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Oskarshamn site investigation

Detailed outcrop mapping on drillsite KLX11

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August 2006

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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 sub area of the site investigation 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 ASM100235 follows the SKB MD 132.003e. The fracture location and geometry was surveyed with a total 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.

The outcrop ASM100235 contained 1,029 fractures longer than or equal to 50 cm, which represents approximately 3.1 fractures per m^2. The mapped area of the outcrop was 332.6 m^2.

Line mapping was conducted along two 10 m lines in a north-south/east-west oriented cross. The truncation limit was 20 cm. The fracture frequencies along the north-south and the east-west trending lines were 1.5 and 4.1 fractures per metre respectively. The difference in frequency is explained by the presence of a strong north south trending fracture set on the outcrop.

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

Four rock types are present in the mapped area of the outcrop ASM100235 – quartz monzodiorite, fine- to medium-grained granite, pegmatite and fine-grained mafic rock. The quartz monzodiorite is the predominant rock of the outcrop. A fracture system filled with sandstone was found in the south part of 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 med 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 mätpunkter etablerats på lämpliga ställen utmed sprickspåret. Samtliga sprickor med sprickspår längre än 0,5 m har karterats.

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 metodbeskrivning SKB MD 132.003e. En detaljerad bergartskartering utfördes även på hällen enligt SKB MD 132.001.

Primäranalys från hällen ger en sprickfrekvens på 3,1 sprickor per m^2. Hällen har totalt en yta på 349 m^2 varav 332,6 m^2 karterats i detalj. Sammanlagt identifierades och karterades 1,029 sprickor över trunkeringslängden 0,5 m.

Den dominerande bergarten på den karterade hällen utgörs av en kvarts monzodiorit. Fin- till medelkornig granit och pegmatit förekommer som gångbergarter inom kvarts monzodioriten. Ett sandstensfyllt spricksystem identifierades i den södra delen av hällen.

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, ASM100235, was mapped in October 2005.

The detailed fracture mapping was conducted according to the activity plan AP PS 400-04-045 and the method description SKB MD 132.003e version 1.0, (SKB internal controlling document). A significant discrepancy of the SKB MD 132.003e version 1.0 and the SKB MD 132.003e version 2.0 is the method of measuring open fracture surfaces. In this survey the fracture trace was defined as the longest straight line possibly drawn on an open surface. In the SKB MD 132.003e version 2.0 the circumference is instead measured. There have also been a change of parameter codes in the circumference, but the codes used in this project are declared in this document (Table 5-2). Finally a couple of additional parameters have been added in the SKB MD 132.003e version 2.0, these were not mapped in this survey. Apart from that, the project followed the SKB MD 132.003e version 2.0 method description.

The location 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 349 m^2 and the mapped area is 332.6 m^2.

In Table 1-1 controlling documents for performing this activity are listed. Both activity plan and method descriptions are SKB's internal controlling documents.

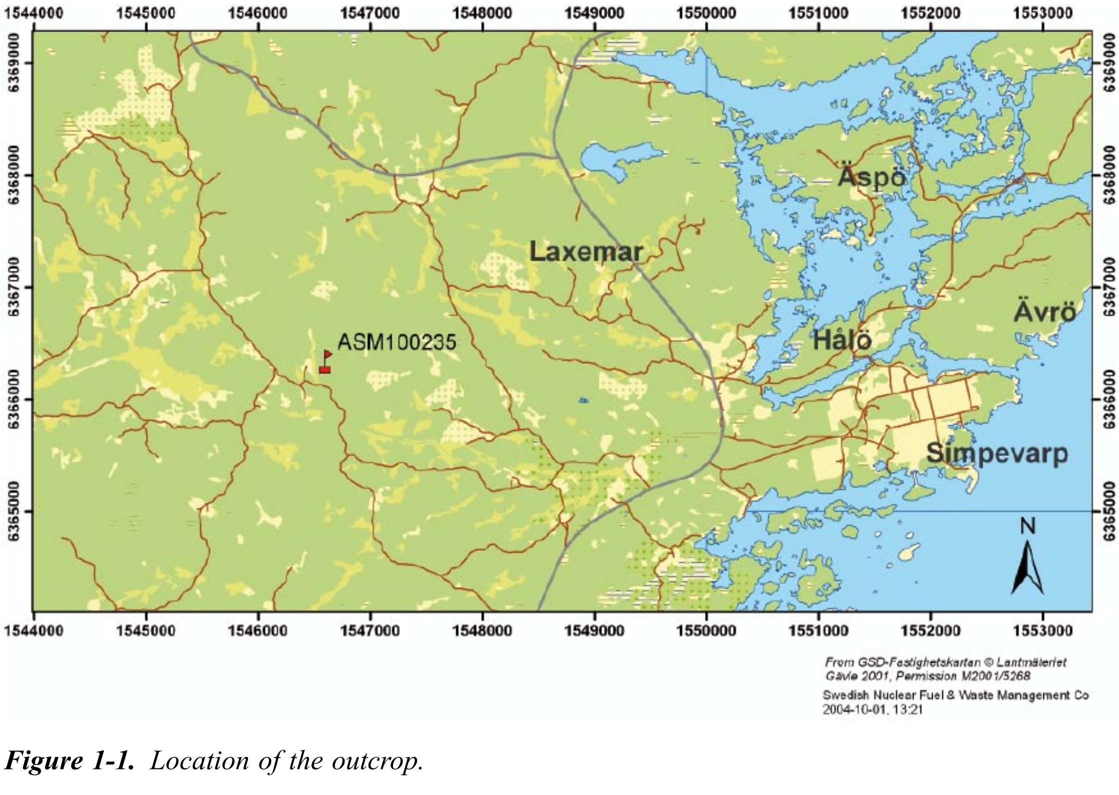

Figure 1-1. *Location of the outcrop.*

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

Activity plan	Number	Version
Detaljerad sprickkartering av borrplats KLX11	AP PS 400-05-078	1.0
Method descriptions	**Number**	**Version**
Detailed fracture mapping of rock outcrops	SKB MD 132.003e	draft version 1.0
Metod för berggrundskartering	SKB MD 132.001	1.0

2 Objective and scope

The activity aimed at collecting detailed fracture data at a location within the Laxemar sub area. 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 are also studied.

The line mapping aims at giving some information about the statistic behaviour around and below the truncation limit, set at 0.5 m for the area mapping. The line mapping has thus a lower truncation limit of 0.2 m.

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 field conditions the error may be larger. Each measurement is therefore estimated to be performed with an x, y accuracy better than 2 cm. The elevation error is estimated to be less than 0.5 cm.

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 132.003e), with some modifications described in the introduction (Chapter 1), 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 set out, but not positioned at the onset of the surveying. The coordinates (listed in Table 4-1) was delivered from SKB after the field work was finished. The survey instrument was calibrated against the fix points after each time data was downloaded from the instrument and at the beginning of each fieldwork session. The instrument was also recalibrated to reflect temperature changes during the day. The survey results were converted to the RT90 after the field trip when the coordinates where at hand.

Table 4-1. Fix points for the outcrop ASM100235. in RT90 2.5 gon V 0:-15.

Pnr	Northing	Easting	Elevation
AKLX11	6 366 356.628	1 546 603.462	26.625
BKLX11	6 366 341.808	1 546 626.099	26.008
CKLX11	6 366 340.220	1 546 587.291	27.216
DKLX11	6 366 314.713	1 546 620.628	24.862

4.3 Execution of work

4.3.1 Field work

Site establishment involved the following activities

1. A start meeting was held on the outcrop. General features, time plan etc were set up.
2. The survey instrument was calibrated against known and appointed fix points in the vicinity to the outcrop.
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 grid has no imprint on the collected data.
4. The coordinates of the grid nodes was 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 were identified and marked with crayons.
7. The lithologic boundaries were 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.
10. A fracture system with a specially interesting conglomerate/sandstone infill was studied, photographed and surveyed.

The methodology for mapping fractures follows the method presented in the method description SKB MD 132.003e (SKB internal controlling document) with some modifications described in the introduction (Chapter 1) . The work process was conducted as follows:

11. Each fracture trace was marked with a metal marker at its start (A) and end (B) points 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.
12. A fracture characterisation start meeting was conducted. The aim was to achieve a common judgement of the more general fracture characteristics on the outcrop.
13. 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. The measurements of the day where opened in a CAD software where a reasonability check was performed.
14. Each fracture was mapped with respect to the given geological parameters outlined in SKB MD 132.003e, also given in Tables 5-1 and 5-2.
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. The outcrop was cleared from markers, nails and plastic tape.

4.3.2 Post processing

Off field activities conducted:

17. Construction of ArcMap shape files of fracture traces, lithologic features, outcrop grid and boundary.
18. Calculation of the compass declination by comparing a bearing taken in field with the corresponding survey data
19. Calculation of fracture lengths from the fracture survey data. All fractures shorter than 50 cm where removed from SICADA, CAD and GIS data.

20. Spatial calculation of fracture host rock from the fracture survey and the lithology survey data.
21. Quality control of the survey data with respect to reasonability and permitted codes, as well as a consistency check between calculated orientations from the survey data with the orientations registered on the mapping protocols.
22. 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
Start meeting protocol	SE-P1_05_RL0_StartmötePåHäll.doc	Hard copy
Daily log of activities	Aktivitetsdagbok V2.0.1	Hard copy
SHM protocol	SHM protokoll	Hard copy

Table 4-3. Primary data.

Folders	Files	Description	Gis format
ASM100235_Bedrock_GIS	ASM100235_Bedrock.shp	Bedrock lithology.	Polygon
	ASM100235_Struct-Orient.shp	Structure orientation in bedrock.	Point
	ASM100235_Fault.shp	Fractures along which movement has occurred.	Line
	ASM100235_Bedrock_ Description.jpg/pdf	Map displaying the GIS-layers.	
ASM100235_Fractures_GIS	ASM100235_Fractures.shp	Fracture traces. Contains all fractures having any part within the mapped area.	Line
	LSM000547&8 _FracturesLineM.shp	The traces from the line mapping. Contains all fractures that intersect the lines.	Line
	ASM100235_Sandstone.shp	Fractures with an infill of silty sandstones – conglomerate.	Line
	ASM100235_Fractures.jpg	Map displaying the fracture layers.	
ASM100235_Site_GIS	ASM100235_Grid.shp	The grid established on the outcrop.	Line
	ASM100235_outcrop_mapped.shp	Mapped extent of the outcrop.	Polygon
	ASM100235_outcrop_area.shp	Complete extent of the outcrop.	Polygon
	ASM100235_Rock_samples.shp	The outtake points of the geological specimen of the sandstone infill.	Polygon
	ASM100235_coordinate.shp	A coordinate on the KLX11 outcrop.	Point
	LSM000547&8 _Scanlines.shp	The lines along which the line mapping was executed.	Line
	ASM100235_sitedescription.jpg	Map displaying the outcrop descriptive layers.	

Each shape file is a combination of several files;, such as a database file, different binary files an xls metadata file and sometimes a layout (lyr) file.		
ASM100235_DGN	ASM100235_Outcrop_area.dgn	The boundary of the washed outcrop.
	ASM100235_Grid.dgn	The grid established on the outcrop.
	ASM100235_Scanlines.dgn	The lines along which the line mapping was executed.
	LSM000547&8 _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.
	ASM100235_Fractures.dgn	The mapped fracture traces from the out-crop in cad format.
	ASM100235_Bedrock.dgn	Bedrock lithology.
	ASM100235_Topography.dgn	Extra topographic points needed to sample the 3D form of the outcrop.
	ASM100235_Rock_samples.dgn	The outtake points of the geological speci-men of the sandstone infill.
	ASM100235_Sandstone.dgn	Fractures with an infill of silty sandstones – conglomerate.
ASM100235_Tables	LSM000547&8 _FracturesLineM.xls	The mapped fracture traces from the line mapping in table format.
	ASM100235_Fractures.xls	The mapped fracture traces from the out-crop in table format.
	ASM100235_Topography.xls	Extra topographic points needed to sample the 3D form of the outcrop.
ASM100235_Pictures	jpg-files as listed in:	
	ASM100235 _Photo_texts.xls	
	AFM100235-#.jpg (# ; 1 – 14)	
ASM100235_SICADA	EG165 - ASM100235 _OutcropArea_surveying.xls	Coordinates of the complete extent of the outcrop in a SICADA template.
	EG170 -LSM000547&8 Surveying.xls	Coordinates of the scanlines in a SICADA template.
	GE075 -LSM000547&8 _ 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 - ASM100235 _ 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.

Table 4-4. Documentation.

Description	File name
Report	Report-Detailed outcrop mapping On Drillsite KLX11.Doc
File list	Fillista.doc
QA-protocol	Kontroll av sprickdata för häll klx11.doc
Calibration notes	CompassDeclination

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.
- Scan line fracture mapping.

The compass declination was calculated. The bearings from the south east and south west corners of the survey grid diagonally to the opposite corners where measured in field with compass and the directions were compared to the survey data. A difference of 4° appeared. 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 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) on each square metre of the outcrop. ASM100235 contained 1,029 fractures longer than 0.5 m, which equals approximately 3.1 fractures per m^2, It is quite high in comparison to earlier mapped outcrops in the Laxemar area.

The scan line mapping was performed along two 10 m long lines in a perpendicular cross. One line directed to the north (LSM000547) and the other to the east (LSM000548). The truncation length for fracture traces in the scan line survey was 0.2 m. The fracture frequency along the north trending line was 1.5 fractures per metre, and the frequency along the east trending line was 4.1 fractures per metre respectively. This difference is primarily explained by a strong fracture set trending in a north south direction on the outcrop.

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 ASM100235 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	o	The fracture termination is not visible.
(see Figure A2-1)	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.

ASM100235- Site description

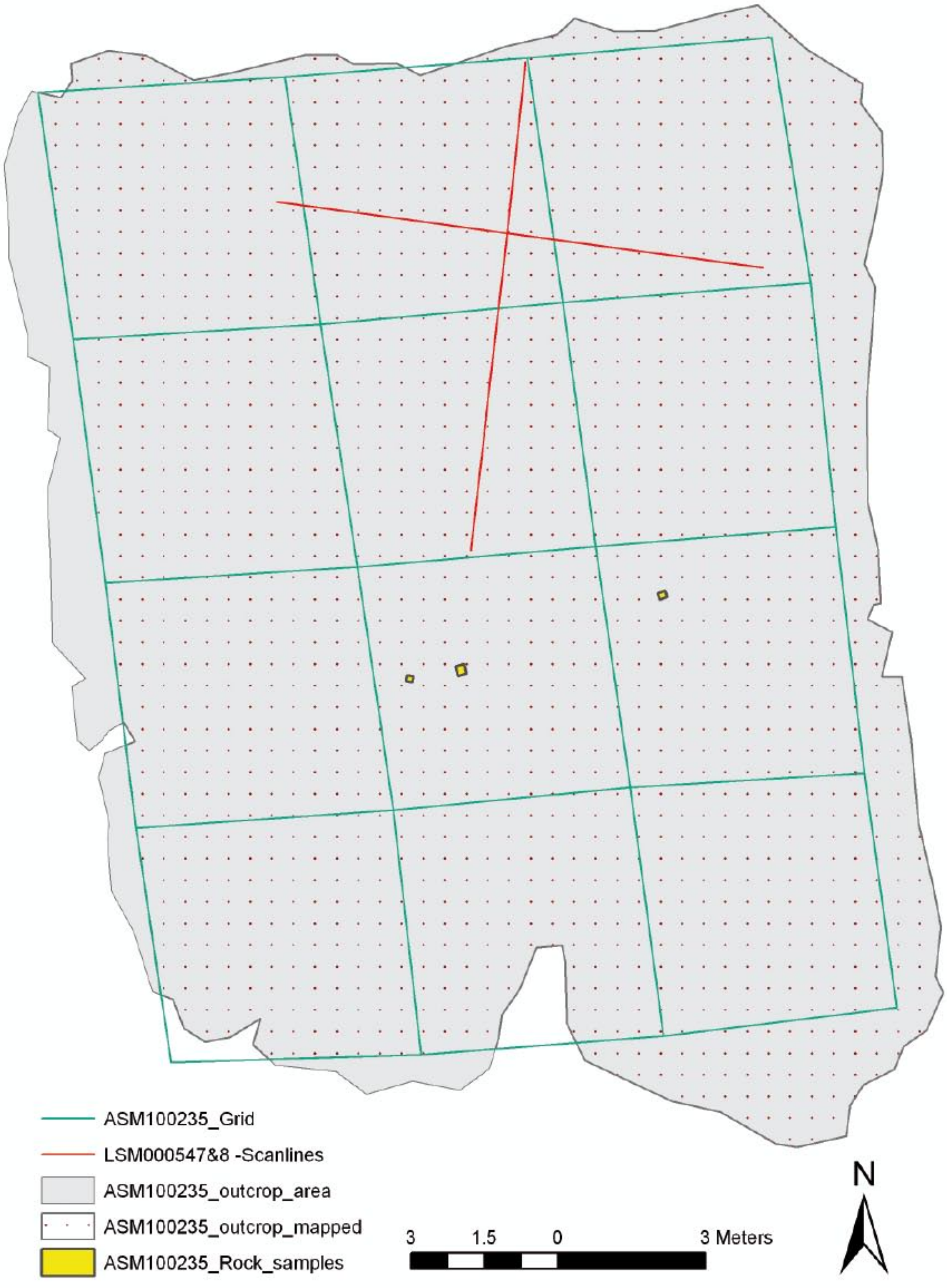

***Figure 5-1**. Outcrop ASM100235. The measuring grid and the different mapping areas displayed. Each grid cell is approximately 5×5 m.*

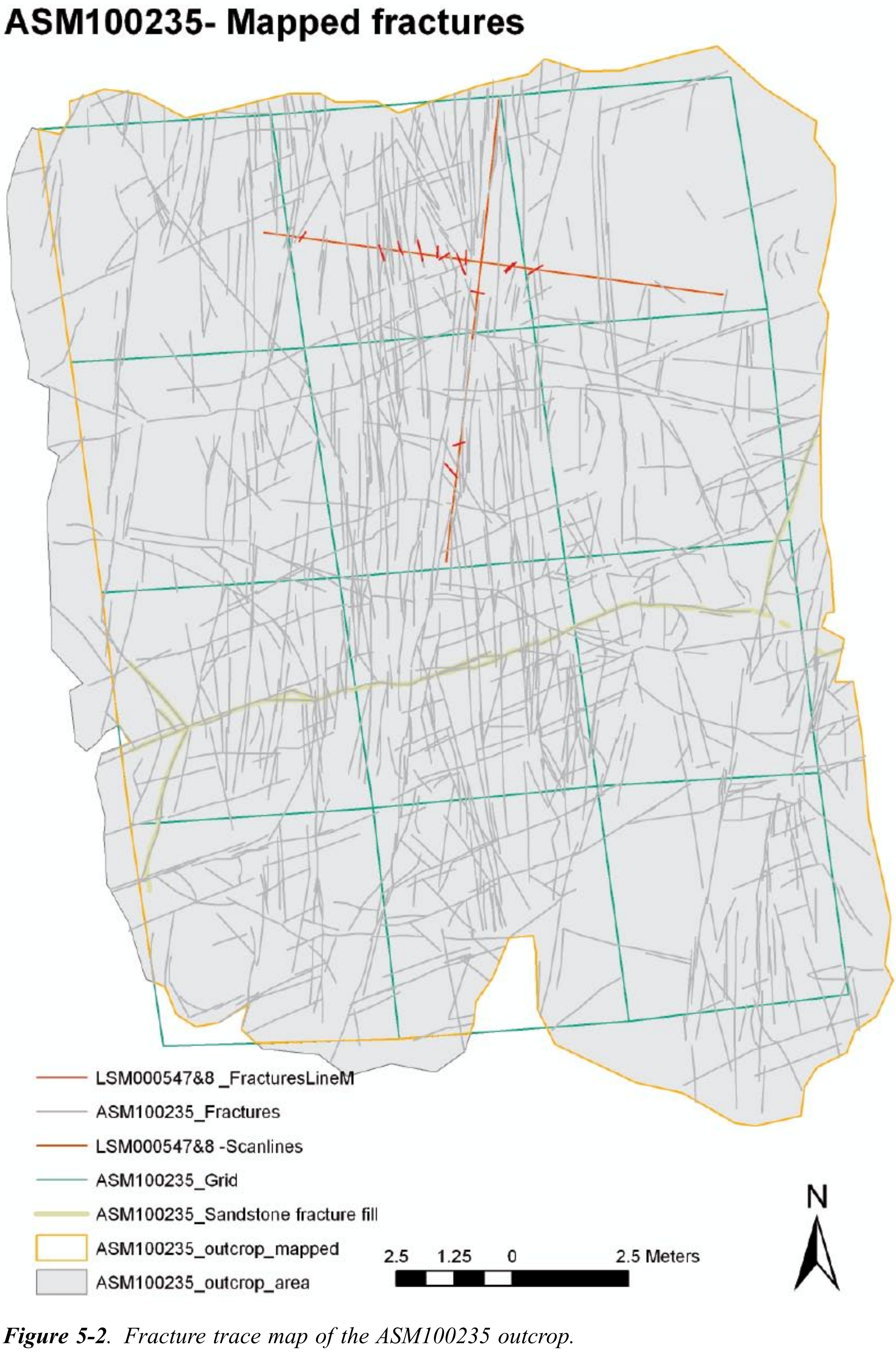

Figure 5-2. *Fracture trace map of the ASM100235 outcrop.*

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 ASM100235 outcrop, that was bedrock mapped, was 349 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).

ASM100235 Outcrop

Four rock types are present in the mapped area of the outcrop ASM100235 – quartz monzodiorite, fine- grained granite, pegmatite and fine-grained diorite- gabbro (Figure 5-3). The quartz monzodiorite is predominant. It is medium grained equigranular and displays a grey color.

No foliation was visible in the rock. Two inclusions of the fine-grained diorite- gabbro rock are arranged in a direction of N340 and N320 respectively, within the quartz monzodiorite.

The red fine- grained granite occurs as dykes that cross-cut the quartz monzodiorite. The width varies from 2 cm to c. 20 cm and the strike and dip varies. The dykes that dominate the outcrop are two sub-parallel dykes in the south-western part, striking approximately N90° with a dip varying between 41° and 50°. The minor dykes vary in direction and the dominating orientations are c. N210/25–40, N290/35, N110–120/50–80, N315/60 and N60/80. The dykes occur as straight or gently curved dykes and the contacts between the dykes and the host rock are sharp. The major dykes, in the south-western part, are coarse grained (outer two centimetres) at the contact to the quartz monzodiorite.

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 predominant orientation is c. N80/70.

Within the quartz monzodiorite two fine-grained diorite- gabbro inclusions occur. The shape of the inclusions is ellipsoidal. The inclusions are heavily weathered compared to the host rock.

At the outcrop several fractures affected by faulting, with a sinistral component of displacement, were mapped. No dextral faulting was observed.

In the southern part of the outcrop several fractures are filled with sandstone. The width varies from 0.5 cm up to 3 cm (Figure 5-2). Within the sandstone rounded rock fragments were detected. In the thin fractures the filling consists of siltstone. A number of fractures, that crossed the sandstone filled fractures, were studied in detailed and none of the fractures could be detected within the sandstone filling.

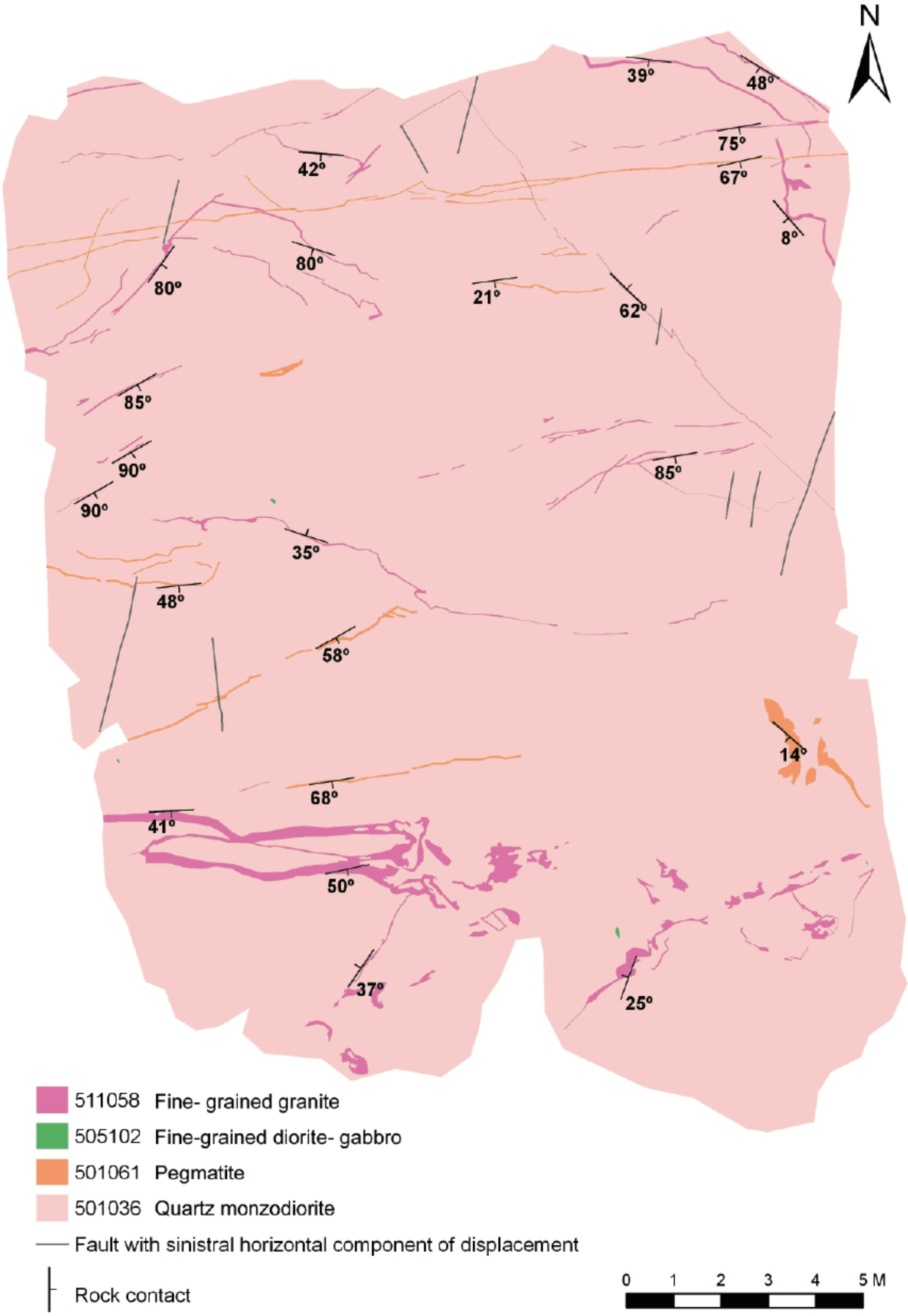

Figure 5-3. Geological map of outcrop ASM100235.