P-04-88

Forsmark site investigation

Detailed fracture mapping of two trenches at Forsmark

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Abstract

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

The aim of trenching was to investigate N-S and NE-SW striking lineaments, as indicated by topography and magnetic data, and also to collect data for statistical analyses of fractures for the DFN model. The DFN model aims to stochastically model the fracture network.

Fracture trace geometry and rock contacts were surveyed with a total station, with the survey points along the fracture traces adapted to fracture geometry. Survey points varied from two for a straight trace on a flat surface to several points along an undulating trace or an irregular rock surface. All fractures with a length over 0.5 m were surveyed. All surveyed data has been converted to the RT 90 survey system.

Strike, dip and other properties such as rock type, termination, rock type contact relationships, aperture, shape, roughness, indications of movement, mineral infillings and weathering were registered manually, in accordance with the SKB internal controlling document (132.003). Detail bedrock mapping, including magnetic susceptibility measurements, were carried out by personnel from SwedPower AB.

The trench AFM001243 runs perpendicular to the NE-SW lineament. The detail fracture mapping covers an area of 74 square metres, 215 fractures were mapped, resulting in a fracture frequency of 2.9 fractures per square metre. The trench AFM001244, perpendicular to the N-S lineament, features a detail mapped area of 211 square metres, 795 mapped fractures and a frequency of 3.8 fractures per square metre.

In the trench AFM 001244 scan line mapping was also made. The mapping was performed along a 10 m long east-west trending scan line and three, perpendicular, ca 3 m long north-south trending scan lines. Truncation of the fracture trace in the scan lines was 0.2 m. No scan line survey was performed in the trench AFM001243.

A comparison was made between surveyed points using the total station and manually recorded data, mainly concerning fracture host rock and fracture strike in order to detect errors such as magnetic disturbance, compass reading errors, etc.

The dominating rock type in both trenches is medium-grained metagranite and a fine- to medium grained, more leucocratic granite. In the trench AFM001244 (perpendicular to the N-S lineament) the metagranite has been intruded by a swarm of roughly NNE striking veins and dykes of leucocratic granite and pegmatitic granite.

The mean susceptibility values are more than five times higher for corresponding rock types in AFM001244 compared with AFM001243. The lowest values were measured in dykes and veins of pegmatitic granite.

In the deepest part of the trench AFM001243 there are fractures filled with adularia and quartz as well as oxidised bedrock.

Sammanfattning

SKB utför platsundersökningar i Östhammar och Oskarshamn för att finna en plats att djupförvara använt kärnbränsle. Följande rapport beskriver en detaljkartering av sprickor och bergarter på hällar i två grävda diken i Forsmarksområdet nära Östhammar.

Syftet med detaljkarteringen var att undersöka två lineament, orienterade i N-S och i NE-SW, som har tolkats från topografiska och magnetiska data. I undersökningen har sprickdata samlats in för statistisk analys (DFN) av sprickor. Denna analys ger en stokastisk modell av spricknätverket.

Sprickornas geometri har karterats med totalstation, där erforderligt antal punkter uppmätts längs sprickspår på hällytan. Om sprickan är rak och hällens topografi jämn, har endast de två ändpunkterna uppmätts. Om sprickan är undulerande eller om hällytans topografi varierar, har flera mätpunkter registrerats på lämpliga ställen längs med sprickspåret. Samtliga sprickor med sprickspår längre än 0,5 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 -vidd, -form, relation till bergartsgränser, strävhet, rörelseindikationer, sprickmineral och vittring, i enlighet med vad som beskrivs i SKB: s metodbeskrivning (132.003). Detaljerad bergartskartering samt mätningar av magnetisk susceptibilitet utfördes av SwedPower AB.

Den detaljkarterade arean vid AFM001243 (vinkelrät det NE-SW-liga lineamentet) är 74 m^2 (total area 104 m^2). Här karterades 215 sprickor som gav en sprickfrekvens på 2,9 sprickor per m^2. Motsvarande för AFM001244 (vinkelrät det N-S-liga lineamentet) är en karterad area på 211 m^2, 795 karterade sprickor och en sprickfrekvens på 3,8 sprickor per m^2.

På berghällen i diket AFM001244 utfördes även linjekartering längs en ca 10 meter lång linje i ungefär öst-västlig riktning och tre, sammanlagt 10 meter långa, nord-sydliga linjer. I anslutning till dessa linjer karterades samtliga sprickor med sprickspårslängd längre än 0,2 m.

En jämförelse mellan totalstationsinmätning och manuellt insamlade data gjorts särskilt med avseende på sprickstrykning och sidoberg, för att komma åt fel som uppstår i fält t ex på grund av magnetisk störning, felavläsning av kompass.

De dominerande bergarterna i båda dikerna är medelkorning metagranit samt en fin- till medelkornig leucokratisk granit. I diket AFM0012144 (vinkelrät mot det N-S-liga lineamentet) finns en svärm av NNO-liga gångar och ådror av leucokratisk och pegmatitisk granit.

Den magnetiska susceptibiliteten är mer än fem gånger högre för samma bergart i AFM001244 jämfört med AFM001243. De lägsta värdena uppmättes i gångar och ådror av pegmatitisk granit.

I den djupaste delen av dike AFM001243, är bergarten starkt oxiderad och innehåller kvarts- och adulariafyllda sprickor.

Contents

1 Introduction

SKB performs site investigations in Östhammar and Oskarshamn for location of a deep repository for high radioactive waste. This document reports the data gained during detailed bedrock mapping and subsequent detailed fracture mapping of two trenched outcrops at the Forsmark area in Östhammar. The outcrops AFM001243 and AFM001244 were mapped during October 2004.

The aim of trenching was to investigate N-S and NE-SW trending lineaments interpreted from topography and airborne geophysical measurements. In the study the rock types were mapped and fracture data was collected for statistical analyses for the DFN model, which aims to describe the stochastic fractures.

The mapping was used to determine certain parameters, namely fracture relation to rock contacts, such as termination, crossing or coincidence, according to SKB internal controlling documents, as listed in Table 1-1.

The locations of the two investigated trenches are shown in Figure 1-1. The outcrops were stripped from the soil cover and thoroughly cleaned prior to mapping. The areas of the two outcrops (AFM001243 and AFM001244) are 104 m^2 and 211 m^2 respectively. The area covered with the detailed fracture mapping on outcrop AFM001243 was 74 m^2 (see nonconformities).

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

Activity plan	**Number**	**Version**
Detaljerad sprickkartering av lokaler inom delområdet Forsmark	AP PF 400-04-81	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

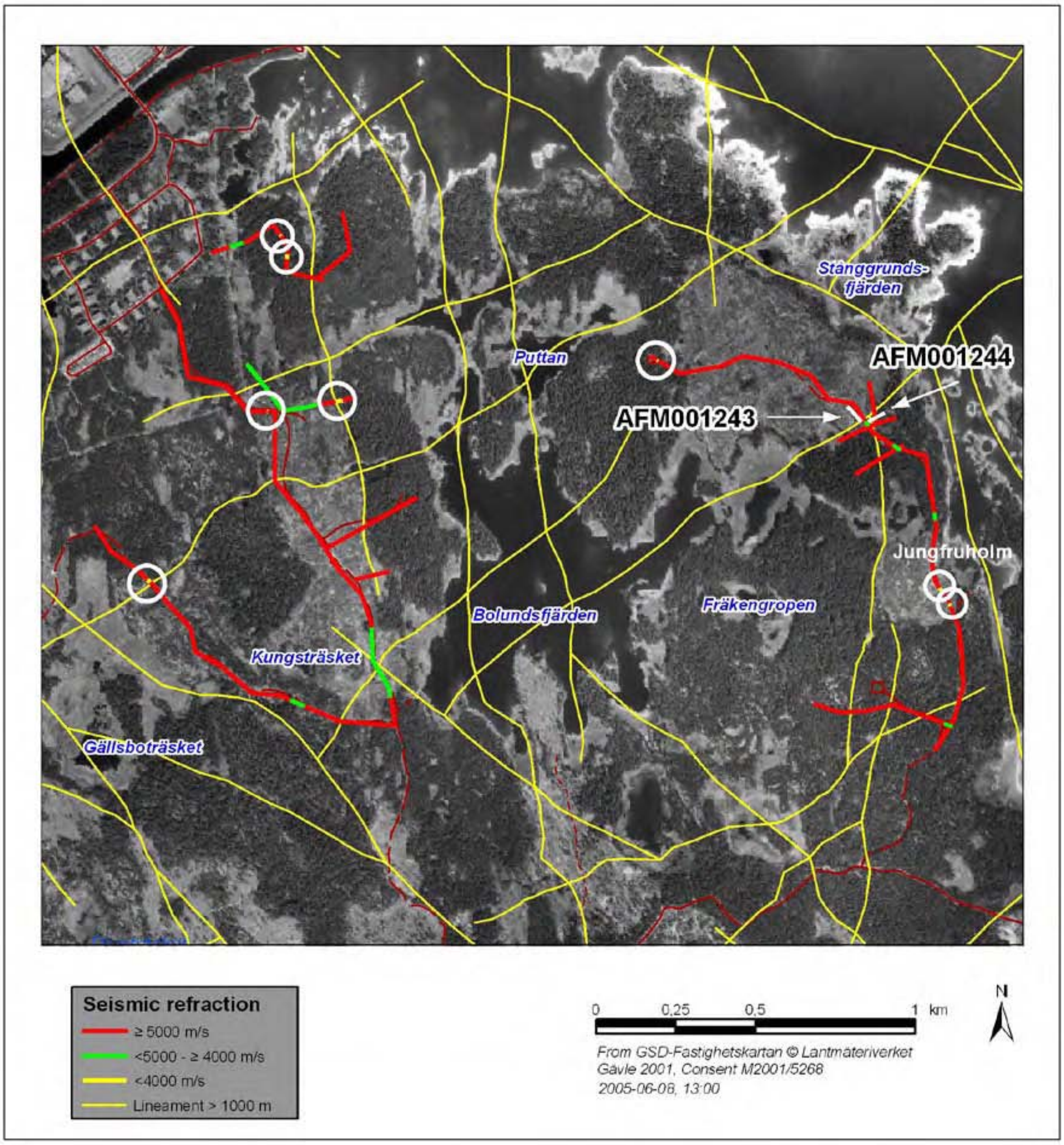


Figure 1-1. *Location of trench 3 and 4 (AFM001243 and AFM001244) in the Forsmark area.*

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 two outcrops. The results are indicative of the properties of the local fracture network and can provide important information of the variability of the fractures over the investigation area. The variability and properties of the fractures may also depend on rock type and the bedrock structures which is presented in Appendix A.

3 Equipment

3.1 Description of equipment

Fracture trace geometry and rock boundaries were measured with a Geodimeter 640S total station. Theoretically, 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 2 cm. The elevation error 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 topography of the rock surface. The number of points along a rock boundary varies between a few and up to a hundred. More measurements result in a better definition of the extent of the fracture trace or rock boundaries. 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 fracture orientation and fracture characteristics were mapped manually. Equipment includes compass, clinometers and hand lens.

4 Execution

4.1 General

The mapping was performed using standard protocols, following methods described in SKB internal controlling documents SKB MD 132.003 and SKB MD 132.001. Detailed bedrock mapping was carried out prior the detailed fracture mapping by Jesper Petersson and Göran Skogsmo, SwedPower AB (Appendix A).

4.2 Preparations

The survey instrument was positioned outside the outcrop and was calibrated against at least three fixed points on each outcrop. These fixed points were also related to the regional coordinate survey established by SKB. The fixed points are listed in Table 4-1. The survey instrument was calibrated against the fixed points at the beginning of a fieldwork session and each time data was downloaded from the instrument. 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. Fixed points for outcrops AFM001243, AFM001244.

Pnr	X	Y	Z	TYPE
SKB:				
4171	6699462,847	1633257,301	3,734	PP
4172	6699444,118	1633308,128	2,433	PP
Trench 4 (perpendicular to the road, AFM001244)				
101	6699505,057	1633161,719	2,098	SPI
102	6699509,925	1633184,907	2,732	SPI
103	6699522,151	1633209,819	4,088	SPI
104	6699511,933	1633220,130	3,704	SPI
105	6699518,368	1633248,826	3,549	SPI
Trench 3 (along the road, AFM001243)				
201	6699523,870	1633159,627	1,818	SPI
202	6699562,244	1633134,052	1,897	SPI

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. The survey instrument was calibrated against known and appointed fix points in the vicinity to the outcrop.
2. 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 applied truncation length for mapping fracture traces was 0.5 m.
3. Fracture position 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 certain fractures to determine their particular termination characteristics.
4. 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.
5. Scan line mapping was performed only at outcrop AFM001244, as outcrop AFM001243 did not feature a sufficient area with a rock mass quality high enough to fulfil the criteria for a relevant scan line mapping (approximately 1 fracture per sq m). Scan line mapping at AFM001244 was carried out along one 10 m long approximately East trending line and three 3–3.5 m long approximately North trending lines.
6. Fracture locations were measured along each scan line. The used truncation length for scan line fracture measurements was 0.2 m.
7. Each fracture was mapped with respect to the geological parameters given in SKB MD 132-003 (SKB internal controlling document).
8. The outcrop was cleared from markers.
9. Construction of an ArcMap shape file of fracture traces, square pattern and outcrop boundary.
10. Quality control of the survey data and consistency check with survey instrument digital data with the mapping protocols. This has in particular been the case for fracture strike and fracture host rock.
11. Report production.

4.4 Data handling/post processing

The deliverables to SKB for the mapping of the AFM001243 and AFM001244 trenches (field note Forsmark 479, 480, 507) include:

Trench No	Folders	Files
AFM001243	AFM001243_Bedrock_GIS	
	AFM001243_Bergarter.shp	
	AFM001243_Bergarter.xls	
	AFM001243_Struct-Orient.shp	
	AFM001243_Struct-Orient.xls	
	AFM001243_CAD	
	AFM001243_Begrans_karterad.dwg	
	AFM001243_Begrans.dwg	
	AFM001243_Sprickor_kod.dwg	
	AFM001243_pictures	
	.jpg-files as listed in:	
	AFM001243_fototexter.xls	
	AFM001243_Fractures_GIS	
	AFM001243_outcrop_MAPPED.shp	
	AFM001243_outcrop_MAPPED.xls	
	AFM001243_outcrop_area.shp	
	AFM001243_outcrop_area.xls	
	AFM001243_TRACES.shp	
	AFM001243_TRACES.xls	
	AFM001243_SICADA	
	EG165 – MappedArea_surveying_ AFM001243.xls	
	EG165 – OutcropArea_surveying_ AFM001243.xls	
	GE076_Ytkartering_AFM001243.xls	
	AFM001243_sprickor+extra	
	AFM001243_Sprickor_kod.	
	AFM001243_Suscept.xls	
	AFM001243_Pinnar.xls	

Trench No	Folders	Files
AFM001244	AFM001244_Bedrock_GIS	
	AFM001244_SZ.shp	
	AFM001244_SZ.xls	
	AFM001244_ Struct-Orient.shp	
	AFM001244_ Struct-Orient.xls	
	AFM001244_Shear_zone.shp	
	AFM001244_Shear_zone.xls	
	AFM001244_Bergarter.shp	
	AFM001244_Bergarter.xls	
	AFM001244_CAD	
	AFM001244 _BEGRANS_.dwg	
	AFM001244 _LINJEKARTERING.dwg	
	AFM001244_SPRICKOR_KOD.dwg	
	AFM001244_pictures	
	.jpg-files as listed in:	
	AFM001244_fototexter.xls	
	AFM001244_Fractures_GIS	
	AFM001244_outcrop.shp	
	AFM001244_outcrop.xls	
	AFM001244_TRACES.shp	
	AFM001244_TRACES.xls	
	LFM000821-824.xls	
	LFM000821-824.shp	
	AFM001244_SICADA	
	EG165 -Area_surveying_AFM001244.xls	
	EG170 –Line_surveying_AFM001244.xls	
	GE075_Linjekartering_AFM001244.xls	
	GE076_Ytkartering_AFM001244.xls	
	AFM001244_sprickor+extra	
	AFM001244_sprickor_kod.xls	
	AFM001244_Suscept.xls	
	AFM001244_Pinnar.xls	

4.5 Analyses and interpretation

Analyses such as modelling and interpretation are subject to separate project reports, and therefore not treated here.

4.6 Nonconformities

The slope stability conditions in the trench along the road (AFM001243) were regarded not to fulfil safety requirements for the time consuming detailed fracture mapping. Therefore, a more generalised mapping was performed. This included orientation for groups of fractures, and an approximation of the location of the fractures. Due to the remote character of the mapping, not every fracture was mapped in this part of the trench. For this reason, the number of fractures registered at the locality using the truncation level of 0.5 m is underestimated. Furthermore, the southernmost and the deepest part of the trench was not mapped because the rock surface was covered by mud.

Scan line mapping was not performed at outcrop AFM001243, since it did not feature a sufficient area with a rock mass quality high enough to fulfil the criteria for a relevant scan line mapping (approximately 1 fracture per sq m).

5 Results

The results of the detailed fracture mapping include data tables and ArcMap shapefiles for the area fracture mapping and for the scan line fracture mapping (only data, no shape files).

Based on experience from work on 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 AFM001243 contained 215 fractures and AFM001244 795 fractures. This represents approximately 2.9 and 3.8 fractures per m^2 respectively.

However, it must be stressed that the mapping of the deepest part of AFM001243 was generalised, and not all fractures were registered. The number of fractures in AFM001243 is therefore underestimated. Also the truncation level (0.5 m), together with the limited exposure in this part of trench AFM001243 contributed to underestimation of the fracture frequency. The relative fracture frequency in this part is actually higher than in the northern, more shallow part of the trench, which was mapped in detail. A conspicuous fracture set in the deepest part consists of adularia and quartz filled fractures with oxidised walls (Figure 5-1). Another feature of interest is that the exposed central part of AFM001243 (i.e. the part that was mapped in detail) corresponds to pre-existing, flat-lying fracture planes, of which some had coating remnants of calcite, chlorite and, more rarely, asphalt on the fracture surface (Figure A-1a).

Scan line mapping at AFM001244 resulted in a fracture frequency along the northerly trending line of 2.3 fractures per metre and along the three westerly trending lines 1.4 fractures per metre.

The Tables 5-2 to 5-4 are showing the codes applied for the mapped geological parameters on the fracture traces. The parameters have been coded according to a specified system suitable for retrieving data from SICADA.

Figure 5-2 is showing the outcrop survey pattern and scan lines at site AFM001244. Figure 5-3 shows the actual trace maps of outcrop AFM001243 and Figure 5-4 shows the actual trace maps of outcrop AFM001244.

The generalised mapping of the deepest part of AFM001243 includes orientation for groups of fractures, as shown in Table 5-4 and an approximation of fracture location, as shown in Figure 5-5.

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

code	Rock type (the two first digits relate to the Forsmark site)
111058	Granite, metamorphic, fine- to medium-grained
101061	Pegmatite, pegmatitic granite, metamorphic
101057	Granite to granodiorite, metamorphic, medium-grained
101058	Granite, metamorphic, aplitic
	Hydrothermal quartz vein/segregation
	Structure, appearance, grain-size of matrix, Colour
	Code explanations are given in the SICADA data tables GE076 and GE075
	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 and codes applied.

	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)

	Fracture trace = Visible length of the fracture in meters
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 and codes applied.

code	Fracture minerals
	Code explanations are given in the SICADA data tables GE076 and GE075
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)

Table 5-4. Orientation data for fractures at the deepest part of AFM001243.

Strike	Dip	Quantity
0	60	7
0	40	4
13	60	4
33	90	4
147	70	1
150	70	11
180	80	2
202	85	2
235	80	5
237	80	10
312	90	3
345	90	5

Figure 5-1. *Deepest part of the trench AFM00124, showing bands of oxidised rock comprising fractures filled with adularia and quartz.*

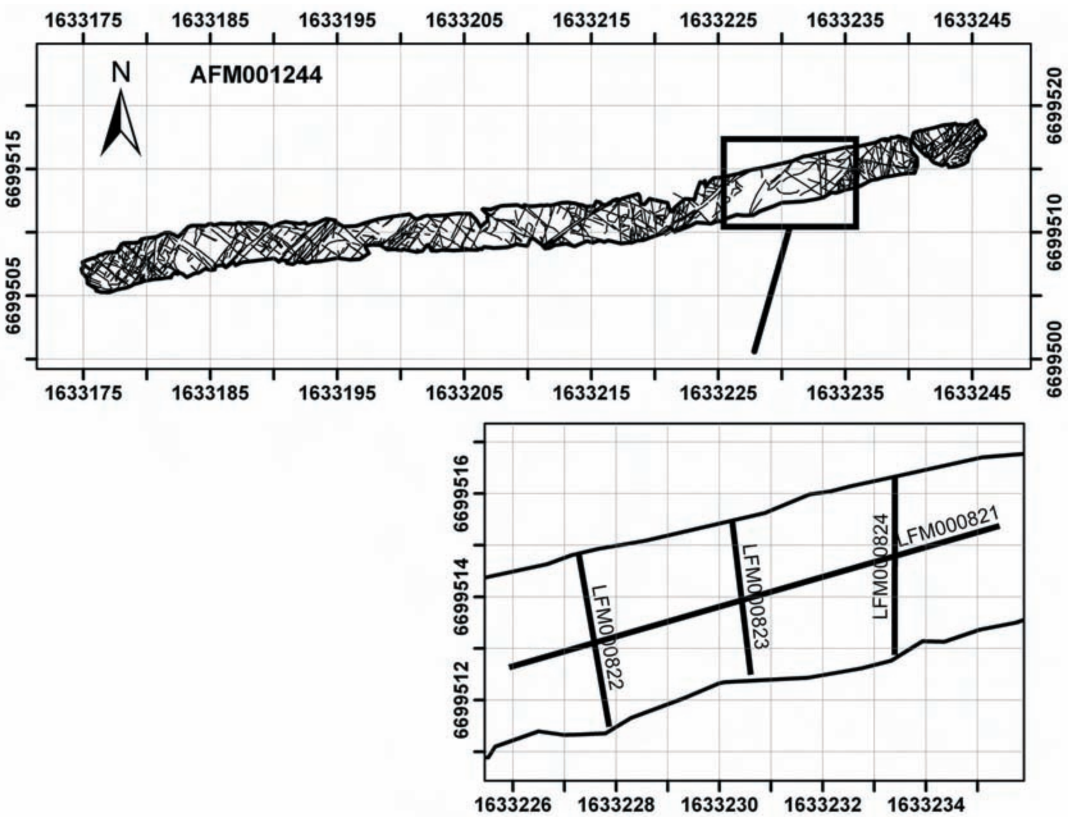


Figure 5-2. *Mapped area at the AFM001244 outcrop, also showing scan lines LFM000821, LFM000822, LFM000823, and LFM000824.*

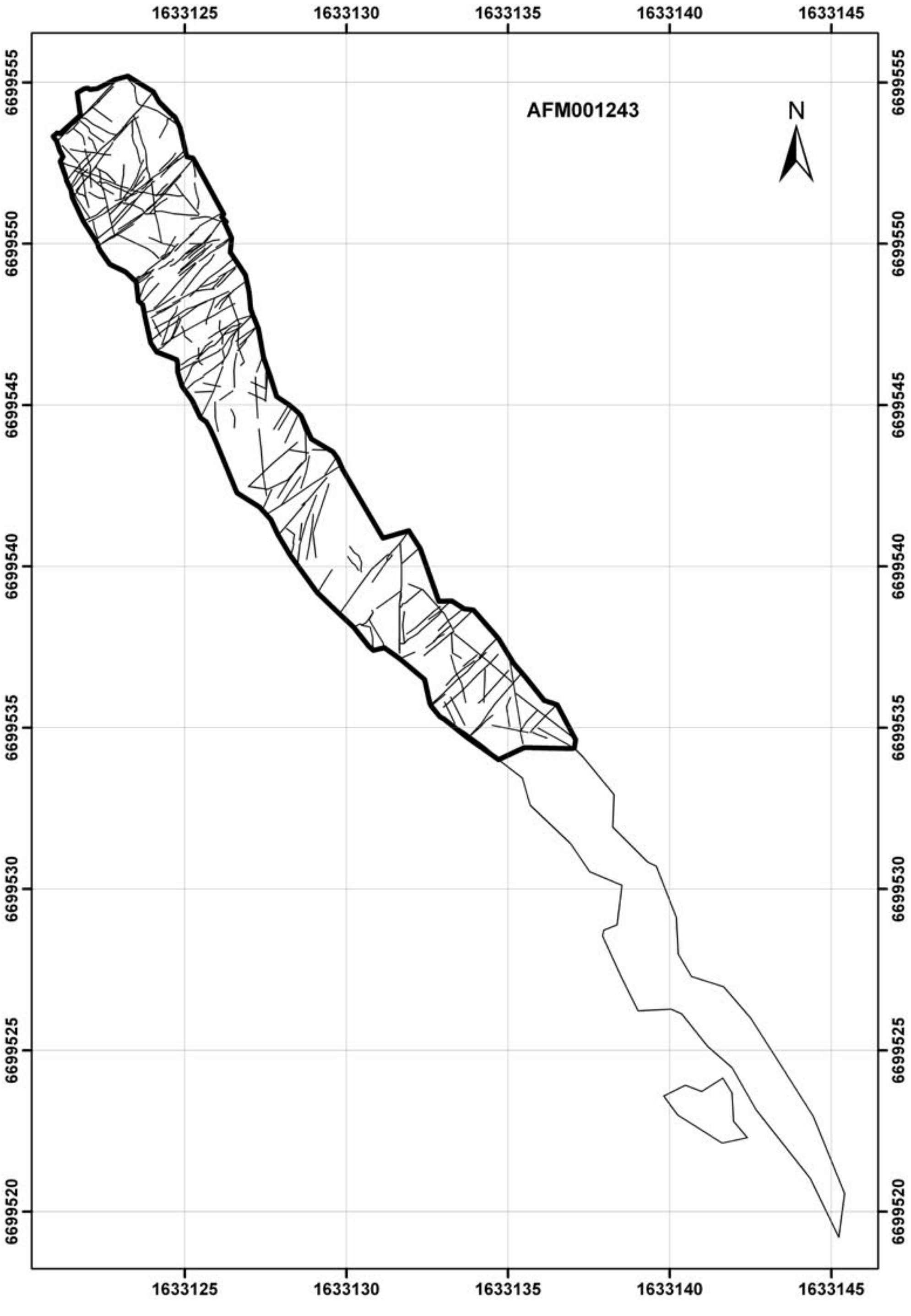


Figure 5-3. *Fracture trace map of the AFM001243 outcrop.*

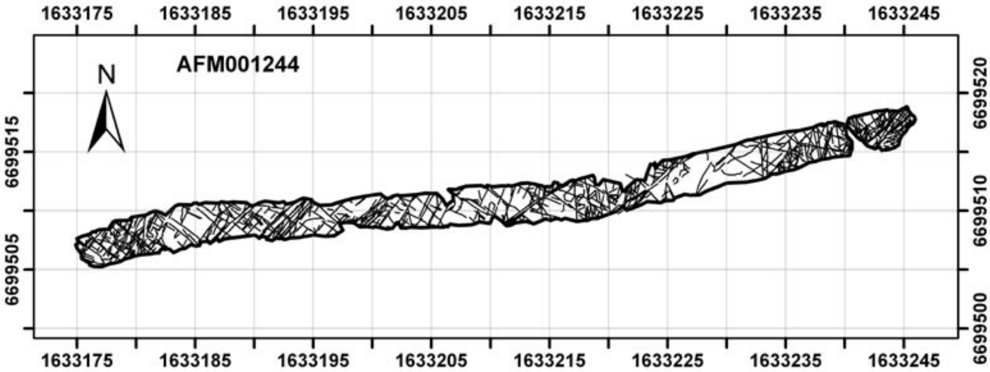


Figure 5-4. *Fracture trace map of the AFM001244 outcrop.*

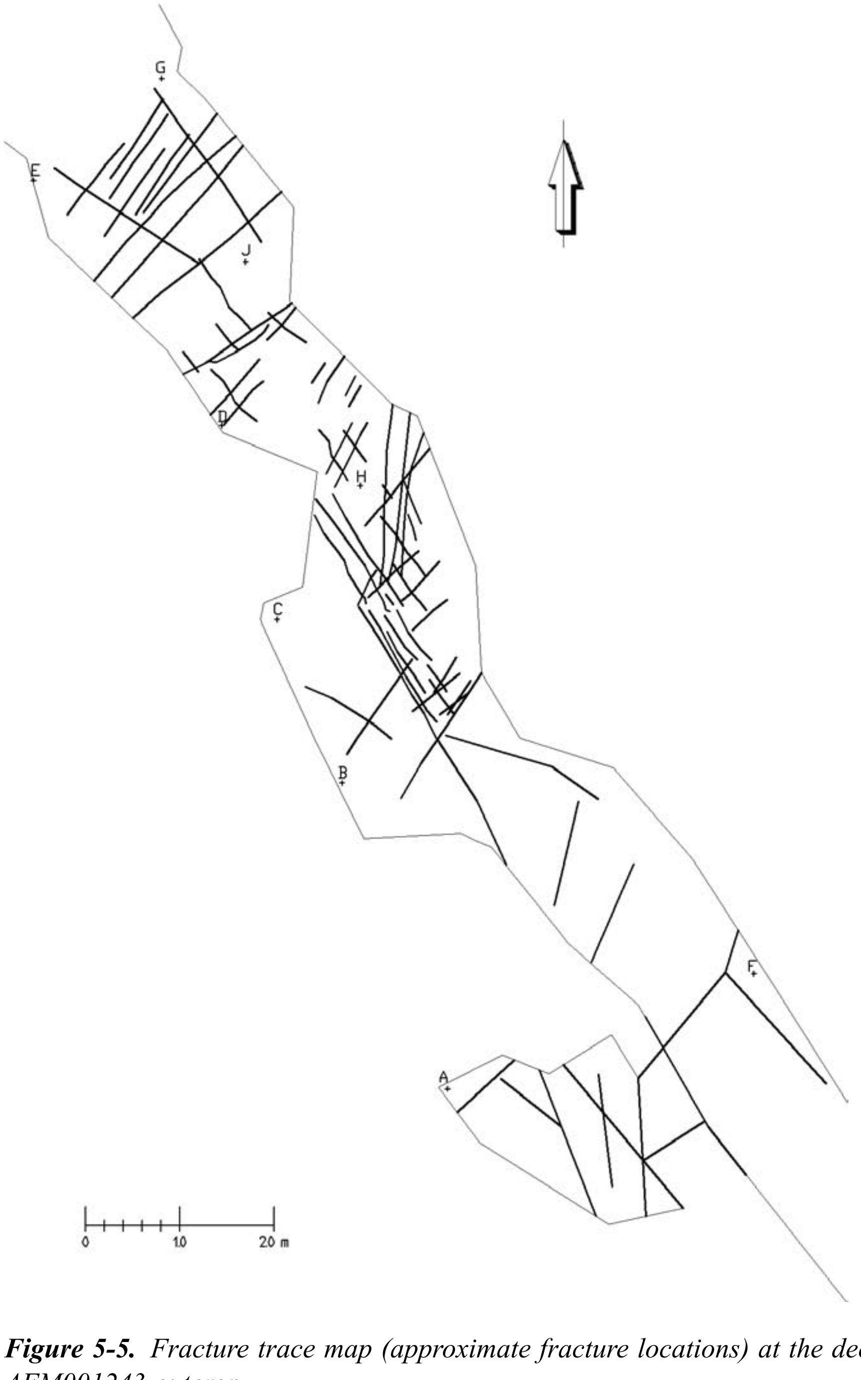


Figure 5-5. *Fracture trace map (approximate fracture locations) at the deepest part of the AFM001243 outcrop.*

Appendix A

Detailed bedrock mapping of two trenches, AFM001243 and AFM001244

Jesper Petersson and Göran Skogsmo

SwedPower AB

October 2004

Two trenches have been excavated and the bedrock was thoroughly cleaned in order to investigate N–S and NE–SW striking lineaments in the Forsmark area, as indicated by topography and airborne magnetic data. The trenches were excavated perpendicular to the inferred lineaments. The first trench referred to as AFM001243, strikes NW–SE and has a total length of about 42 m. The thickness of the soil cover range from a few decimetres in the NW up to about 4 m in the SE, and the total area of the exposed bedrock in the bottom is 103 m^2. The other trench referred to as AFM001244, strikes E–W and has a total length of 72 m. In this trench, the thickness of the soil cover range up to about 2 m, and the total area of exposure is 210 m^2.

A detailed bedrock mapping, complemented by measurements of the magnetic susceptibility, has been carried out in the two trenches. The mapping focused mainly on rock types, contact relations and ductile deformational structures. All mapping was done in accordance with the method description for bedrock mapping, SKB MD 132.001 (SKB internal controlling document). The spatial distribution and contacts of different rock types were measured with a Geodimeter 640S total station (see the methodology section). The data for both AFM001243 and AFM001244 are archived in the SKB database SICADA.

Trench AFM001243

The soils in the walls of trench AFM001243 was constantly collapsing in the deepest parts during the mapping. Consequently, some areas mapped immediately after the excavation were covered by soil before contact relations were accurately positioned. Another noteworthy feature is that about one third of the exposed surface corresponds to pre-existing, flat-lying fracture planes, some even with coating remnants of calcite, chlorite and, more rarely, asphalt (Figure A-1a).

Lithologically, the exposed bedrock is dominated by a medium-grained metagranite (rock code 101057) and a fine- to medium-grained, more leucocratic granite (rock code 111058). Subordinate veins of pegmatitic granite (rock code 101061) are mainly restricted to the metagranite. The leucocratic granite forms a single intrusive, which occupies about two thirds of the exposure (Figure A-2). The contacts with the metagranite are sharp and discordant to the tectonic fabric. All rocks are more or less affected by a faint to weak oxidation. More intense oxidation is normally associated with NE–SW trending fractures.

The medium-grained metagranite (101057) is typically greyish red to reddish grey with a tendency to be slightly granodioritic. Texturally, the rock is rather equigranular with a distinct planar mineral fabric defined by elongated aggregates of quartz and feldspar as well as a preferred orientation of biotite. This planar fabric shows a rather consistent orientation, plunging 295–333° and dipping 52–70°.

The leucocratic granite (111058) is rather quartz-rich, equigranular and finely medium-grained. However, some streaks tend to be slightly pegmatitic, whereas others are richer in biotite and magnetite. The colour of the rock ranges from greyish red to red.

Pegmatitic granite (101061) occurs mainly as narrow up to 0.1–0.2 m wide veins and dikes in the metagranite. There are, however, two exceptions; a 2 m wide dike in the southernmost part of the trench (partially covered by soil during the position measurements), and an up to 0.1 m wide pegmatitic vein (166°/50°) within the leucocratic granite. The latter consists of up to 2.5 cm long K-feldspar crystals in a more fine-grained, biotite-rich matrix. The impression is that this occurrence is coeval with the surrounding leucocratic granite. All pegmatitic granites within the metagranite are apparently massive and texturally heterogeneous, with variable grain-size. The general orientation of the veins in the north-western part of the trench is striking 008–028° and dipping 38–60°.

A centimetre-wide vein of hydrothermal quartz, about one metre long, occurs centrally in the intrusive of leucocratic granite.

Trench AFM001244

Volumetrically the most important rock in trench AFM001244 is the medium-grained metagranite (101057), described above. The metagranite has been intruded by a swarm of roughly NNE striking veins and dykes of leucocratic granite (111058) and pegmatitic granite (101061). These dykes are mainly concentrated to the central part of the trench and the widest reach up to 6 m in width (Figure A-3). All rock types have been variably affected by oxidation or red pigmentation of the feldspars, especially along NE–SW striking fractures. There are, however, up to 10 m wide areas that appears to be unaffected by oxidation.

Similar to the metagranite described for trench AFM001243, this rock is medium-grained, equigranular and has a tectonic mineral fabric defined by elongated aggregates of alternating quartz and feldspar as well as a preferred orientation of biotite. In addition to the planar fabric (330–353°/40–66°), the metagranite in the easternmost part of the exposure also shows a weakly defined linear mineral fabric, oriented 110°/34° and 102°/40°. The rock colour range from reddish grey to red in the more oxidised parts.

Major dykes and veins are generally oriented 3–20°/62–85°. Virtually all contacts are discordant to the tectonic fabric in the metagranite (Figure A-1b and c). The wider dykes are typically composite, and range from fine- to finely medium-grained, leucocratic granite to pegmatite. This variability in grain-size and mineralogy is rather fine-scaled over centimetres or decimetres, and is generally parallel with the outer contacts of the intrusive (Figure A-1b and d). Some dykes of finely medium-grained, leucocratic granite have, for example, decimetre-wide pegmatitic margins. Other dykes and veins are more homogeneous with a consistent grain-size (cf Figure A-1c). Since most of these variations are gradual and less than a few decimetres, they are not shown in Figures A-2 and A-3. A majority of the dykes appears to be massive, though some leucocratic granites exhibit a poorly defined mineral fabric. Besides of being a prime component in the NNE striking dykes and veins, the pegmatitic granite also forms minor veins and irregular bodies of more variable orientation. One of the composite dykes includes a less than 4 cm wide vein of hydrothermal quartz that runs parallel with an internal contact in the dyke.

The leucocratic granite is quartz-rich and equigranular with a grain-size that ranges from fine- to medium-grained. Locally, it grades into streaks of pegmatitic granite. The colour of the rock is normally greyish red, though red to reddish grey varieties are not uncommon.

In addition, two minor occurrences of aplitic metagranite (rock code 101058) were found during the mapping. Both are about one metre in length and strike roughly parallel with the tectonic foliation in the surrounding, medium-grained metagranite.

Magnetic susceptibility

The instrument used to measure the magnetic susceptibility is a SM-20 magnetic susceptibility meter (GF instruments, Czech Republic) with a sensitivity of 10^{-6} SI units (see www.gfinstruments.cz for more details). Measurements were done with about one meter intervals, directly on the outcrop, along a central profile in each trench. Each measurement represents the mean of nine instrument readings, within an area with a radius less than about 0.5 m. Special care has been taken to avoid composite measurements comprising readings from more than one rock type. In the south-easternmost 10 m in trench AFM001243, where the contact between the fine- to medium-grained leucogranite and medium-grained metagranite runs more or less parallel to the trench, it was decided to measure the susceptibility along two, instead of one, profiles. The result is one profile with 42 measurement points and a second with 6 measurement points (Figure A-4). However, only three measurement points in the second profile were exposed during the position measurements, the other three were covered by soil slide. The profile in trench AFM001244, on the other hand, comprises 71 measurement points (Figure A-4). Rough scanning over narrow veins or oxidation around steeply dipping fractures were investigated by using the continuous measuring mode of the kappameter.

In summary, all three major rock types of AFM001244 show mean susceptibility values that are more than five times higher than those of the corresponding rock types in trench AFM001243 (Table A-1). The medium-grained metagranite has generally the highest susceptibility, whereas the lowest values were measured in the dykes and veins of pegmatitic granite. However, the variability within individual rock types does, even in decimetre-scale, typically outrange the differences in the mean susceptibility values of the three rock types. This variability is most conspicuous in the medium-grained metagranite, which typically shows a systematic susceptibility decrease towards wider dykes of fine- to medium-grained leucogranite and pegmatitic granite (Figure A-4). Also the pegmatitic granites exhibit a considerable variability. Some decimetre-wide veins yield susceptibility values in the same magnitude as the surrounding medium-grained metagranite, whereas wider dykes often yield anomalously low values relative to the wall rock. The lithological variability, ranging from fine-grained leucogranite to pegmatitic granite, in some of the wider dykes in AFM001244, have no or small effect on the susceptibility.

Fresh rocks, apparently unaffected by oxidation or other forms of hydrothermal alteration, consistently yielded the highest susceptibility. Generally, the susceptibility decreases with an increasing intensity of oxidation. However, the susceptibility typically tends to drop to about half the original value, regardless of the intensity, over the often decimetre-wide oxidation zones that surround some of the more prominent NO–SW striking fractures in the trenches. Also, parts of the trenches that evidently correspond to pre-existing, flat lying fracture planes (e.g. an about 15 m wide area in the north-western to central part of N001243; cf Figure A-3) normally yield low susceptibility. Thus, inexplicable susceptibility drops might well be related to the fact that some surfaces are old fracture planes.

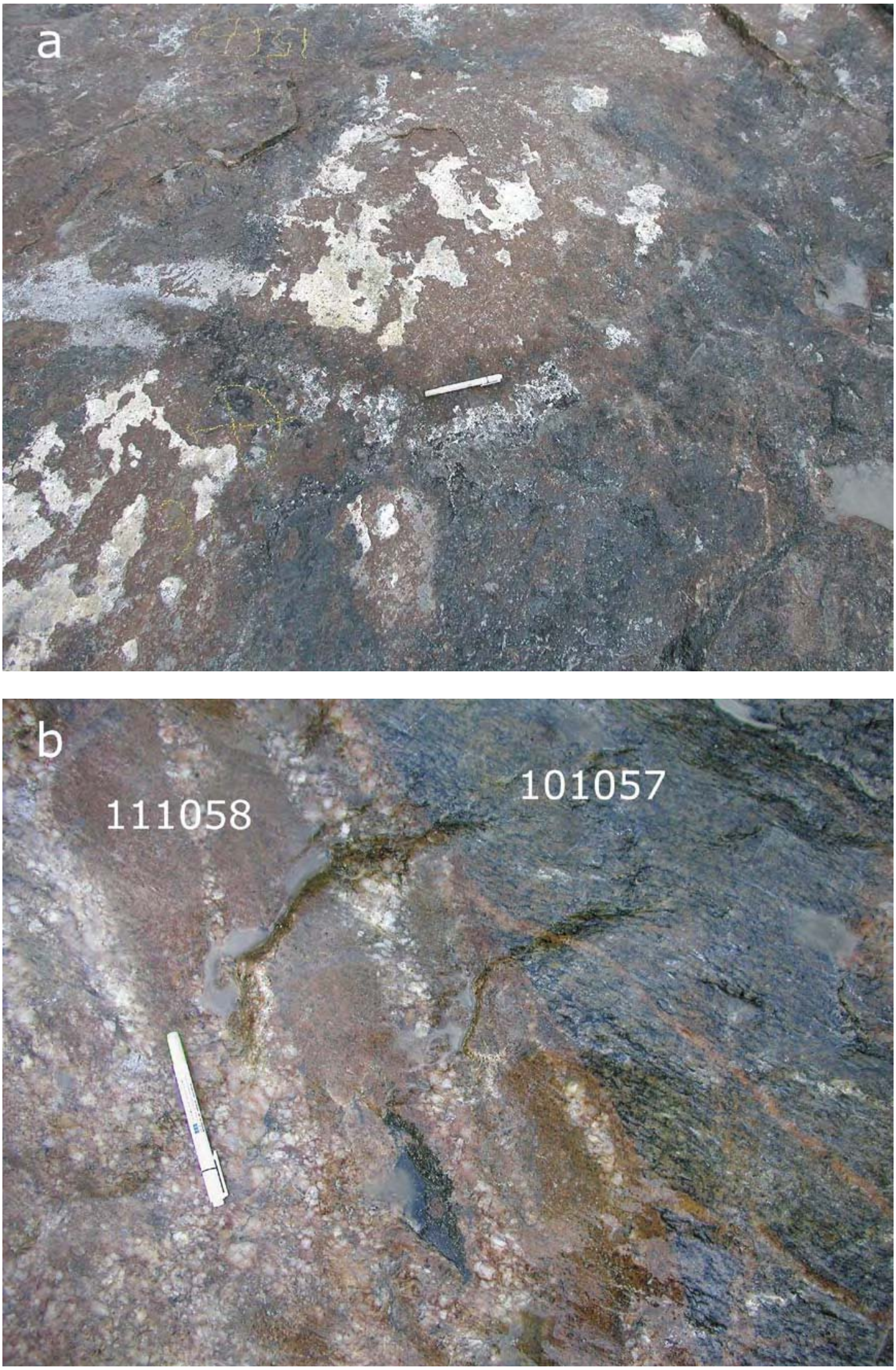
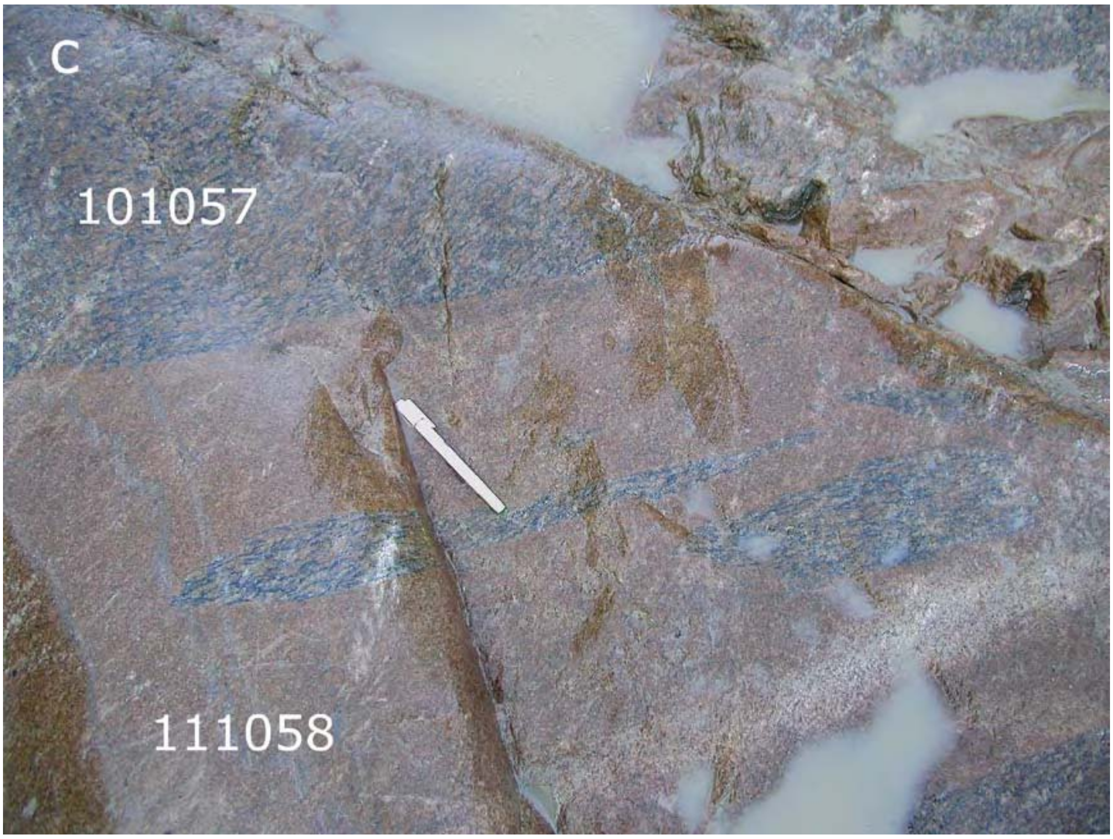


Figure A-1. *Photographs of various lithological features ofAFM001243 and AFM001244. Length of the pen used as scale is 14 cm. The exact location of the photographs are shown in Figures A-2 and A-3. (a) Flat-lying fracture surface with relict coatings of calcite, chlorite and asphalt in AFM001243. (b) Contact between the metagranite (101057) and a composite dyke of leucocratic granite (111058) with minor volumes of more pegmatitic material. AFM001244.*



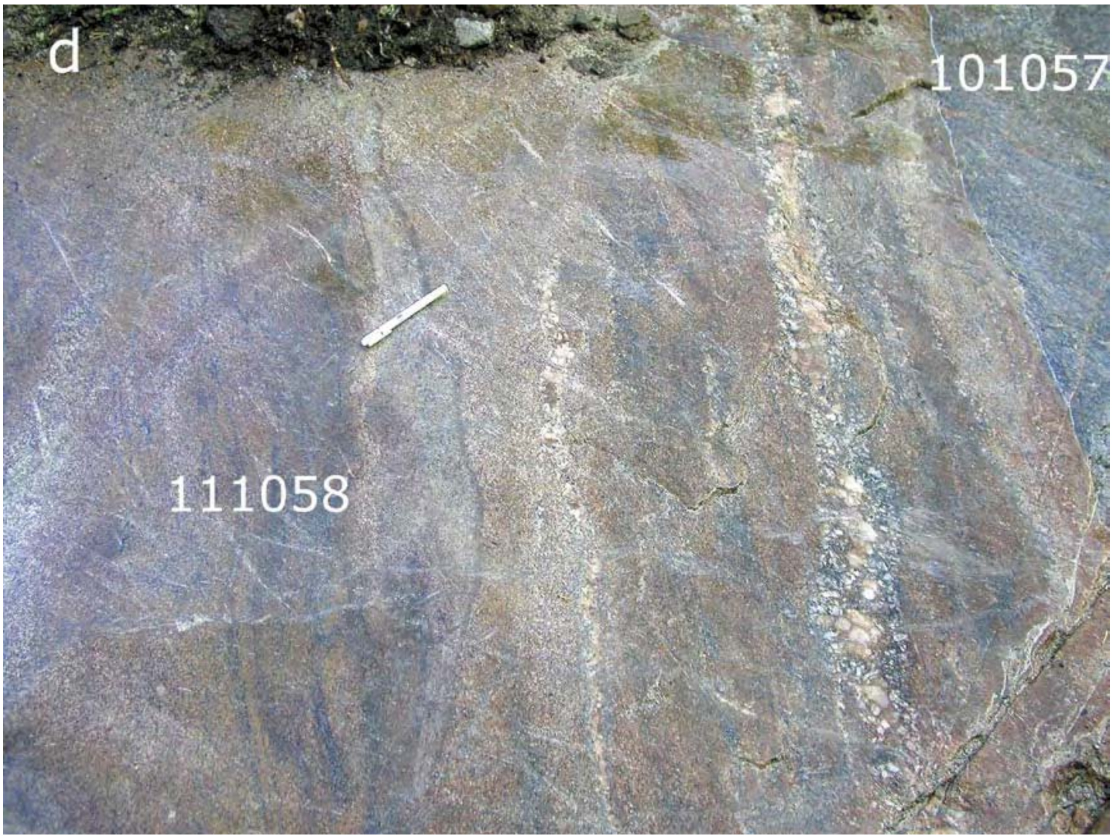


Figure A-1 (cont). *(c) Contact between the metagranite (101057) and a dyke of fine- to finely medium-grained, leucocratic granite (111058). AFM001244. (d) Compositionally and texturally banding of a major dyke of leucocratic granite (111058) in AFM001244.*

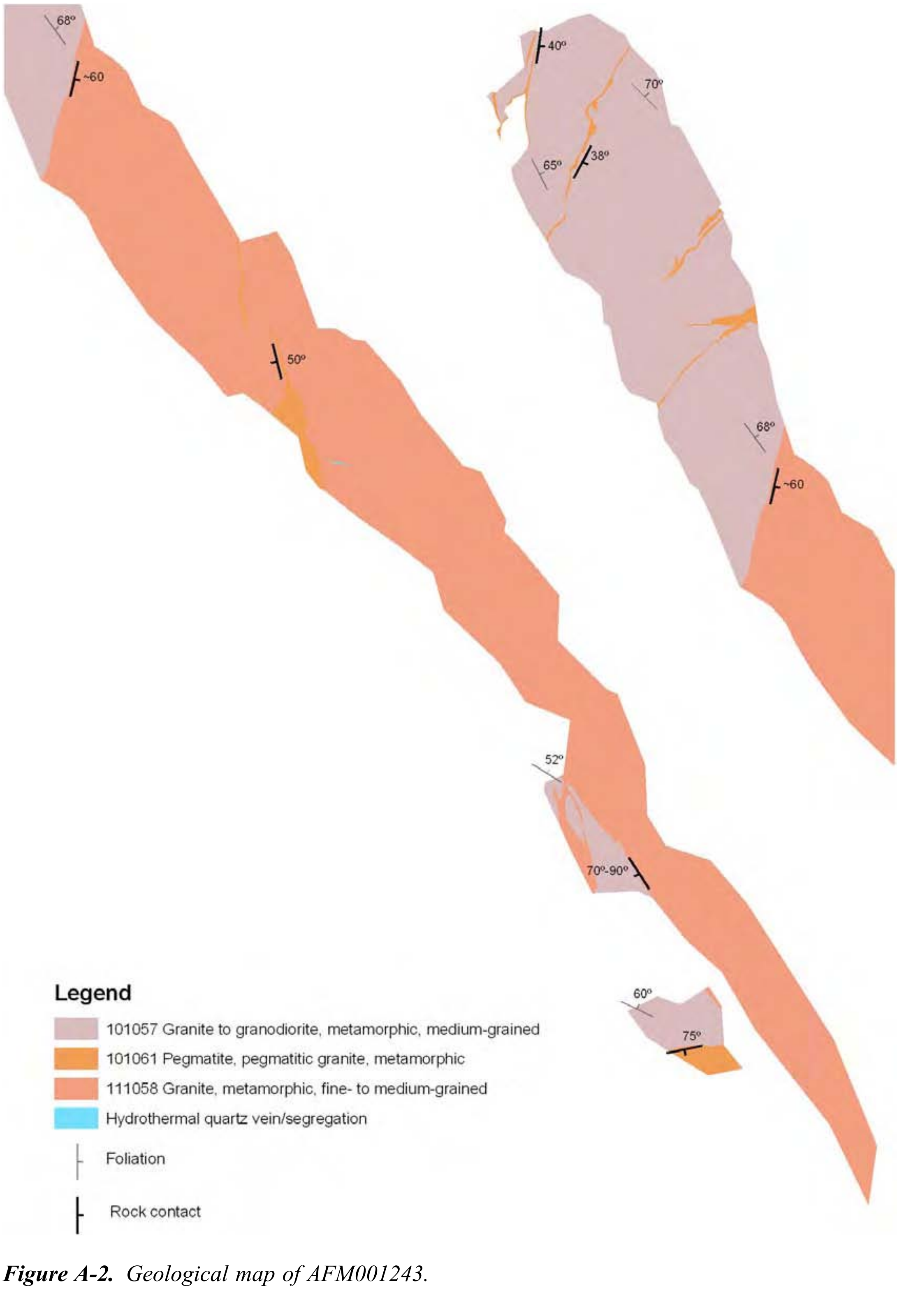


Figure A-2. *Geological map of AFM001243.*

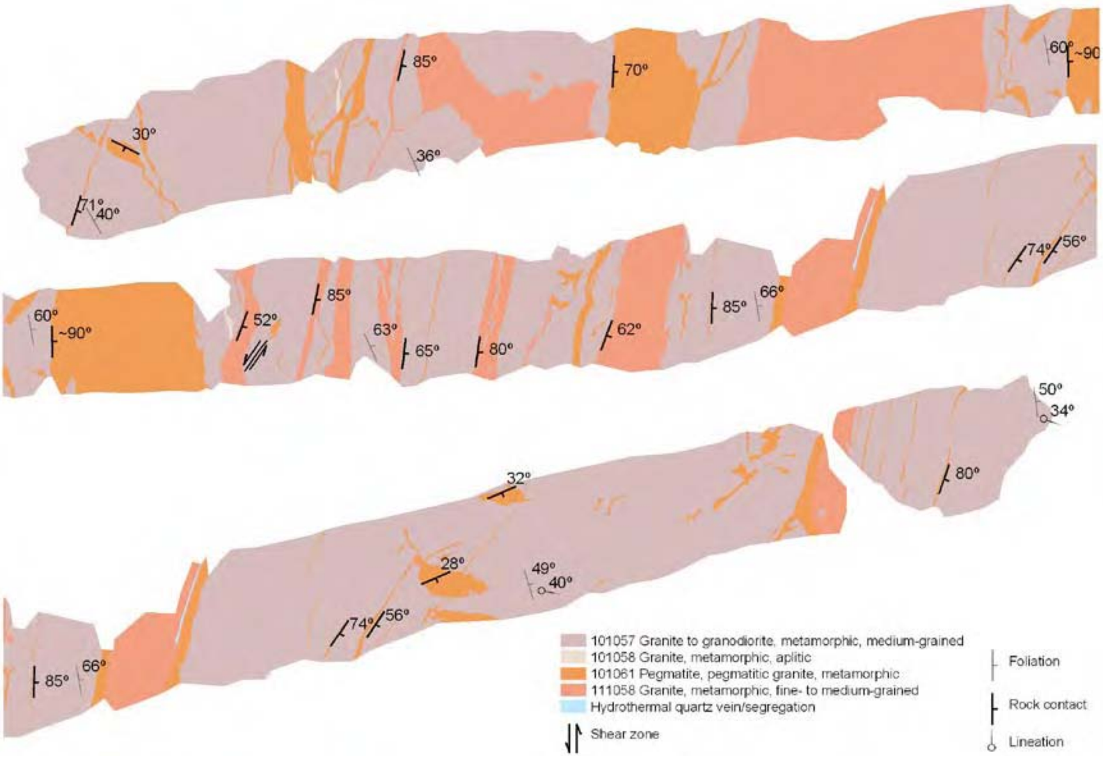


***Figure A-3.** Geological map of AFM001244.*

Table A-1. Magnetic susceptibility (10^{-3} SI units) of the three major rock types in AFM001243 and AFM001244.

	Mean	σ	Max	Min	Readings
AFM001243 (NNW)					
Metagranite-granodiorite (101057)	0.46	0.86	5.29	0.001	153
Pegmatitic granite (101061)	0.033	0.017	0.062	0	18
Leucogranite (111058)	0.14	0.28	2.81	0	270
AFM001244 (ENE)					
Metagranite-granodiorite (101057)	2.43	2.74	9.89	0.001	432
Pegmatitic granite (101061)	0.54	0.86	4.01	0.011	63
Leucogranite (111058)	0.86	1.17	6.68	0.004	144

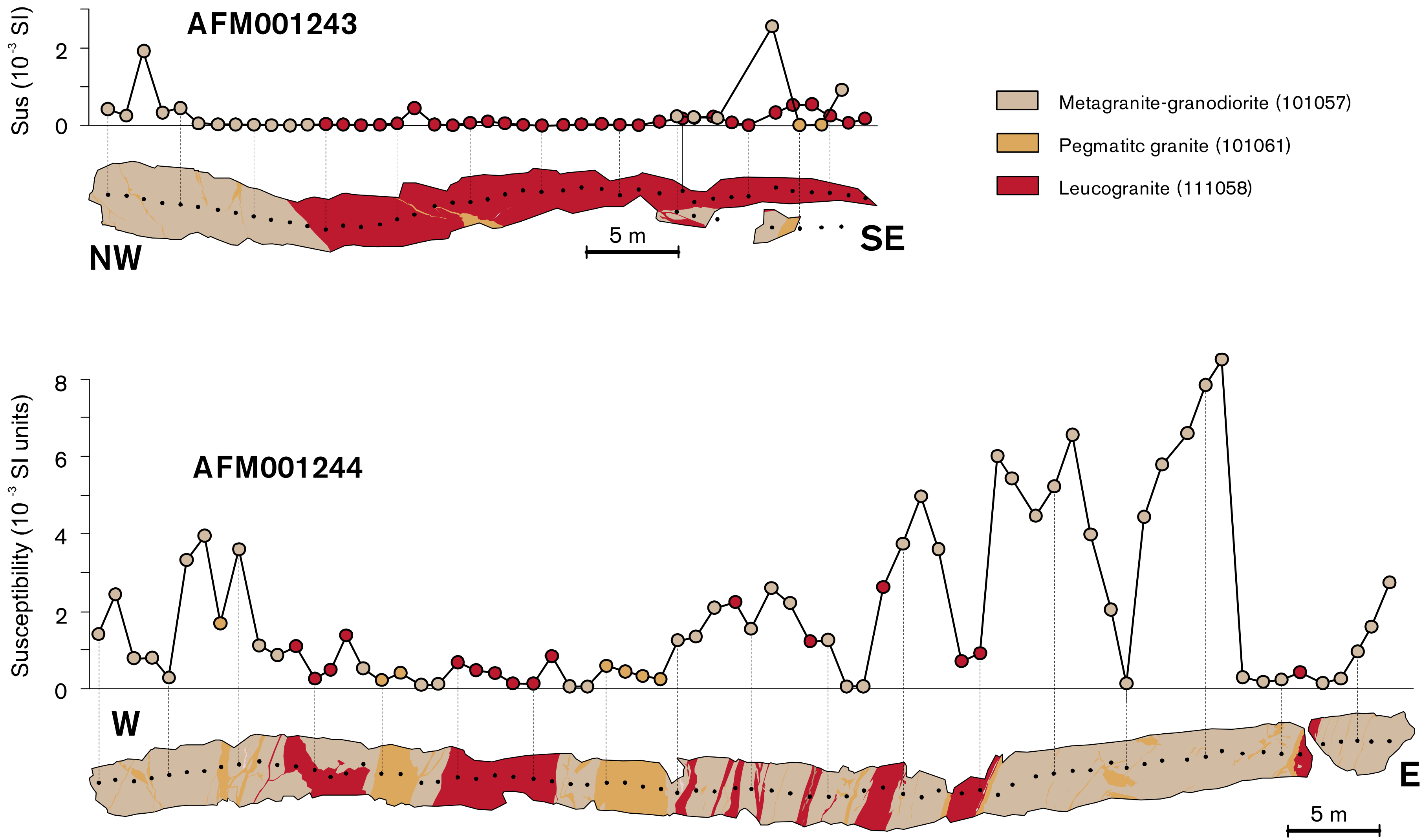


Figure A-4. *Magnetic susceptibility profiles along AFM001243 and AFM001244. Exact locations of measurement areas are indicated by dots on the geological maps. The rock type in each measurement area is also indicated by the symbol colour in the diagram.*