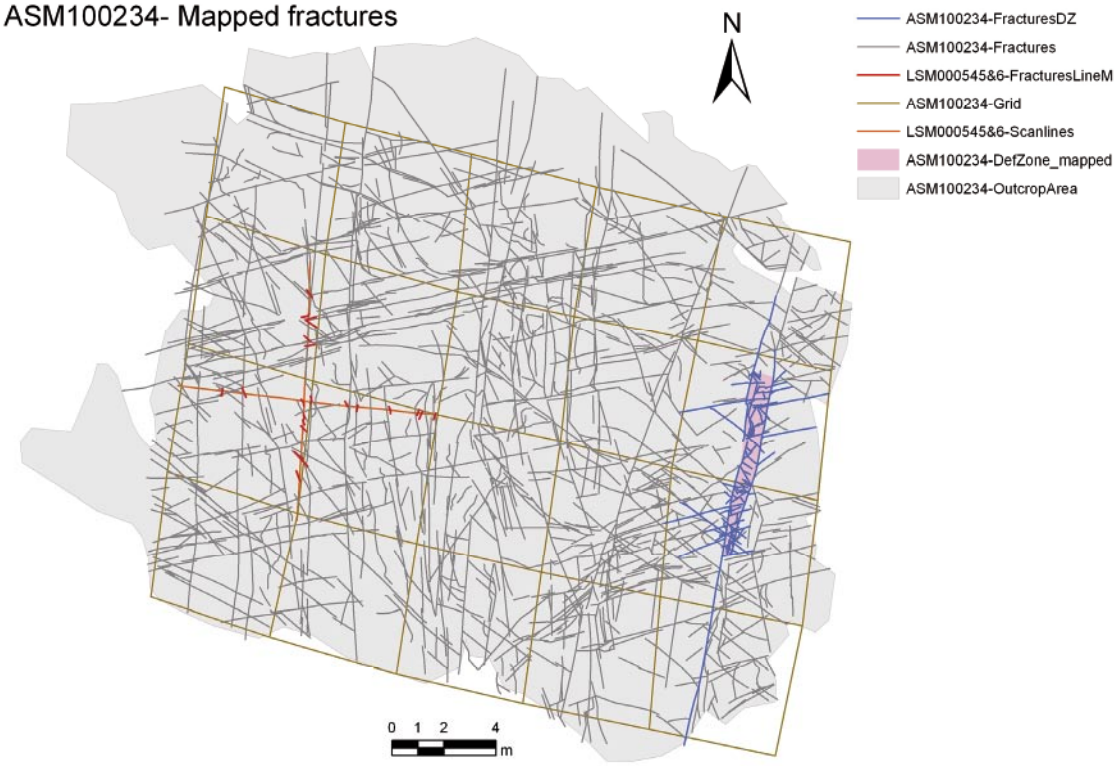

Figure 5-2. *Fracture trace map of the ASM100234 outcrop.*

5.2 Detailed bedrock mapping

Detailed bedrock mapping was conducted at the site in the Laxemar area. The outcrop was exposed from the soil cover prior to mapping. The area of the ASM100234 outcrop, that was bedrock mapped, was 600.75 m^2. The mapping focused on lithology, contact relations and deformational structures. The bedrock maps were subsequently used for the detailed fracture mapping.

The bedrock mapping was carried out according to method description for bedrock mapping, SKB MD 132.001 (SKB internal controlling document). The spatial distribution of rock types was measured with a Geodimeter 640S Total Station (see chapter Description of equipment).

ASM100234 Outcrop

Four rock types are present in the mapped area of the outcrop ASM100234 – Ävrö granite (granite to quartz monzodiorite, generally porphyric), fine- to medium-grained granite, pegmatite and fine-grained mafic rock (Figure 5-3).

The Ävrö granite is the predominant rock of the outcrop. It is medium- to coarse-grained often with 1–3 cm large phenocrysts of feldspar, both of euhedral and anhedral appearance, and it displays a reddish grey color.

No foliation was visible in the Ävrö granite though inclusions of the fine-grained mafic rock are arranged in a predominated direction of N320–330 within the Ävrö granite.

The red fine- to medium-grained granite occurs as dykes that cross-cut the Ävrö granite. The width varies from 1 cm to c 90 cm and the strike and dip diverges. The dykes that dominate the outcrop are two sub-parallel dykes in the south-eastern part, striking approximately N50° with a dip varying between 28° and 82°. The minor dykes vary in directions and the dominating strikes and dips are c N145/50, N320/45 and N70/35–90. The dykes occur as straight or gently curved dykes and the contacts between the dykes and the host rock are sharp. Some of the minor granite dykes that intersect the larger have sometime a more coarse grained appearance.

A red pegmatite occurs as thin dykes (c 2–4 cm) that cross-cut all rock-units. The grain-size ranges from medium- to coarse-grained. The predominated strike and dip is c N10/80.

Within the Ävrö granite a large amount (c 270) of fine-grained mafic inclusions occurs. The shape of the inclusions is mostly ellipsoidal. The size varies from a few cm up to 50×15 cm. The inclusions are highly weathered compared to the host rock. The main strike of the inclusions is N320–330. Strike and dip of N330/80 were possible to measure for one inclusion.

At the outcrop several fractures affected by faulting, where a sinistral component of displacement predominates, has been mapped. A zone, approximately striking in a north-south direction in the eastern part of the outcrop, displays dense brittle deformation. In the vicinity of this zone, several fractures are affected by faulting up to c 150 cm. One of the fractures (fracture Id. 57) displays a mylonitic structure within the fracture mineralization.

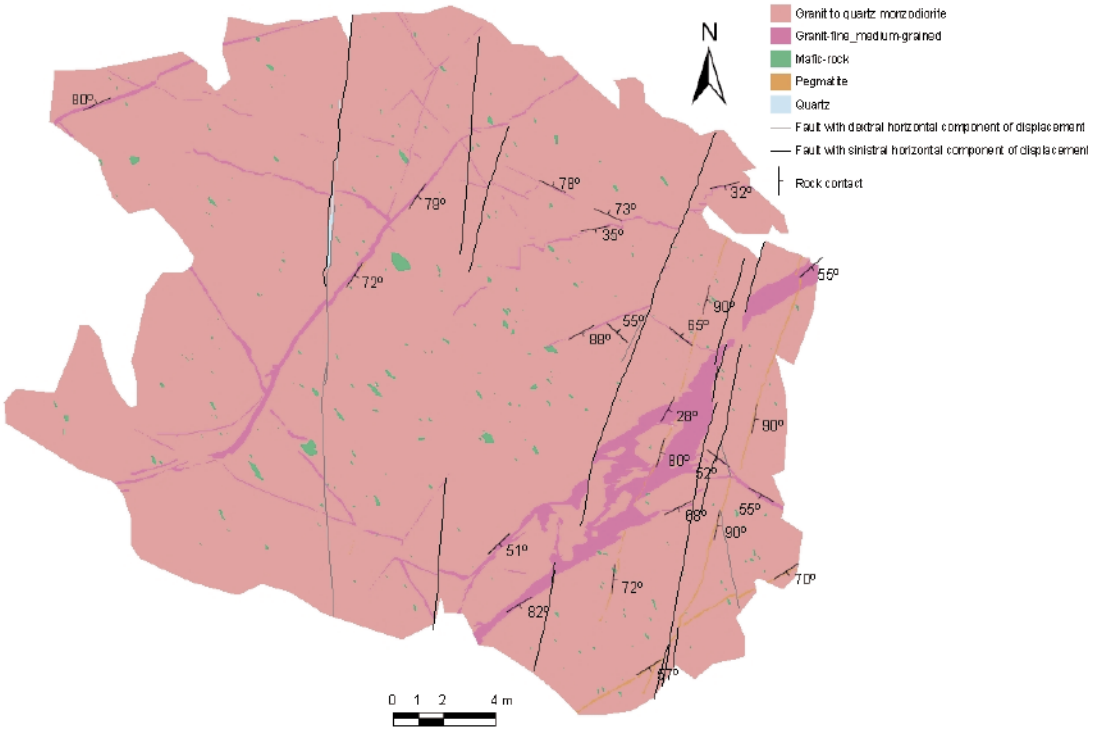

Figure 5-3. *Geological map of outcrop ASM100234.*