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October 2004

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*Keywords:* Fracture, Bedrock, Mapping.

# Abstract

SKB performs site investigations in Forsmark and Oskarshamn for location of a deep repository for high radioactive waste. This document reports data gained during detailed fracture and bedrock mapping of two outcrops (ASM000208 and ASM000209) at the Laxemar area in Oskarshamn.

The activity aimed at collecting fracture data to be used in discrete fracture analysis and discrete fracture modelling.

Fracture trace geometry and contacts between rock types was measured with a Geodimeter 640S Total Station. The number of points measured along each fracture trace varies between 2 and up to several points depending on the complexity of the trace and the rock surface. All fractures with a trace length interval between 0.5 m to 10 m have been mapped.

Scan line mapping was performed along two 10 m long lines of each 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 survey results were converted to the RT90 system after each completed survey.

Fracture orientation was manually mapped. Each fracture were described with respect to termination, relation to rock boundary, width, shape, roughness, indication of movement, fracture minerals and alteration as described in SKB MD 132-003 (SKB internal controlling document). Detailed bedrock mapping was conducted on both outcrop.

A check of the survey data and consistency check with survey instrument digital data with the mapping protocols have been made to detect magnetic distortion or other erroneous in the field.

The ASM000208 contained 1034 fractures and ASM000209 1030 fractures with a trace length interval between 0.5 m to 10 m. This represents approximately 3.1 and 2.3 fractures per $m^2$, respectively.

# 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 två berghällar (ASM000208 och ASM000208) i Laxemarområdet nära Oskarshamn.

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

Sprickornas geometri har karterats med en totalstation, där ett erforderligt 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 respektive berghäll 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 på varje berghäll.

Slutligen har en jämförelse mellan totalstationsinmätning och kompassinmätning gjorts med avseende på sprickstrykning för att komma åt fel som uppstår på grund av t ex magnetisk störning och andra fel som uppstår i fält.

På ASM000208 och ASM000209 karterades det 1 034 respektive 1 030 sprickor med sprickspår längre än 0.5 m. Detta ger en sprickintensitet av 3.1 sprickor per $m^2$ för ASM000208 och 2.3 sprickor per $m^2$ för ASM000209.

# 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 two outcrops at the Laxemar area in Oskarshamn. The outcrops ASM000208 and ASM000209 were mapped during September 2004.

The detailed fracture mapping campaign was conducted according to the activity plan AP PS 400-04-045. The mapping was used to determine certain parameters, namely fracture relation to rock contacts, such as termination, crossing or coincidence. Cf SKB MD 132-003 (SKB internal controlling document).

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 lokaler inom delområdet Laxemar. | AP PS 400-04-045 | 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 |

The locations of the two investigated outcrops can be seen in Figure 1-1. The outcrops have been exposed from the soil cover prior to mapping. The area of the ASM000208 and ASM000209 outcrops are 331 $m^2$ and 442 $m^2$ respectively.

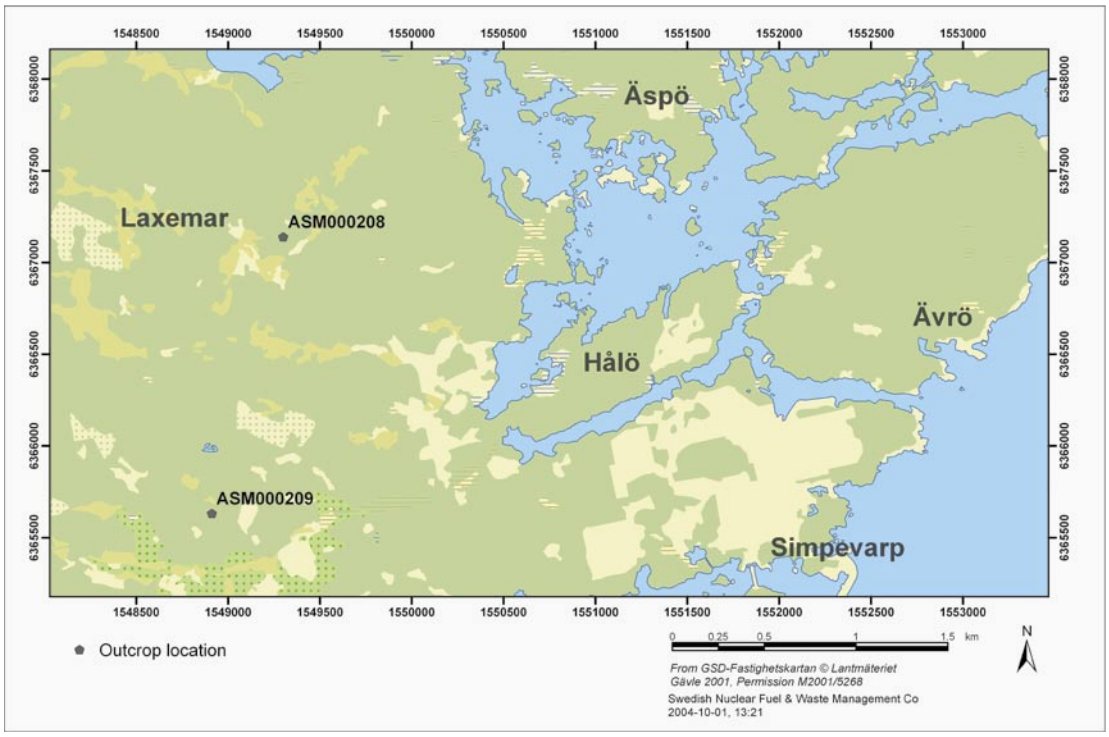


***Figure 1-1.*** *Locations of the outcrops ASM000208 and ASM000209 in the Laxemar area.*

# 2 Objective and scope

The activity aimed at collecting fracture data to be used in discrete fracture analysis and discrete fracture modelling in the regional and local site investigation scale. The survey is expected to indicate the geometric properties for open and sealed fractures in the trace length interval between 0.5 m to 10 m at the sites. The results are indicative of the properties of the local fracture network and can provide important information of the variability of the fractures between the sites. The variability and properties of the fractures may also depend on type of bedrock and its structures witch is presented in appendix.

# 3 Equipment

## 3.1 Description of equipment

The fracture trace geometry and contacts between rock types was measured with a Geodimeter 640S Total Station. In theory, the survey instrument gives an accuracy 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 of 1 cm. The elevation accuracy is estimated to be less than 0.5 cm.

The number of points measured along each fracture trace varies between 2 and up to several points depending on the complexity of the trace and the rock surface. 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 the other fracture parameters were mapped by hand. Equipment includes compass and inclinometers etc.

# 4 Execution

## 4.1 General

The mapping was performed using standardized protocols following methods described in method description for detailed fracture mapping at outcrops and for bedrock mapping, SKB MD 132.003 (SKB internal controlling document) and SKB MD 132.001 (SKB internal controlling document) respectively.

## 4.2 Preparations

The survey instrument was positioned outside the outcrop and was calibrated against at least three fix points on each outcrop. These fix points have also been measured by the regional coordinate survey performed by SKB for outcrop ASM000208 and thus provided the coordinate translation to our local outcrop system. For outcrop ASM000209 coordinates of the regional system were used as fix points. The fix points are listed in Table 4-1. The survey instrument was calibrated against the fix points after each time data was downloaded from the instrument or 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 system after each completed survey.

**Table 4-1. Fix points for outcrops ASM000208, ASM000209.**

| PNR | X | Y | Z |
|---|---|---|---|
| **ASM000208, Laxemar** | | | |
| 1001 | 6 367 117,985 | 1 549 302,297 | 15,285 |
| 1002 | 6 367 156,187 | 1 549 270,818 | 14,191 |
| 1003 | 6 367 162,915 | 1 549 321,384 | 14,435 |
| **ASM000209, Laxemar** | | | |
| 1001 | 6 365 613,12 | 1 548 886,58 | 17,321 |
| 1002 | 6 365 645,06 | 1 548 887,83 | 17,699 |
| 1003 | 6 365 631,58 | 1 548 933,41 | 15,282 |

## 4.3 Execution of field work

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:

1. An approximately square shaped 5×5 m pattern of plastic bands, cf Figure 5-1, was applied over the outcrop as a help to subdivide the outcrop in smaller sub domains during the mapping campaign. These squares have no imprint on the collected data.
2. The survey instrument was calibrated against known and appointed fix points in the vicinity to the outcrop.

3. Each fracture trace was marked with a metal marker at its starting (A) and ending (B) point on the outcrop to keep track of measured fractures. The used truncation length for mapping fracture traces was 0.5 m.
4. 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 controlled by the complexity of the structure. Special attention was made to the ending of each fracture to capture fracture termination behaviour.
5. Each fracture was mapped with respect to the given geological parameters outlined in SKB MD 132-003 (SKB internal controlling document), also given in Tables 5-1, 5-2 and 5-3.
6. Scan line measurements were performed along two 10 m long, approximately orthogonal scan lines.
7. Fracture locations were measured along the scan line. The used truncation length for scan line measurements was 0.2 m.
8. Each fracture was mapped with respect to the geological parameters given in SKB MD 132-003 (SKB internal controlling document).
9. The outcrop was cleared from markers.
10. Digital conversion of survey instrument data to RT90-RHB70 coordinate data,
11. Construction of an ArcMap shape file of fracture traces, square pattern and outcrop boundary.
12. Quality control of the survey data and consistency check with survey instrument digital data with the mapping protocols.
13. Report production.

## 4.4 Data handling/post processing

The deliverables to SKB for the mapping of the ASM000208 and ASM000209 outcrops include:

1. Geological and survey parameters for the areal mapping of the outcrops.
   *Filenames: GE076_Ytkartering_ASM000208.xls, GE076_Ytkartering_ASM000209.xls, ASM000208_survey.xls, ASM000209_survey.xls*
2. Geological and survey parameters for the scan line mapping of the outcrops.
   *Filenames: GE075Linjekartering_ASM000208.xls, GE075Linjekartering_ASM000209.xls, LSM000293_LSM000294_survey.xls, LSM000295_LSM000296_survey.xls*
3. Coordinate points of each survey result of the fracture traces.
   *Filenames: ASM000208_sprickor_kod_pxy.xls, ASM000209_sprickor_kod_pxy.xls, ASM000208_Topo.xls, ASM000209_Topo.xls*
4. ArcMap shapefiles for fracture traces. The shape trace map file has each fracture identified with its elevation (1st coordinate and average), ID number and length.
   *Filenames: ASM000208_TRACES.shp, ASM000209_traces.shp*
5. ArcMap shapefiles for outcrop extent and applied measurement grid.
   *Filenames: ASM000208_OUTCROP.shp, ASM000209_ OUTCROP.shp : ASM000208_ GRID.shp,ASM000209_GRID.shp*
6. ArcMap shapefiles for scan lines.
   *Filenames: GIS_LSM000293_LSM000294.shp, GIS_LSM000295_LSM000296.shp*

7. ArcMapshapefiles for the lithology mapping.
   *Filenames: ASM000208_Contact_Foliation-1.shp, ASM000208_Laxemar1-bergkart.shp, ASM000208_Sprickor-1.shp, ASM000209_Contact_Foliation-2.shp, ASM000209_Laxemar2-bergkart.shp, ASM000209_Sprickor-2.shp*
8. Digital photos and description from the outcrops.
   *Filenames: ASM000208_fototexter.xls, ASM000209_fototexter.xls. These file contain filenames for all photos in ASM000208_foto.zip and ASM000209_foto.zip*
9. Controlling document for metadata for GIS archiving.
   *Filenames: ASM000208_TRACES.xls, ASM000209_TRACES .xls, ASM000208_OUTCROP.xls, ASM000209_ OUTCROP.xls, ASM000208_GRID.xls, ASM000209_GRID.xls, GIS_LSM000293_LSM000294.xls, GIS_LSM000295_LSM000296.xls, ASM000208_Contact_Foliation-1.xls, ASM000208_Laxemar1-bergkart.xls, ASM000208_Sprickor-1.xls, ASM000209_Contact_Foliation-2.xls, ASM000209_Laxemar2-bergkart.xls, ASM000209_Sprickor-2.xls*
10. CAD files for 3d representation of outcrops, scanlines, grids, fractures and additional topography.
    *Filenames: ASM000208_BEGRANS_R14.dwg, ASM000208_LINJEKARTERING_R14.dwg, ASM000208_RUTNAT_R14.dwg, ASM000208_SPRICKOR_KOD_R14.dwg, ASM000208_Topografi.dwg, ASM000209_Begrans.dwg, ASM000209_Linjekartering.dwg, ASM000209_Rutnat.dwg, ASM000209_Sprickor_kod.dwg, ASM000209_Topografi.dwg*
11. Report (this).
    *Filename: Rapport_LaxemarV1.0.doc*

# 5 Results

The results of the fracture mapping campaign include data tables and ArcMap shapefiles of:

- Area fracture mapping.
- Scan line fracture mapping (only data, no shape files).

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. The ASM000208 contained 1034 fractures and ASM000209 1030 fractures. This represents approximately 3.1 and 2.3 fractures per $m^2$ respectively.

The scan line mapping was performed along two 10 m long lines of each 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 ASM000208 is 3.2 and 2.6 factures per meter, respectively. For ASM000209 the fracture frequency along the North trending and West trending line is 2.3 and 3.0 fractures per meter, respectively.

Table 5-1, Table 5-2 and Table 5-3 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 and 5-2 shows the outcrop survey patterns and scan lines at sites ASM000208 and ASM000209 and Figure 5-3 and Figure 5-4, 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) |
|---|---|
| 501033 | Diorite/Gabbro |
| 501044 | Ävrö granite (Småland-Ävrö granite) |
| 505102 | Mafic rock, fine-grained |
| 511058 | Fine-grained granite |
| **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. Physical properties of fractures with codes.**

| | |
|---|---|
| | **Fracture trace** = Visible length of the fracture in meters |
| **Code** | **Fracture termination** |
| | Right-hand rule. Fracture termination A is starting point and B ending point. At vertical dip, the strike (B-direction) is against the northern hemisphere (271–90 degrees). Horizontal fractures are defined with strike=0 |
| o | Termination outside outcrop (under soil cover, water or vegetation) |
| p | Termination within outcrop, not against any other fracture |
| t | Termination against another fracture |
| y | Fracture terminates in a y-shape (one or several times) |
| x | Fracture terminates against a rock boundary. Rock code is given in column for rock termination, respectively |
| **Code** | **Fracture relation to rock boundary** (except termination against, cf above) |
| a | Fracture crosses no rock boundary |
| b | Fracture crosses one rock boundary |
| c | Fracture crosses several rock boundaries |
| d | Fracture is oriented in a rock boundary (rock types given in “comment” column) |
| **Code** | **Fracture aperture** |
| o | Fracture appears to be open |
| s | Fracture appears to be closed |
| **Code** | **Fracture shape** |
| t | Fracture is stepped up to approximately 1 cm (if the distance is greater, each part is mapped separately) |
| u | Fracture is undulating |
| p | Fracture is planar |
| **Code** | **Fracture roughness** |
| r | Fracture surface is rough |
| s | Fracture surface is smooth |
| h | Fracture surface indicate movement (e.g. slickensides) |
| **Code** | **Indication of movement** |
| 0 | There is an indication that movement have not occurred along the fracture (e.g. no displacement along a crossing rock boundary) |

| | |
|---|---|
| s | Sinistral |
| d | Dextral |
| 1 | Indication of movement with unknown direction |
| – | None of above indications has been observed |

**Table 5-3. Fracture mineralogy and chemistry with codes.**

| **Code** | **Fracture minerals** |
|---|---|
| 16 | Epidot |
| 30 | Calcite |
| 33 | Chlorite |
| 36 | Quartz |
| 44 | Muscovite |
| 106 | Zeolite (assumed) |
| 104 | Jasper (red chalcedony) |
| 45 | Other or unidentified fill |
| **Code** | **Alteration of side-rock** |
| r | The rock in the vicinity of the fracture is red coloured < 1 cm on each side, if its more wide see comments |
| rr | The rock in the vicinity of the fracture is deep red coloured < 1 cm on each side, if its more wide see comments |
| 0 | No alteration (equivalent to ISRM** weathering class I) |
| 1 | County rock is discoloured, not red (ISRM weathering class II) |
| 2 | Weathering due to mineral hardness with no disintegration (ISRM weathering class III) |

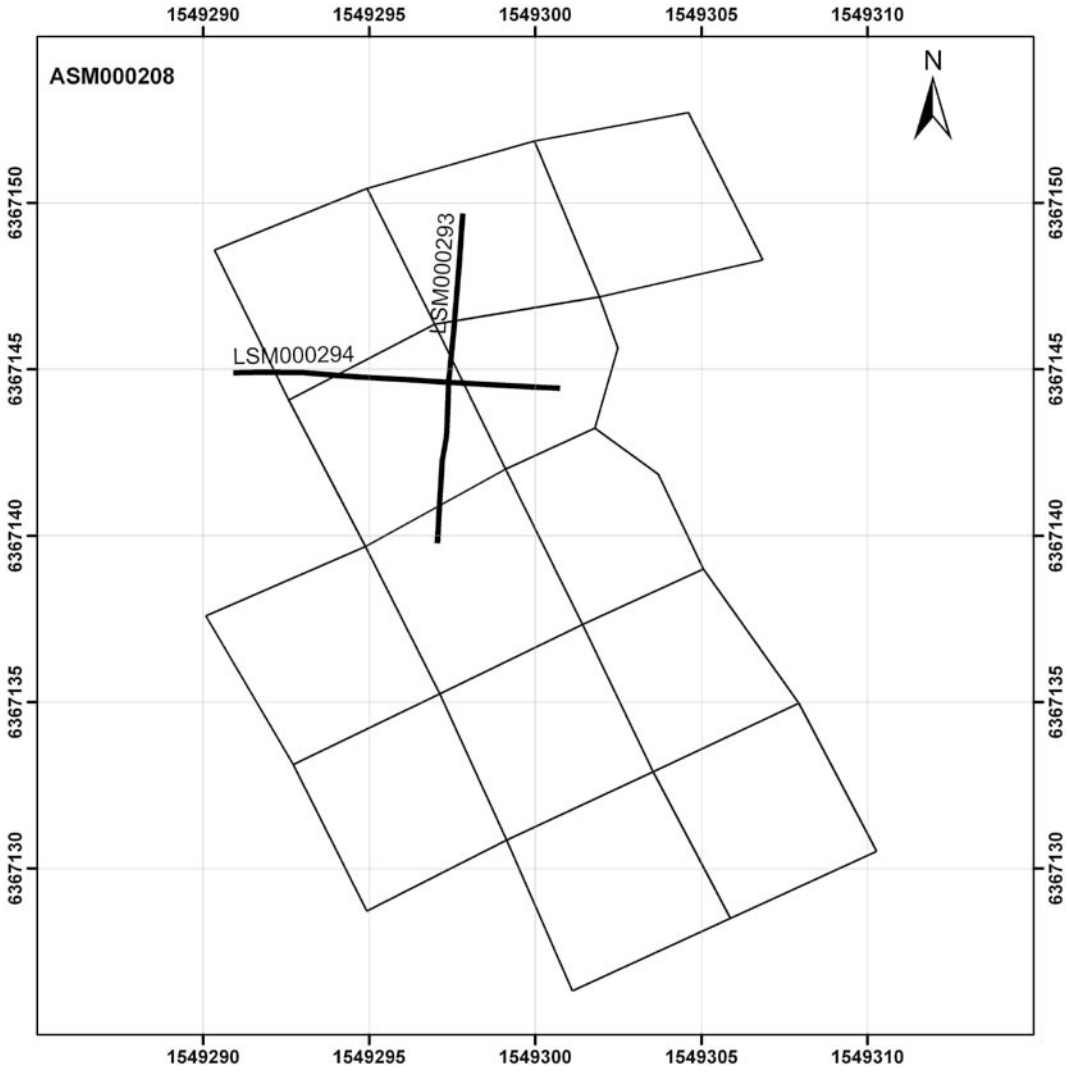


***Figure 5-1.*** *Mapping grid and mapped area at the ASM000208 outcrop, also showing the scan lines LSM000293 and LSM000294. Each grid cell is approximately 5×5 m.*

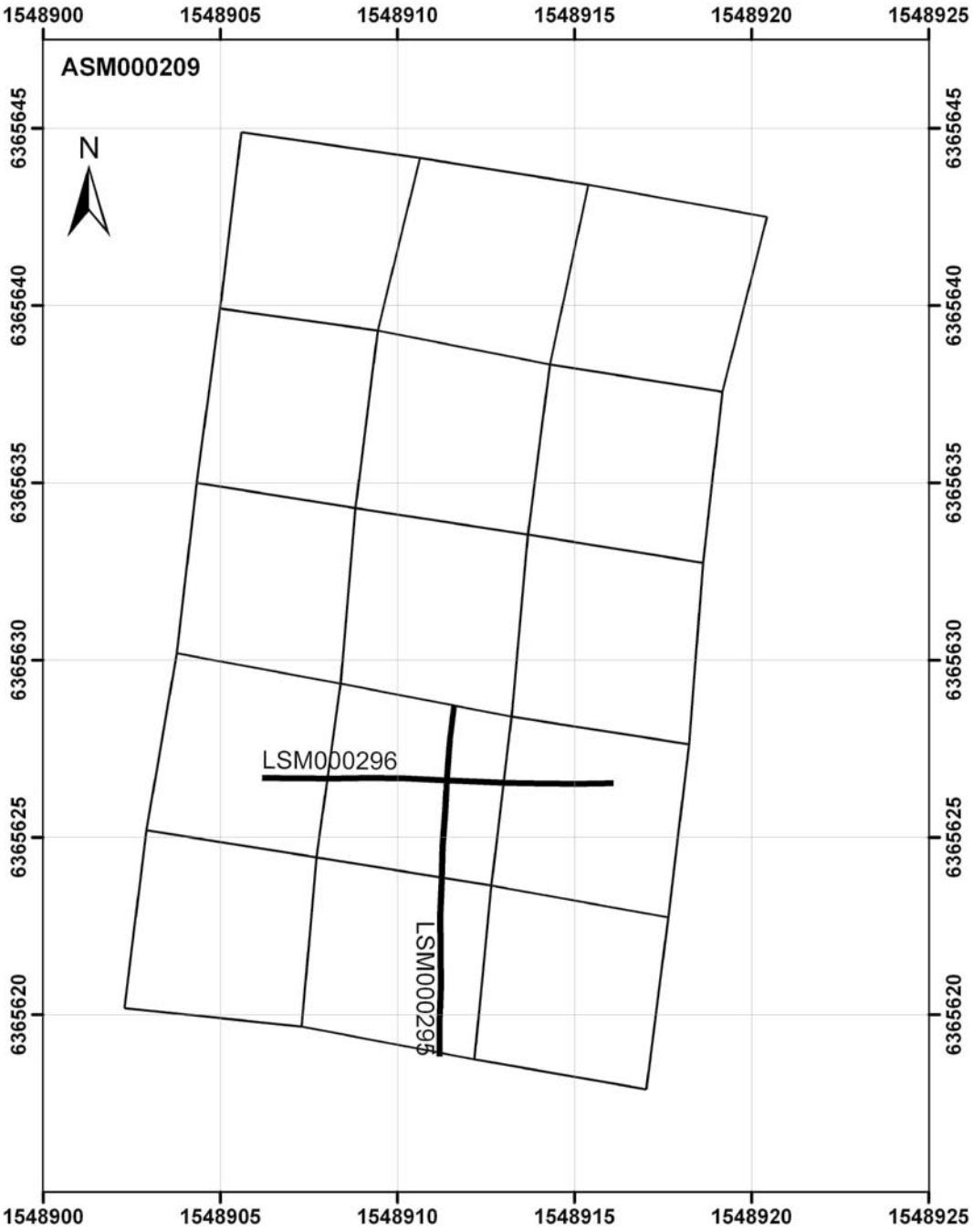


***Figure 5-2.*** *Mapping grid and mapped area at the ASM000209 outcrop, also showing the scan lines LSM000295 and LSM000296. Each grid cell is approximately 5×5 m.*


***Figure 5-3.*** *Fracture trace map of the ASM000208 outcrop.*

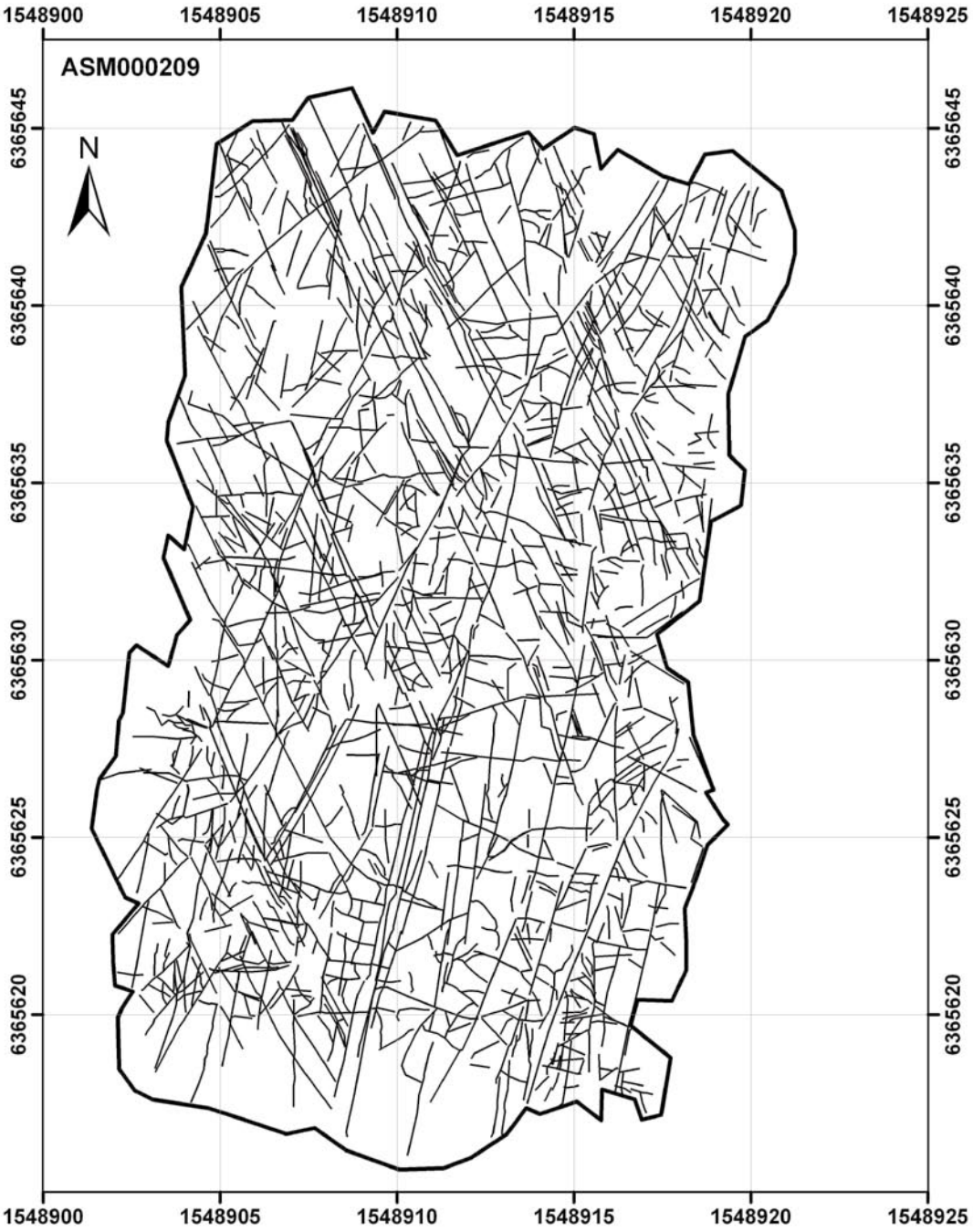


***Figure 5-4.*** *Fracture trace map of the ASM000209 outcrop*

# Appendix 1

## Detailed bedrock mapping at two sites, ASM000208 and ASM000209, at Laxemar area, Oskarshamn

Detailed bedrock mapping was conducted at two localities in the Laxemar area. Both outcrops were exposed from the soil cover prior to mapping. The area of ASM000208 outcrop was 331 $m^2$ and the area of ASM000209 was 442 $m^2$. 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 areal distribution of rock types was measured with a Geodimeter 640S Total Station (see chapter Description of equipment).

### *ASM000208*

Four rock types are present in the mapped area of the outcrop ASM000208 – Ävrö granite (granite to quartz monzodiorite, generally porphyric), fine- to medium-grained granite, diorite/gabbro and fine-grained mafic rock (Figure A1-1).

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. The Ävrö granite displays a weak foliation that strikes and dips approximately N285/80 in the northern part of the outcrop.

In the southern part of the mapped area, there is a c 5 m wide part of a diorite/gabbro with a greenish dark grey color and that is fine- to medium-grained. The contact between the diorite/gabbro and the Ävrö granite is diffuse in character where it can be observed. The diorite/gabbro is deeper weathered, up to 10 cm, than all the other rock units.

The red fine- to medium-grained granite occurs as dykes that cross-cut all rock units. The width varies from 1 cm to c 60 cm and the strike and dip diverges, but the main strike and dip are N225–255/45–75 and N50–65/45–80. The dykes occur as straight or gently curved dykes and the contacts between the dykes and the host rock are sharp. In the southern part of the outcrop the contact between the Ävrö granite and the diorite/gabbro is intensively intruded by the granite dyke, generating angular fragments of the diorite/gabbro.

Within the southern dyke of the fine to medium grained granite inclusions of grey fine-grained mafic rock (diorite to gabbro). The inclusions are rounded, ellipsoidal or in some cases irregular and not that deep weathered as the fine- to medium-grained diorite/gabbro. The size varies from 4×4 cm up to 80×40 cm

Within the Ävrö granite a large amount (c 150) of mafic inclusions occurs. The shape of the inclusions is rounded or ellipsoidal and in some cases irregular. The size varies from 2×2 cm up to 40×10 cm. The inclusions are almost totally weathered compared to the host rock. The main strike and dip of the inclusions is N285/80 in the northern and central part of the mapped area, while in the southern part a strike and dip of N248/70 predominate.

At the outcrop two fractures affected by faulting with a sinistral component of displacement have been mapped.

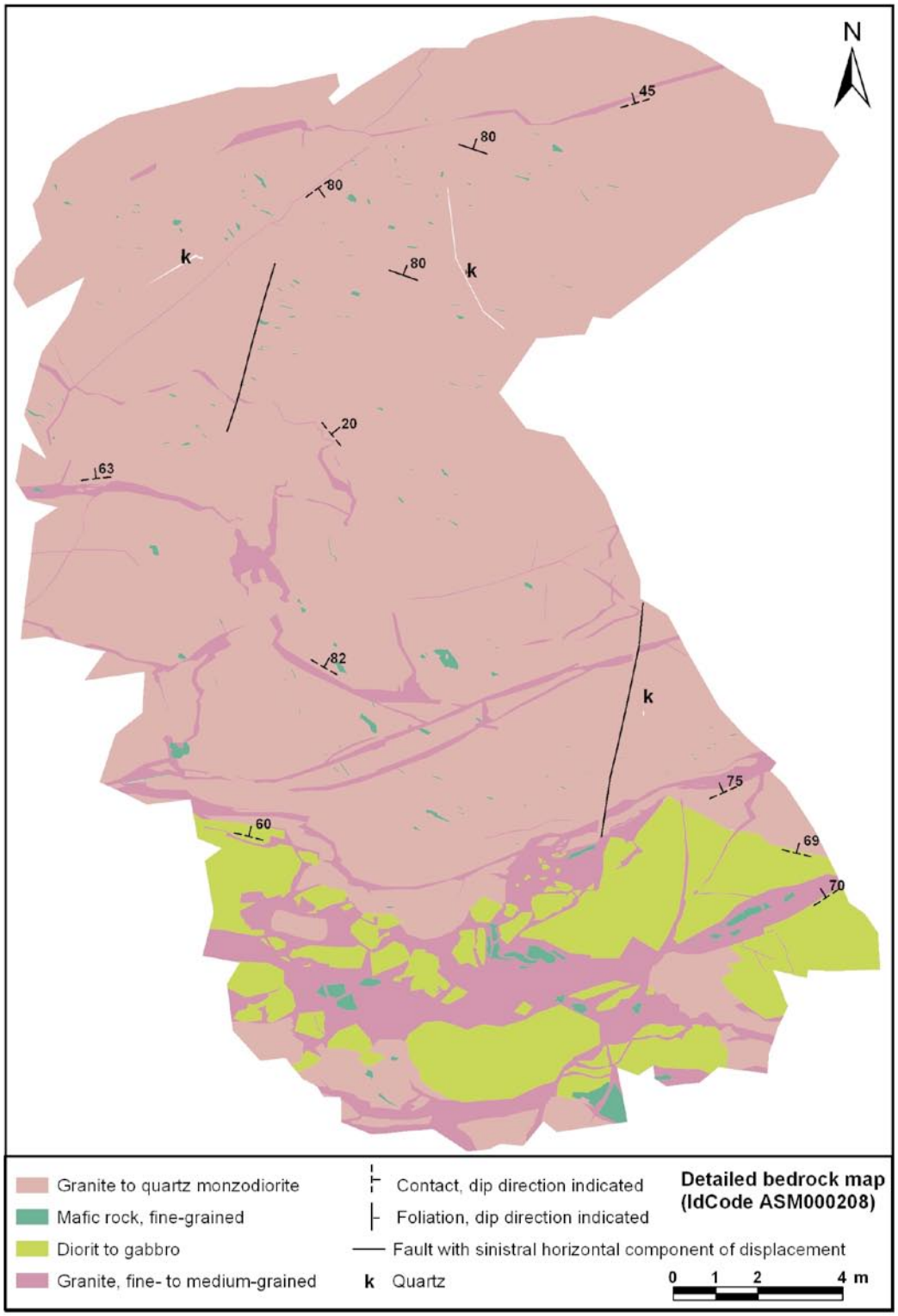


***Figure A1-1.*** *Geological map of outcrop ASM000208.*

### *ASM000209*

Three rock types are present in the mapped area of the outcrop ASM000209 – Ävrö granite (granite to quartz monzodiorite, generally porphyric), fine- to medium-grained granite and diorite/gabbro (Figure A1-2).

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. Especially in the northern part of the mapped area, the Ävrö granite displays a weak foliation that strike and dip approximately N120–130/80. At the upper central part of the outcrop, there is a 5–7 m wide zone of a mixture (mapped as diorite/gabbro, see Figure A-2) of the Ävrö granite and the diorite/gabbro which is greenish grey and which is medium- to coarse-grained. This indicates that the rock types are coeval and a mixing of magmas may have occurred. All the rock contacts of the Ävrö granite and the diorite/gabbro are more or less diffuse in character. The mixture zone has a banded appearance (strike N120–130) due to that the grain size and distribution of the phenocrysts of feldspar differs.

In the southern and northern part of the mapped area the diorite/gabbro occurs without influence of the Ävrö granite and displays a greenish dark grey color and that is fine- to medium-grained.

The red fine- to medium-grained granite occurs as dykes that cross-cut all rock units. The width varies from 1 cm to c 20 cm and the strike and dip diverges, but the main strike and dip are N230–250/65–80 and N65–70/35–90. The dykes occur mainly as straight or gently curved dykes and the contacts between the dykes and the host rock are sharp.

Within the Ävrö granite a few mafic inclusions occur. The shape of the inclusions is rounded or ellipsoidal. The size is approximately 5 to 10 cm. The inclusions are almost totally weathered compared to the host rock.

Within the outcrop 30 fractures affected by faulting with a sinistral component of displacement have been mapped. The dominating strike and dip of these faults is c N200/80. Furthermore, four faults with a dextral component of displacement have been mapped.

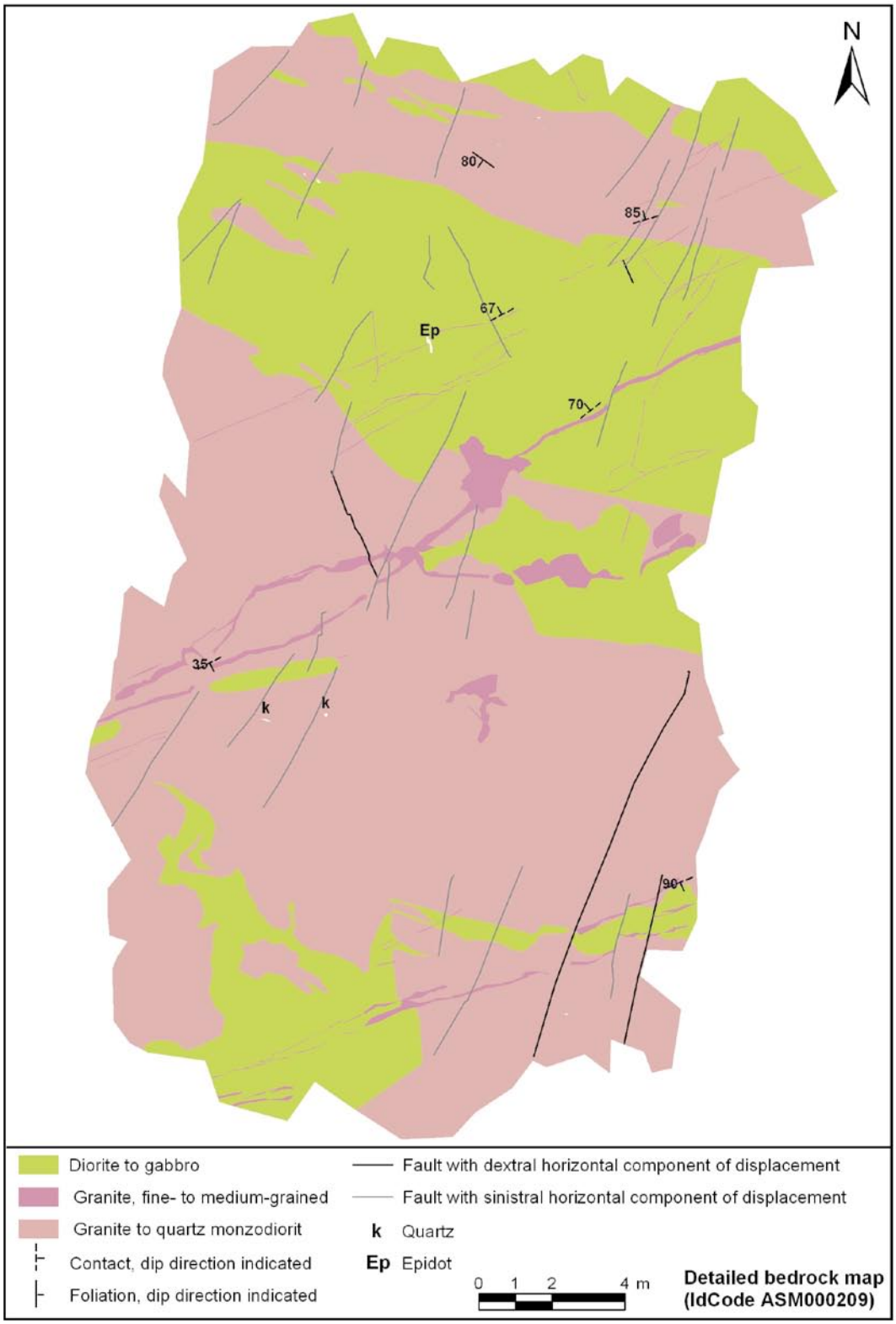


***Figure A1-2.*** *Geological map of outcrop ASM000209.*