P-06-80

Forsmark site investigation

Boremap mapping of core drilled borehole KFM07B

Christin Döse, Eva Samuelsson, Geosigma AB

May 2006

Svensk Kärnbränslehantering AB
Swedish Nuclear Fuel
and Waste Management Co
Box 5864
SE-102 40 Stockholm Sweden
Tel 08-459 84 00
+46 8 459 84 00
Fax 08-661 57 19
+46 8 661 57 19

ISSN 1651-4416
SKB P-06-80

Forsmark site investigation

Boremap mapping of core drilled borehole KFM07B

Christin Döse, Eva Samuelsson, Geosigma AB

May 2006

Keywords: KFM07B, Geology, Drill core mapping, Fractures, BIPS, Boremap, Forsmark, AP PF 400-05-105.

Abstract

This report presents the results from the Boremap mapping of core drilled borehole KFM07B at drill site 7 in the Forsmark candidate area. Drill site 7 (DS 7) is situated in the north-western part of the residential area. Geologically the borehole is situated in the north-western part of the tectonic lens. The borehole has a length of 299 m and was drilled towards 134.35° with the inclination –53.71°. The aim was to measure the in situ stresses of the rock with the overcoring technique. The results from these measurements are not in the scope of this activity.

The dominant rock type of KFM07B is a foliated metagranite-granodiorite (~ 76%) followed by massive or lineated pegmatite or pegmatitic granite (~ 15%), foliated amphibolite (~ 4%) and lineated fine- to medium grained metatonalite, granodiorite to granite (~ 3%). Minor occurrences of fine- to medium grained granites of different ages also occur (~ 2%). The rocks are generally weakly to faintly oxidised and some millimetre-thin, brittle to ductile deformation bands occur. Albitisation occurs usually in relation to amphibolite occurrences and epidotisation is observed between 131.66 and 133.92 m.

The frequency of sealed fractures in KFM07B is 3.8 fractures/m while the corresponding value for open fractures is 2.1 fractures/m. Sections with high open fracture frequencies occur at 9–10 m, 55–56 m and 95–97 m. One of them coincides with the only observed crushed section in the borehole at 56.45–56.67 m striking roughly 157/63. Suspected outflow from open fractures are observed between 36 and 45.2 m. In several intervals throughout the borehole sealed fractures are abundant.

KFM07B is grouted, which has complicated the estimation of fracture apertures.

Sammanfattning

Denna rapport redovisar resultaten från Boremapkartering av kärnborrhålet KFM07B på borrplats 7 i Forsmark kandidatområde. Borrplats 7 är beläget i den nordvästra delen av bostadsområdet. Geologiskt ligger borrhålet i den nordvästra delen av den tektoniska linsen. Borrhålet är 299 m långt och är borrat med bäringen 134,35 ° och inklinationen –53,71 °. Syftet med borrhålet är att mäta bergspänningen in situ med överborrningstekniken. Resultaten från dessa mätningar innefattas inte av denna rapport.

Den dominerande bergarten i KFM07B är en folierad metagranit-granodiorit (~ 76 %), följt av en massiv till lineerad pegmatit eller pegmatitisk granit (~ 15 %), folierad amfibolit (~ 4 %) och fin- till medelkornig metatonalit, granodiorit till granit (~ 3 %). Även mindre förekomster av fin- till medelkorniga graniter av olika åldrar förekommer (~ 2 %). Bergarterna är generellt svagt till mycket svagt oxiderade och några millimeter tunna spröda till plastiska deformationsband förekommer. Albitisering förekommer vanligen i anslutning till amfibolitförekomsterna och epidotisering observeras mellan 131,66 och 133,92 m.

Frekvensen läkta sprickor i KFM07B är 3,8 sprickor/m, medan det motsvarande värdet för öppna sprickor är 2,1 sprickor/m. Sektioner med hög frekvens av öppna sprickor förekommer i intervallen 9–10 m, 55–56 m och 95–97 m. Ett av dessa sammanfaller med den enda observerade krossade sektionen i borrhålet på 56,45–56,67 m. Dess orientering är ca 157/63. Misstänkta observerade utflöden från sprickor förekommer mellan 36,0 och 45,2 m. Sektioner vilka är rika på läkta sprickor förekommer med jämna mellanrum i hela borrhålet.

KFM07B är injekterat med cement, vilket har försvårat uppskattningen av sprickaperturer.

Contents

1 Introduction

This document reports the data gained by the Boremap mapping of the core drilled borehole KFM07B, which is one of the activities performed within the site investigation at Forsmark. The work was carried out in accordance with activity plan SKB PF 400-05-105. In Table 1-1 controlling documents for performing this activity are listed. Both activity plan and method descriptions are SKB's internal controlling documents.

The borehole KFM07B is drilled from drill site 7 (DS 7) in the north-western part of the residential area (Figure 2-1). Geologically the borehole is situated in the north-western part of the tectonic lens /1/. The borehole was drilled in order to measure the in situ stresses of the rock with the over coring technique /2/. When the first 65 m of the borehole was drilled with a diameter of 96 mm, the borehole wall was filmed with borehole-TV (BIPS-IV, 720 pixels) 21st of June in 2005 where after this section was cased and the drilling proceeded, but with a smaller diameter; 76 mm. The drilling was completed 18th of October and the rest of the borehole was filmed with BIPS (BIPS-1500, 360 pixels) 7th of November. The Boremap mapping of the borehole started right after the BIPS-logging and was finished 1st of December.

The geological documentation of core drilled boreholes according to the Boremap method is based on the use of BIPS-images of the borehole wall and the simultaneous study of the drill core. Position, aperture and orientation data of features are based on the adjusted BIPS-image, while other data such as rock type, alteration, fracture mineralogy and surface are observed in the drill core.

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

Activity plan	Number	Version
Boremapkartering av kärnborrhål KFM07B	AP PF 400-05-105	1.0
Method descriptions	**Number**	**Version**
Metodbeskrivning för Boremapkartering	SKB MD 143.006	2.0
Mätsystembeskrivning för Boremap	SKB MD 146.001	1.0
Nomenklatur vid Boremapkartering	SKB MD 143.008	1.0
Instruktion: Regler för bergarters benämningar vid platsundersökningen i Forsmark	SKB MD 132.005	1.0

2 Objective and scope

The aim of this activity was to document lithologies, alterations, ductile structures and the occurrence and character of fractures in the bedrock penetrated by the core drilled borehole KFM07B. The detailed documentation will be used in 3D-modelling of the area.

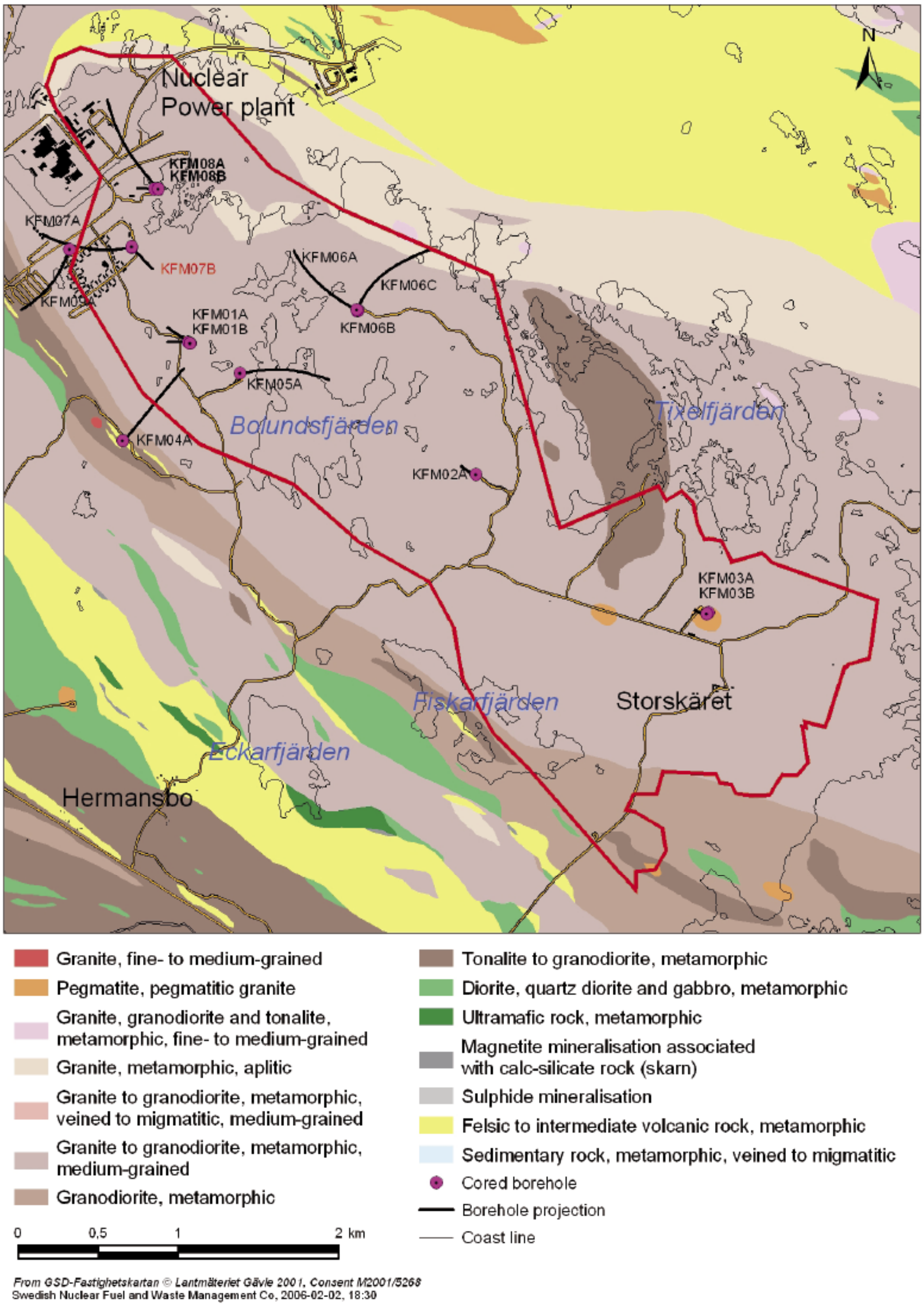


Figure 2-1. *Location of borehole KFM07B.*

3 Equipment

3.1 Description of equipment and interpretation tools

Mapping of BIPS-images and drill core was performed with the software Boremap v 3.7.4. The Boremap software is loaded with the bedrock and mineral standard used for surface mapping at the Forsmark investigation site to enable correlation with the surface geology. The Boremap software calculates actual directions (strike and dip) of planar structures penetrated by the borehole (foliations, fractures, fracture zones, rock contacts etc). Data on inclination, bearing and diameter of the borehole are used as in-data for the calculations (Table 4-1, Appendix 2 and 3). The BIPS-image lengths were calibrated (Table 4-2).

Additional software used during mapping are BIPS Image Viewer and MicroSoft Access 2002. The schematic data presentation was made in WellCad v 4.0.

The following equipment was used to facilitate the core documentation: folding rule, 10% hydrochloric acid, knife, hand lens, paint brush and a tap of water.

3.1.1 BIPS-image quality

The upper part of the borehole (1.85–65.00 m) was filmed with BIP-IV, a BIPS camera owned by Malå Geoscience, while the lower part (65.00–298.43 m) was filmed with BIP-1500, a SKB owned BIPS camera. The image resolution around the borehole wall of the upper image is 720 pixels while it is 360 pixels for the lower image. Both images have the same resolution along the borehole length: 1 pixel/1 mm.

The colours are somewhat different depending on BIPS camera. The BIP-IV images are usually somewhat darker and red and green colours are exaggerated in the image. The colours of the BIP-1500 camera are closer to reality; they are only somewhat bleached. This difference in colour does not affect the mapping, but the following factors may disturb the mapping:

1) blackish coatings probably related to the drilling equipment,
2) vertical bleached bands from the drill cuttings in suspension,
3) light and dark bands at high angle to the drill hole related to the automatic aperture of the video camera,
4) vertical enlargements of pixels due to stick-slip movement of the camera probe.

The BIPS-image quality is listed in Table 3-1. Vertical bleached bands and blackish coatings are usually the main disturbances in the BIPS-image quality. An extreme coating on the borehole wall is shown in Figure 3-1. The very abrupt appearance of the coating lies at a right angle to the borehole. This could be explained by missing BIPS-image, but when checking the BIPS-image lengths with the drill core lengths on both sides of the possible discontinuity they correlate very well. Another possible explanation is that the coating is caused by grouting.

Table 3-1. BIPS Image Quality.

Pixel/row	From	To	% visible	Comment
720	5.2	40	100	Good, but with some diffuse vertical bands.
720	40.0	65.06	100	Somewhat diffuse, suspensions and uneven lightning.
360	65.19	68.6	100	Good.
360	68.6	73	80	Good, but in places blackish coatings.
360	73	75	100	Good.
360	75	142	95	Good, but with dark vertical bands.
360	142			Missing image?
360	142	145.2	30	Probable outfall that covers the borehole walls.
360	145.2	164	70	Good, some dark vertical bands (coating from drill rod).
360	164	182	40–60	Relatively good, dark vertical bands (coating from drill rod).
360	182	183	90	Good.
360	183	200	40–70	Relatively good, dark vertical bands (coating from drill rod).
360	200	213	100	50% good 50% with very thin coating.
360	213	261	100	Good.
360	261	270	70	Some percipitated material on the lower side.
360	270	297.46	60	Some percipitated material on the lower side.

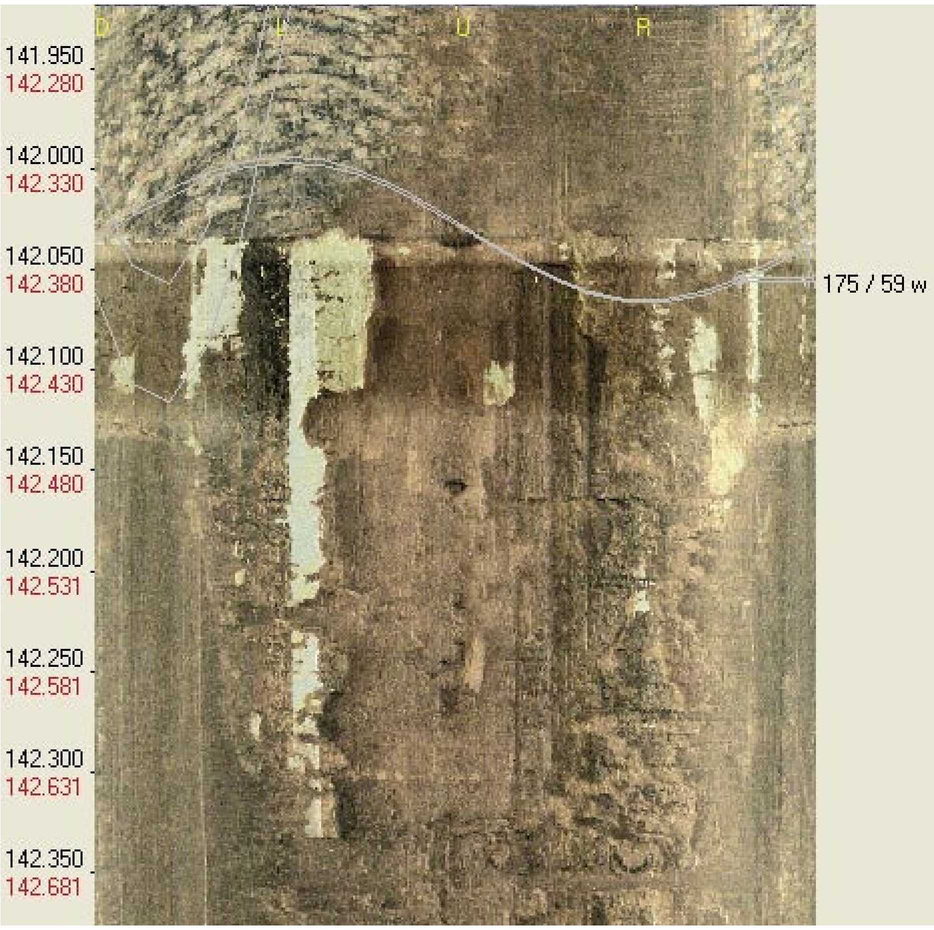


Figure 3-1. *Abrupt appearance of a coating on the borehole wall, KFM07B.*

4 Execution

4.1 General

Boremap mapping of the drill core KFM07B was performed and documented in accordance with the activity plan AP PF 400-05-105 (SKB, internal document) and the method description for Boremap mapping (SKB, MD 143.006, Version 1.0, Metodbeskrivning för Boremap-kartering, SKB, internal controlling document). The mapping was preceded by an overview documentation of the drill cores by Kenneth Åkerström. All observations are made by ocular inspection, since no other data were available.

The mapping was performed between November 15th and December 1st in 2005 by Christin Döse and Eva Samuelsson, both from Geosigma AB.

4.2 Preparations

The lengths registered during the BIPS-logging deviates from the true length, which increases with depth. Therefore length adjustments were made. The length of the BIPS-image covering the range 65.00 to 298.43 m was adjusted with reference to slots cut into the borehole every 50th meter and with reference to the end of casing /3/ (see Table 4-2). The length of the BIPS-image covering the range 1.85 to 65.00 m was adjusted with reference to the casing length /3/ and with a well defined feature in the beginning of the other BIPS-image. The distance from this well defined feature was measured on the drill core to the last well defined feature in the BIPS-image covering the upper part of the borehole and this measurement showed that no other length adjustment was needed than adjusting the image 6 cm downwards. This is because the upper part of the borehole was logged with another BIPS-camera (BIP-IV) which measuring wheel is perfectly calibrated.

Geometrical data for the borehole is given in Table 4-1. Background data collected from SICADA prior to the Boremap mapping included:

- Borehole diameter (Appendix 2).
- Reference slots for length adjustments (Appendix 2).
- Borehole deviation (Appendix 3).

Table 4-1. Borehole data for KFM07B.

ID-code	Northing	Easting	Bearing (degrees)	Inclination (degrees)	Diameter (mm)	Borehole length (m)	BIPS-image interval (m)	End of casing
KFM07B 0–65 m	6700123.6	1631036.83	134.35	–53.71	96	65.69	1.85–65.00	5.24
KFM07B 65–299 m			135.9	–52.9	76	299.93	65.00–298.45	65.06

Table 4-2. Length adjustments.

BIPS-image	Rec length (m)	Adj length (m)	Difference (m)
KFM07B 0–65 m	5.24	5.18	0.06
KFM07B 0–65 m	65.06	65.0	0.06
KFM07B 65–299 m	65.71	65.8	0.09
KFM07B 65–299 m	99.848	100	0.152
KFM07B 65–299 m	149.638	150	0.362
KFM07B 65–299 m	199.433	200	0.567
KFM07B 65–299 m	249.224	250	0.776

4.1 Execution of measurements

Concepts used during the core mapping, are defined in this chapter.

4.1.1 Fracture definitions

Definitions of different fracture types and apertures, crush zones and sealed fracture network are found in SKB MD 143.008 (internal SKB document).

Two types of fractures are mapped in Boremap; broken and unbroken. Broken are fractures that split the core while unbroken fractures do not split the core. All fractures are described with their fracture minerals and other characteristics, e.g. width, aperture and roughness. Visible apertures are measured down to 1 mm in the BIPS-image. Smaller apertures, which are impossible to detect in the BIPS-image, are denoted a value of 0.5 mm. If the core pieces do not fit well, the aperture is considered "probable". If the core pieces do fit well, but the fracture surfaces are dull or altered, the aperture is considered "possible".

Laumontite in fractures tend to dehydrate when exposed to air. Therefore laumontite-sealed fractures usually break apart in the core box. These fractures are mapped as broken fractures with aperture = 0, when it is certain that the fracture was originally sealed.

All fractures with apertures > 0 mm are treated as open in the SICADA database. Only few broken fractures are given the aperture = 0 mm. Unbroken fractures usually have apertures = 0 mm. Unbroken fractures that have apertures > 0 mm are interpreted as partly open and are included in the open-category in SICADA. Open and sealed fractures are finally frequency calculated and shown in Appendix 1.

4.1.2 Fracture alteration and joint alteration number

Joint alteration number is principally related to the thickness of, and the clay content in a fracture /4/. Relatively thick fractures rich in clay minerals are given joint alteration numbers between 2 and 4. The majority of the broken fractures are very thin to extremely thin and seldom contain clay minerals. These fractures receive joint alteration numbers between 1 and 2.

A subdivision of fractures with joint alteration numbers between 1 and 2 was introduced to facilitate both the evaluation process for fracture alterations and the possibility to compare the alterations between different fractures in the boreholes. The subdivision is in accordance with the subdivision introduced by Ehrenborg and Steiskal /5/ and is based on fracture mineralogy as follows:

a) fracture wall alterations,

b) fracture mineral fillings assumed to have been deposited from circulating water-rich solutions,

c) fracture mineral fillings most likely resulting from altered wall rock material.

Joint alteration number equal to 1: Fractures with or without wall rock alteration, e.g. oxidation or epidotization, and without mineral fillings is considered as fresh. The joint alteration number is thus set to 1.

Minerals such as calcite, quartz, fluorite, zeolite, laumontite and sulphides are regarded as deposited by circulating water-rich solutions and not as true fracture alteration minerals. The joint alteration number is thus set to 1.

Joint alteration number equal to 1.5: Epidote, prehnite, hematite, chlorite and/or clay minerals are regarded as fracture minerals most likely resulting from altered wall rock. A weak alteration is thus assumed and the joint alteration number was set to 1.5. Extra considerations have been given to clay minerals since the occurrence of these minerals often resulted in a higher joint alteration number.

Joint alteration numbers higher than 1.5: When the mineral filling is thick and contain a few mm of clay minerals, often together with epidote and chlorite, the joint alteration number is set to 2. In rare cases, when a fracture contains 5–10 mm thick clayey bands, together with chlorite, the joint alteration number is set to 3 or 4.

4.1.3 Mapping of fractures not visible in the BIPS-image

Not all fractures are visible in the BIPS-image, and these fractures are oriented using the *guide-line method* /5/, with one modification. The orientation performed in this work is based on the following data:

- Angle to drill core which is measured with a protractor on the drill core (a modification of the ordinary *guide-line method*).
- The relation between the rotation of the fracture trace and a well defined structure visible in both drill core and BIPS-image. This rotation is measured with measuring tape on the drill core.
- Absolute depth relative to a well defined structure visible in both drill core and BIPS-image.

Orientation of fractures with the *guide-line method* is done in the following way: The first step is to delineate the fracture trace in the BIPS-image the right angle to the drill core. The second step is the correction of strike and dip. This is done by rotating the fracture trace in the BIPS-image relative to a feature with known orientation. The fracture trace is then positioned at the correct depth in the BIPS-image in accordance with the depth measured on the drill core.

The *guide-line method* can be used to orient any feature that is not visible in the BIPS-image. It is also a valuable tool to control that the personnel working with the drill core is observing the same feature as the personnel delineating the trace in the BIPS-image, especially in intervals rich in fractures.

The error of orientating fractures using the *guide-line method* is not known but experience and an estimation using stereographic plots indicated that the error is most likely insignificant. Accordingly, the *guide-line method* is so far considered better than mapping lots of non-oriented fractures. The fractures in question are mapped as "non-visible in BIPS" and can therefore be separated from fractures visible in BIPS which probably have a more accurate orientation.

4.1.4 Definition of veins and dikes

A rock sequence that covers less than 1 m of the drill core is mapped as a "rock occurrence" in Boremap. Rock occurrences that cover more than 1 m of the drill core are mapped as a separate *rock type.*

Chiefly two different types of rock occurrences are mapped: veins and dikes. These two are separated by their respectively length in the drill core; veins are set to 0–20 cm and dikes are set to 20–100 cm if evidence for intrusion is visible in the drill core. If the rock occurrence cannot be classified as a vein or a dyke, the occurrence type is mapped as "unspecified". In Forsmark there are boudinaged veins, xenoliths, blobs etc and the occurrence type is usually difficult to determine from the drill core.

4.1.5 Mineral codes

In cases where properties or minerals are not represented in the mineral list, the following mineral codes have been used in the mapping of KFM07B:

- X1 = bleached fracture walls.
- X2 = interpreted grouting, which is only observed in the borehole wall and hence in the BIPS-image.
- X3 = the drill core is broken at a right angle and the broken surfaces have a polished appearance. This is caused by rotation of two core pieces along an intermediate fracture wearing away possible mineral filling. It is impossible to say whether this fracture was open or sealed in situ.
- X4 = dull surfaces, no fracture mineral.

4.2 Data handling

In order to obtain the best possible data security, the mapping was performed on the SKB network, with regular back-ups on the local drive (SKB MD 143.006, SKB Controlling Document). Each day, a summary report was printed in order to find possible misprints. If misprints were observed, they were corrected before the mapping proceeded. When the mapping was completed fracture minerals were checked once more. Before exporting data to SICADA, borehole lengths, mapping lengths, deviation data and length adjustments were checked where after the mapping was checked by a routine in Boremap which detects logical defects.

4.3 Nonconformities

4.3.1 Core loss

Unusually many *core losses* are documented in KFM07B. Most core losses are mechanical and are related to the rock stress measurements. The positions of the core losses at 96.02–96.13 and 96.34–96.45 m are somewhat uncertain in the section 96.01–96.66 m. This is due to the combination of missing core pieces and many open fractures with probably high apertures (grouting visible in BIPS) and fracture surfaces that do not match well.

4.3.2 Grouting and interpretation of fracture apertures

The grouting of the borehole affects the interpretation of fracture apertures negatively. Grouting in thin fractures is probably always missed, because very thin fractures with no visible aperture usually appear white in the BIPS-image, probably due to light reflection from the edge of the fracture trace. Even though the fracture is over 1 mm wide, grouting may be missed, since grouting is only visible in the BIPS-image and not in the drill core. If, for example, the common white calcite occur as a fracture mineral the grouting may be missed if not the person mapping the drill core tells how much calcite there is. Usually the amount of fracture minerals is not noticed in the mapping in other ways than by given fracture widths, and hence the person mapping the drill core usually only tells the estimated fracture width. Therefore only large grout-filled open fractures are detected with certainty (for example the uppermost fracture in Figure 5-1), and the authors disclaim the responsibility for correct apertures for fractures thinner than 3 mm.

4.3.3 Overrepresented fracture mineral

The frequency of calcite in fractures is *overrepresented* relative to other minerals, since it is detected by reaction with diluted hydrochloric acid even though it is macroscopically invisible.

4.3.4 Fracture roughness

The estimation of roughness of fractures in this work diverges rather much from the mappings by SwedPower. For example: Geosigma considers most fractures as undulating, some as stepped and planar and only few as irregular. The proportion of planar, undulating, stepped and irregular fractures in the mappings of SwedPower is different. This is because the personal interpretation of the definitions of fractures /6/, since the definitions are made for another scale, i.e. tunnels and excavations, and not for boreholes. Work has been started to synchronize the mapping teams.

4.3.5 Few lineation measurements

The well developed foliation in KFM07B made it difficult to measure possible lineation in the borehole, and hence only one lineation measurement was made in a pegmatite where lineation was the only clearly visible structure.

4.3.6 Late in-data

Not all necessary in-data were available in the SICADA database when the mapping was performed. Lacking technical data were received straight from the persons responsible for drilling and measurements /3/.

5 Results

The Boremap mapping of KFM07B is stored in SICADA and it is only these data that shall be used for further interpretation and modelling. The interpreter should be aware of the assumptions mentioned in Chapter 4.

Results from the Boremap mapping are briefly described in this chapter and the graphical presentation of the data are given in Appendix 1 (WellCad-diagram).

5.1 Rock type

The dominant rock type of KFM07B is a foliated metagranite-granodiorite (~ 76%) followed by massive or lineated pegmatite or pegmatitic granite (~ 15%), foliated amphibolite (~ 4%) and fine- to medium grained metatonalite, granodiorite to granite (~ 3%). Minor occurrences of fine- to medium grained granites of different ages occur (~ 2%, codes 101058, 111058 and 1058).

5.2 Fractures and crushed sections

1,108 unbroken and 598 broken fractures were documented in KFM07B (5.2–297.46 m). 58 of the unbroken fractures show an aperture, while 52 of the broken fractures are considered artificial and have an aperture = 0. This result in the following interpreted fracture frequencies: 3.8 sealed fractures/m and 2.1 open fractures/m.

Sections rich in sealed fractures are common in KFM07B (see Appendix 1). The following sections have approximately 10 sealed fractures/m or more (sealed fracture networks included): 6–10, 15–20 m, 52–53 m, 73–75 m, 92–98 m (Figure 5-2), 115–116 m, 119–120 m, 124–125 m, 133–134 m, 232–242 m, 271–273 m and 284–286 m.

Sections with high frequencies of open fractures occur at 9–10 m, 55–56 m and 95–97 m (Figure 5-1 and Appendix 1). One of them coincides with the only observed crushed section in the borehole at 56.45–56.67 m striking roughly 157/63. The fracture surfaces in the crushed section are highly altered, undulating and smooth. The fracture minerals are chlorite and hematite. An example of a borehole section with frequent sealed fractures and where core loss occurs is shown in Figure 5-2.

Suspected outflow from open fractures are observed between 36 and 45.2 m (Figure 5-3). In this section suspensions have settled down on the lower side of the borehole, and there also seem to be some artificial marks in the mud. Therefore only greater outflow can be confidently documented.

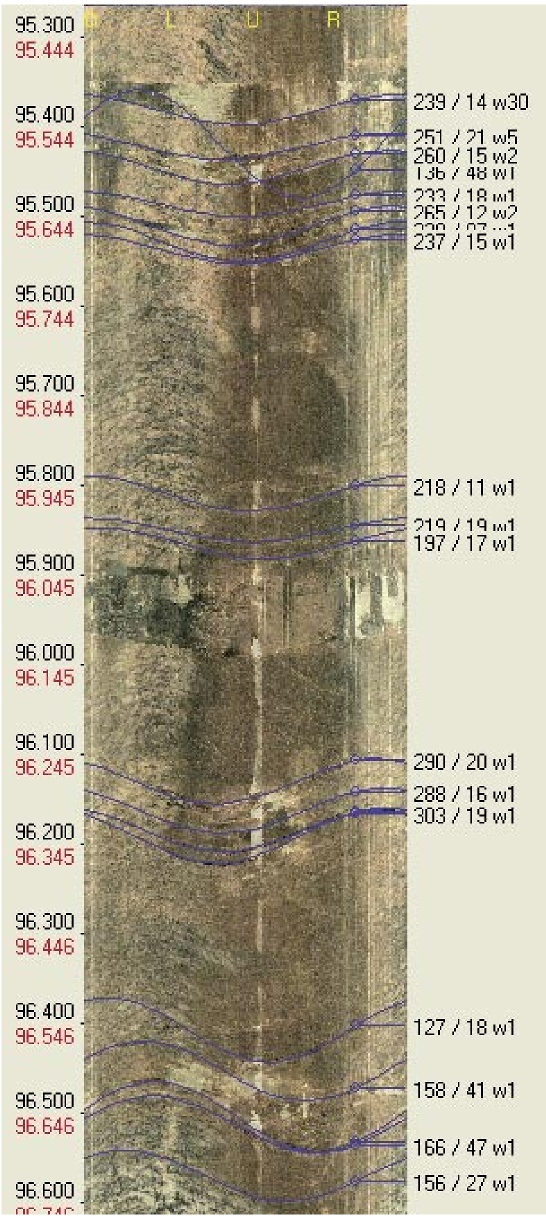


Figure 5-1. *Mapped open fractures in section 95.45–96.74 m.*

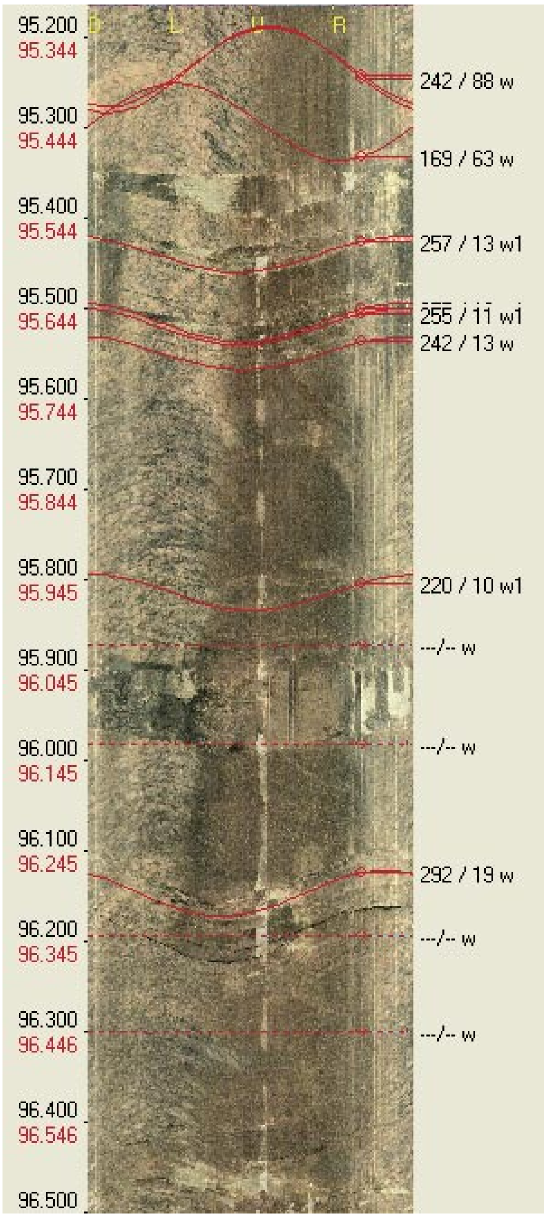


Figure 5-2. *Mapped sealed fractures and core loss (dashed lines) in section 95.35–96.60 m.*

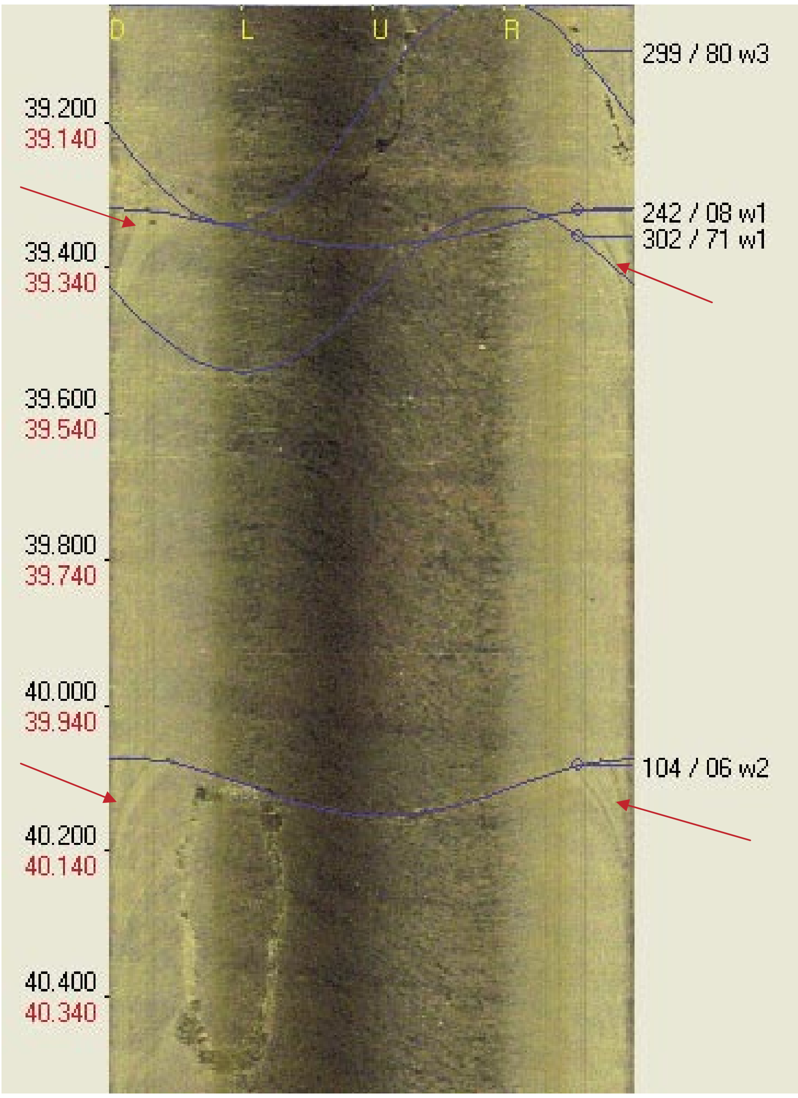


Figure 5-3. *Suspected outflow (marked with red arrows) from open fractures (blue lines).*

5.3 Sealed brittle- to ductile deformation

The rock types in borehole KFM07B show commonly weak to moderate foliation. The foliation is rather consistent in the borehole (see Appendix 1). Various generations of pegmatitic veins occur. They are either foliated, lineated or massive. Very thin deformation bands are quite common and they are listed in Table 5-2 as well as sections with strong foliation.

Table 5-2. Small deformation structures.

From	To	Structural type	Orientation
16.73		Brittle-ductile shear zone	075/87
25.88		Cataclastic, 2 mm	143/34
36.04		Cataclastic, 4 mm	119/18
55.94	55.96	Cataclastic	156/59
55.96	56.06	Mylonitic	156/59
56.42	56.80	Strongly foliated/schistose amphibolite	155/61
79.93	81.22	Strong foliation	161/70
87.1	88.1	Strong foliation	175/72
93.34	93.38	Mylonitic	156/59
93.34		Brecciated	020/72
93.37		Brecciated	188/90
93.38		Brecciated	025/74
99.75		Brecciated	026/76
99.77		Brecciated	025/76
100.58	100.60	Brecciated	030/70
110.10	111.96	Strong foliation	164/65
134.75	134.96	Strong foliation	157/80
136.54	137.63	Strong foliation	164/82
139.58		Brecciated	040/83
139.62	139.63	Brecciated	044/86
146.24	147.45	Strong foliation	162/65
150.37	151.02	Strong foliation	165/66
171.29	171.31	Brittle-ductile shear zone	073/90
233.92	234.52	Brittle-ductily sheared amphibolite	
242.03	242.04	Brittle-ductile shear zone	202/84
262.62	262.69	Brittle-ductile shear zone	137/75
285.64		Cataclastic	151/68
285.66	285.74	Brittle-ductile shear zone	147/66

5.4 Alteration

The rock intersected by KFM07B is weakly to faintly oxidised down to approximately 295 m. Some more intensely oxidised sections occur roughly at: 5–17 m, 23–29 m, 39–48 m, 54–56 m, 93–97 m, 120–121 m, 233–235 m (see Appendix 1). Albitisation occur in shorter sections throughout the borehole in the contacts to amphibolitic dykes /7/. Weak epidotisation is observed at 131.66–133.92 m.

References

/1/ **SKB, 2005.** Preliminary site description, Forsmark area – version 1.2. SKB R-05-18. Svensk Kärnbränslehantering AB.

/2/ **Lindström U, 2006.** Forsmark site investigation. Overcoring rock stress measurements in borehole KFM07B. P-report in progress. Svensk Kärnbränslehantering AB.

/3/ **Claesson L-Å, Nilsson G, 2006.** Forsmark Site Investigation. Drilling of the boreholes KFM07B and KFM07C at drill site DS7. P-report in progress. Svensk Kärnbränslehantering AB.

/4/ **Barton N, 2002.** Some new Q-value correlations to assist in site characterization and tunnel design. International Journal of Rock Mechanics & Mining Sciences Vol. 39 (2002), pp 185–216.

/5/ **Ehrenborg J, Steiskal V, 2004.** Oskarshamn Site Investigation. Boremap mapping of core drilled boreholes KSH01A and KSH01B. SKB P-04-01. Svensk Kärnbränslehantering AB.

/6/ **International Society for Rock Mechanics Commission on Standardization of Laboratory and Field Tests, 1978.** Suggested Methods for the Quantitative Description of Discontinuities in Rock Masses. International Journal of Rock Mechanics & Mining Sciences, Vol.15 (1978), pp 319–368.

/7/ **Petersson J, Berglund J, Danielsson P, Skogsmo G, 2005.** Forsmark Site Investigation. Petrographic and geochemical characterisitics of bedrock samples from boreholes KFM04A-06A, and a whitened alteration rock. SKB-P-05-156. Svensk Kärnbränslehantering AB.

WellCad diagram of KFM07B

Title	LEGEND FOR FORSMARK	KFM07B	Appendix 1

Site	FORSMARK
Borehole	KFM07B
Plot Date	2006-05-14 21:24:33
Signed data	

ROCKTYPE FORSMARK
- Granite, fine- to medium-grained
- Pegmatite, pegmatitic granite
- Granitoid, metamorphic
- Granite, granodiorite and tonalite, metamorphic, fine- to medium-grained
- Granite, metamorphic, aplitic
- Granite to granodiorite, metamorphic, medium-grained
- Granodiorite, metamorphic
- Tonalite to granodiorite, metamorphic
- Diorite, quarts diorite and gabbro, metamorphic
- Ultramafic rock, metamorphic
- Amphibolite
- Calc-silicate rock (skarn)
- Magnetite mineralization associated with calc-silicate rock (skarn)
- Sulphide mineralization
- Felsic to intermediate volcanic rock, metamorphic
- Mafic volcanic rock, metamorphic
- Sedimentary rock, metamorphic

ROCK ALTERATION
- Oxidized
- Chloritisized
- Epidotisized
- Weathered
- Tectonized
- Sericitisized
- Quartz dissolution
- Silicification
- Argillization
- Albitization
- Carbonatization
- Saussuritization
- Steatitization
- Uralitization
- Laumontitization
- Fract zone alteration

MINERAL
- Epidote
- Hematite
- Calcite
- Chlorite
- Quartz
- Unknown
- Pyrite
- Clay Minerals
- Laumontite
- Prehnite
- Asphalt
- Oxidized Walls

STRUCTURE
- Cataclastic
- Schistose
- Gneissic
- Mylonitic
- Ductile Shear Zone
- Brittle-Ductile Zone
- Veined
- Banded
- Massive
- Foliated
- Brecciated
- Lineated

TEXTURE
- Hornfelsed
- Porphyritic
- Ophitic
- Equigranular
- Augen-Bearing
- Unequigranular
- Metamorphic

GRAINSIZE
- Aphanitic
- Fine-grained
- Fine to medium grained
- Medium to coarse grained
- Coarse-grained
- Medium-grained

STRUCTURE ORIENTATION
- Cataclastic
- Bedded
- Gneissic
- Schistose
- Brittle-Ductile Shear Zone
- Ductile Shear Zone
- Lineated
- Banded
- Veined
- Brecciated
- Foliated
- Mylonitic

ROCK ALTERATION INTENSITY
- No intensity
- Faint
- Weak
- Medium
- Strong

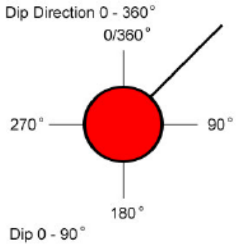
ROUGHNESS
- Planar
- Undulating
- Stepped
- Irregular

SURFACE
- Rough
- Smooth
- Slickensided

CRUSH ALTERATION
- Slightly Altered
- Moderately Altered
- Highly Altered
- Completley Altered
- Gouge
- Fresh

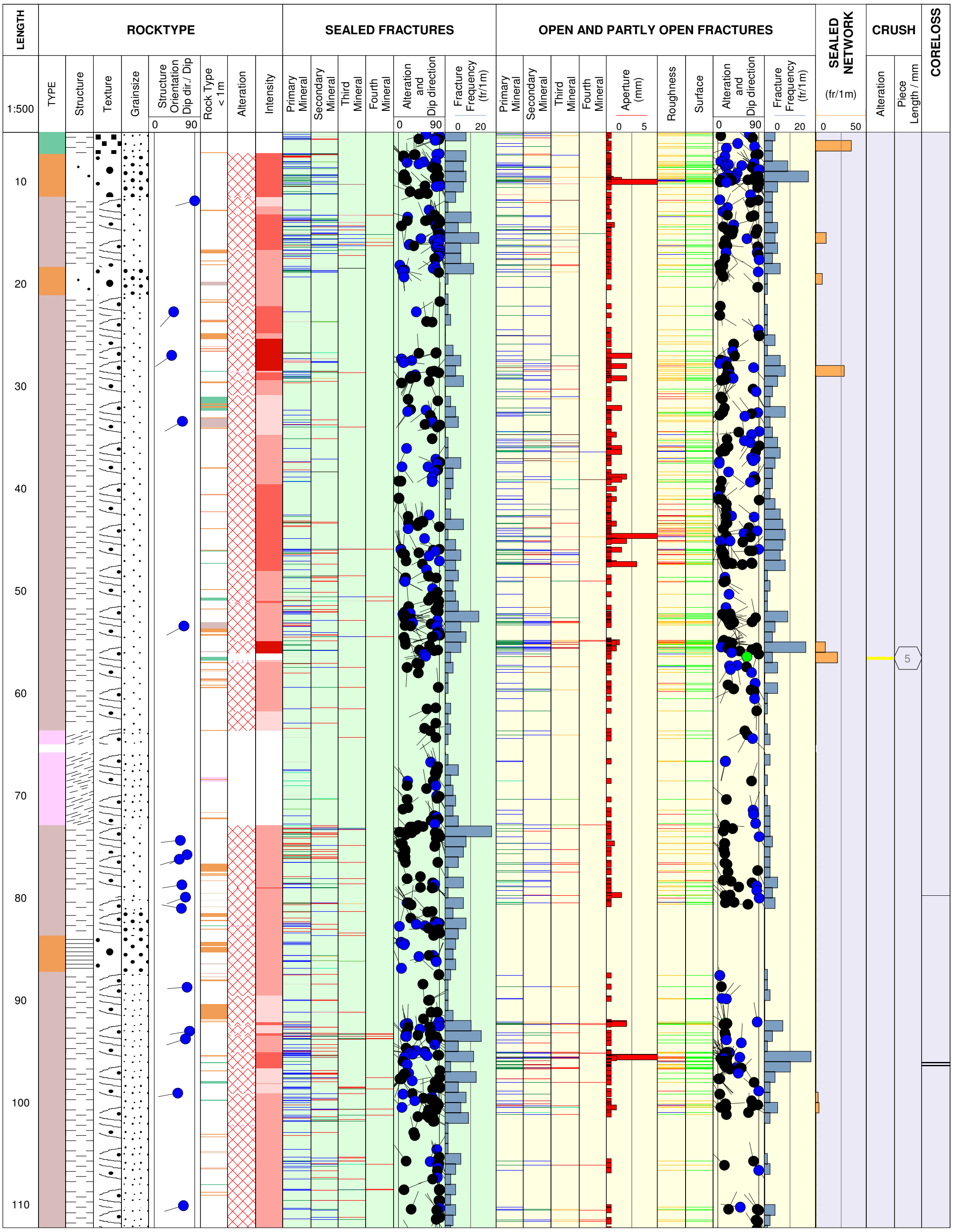
FRACTURE ALTERATION
- Fresh
- Gouge
- Completely Altered
- Highly Altered
- Moderately Altered
- Slightly Altered

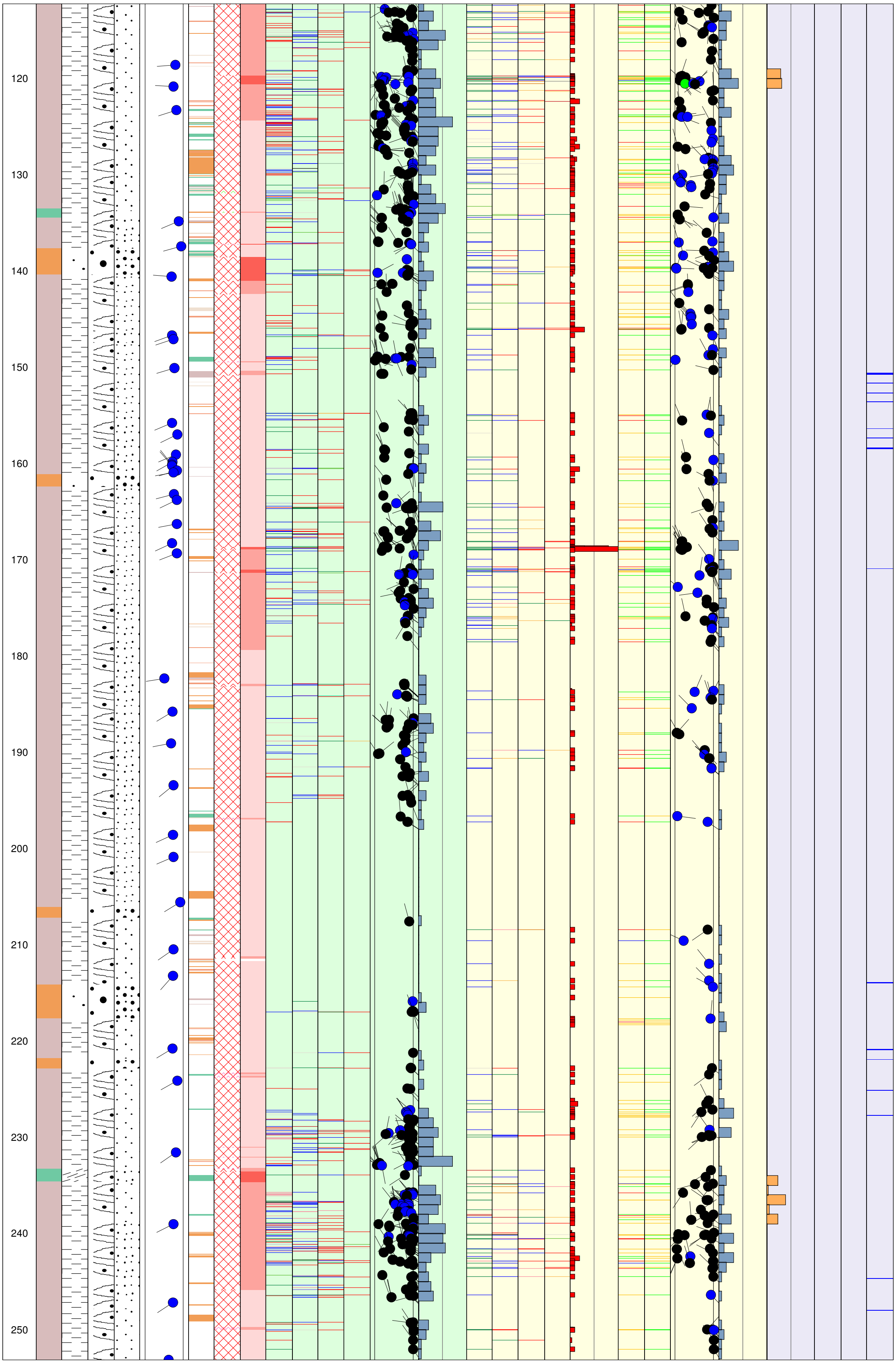
FRACTURE DIRECTION
STRUKTURE ORIENTATION

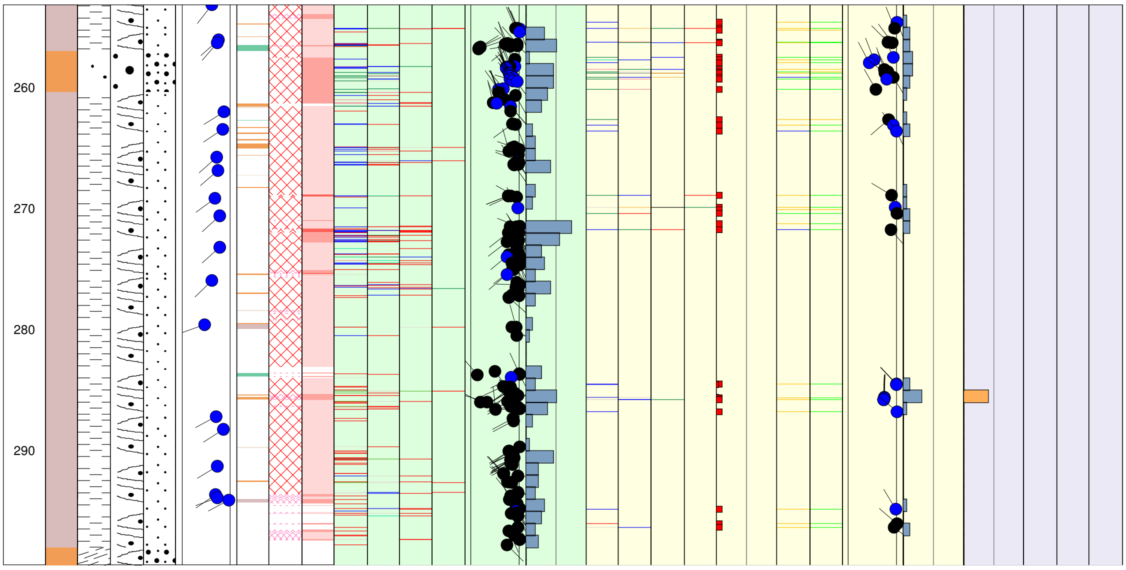


Title GEOLOGY IN KFM07B **Appendix:**

Site	FORSMARK	**Coordinate System**	RT90-RHB70
Borehole	KFM07B	**Northing [m]**	6700123.62
Diameter [mm]	76	**Easting [m]**	1631036.83
Length [m]	298.930	**Elevation [m.a.s.l.]**	3.36
Bearing [°]	134.35	**Drilling Start Date**	2005-05-31 16:20:00
Inclination [°]	-53.70	**Drilling Stop Date**	2005-10-18 10:24:00
Date of coremapping	2005-11-10 10:03:00	**Plot Date**	2006-04-23 21:13:19
Rocktype data from	p_rock	**Signed data**	




120
130
140
150
160
170
180
190
200
210
220
230
240
250


260
270
280
290

Indata: Length reference marks, borehole diameter and borehole length

Reference Mark T – Reference mark in drillhole

KFM07B, 2005-10-18 14:30:00 – 2005-10-24 15:30:00 (100.000–250.000 m).

Bhlen (m)	Rotation speed (rpm)	Start flow (l/min)	Stop flow (l/min)	Stop pressure (bar)	Cutter time (s)	Trace detectable	Cutter diameter (mm)	Comment
100.00	400.00	300	350	30.0	1,800	JA		100.33/1,090.43
150.00	400.00	300	350	30.0	1,500	JA		150.57/150.67
200.00	400.00	300	350	30.0	1,200	JA		200.62/200.72
250.00	400.00	300	350	30.0	1,200	JA		250.88/250.98

Printout from SICADA 2006-01-04 16:29:23.

Hole Diam T – Drilling: Borehole diameter

KFM07B, 2005-05-31 16:20:00 – 2005-10-18 10:24:00 (0.000–298.930 m).

Sub secup (m)	Sub seclow (m)	Hole diam (m)	Comment
0.000	5.180	0.1160	
5.180	65.690	0.0960	HQ
65.690	298.930	0.0758	N

Printout from SICADA 2006-01-04 16:26:37.

Appendix 3

Indata: Borehole deviation data

Maxibor T – Borehole deviation: Maxibor

KFM07B, 2005-10-19 00:00:00.

Length (m)	Northing (m)	Easting (m)	Elevation (m)	Coord system	Inclination (degrees)	Bearing (degrees)	Local A (m)	Local B (m)	Local C (m)	Extrapol flag
0.00	6700123.62	1631036.83	–3.36	RT90-RHB70	–53.71	134.35				
3.00	6700122.38	1631038.11	–0.94	RT90-RHB70	–53.71	134.35	0.0000	0.0000	0.0000	
6.00	6700121.14	1631039.38	1.48	RT90-RHB70	–53.78	134.26	1.7800	0.0000	0.0000	
9.00	6700119.90	1631040.65	3.90	RT90-RHB70	–53.72	134.27	3.5500	0.0000	0.0000	
12.00	6700118.66	1631041.92	6.32	RT90-RHB70	–53.73	134.33	5.3200	-0.0100	0.0000	
15.00	6700117.42	1631043.19	8.74	RT90-RHB70	–53.71	134.42	7.1000	-0.0100	-0.0100	
18.00	6700116.18	1631044.46	11.15	RT90-RHB70	–53.69	134.49	8.8700	0.0000	0.0000	
21.00	6700114.93	1631045.73	13.57	RT90-RHB70	–53.66	134.49	10.6500	0.0000	0.0000	
24.00	6700113.69	1631046.99	15.99	RT90-RHB70	–53.59	134.66	12.4300	0.0100	0.0000	
27.00	6700112.44	1631048.26	18.40	RT90-RHB70	–53.59	134.78	14.2100	0.0100	0.0000	
30.00	6700111.18	1631049.52	20.82	RT90-RHB70	–53.54	134.87	15.9900	0.0300	0.0100	
33.00	6700109.92	1631050.79	23.23	RT90-RHB70	–53.47	134.99	17.7700	0.0400	0.0200	
36.00	6700108.66	1631052.05	25.64	RT90-RHB70	–53.39	135.07	19.5600	0.0600	0.0300	
39.00	6700107.40	1631053.31	28.05	RT90-RHB70	–53.36	135.18	21.3500	0.0900	0.0500	
42.00	6700106.13	1631054.58	30.45	RT90-RHB70	–53.32	135.35	23.1400	0.1100	0.0700	
45.00	6700104.85	1631055.84	32.86	RT90-RHB70	–53.28	135.36	24.9300	0.1400	0.0900	
48.00	6700103.57	1631057.10	35.27	RT90-RHB70	–53.20	135.38	26.7200	0.1800	0.1100	
51.00	6700102.30	1631058.36	37.67	RT90-RHB70	–53.11	135.48	28.5200	0.2100	0.1400	
54.00	6700101.01	1631059.62	40.07	RT90-RHB70	–53.04	135.57	30.3200	0.2400	0.1700	
57.00	6700099.72	1631060.88	42.46	RT90-RHB70	–53.01	135.59	32.1200	0.2800	0.2000	

Length (m)	Northing (m)	Easting (m)	Elevation (m)	Coord system	Inclination (degrees)	Bearing (degrees)	Local A (m)	Local B (m)	Local C (m)	Extrapol flag
60.00	6700098.43	1631062.15	44.86	RT90-RHB70	–52.91	135.58	33.9300	0.3200	0.2400	
63.00	6700097.14	1631063.41	47.25	RT90-RHB70	–52.91	135.68	35.7400	0.3600	0.2800	
66.00	6700095.85	1631064.68	49.65	RT90-RHB70	–52.92	135.68	37.5400	0.4000	0.3200	
69.00	6700094.55	1631065.94	52.04	RT90-RHB70	–52.93	135.67	39.3500	0.4400	0.3600	
72.00	6700093.26	1631067.20	54.43	RT90-RHB70	–52.90	135.64	41.1600	0.4800	0.4000	
75.00	6700091.97	1631068.47	56.83	RT90-RHB70	–52.83	135.64	42.9700	0.5300	0.4400	
78.00	6700090.67	1631069.74	59.22	RT90-RHB70	–52.74	135.66	44.7800	0.5700	0.4900	
81.00	6700089.37	1631071.01	61.60	RT90-RHB70	–52.62	135.72	46.6000	0.6100	0.5400	
84.00	6700088.07	1631072.28	63.99	RT90-RHB70	–52.52	135.73	48.4200	0.6500	0.6000	
87.00	6700086.76	1631073.55	66.37	RT90-RHB70	–52.40	135.72	50.2400	0.7000	0.6600	
90.00	6700085.45	1631074.83	68.75	RT90-RHB70	–52.29	135.69	52.0700	0.7400	0.7300	
93.00	6700084.14	1631076.11	71.12	RT90-RHB70	–52.19	135.66	53.9100	0.7800	0.8000	
96.00	6700082.82	1631077.40	73.49	RT90-RHB70	–52.10	135.66	55.7500	0.8200	0.8800	
99.00	6700081.50	1631078.69	75.86	RT90-RHB70	–51.99	135.76	57.5900	0.8700	0.9600	
102.00	6700080.18	1631079.97	78.22	RT90-RHB70	–51.88	135.91	59.4400	0.9100	1.0500	
105.00	6700078.85	1631081.26	80.58	RT90-RHB70	–51.74	136.13	61.2900	0.9600	1.1500	
108.00	6700077.51	1631082.55	82.94	RT90-RHB70	–51.58	136.29	63.1400	1.0200	1.2500	
111.00	6700076.16	1631083.84	85.29	RT90-RHB70	–51.49	136.37	65.0100	1.0800	1.3600	
114.00	6700074.81	1631085.13	87.63	RT90-RHB70	–51.42	136.42	66.8700	1.1500	1.4800	
117.00	6700073.46	1631086.42	89.98	RT90-RHB70	–51.35	136.48	68.7400	1.2200	1.6000	
120.00	6700072.10	1631087.71	92.32	RT90-RHB70	–51.26	136.54	70.6200	1.2900	1.7200	
123.00	6700070.73	1631089.00	94.66	RT90-RHB70	–51.18	136.61	72.4900	1.3600	1.8500	
126.00	6700069.37	1631090.29	97.00	RT90-RHB70	–51.10	136.66	74.3700	1.4300	1.9800	
129.00	6700068.00	1631091.58	99.33	RT90-RHB70	–51.03	136.71	76.2500	1.5100	2.1100	
132.00	6700066.62	1631092.88	101.67	RT90-RHB70	–50.91	136.76	78.1400	1.5900	2.2500	
135.00	6700065.25	1631094.17	104.00	RT90-RHB70	–50.78	136.79	80.0300	1.6600	2.4000	
138.00	6700063.86	1631095.47	106.32	RT90-RHB70	–50.66	136.81	81.9200	1.7500	2.5500	
141.00	6700062.48	1631096.77	108.64	RT90-RHB70	–50.61	136.84	83.8200	1.8300	2.7100	

Length (m)	Northing (m)	Easting (m)	Elevation (m)	Coord system	Inclination (degrees)	Bearing (degrees)	Local A (m)	Local B (m)	Local C (m)	Extrapol flag
144.00	6700061.09	1631098.08	110.96	RT90-RHB70	–50.53	136.85	85.7300	1.9100	2.8700	
147.00	6700059.70	1631099.38	113.27	RT90-RHB70	–50.48	136.80	87.6300	1.9900	3.0300	
150.00	6700058.31	1631100.69	115.59	RT90-RHB70	–50.43	136.80	89.5400	2.0700	3.2000	
153.00	6700056.91	1631102.00	117.90	RT90-RHB70	–50.41	136.81	91.4500	2.1600	3.3700	
156.00	6700055.52	1631103.30	120.21	RT90-RHB70	–50.37	136.83	93.3600	2.2400	3.5400	
159.00	6700054.12	1631104.61	122.52	RT90-RHB70	–50.38	136.82	95.2700	2.3200	3.7200	
162.00	6700052.73	1631105.92	124.83	RT90-RHB70	–50.39	136.81	97.1800	2.4000	3.8900	
165.00	6700051.33	1631107.23	127.14	RT90-RHB70	–50.59	136.73	99.0900	2.4900	4.0600	
168.00	6700049.95	1631108.54	129.46	RT90-RHB70	–51.08	136.47	101.0000	2.5600	4.2200	
171.00	6700048.58	1631109.84	131.80	RT90-RHB70	–51.36	136.27	102.8800	2.6300	4.3600	
174.00	6700047.23	1631111.13	134.14	RT90-RHB70	–51.64	136.04	104.7500	2.7000	4.4800	
177.00	6700045.89	1631112.42	136.49	RT90-RHB70	–51.84	135.90	106.6100	2.7500	4.5900	
180.00	6700044.55	1631113.71	138.85	RT90-RHB70	–52.11	135.74	108.4700	2.8000	4.6900	
183.00	6700043.24	1631115.00	141.22	RT90-RHB70	–52.20	135.71	110.3100	2.8500	4.7700	
186.00	6700041.92	1631116.28	143.59	RT90-RHB70	–52.23	135.59	112.1500	2.8900	4.8500	
189.00	6700040.61	1631117.57	145.96	RT90-RHB70	–52.46	135.42	113.9800	2.9300	4.9300	
192.00	6700039.30	1631118.85	148.34	RT90-RHB70	–52.67	135.33	115.8100	2.9600	4.9900	
195.00	6700038.01	1631120.13	150.73	RT90-RHB70	–52.86	135.26	117.6300	3.0000	5.0500	
198.00	6700036.72	1631121.41	153.12	RT90-RHB70	–52.83	135.24	119.4400	3.0200	5.0900	
201.00	6700035.44	1631122.68	155.51	RT90-RHB70	–52.73	135.31	121.2500	3.0500	5.1400	
204.00	6700034.15	1631123.96	157.89	RT90-RHB70	–52.78	135.31	123.0700	3.0800	5.1900	
207.00	6700032.86	1631125.24	160.28	RT90-RHB70	–52.99	135.27	124.8800	3.1100	5.2400	
210.00	6700031.57	1631126.51	162.68	RT90-RHB70	–52.96	135.27	126.6900	3.1400	5.2700	
213.00	6700030.29	1631127.78	165.07	RT90-RHB70	–52.86	135.36	128.5000	3.1700	5.3100	
216.00	6700029.00	1631129.05	167.47	RT90-RHB70	–52.74	135.39	130.3100	3.2000	5.3600	
219.00	6700027.71	1631130.33	169.85	RT90-RHB70	–52.68	135.40	132.1200	3.2400	5.4100	
222.00	6700026.41	1631131.60	172.24	RT90-RHB70	–52.62	135.40	133.9400	3.2700	5.4600	
225.00	6700025.12	1631132.88	174.62	RT90-RHB70	–52.58	135.46	135.7600	3.3000	5.5200	

Length (m)	Northing (m)	Easting (m)	Elevation (m)	Coord system	Inclination (degrees)	Bearing (degrees)	Local A (m)	Local B (m)	Local C (m)	Extrapol flag
228.00	6700023.82	1631134.16	177.01	RT90-RHB70	–52.51	135.51	137.5800	3.3400	5.5800	
231.00	6700022.51	1631135.44	179.39	RT90-RHB70	–52.48	135.52	139.4100	3.3800	5.6400	
234.00	6700021.21	1631136.72	181.76	RT90-RHB70	–52.43	135.56	141.2400	3.4100	5.7000	
237.00	6700019.90	1631138.00	184.14	RT90-RHB70	–52.39	135.56	143.0700	3.4500	5.7700	
240.00	6700018.60	1631139.28	186.52	RT90-RHB70	–52.32	135.54	144.9000	3.4900	5.8400	
243.00	6700017.29	1631140.57	188.89	RT90-RHB70	–52.26	135.51	146.7300	3.5300	5.9100	
246.00	6700015.98	1631141.85	191.27	RT90-RHB70	–52.20	135.53	148.5700	3.5600	5.9900	
249.00	6700014.67	1631143.14	193.64	RT90-RHB70	–52.16	135.51	150.4000	3.6000	6.0700	
252.00	6700013.35	1631144.43	196.01	RT90-RHB70	–52.11	135.51	152.2400	3.6400	6.1500	
255.00	6700012.04	1631145.72	198.37	RT90-RHB70	–52.04	135.48	154.0900	3.6800	6.2300	
258.00	6700010.72	1631147.02	200.74	RT90-RHB70	–52.04	135.48	155.9300	3.7100	6.3200	
261.00	6700009.41	1631148.31	203.10	RT90-RHB70	–52.03	135.47	157.7800	3.7500	6.4000	
264.00	6700008.09	1631149.61	205.47	RT90-RHB70	–52.09	135.44	159.6200	3.7900	6.4900	
267.00	6700006.78	1631150.90	207.84	RT90-RHB70	–52.13	135.39	161.4600	3.8200	6.5800	
270.00	6700005.47	1631152.19	210.20	RT90-RHB70	–52.11	135.36	163.3100	3.8500	6.6600	
273.00	6700004.16	1631153.49	212.57	RT90-RHB70	–52.06	135.34	165.1500	3.8900	6.7400	
276.00	6700002.84	1631154.78	214.94	RT90-RHB70	–52.03	135.31	166.9900	3.9200	6.8300	
279.00	6700001.53	1631156.08	217.30	RT90-RHB70	–51.99	135.29	168.8400	3.9500	6.9200	
282.00	6700000.22	1631157.38	219.67	RT90-RHB70	–51.95	135.26	170.6800	3.9800	7.0100	
285.00	6699998.91	1631158.68	222.03	RT90-RHB70	–51.90	135.25	172.5300	4.0100	7.1000	
288.00	6699997.59	1631159.99	224.39	RT90-RHB70	–51.84	135.25	174.3800	4.0400	7.1900	
291.00	6699996.27	1631161.29	226.75	RT90-RHB70	–51.77	135.26	176.2400	4.0700	7.2900	
297.00	6699993.63	1631163.91	231.46	RT90-RHB70	–51.65	135.21	179.9600	4.1200	7.5000	

Printout from SICADA 2005-11-23 11:58:41.