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Revised October 2006

Forsmark site investigation

Geological single-hole interpretation of KFM06A and KFM06B (DS6)

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November 2005

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Keywords: Forsmark, Geophysics, Geology, Borehole, Bedrock, Fractures, P-PF 400-04-114.

Reading instruction

For revision no. 1 of this report a recalculation of the oriented radar data has been carried out.

The strike and dip of the oriented radar data are now recalculated using the right-hand-rule method, e.g. 040/80 corresponds to a strike of N40°E and a dip of 80° to the SE. The new values for strike and dip are updated in Chapter 5.1 and 5.2 as well as in Appendix 1 and Appendix 2.

The revised report also presents updated identification codes from rock units, in accordance with the revised method description for single-hole interpretation. The term “confidence level” also replaces the term “uncertainty” in accordance with the revised method description.

Appendices 1 and 2 are updated.

Abstract

This report contains geological single-hole interpretations of the cored boreholes KFM06A and KFM06B in Forsmark. The geological single-hole interpretation combines the geological core mapping, interpreted geophysical logs and borehole radar measurements to interpret where lithological rock units and possible deformation zones occur in the boreholes.

The geological single-hole interpretation shows that five rock units (RU1–RU5) occur in KFM06A. The borehole can be divided into six separate sections along the borehole length due to the repetition of rock unit RU1. Medium-grained metagranite-granodiorite (101057), fine- to medium-grained metagranite-granodiorite (101051) and aplitic metagranite (101058) dominate the borehole. A large interval characterized by strongly bleached, altered rocks also occurs in the borehole. Fine- to medium-grained metagranitoid (101051), pegmatitic granite (101061) and amphibolite (102017) occur in small sections. Eleven possible deformation zones have been identified in KFM06A (DZ1–DZ11).

The geological single-hole interpretation shows that one rock unit occurs in KFM06B (RU1). Medium-grained metagranite-granodiorite (101057) dominates the borehole. Pegmatitic granite (101061), amphibolite (102017) and fine- to medium-grained metagranitoid (101051) occur in small sections. One possible deformation zone has been identified in KFM06B (DZ1).

Sammanfattning

Denna rapport behandlar geologisk enhålstolkning av kärnborrhålen KFM06A och KFM06B i Forsmark. Den geologiska enhålstolkningen syftar till att utifrån data från den geologiska karteringen, tolkade geofysiska loggar och borrhålsradarmätningar indikera olika litologiska enheters fördelning i borrhålen samt möjliga deformationszoners läge och utbredning.

Denna undersökning visar att det i KFM06A finns fem litologiska enheter (RU1–RU5). Baserat på repetition av enheten RU1 kan borrhålet delas in i sex sektioner. Medelkorning metagranit-granodiorit (101057), fin- till medelkornig metagranit-granodiorit (101051) samt aplitisk metagranit (101058) förekommer i större delen av borrhålet. Ett mer omfattande intervall med starkt blekta, omvandlade bergarter förekommer. I mindre omfattning förekommer dessutom fin- till medelkornig metagranitoid (101051), pegmatitisk granit (101061) och amfibolit (102017). Elva möjliga deformationszoner har identifierats i KFM06A (DZ1–DZ11).

I KFM06B finns en litologisk enhet (RU1). Borrhålet domineras av medelkorning metagranit-granodiorit (101057). I mindre omfattning förekommer pegmatitisk granit (101061), amfibolit (102017) och fin- till medelkornig metagranitoid (101051). En möjlig deformationszon har identifierats i KFM06B (DZ1).

Contents

1 Introduction

Much of the primary geological and geophysical borehole data stored in the SKB database SICADA need to be integrated and synthesized before they can be used for modelling in the 3D-CAD system Rock Visualisation System (RVS). The end result of this procedure is a geological single-hole interpretation, which consists of an integrated series of different logs and accompanying descriptive documents. The activity is performed according to the activity plan AP PF 400-04-114 (SKB internal document)

This document reports the geological single-hole interpretation of boreholes KFM06A and KFM06B at drill site 6 (DS6) in the Forsmark area (Figure 1-1). The horizontal projection of the boreholes in the candidate area is shown in Figure 1-2.

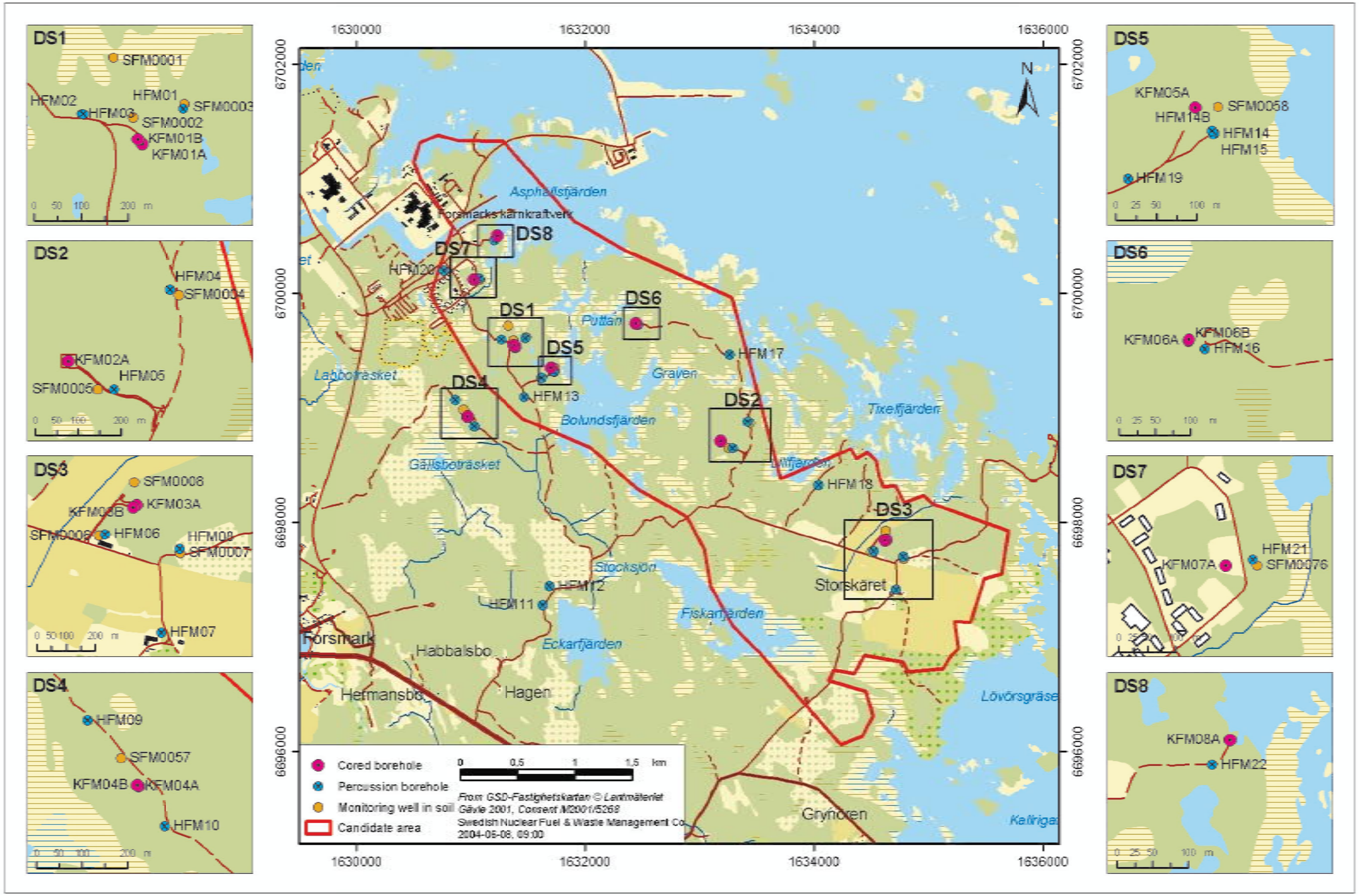

Figure 1-1. Map showing drill site 6 (DS6) and the position of the cored boreholes KFM06A and KFM06B.

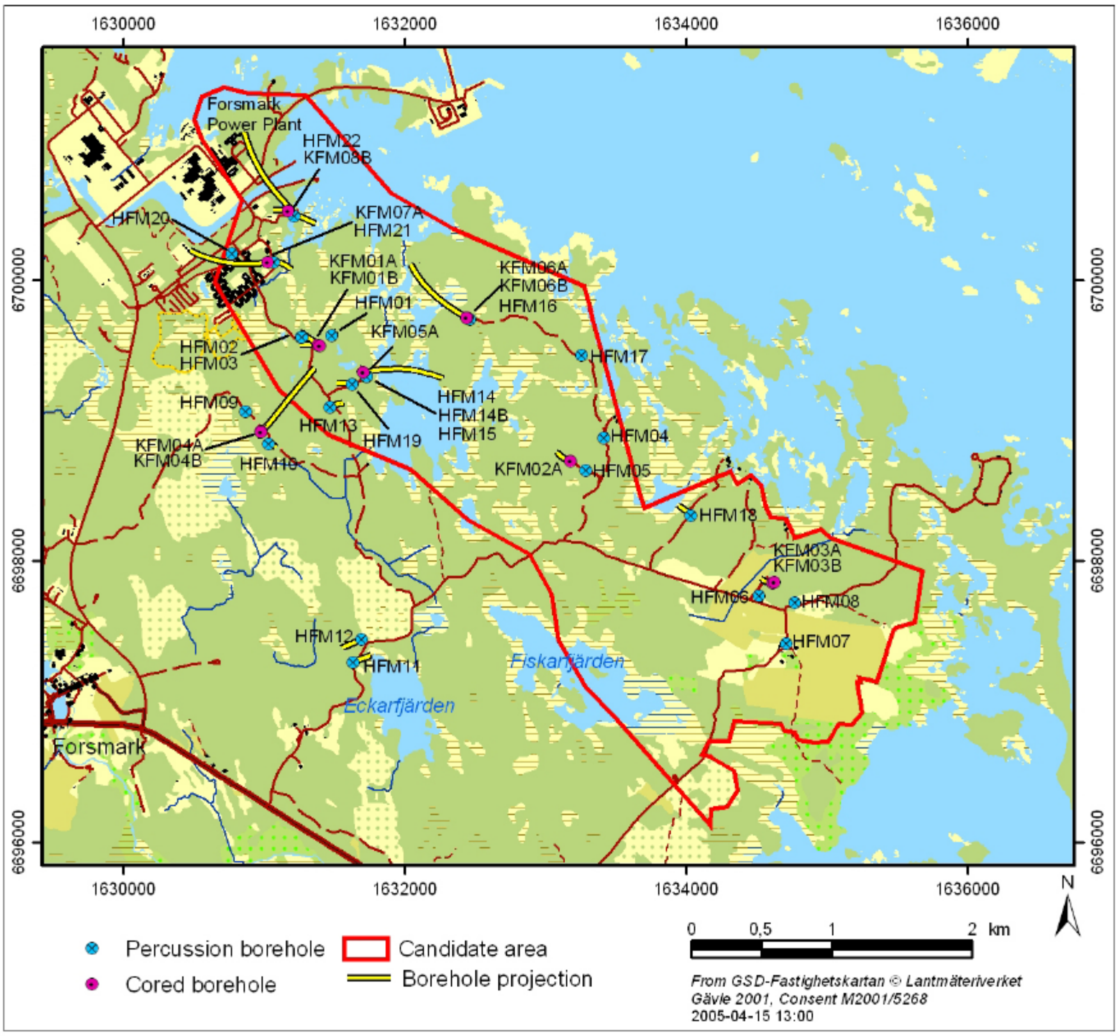

Figure 1-2. *Map showing horizontal projection of the boreholes in the candidate area. The cored borehole is KFM06A drilled inclined (60° from horizontal plane), while the cored borehole KFM06B is drilled sub-vertical (c 85° from horizontal).*

2 Objective and scope

A geological single-hole interpretation is carried out in order to identify and to describe briefly the characteristics of major rock units and possible deformation zones within a borehole. The work involves an integrated interpretation of data from the geological mapping of the borehole (Boremap), different borehole geophysical logs and borehole radar data. The geological mapping of the cored boreholes involves a documentation of the character of the bedrock in the drill core. This work component is carried out in combination with an inspection of the oriented image of the borehole walls that is obtained with the help of the Borehole Image Processing System (BIPS). The geological mapping of the percussion boreholes focuses more attention on an integrated interpretation of the information from the geophysical logs and the BIPS images. For this reason, the results from the percussion borehole mapping are more uncertain. The interpretations of the borehole geophysical and radar logs are available when the single-hole interpretation is completed. The result from the geological single-hole interpretation is presented in a WellCad plot. A more detailed description of the technique is provided in the method description for geological single-hole interpretation (SKB MD 810.003, internal document).

3 Data used for the geological single-hole interpretation

The following data and interpretations have been used for the single-hole interpretation of the cored boreholes at drill site 6:

- Boremap data (including BIPS and geological mapping data) /1/.
- Generalized geophysical logs and their interpretation /2, 3/.
- Radar data and their interpretation /4/.

The geological single-hole interpretation of the percussion drill hole HFM16 is reported in /6/.

The material used as a basis for the geological single-hole interpretation was a WellCad plot consisting of parameters from the geological mapping in the Boremap system, geophysical logs and borehole radar. An example of a WellCad plot used during the geological single-hole interpretation is shown in Figure 3-1. The plot consists of ten main columns and several subordinate columns. These include:

1: Length along the borehole

2: Rock type
- 2.1: Rock type
- 2.2: Rock type structure
- 2.3: Rock type texture
- 2.4: Rock type grain size
- 2.5: Structure orientation
- 2.6: Rock occurrence (< 1 m)
- 2.7: Rock alteration
- 2.8: Rock alteration intensity

3: Unbroken fractures
- 3.1: Primary mineral
- 3.2: Secondary mineral
- 3.3: Third mineral
- 3.4: Fourth mineral
- 3.5: Alteration, dip direction

4: Broken fractures
- 4.1: Primary mineral
- 4.2: Secondary mineral
- 4.3: Third mineral
- 4.4: Fourth mineral
- 4.5: Aperture (mm)
- 4.6: Roughness
- 4.7: Surface
- 4.8: Alteration, dip direction

5: Crush zones
- 5.1: Primary mineral
- 5.2: Secondary mineral
- 5.3: Third mineral

- 5.4: Fourth mineral
- 5.5: Roughness
- 5.6: Surface
- 5.7: Crush alteration, dip direction
- 5.8: Piece (mm)
- 5.9: Sealed network
- 5.10: Core loss

6: Fracture frequency
- 6.1: Open fractures
- 6.2: Sealed fractures

7: Geophysics
- 7.1: Magnetic susceptibility
- 7.2: Natural gamma radiation
- 7.3: Possible alteration
- 7.4: Silicate density
- 7.5: Estimated fracture frequency

8: Radar
- 8.1: Length
- 8.2: Angle

9: Reference mark (not used for percussion-drilled boreholes)

10: BIPS

The geophysical logs are described below:

Magnetic susceptibility: The rock has been classified into sections of low, medium, high, and very high magnetic susceptibility. The susceptibility measurement is strongly connected to the magnetite content in the different rock types.

Natural gamma radiation: The rock has been classified into sections of low, medium, and high natural gamma radiation. Low radiation may indicate mafic rock types and high radiation may indicate younger fine-grained granite or pegmatite. The rock with high natural gamma radiation has been included in the younger, Group D intrusive suite /6/.

Possible alteration: This parameter has not been used in the geological single-hole interpretation in the Forsmark area.

Silicate density: This parameter indicates the density of the rock after subtraction of the magnetic component in the rock. It provides general information on the mineral composition of the rock types, and serves as a support during classification of rock types.

Estimated fracture frequency: This parameter provides an estimate of the fracture frequency along 5 m sections, calculated from short and long normal resistivity, SPR, sonic as well as focused resistivity 140 and 300. The estimated fracture frequency is based on a statistical connection after a comparison has been made between the geophysical logs and the mapped fracture frequency. The log provides an indication of sections with low and high fracture frequencies.

Close inspection of the borehole radar data was carried out during the interpretation process, especially during the identification of possible deformation zones. The occurrence and orientation of radar anomalies within the possible deformation zones are commented upon in the text that describes these zones.

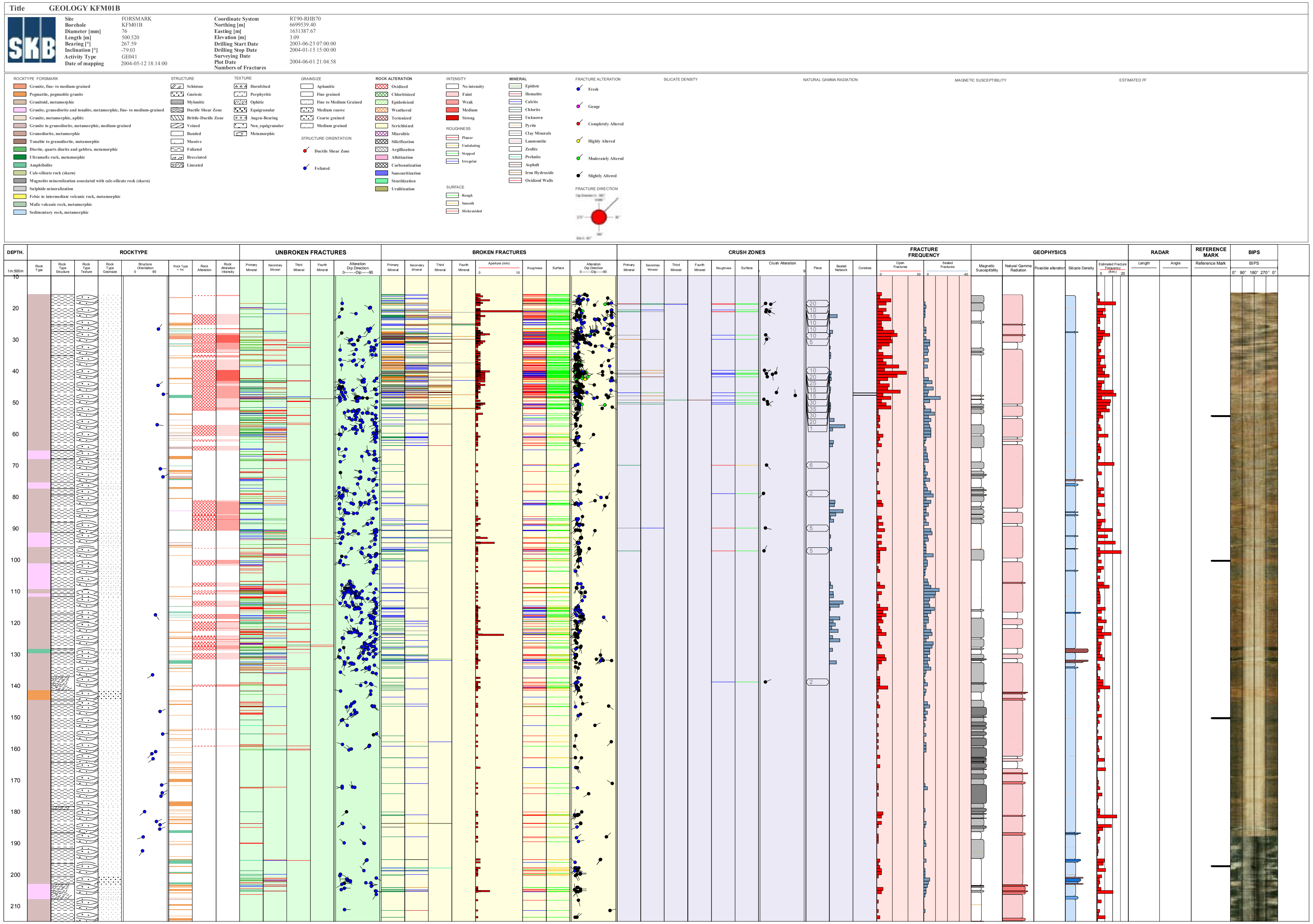

Figure 3-1. Example of WellCad plot (from borehole KFM01B) used as a basis for the single-hole interpretation.

4 Execution

4.1 General

The geological single-hole interpretation has been carried out by a group of geoscientists consisting of both geologists and geophysicists. (SKB MD 810.003, SKB internal document) Several of these participants previously participated in the development of the source material for the single-hole interpretation. All data to be used (see above) are visualized side by side in a borehole document extracted from the software WellCad. The working procedure is summarized in Figure 4-1 and in the text below.

Stage 1 in the working procedure is to study all types of data (rock type, rock alteration, silicate density, natural gamma radiation, etc) related to the character of the rock type and to merge sections of similar rock types, or sections where one rock type is very dominant, into rock units (minimum length of c 5–10 m). Each rock unit is defined in terms of the borehole length interval and provided with a brief description for inclusion in the WellCad plot. The confidence in the interpretation of a rock unit is made on the following basis: 3 = high, 2 = medium and 1 = low.

Stage 2 in the working procedure is to identify possible deformation zones by visual inspection of the results of the geological mapping (fracture frequency, fracture mineral, aperture, alteration, etc) in combination with the geophysical logging and radar data. The section of each identified possible deformation zone is defined in terms of the borehole length interval and provided with a brief description for inclusion in the WellCad plot. The confidence in the interpretation of a deformation zone is made on the following basis: 3 = high, 2 = medium and 1 = low.

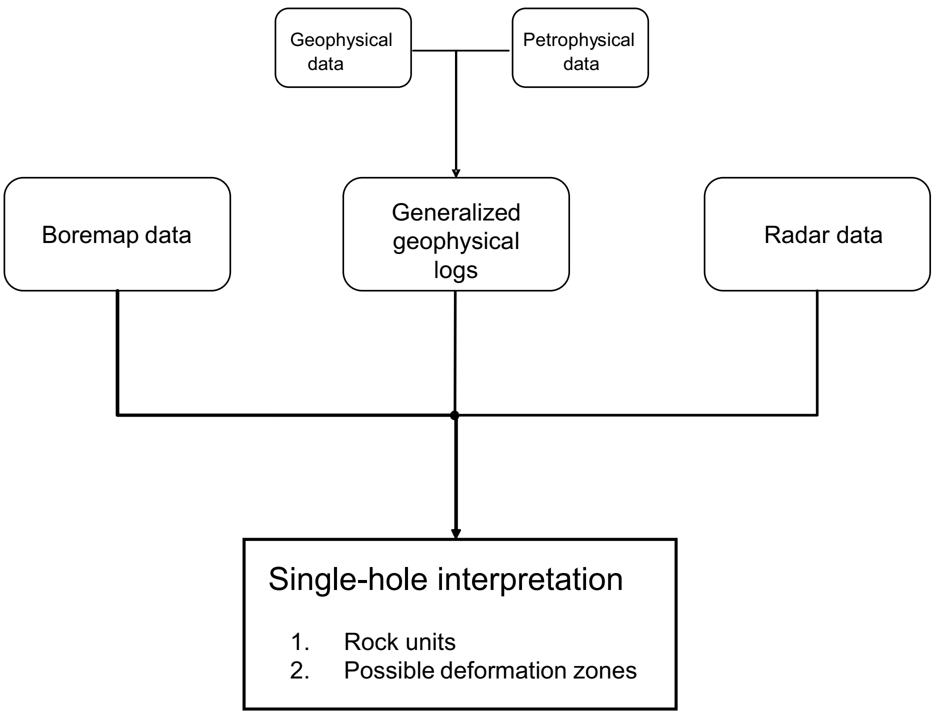

Figure 4-1. *Schematic chart that shows the procedure for the development of a geological single-hole interpretation.*

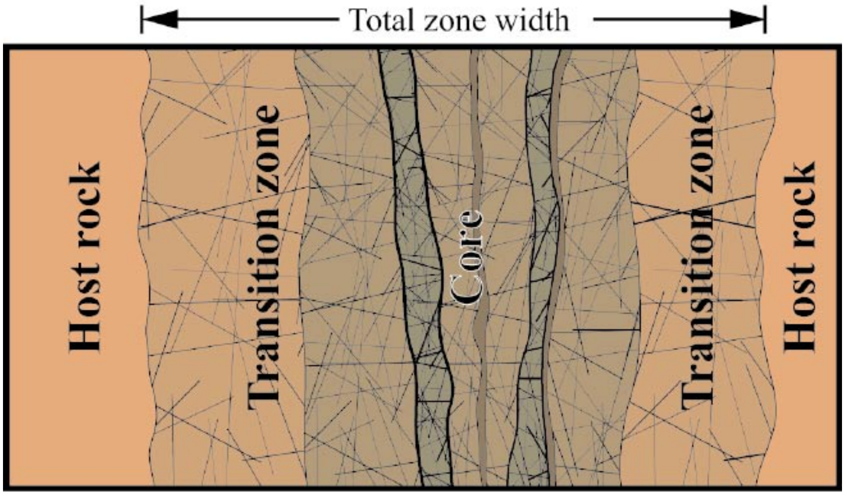

***Figure 4-2.** Terminology for brittle deformation zones (after /8/).*

Inspection of BIPS images is carried out wherever it is judged necessary during the working procedure. Furthermore, following definition of rock units and possible deformation zones, the cored boreholes are inspected in order to check the selection of the boundaries between these geological entities. If judged necessary, the location of these boundaries is adjusted.

Deformation zones that are brittle in character have been identified primarily on the basis of the frequency of fractures, according to the recommendations in /8/. Both the transitional part, with a fracture frequency in the range 4–9 fractures/m, and the cored part, with a fracture frequency > 9 fractures/m, have been included in each zone (Figure 4-2). The frequencies of open and sealed fractures have been assessed in the identification procedure, and the character of the zone has been described accordingly. Partly open fractures are included together with open fractures in the brief description of each zone. The presence of bedrock alteration, the occurrence and, locally, the inferred orientation of radar reflectors, and the resistivity, SPR, P-wave velocity, caliper and magnetic susceptibility logs have all assisted in the identification of the zones.

Since the frequency of fractures is of key importance for the definition of the possible deformation zones, moving average plots for this parameter are shown for KFM06A (Figure 4-3) and KFM06B (Figure 4-4), respectively. A 5 m window and 1 m steps have been used in the calculation procedure. In each diagram, the moving averages for open fractures alone, the total number of open fractures (open, partly open and crush), the sealed fractures alone, and the total number of sealed fractures (sealed and sealed fracture network) are shown.

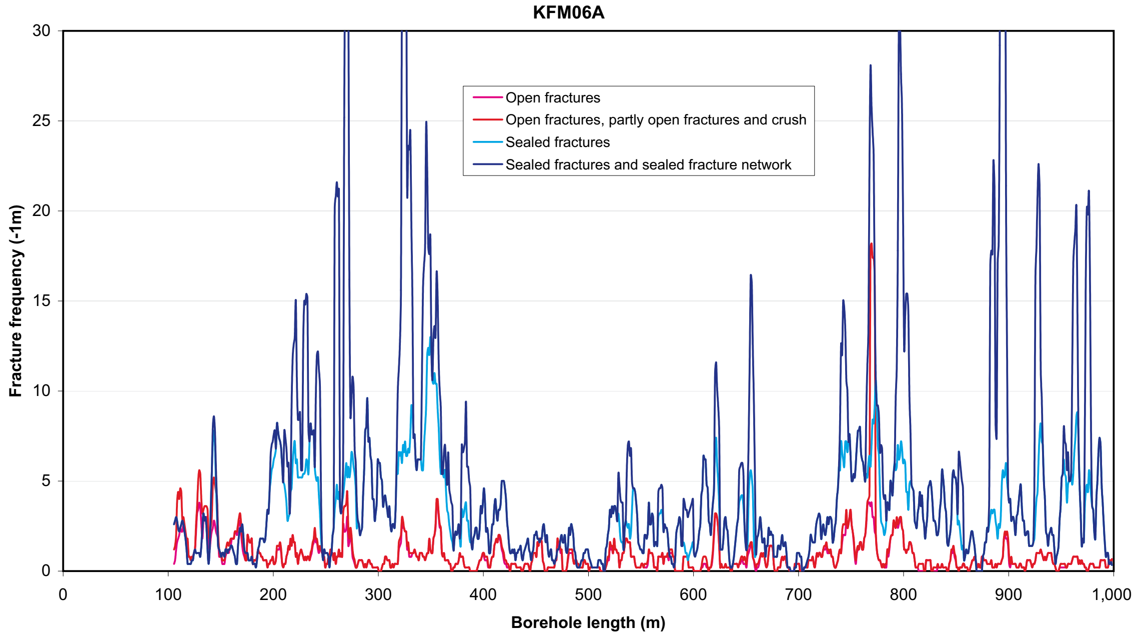

Figure 4-3. *Fracture frequency plot for KFM06A. Moving average with a 5 m window and 1 m steps.*

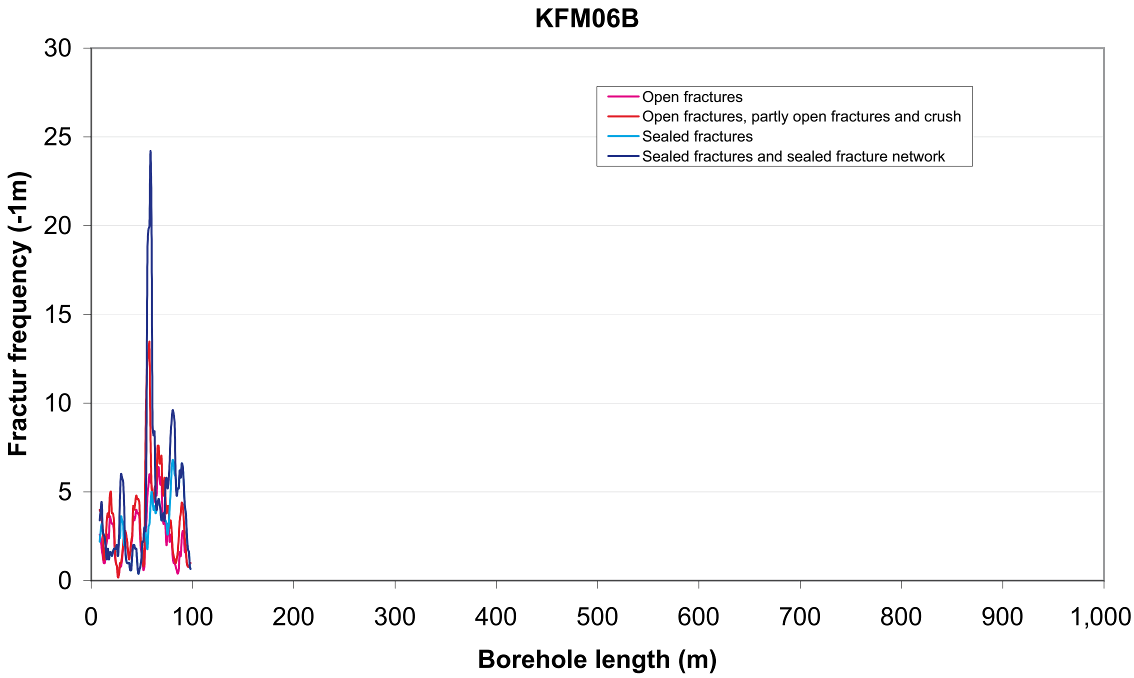

Figure 4-4. *Fracture frequency plot forKFM01B. Moving average with a 5 m window and 1 m steps.*

4.2 Nonconformities

In some cases alternative orientations for oriented radar reflectors are presented. One of the alternatives is considered to be correct, but due to uncertainty in the interpretation of radar data, a decision concerning which of the alternatives that represent the true orientation cannot be made.

5 Results

The detailed result of the geological single-hole interpretation is presented as print-outs from the software WellCad (Appendix 1 for KFM06A and Appendix 2 for KFM06B). The data is stored at SKB under field note Forsmark 445.

5.1 KFM06A

The borehole direction at the start is 300.9/–60.3. The borehole can be divided into five different rock units, one of which is recurrent in the borehole. For this reason, the borehole is divided into six rock sections:

100–582.4 m	RU1a: Medium-grained metagranite-granodiorite (101057) with subordinate occurrences of pegmatitic granite (101061), amphibolite (102017) and fine- to medium-grained leucocratic granite (111058). Sub-parallel radar reflector 30–40 m from the borehole along the interval 105–230 m and 420–450 m. Confidence level = 3.
582.4–634.8 m	RU2: Fine- to medium-grained metagranitoid (101051) of granodioritic to tonalitic composition consistent with increased magnetic susceptibility and silicate density (c 2,700–2,740 kg/m^3), and lower natural gamma radiation rate (10–20 μR/h). Subordinate occurrences of medium-grained metagranite-granodiorite (101057) and pegmatitic granite (101061). Confidence level = 3.
634.8–699.0 m	RU3: Fine-grained and foliated metagranite (101058) with subordinate occurrences of pegmatitic granite (101061), fine- to medium-grained metagranitoid (101051), medium-grained metagranite-granodiorite (101057) and amphibolite (102017). Diffuse contacts between the fine-grained metagranite and medium-grained metagranite-granodiorite. Confidence level = 3.
699.0–750.9 m	RU1b: Medium-grained metagranite-granodiorite (101057) with subordinate occurrences of pegmatitic granite (101061), amphibolite (102017), fine- to medium-grained metagranitoid (101051) and fine- to medium-grained leucocratic granite (111058). Confidence level = 3.
750.9–965.9 m	RU4: Lithologically heterogeneous interval characterised by strongly bleached, altered (quartz-rich and possibly albite-rich) rocks, including aplitic metagranite (101058), medium-grained metagranite-granodiorite (101057), and a banded, fine-grained rock (for example around 808–819 m). Sub-parallel radar reflector outside the borehole along the interval 770–820 m. The entire interval is dominated by anomalous low density (2,590–2,640 kg/m^3) and low natural gamma radiation rate (< 20μR/h). The interval at c 750–820 m has markedly low magnetic susceptibility (< 0.001 SI). Confidence level = 3.

965.9–998.4 m RU5: Heterogeneous interval with fine- to medium-grained metagranite (111058), fine- to medium-grained metagranodiorite-tonalite (101051), medium-grained metagranite-granodiorite (101057) and aplitic metagranite (101058). The fine- to medium-grained metagranite has an anomalously high natural gamma radiation rate (> 35μR/h) relative to the remaining rocks in the borehole that averages at 20–25 μR/h. Confidence level = 3.

Eleven deformation zones that have been recognised with a variable degree of confidence are present in KFM06A:

126–148 m DZ1: Increased frequency of mostly open, gently dipping fractures and sealed fractures at the base of the zone. The sealed fractures strike NE with steep dips. Gently dipping sealed fractures are also present. Predominant fracture filling minerals are calcite and clay minerals. Apertures up to 6–7 mm. One 5 cm wide crush zone. Faint to weak oxidation. Nine radar reflectors of which four are oriented: 340/16 or 158/53 (133.6 m), 050/75 (142.6 m), 014/84 (145.6 m) and 043/72 (145.9 m). Low resistivity anomalies. Minor indications in P-wave velocity and caliper data. Low magnetic susceptibility in the interval 133–148 m. Confidence level = 3.

195–245 m DZ2: Increased frequency of mostly sealed, steeply dipping fractures that strike NE. Gently dipping fractures are also present. Two fractures with apertures up to 5 mm. Predominant fracture filling minerals are calcite, chlorite and adularia. Faint to medium oxidation. Twelve radar reflectors of which six are oriented: 033/15 (206 m), 045/16 or 032/45 (218.8 m), 207/38 or 211/81 (225.9 m), 228/85 or 056/66 (226.0 m), 041/51 or 018/10 (238.8 m) and 027/65 (243.7 m). Distinct low resistivity anomalies and a general decrease of the bulk resistivity in the interval c 230–240 m. Confidence level = 3.

260–278 m DZ3: Increased frequency of sealed and to a less extent open fractures, with calcite and chlorite as the predominant infilling minerals. Also some epidote sealed fractures. Fractures are both gently dipping and strike NE and NS with steep dips. Apertures up to 3 mm. Two crush zones (2 and 4 cm wide). Faint to weak oxidation. Four radar reflectors, two of these are oriented: 217/09 (269.3 m) and 043/47 (269.4 m). A general decrease in the resistivity in the interval 267–276 m. One distinct sonic anomaly at 268 m. Confidence level = 3.

318–358 m DZ4: Increased frequency of sealed and to a less extent open fractures with chlorite and calcite as the main infilling minerals. Fractures strike NE, NS and EW with steep dips. Gently dipping fractures are also present. Apertures up to 3 mm. Faint to medium, and locally strong, oxidation. Vuggy metagranite associated with the stronger oxidation in the interval c 330–337 m. This interval also shows a low P-wave velocity. Twelve non-oriented and two oriented radar reflectors are present in the interval. The orientations are 209/26 or 034/89 (335.6 m) and 209/79 or 202/38 (354.0 m). A general decrease in the resistivity in the entire interval. Low magnetic susceptibility in the interval 343–358 m. Confidence level = 3.

619–624 m DZ5: Increased frequency of steeply dipping sealed and open fractures that strike NE. Chlorite, calcite and quartz are the main infilling minerals. Apertures up to 4 mm. Locally weak oxidation. Two oriented radar reflectors occur: 209/81 (622.6 m) and 117/42 (624.0 m). Three distinct low resistivity anomalies at 620.3 m, 622.5 m and 624.5 m. Only minor anomalies in the P-wave velocity and caliper data. Confidence level = 2.

652–656 m DZ6: Increased frequency of steeply dipping sealed fractures with chlorite and calcite as the main infilling minerals. Apertures up to 2 mm. In part faint to weak oxidation. One radar reflector with the orientation 047/88 (656.2 m). Low resistivity along the entire interval. No indications in the P-wave velocity or caliper data. Confidence level = 2.

740–775 m DZ7: Increased frequency of predominantly steeply dipping sealed fractures and both gently and steeply dipping open fractures. Steeply dipping fractures with a NE strike dominate. One 56 cm wide crush zone in the lower part of the interval. Chlorite, calcite and to some extent quartz as the main infilling minerals. Apertures up to 4 mm. Locally faint to weak oxidation. Seven non-oriented and five oriented radar reflectors occur. The orientations are: 168/25 (743.4 m), 249/80 (756.7 m), 236/17 or 057/89 (771.2 m), 027/35 or 080/44 (772.3 m) and 011/39 (772.4 m). Distinct low resistivity anomalies at 743.5 m and 770.5 m, and a general decrease in the bulk resistivity along the entire section. Distinct P-wave velocity and caliper anomalies at 770.5 m. Confidence level = 3.

788–810 m DZ8: Increased frequency of steeply dipping sealed and open fractures with chlorite and calcite as the main infilling minerals. Quartz and laumontite are subordinate minerals. Fractures with a NE strike dominate. Gently dipping fractures are also present. Apertures up to 1 mm. Four non-oriented radar reflectors with angle to borehole axis in the interval 44-72 degrees. Several low resistivity anomalies along the section. Only minor indications in the P-wave velocity and caliper data. Confidence level = 3.

882–905 m DZ9: Increased frequency of steeply dipping sealed fractures with laumontite and calcite as the main infilling minerals. Chlorite is subordinate. The steeply dipping fractures strike both NNE and ENE. Gently dipping fractures are also present. Two non-oriented and two oriented radar reflectors occur. The orientations are 276/76 or 294/45 (886.1 m) and 241/23 or 241/81 (887.2 m). Several small low resistivity anomalies and minor caliper anomalies at c 896 m, 898 m and 902 m. No clear indications in the P-wave velocity data. Confidence level = 3.

925–933 m DZ10: Increased frequency of steeply dipping sealed fractures with chlorite, calcite and laumontite as the main infilling minerals. The steeply dipping fractures strike NE. Gently dipping fractures are also present. Locally faint to weak oxidation. Two non-oriented and one oriented radar reflector occur. The orientation is 239/76 (925.7 m). Large decrease in the resistivity along the interval 926.0–929.0 m and a distinct caliper anomaly at 927.4 m. Minor decrease in the P-wave velocity at 926.4 m and c 929.0–930.0 m. Confidence level = 3.

950–990 m DZ11: Increased frequency of steeply dipping sealed fractures and in the upper half even gently dipping sealed fractures. The steeply dipping fractures strike NE. Chlorite, hematite, laumontite, calcite and quartz as the main infilling minerals. Locally faint oxidation. Six non-oriented and one oriented radar reflector occur. The orientation is 062/10 or 062/66 (962.5 m). Minor low resistivity anomalies occur along the entire interval. No indication in the P-wave velocity or caliper data. Confidence level = 3.

5.2 KFM06B

The borehole direction at the start is 296.9/–83.5. No geophysical logging was carried out in this borehole. The borehole is composed of one rock unit:

6.3–98.1 m RU1: Medium-grained metagranite-granodiorite (101057) with subordinate occurrences of pegmatitic granite (101061), amphibolite (102017) and fine- to medium-grained metagranitoid (101051). Faint to strong oxidation along more or less the whole borehole length. Three crush zones in the upper 20 m of the borehole, and two fractures with apertures of 7 mm at about 20 and 35 m borehole length. Sub-parallel radar reflector in the length interval 10–40 m and 20 m from the borehole. Confidence level = 3.

One deformation zone is indicated in KFM06B:

55–93 m DZ1: Increased frequency of both open and sealed fractures. Open fractures dominate in the upper part, sealed fractures in the lower part. The open fractures are predominantly gently dipping. The sealed fractures are both gently and steeply dipping. The latter strike predominantly NE. Two crush zones in the uppermost part. Fracture apertures up to 2 mm. Predominant fracture minerals in decreasing abundance are clay minerals, chlorite, calcite, quartz, asphalt and pyrite. Faint to strong oxidation throughout the zone. A few minor intervals of porous granite at a borehole length of about 70 m. Nine radar reflectors, of which three are oriented. The orientations are 084/9 (55.6 m), 235/33 (68.5 m) and 029/49 (86.1 m). Six non-oriented radar reflectors with angles to borehole axis in the interval 25-67 degrees. Confidence level = 3.

6 Comments

The results from the geological single-hole interpretation of KFM06A and KFM06B are presented in WellCad plots (Appendix 1 and appendix 2). The WellCad plot consists of the following columns:

1: Depth (Length along the borehole)

2: Rock type

3: Rock alteration

4: Sealed fractures

5: Open fractures

6: Silicate density

7: Magnetic susceptibility

8: Natural gamma radiation

9: Estimated fracture frequency

10: Description: Rock unit

11: Stereogram for sealed fractures in rock unit (blue symbols)

12: Stereogram for open and partly open fractures in rock unit (red symbols)

13: Description: Possible deformation zone

14: Stereogram for sealed fractures in possible deformation zone (blue symbols)

15: Stereogram for open and partly open fractures in possible deformation zone (red symbols)

The geological single-hole interpretation shows that five rock units (RU1–RU5) occur in KFM06A. The borehole can be divided into six separate sections along the borehole length due to the repetition of rock unit RU1. Medium-grained metagranite-granodiorite (101057), fine- to medium-grained metagranite-granodiorite (101051) and aplitic metagranite (101058) dominate the borehole. A large interval characterized by strongly bleached, altered rocks also occurs in the borehole. Fine- to medium-grained metagranitoid (101051), pegmatitic granite (101061) and amphibolite (102017) occur in small sections. Eleven possible deformation zones have been identified in KFM06A (DZ1–DZ11).

The geological single-hole interpretation shows that one rock unit occurs in KFM06B (RU1). Medium-grained metagranite-granodiorite (101057) dominates the borehole. Pegmatitic granite (101061), amphibolite (102017) and fine- to medium-grained metagranitoid (101051) occur in small sections. One possible deformation zone has been identified in KFM06B (DZ1).

7 References

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/3/ **Mattsson H and Keisu M, 2005.** Interpretation of geophysical borehole measurements from KFM06A and HFM20, HFM21 and HFM22. SKB P-05-51. Svensk Kärnbränslehantering AB.

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/5/ **Gustafsson J and Gustafsson C, 2005.** RAMAC and BIPS logging in borehole KFM06B. SKB P-05-53. Svensk Kärnbränslehantering AB.

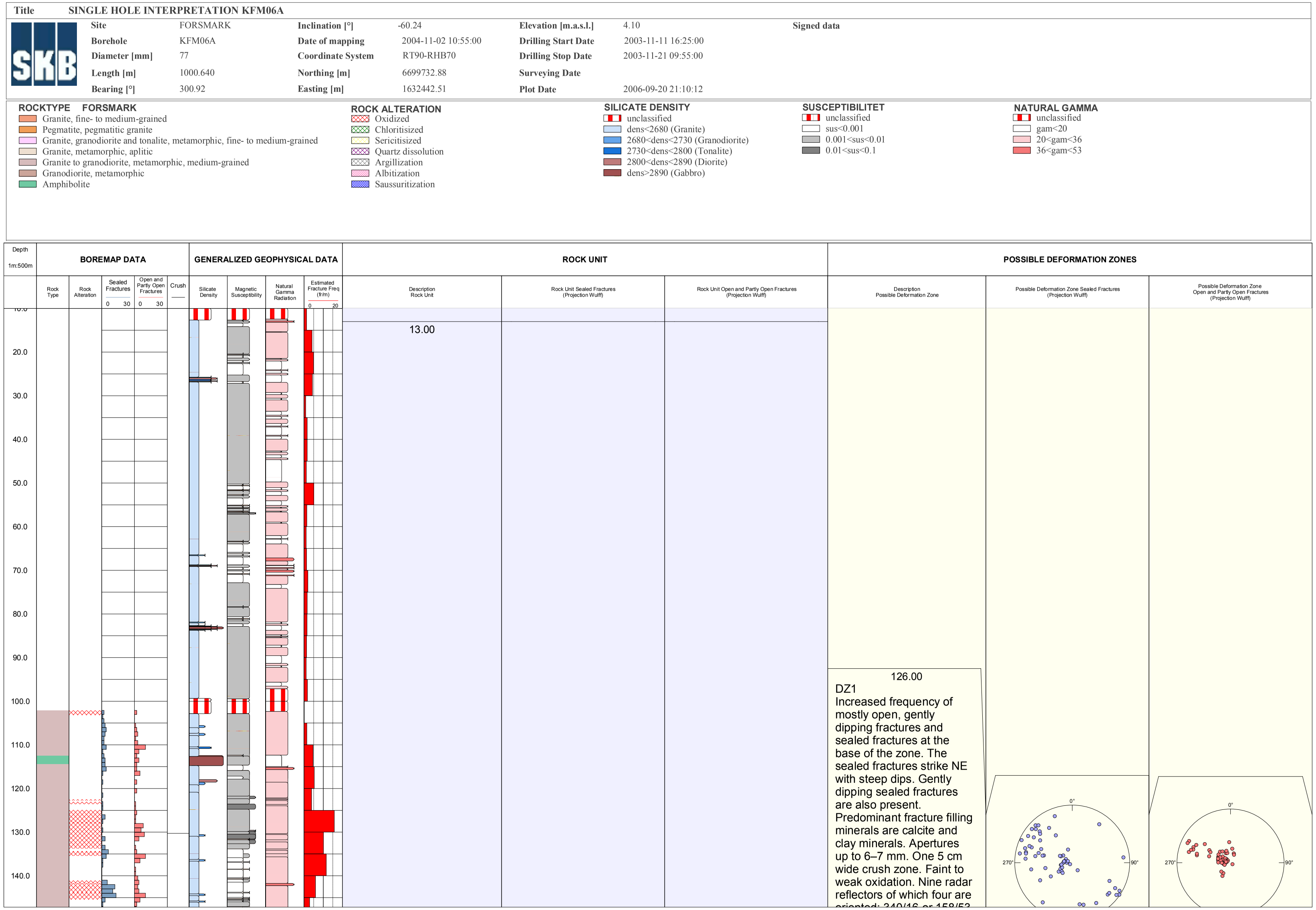
/6/ **Carlsten S, Petersson J, Stephens M, Thunehed M, Gustafsson J, 2004.** Geological single-hole interpretation of HFM11–13 and HFM16–18. SKB P-04-120. Svensk Kärnbränslehantering AB.

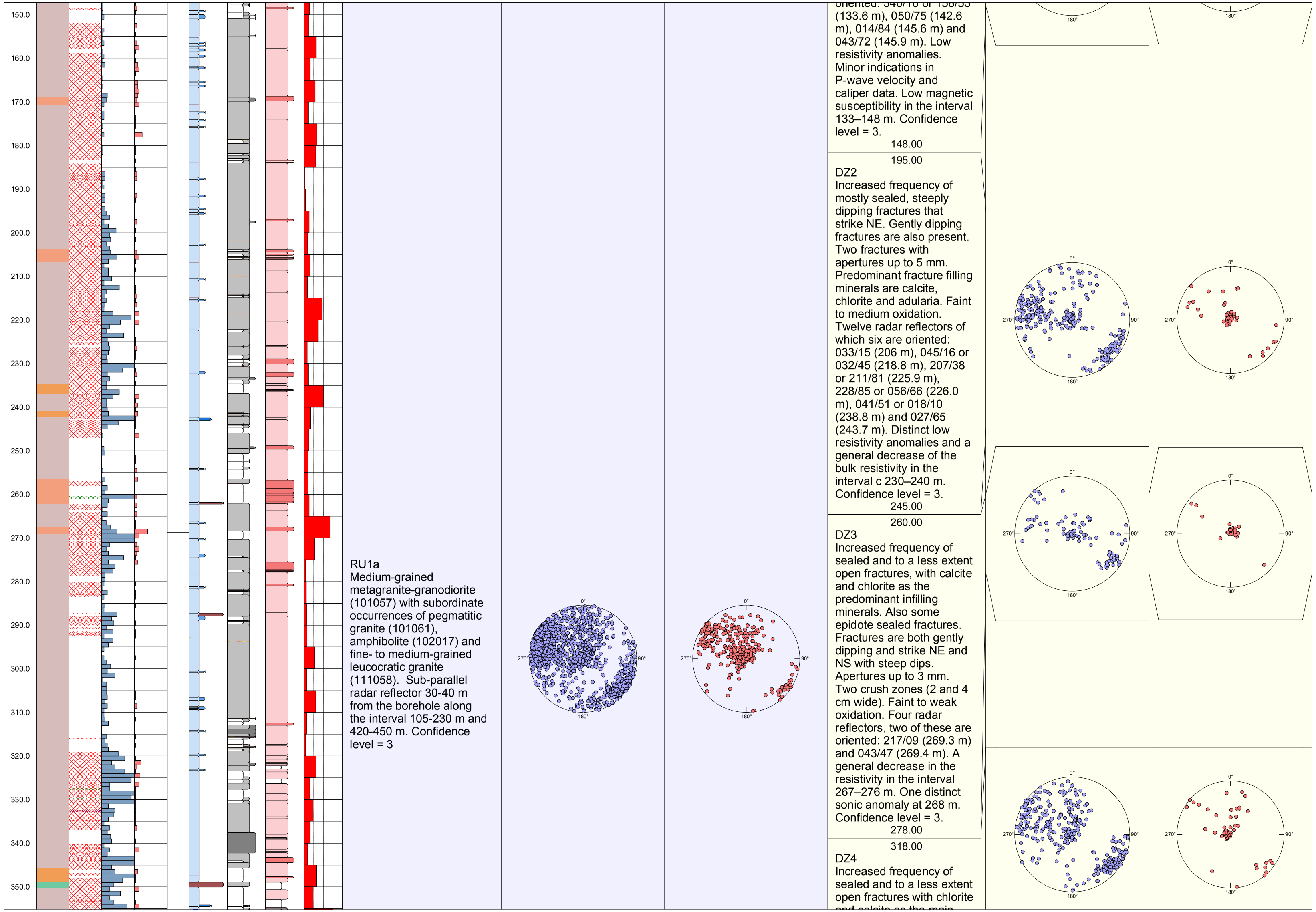
/7/ **Stephens M B, Lundqvist S, Bergman T, Andersson J, 2003.** Forsmark site investigation. Bedrock mapping. Rock types, their petrographic and geochemical characteristics, and a structural analysis of the bedrock based on Stage 1 (2002) surface data. SKB P-03-75. Svensk Kärnbränslehantering AB.

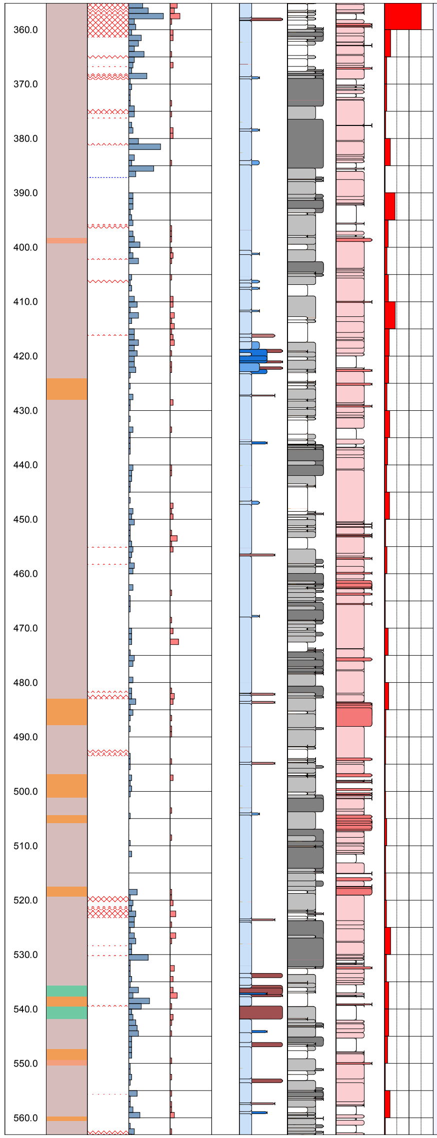
/8/ **Munier R, Stenberg L, Stanfors R, Milnes A G, Hermanson J, Triumf C-A, 2003.** Geological site descriptive model. A strategy for the model development during site investigations. SKB R-03-07. Svensk Kärnbränslehantering AB.

Appendix 1

Geological single-hole interpretation for KFM06A

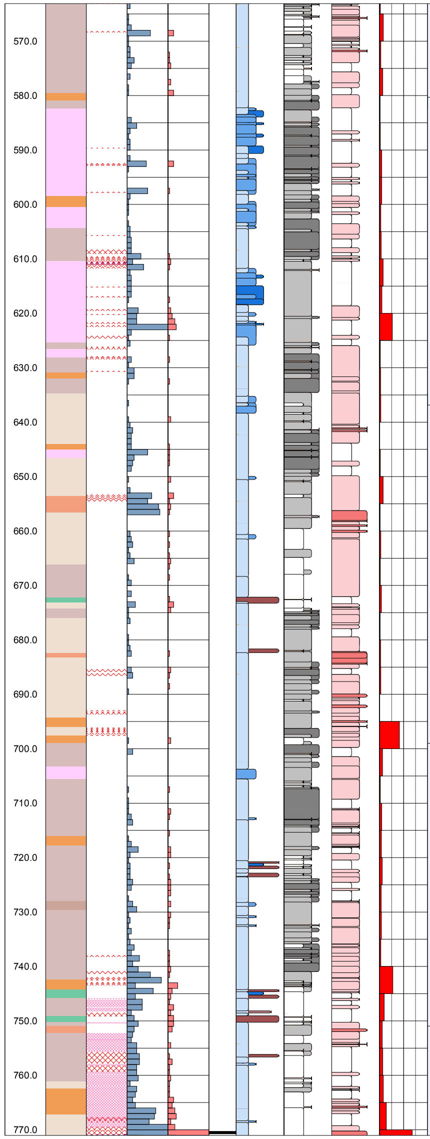



150.0
160.0
170.0
180.0
190.0
200.0
210.0
220.0
230.0
240.0
250.0
260.0
270.0
280.0
290.0
300.0
310.0
320.0
330.0
340.0
350.0
RU1a
Medium-grained metagranite-granodiorite (101057) with subordinate occurrences of pegmatitic granite (101061), amphibolite (102017) and fine- to medium-grained leucocratic granite (111058). Sub-parallel radar reflector 30-40 m from the borehole along the interval 105-230 m and 420-450 m. Confidence level = 3
oriented: 340/16 or 158/53 (133.6 m), 050/75 (142.6 m), 014/84 (145.6 m) and 043/72 (145.9 m). Low resistivity anomalies. Minor indications in P-wave velocity and caliper data. Low magnetic susceptibility in the interval 133–148 m. Confidence level = 3.
148.00
195.00
DZ2
Increased frequency of mostly sealed, steeply dipping fractures that strike NE. Gently dipping fractures are also present. Two fractures with apertures up to 5 mm. Predominant fracture filling minerals are calcite, chlorite and adularia. Faint to medium oxidation. Twelve radar reflectors of which six are oriented: 033/15 (206 m), 045/16 or 032/45 (218.8 m), 207/38 or 211/81 (225.9 m), 228/85 or 056/66 (226.0 m), 041/51 or 018/10 (238.8 m) and 027/65 (243.7 m). Distinct low resistivity anomalies and a general decrease of the bulk resistivity in the interval c 230–240 m. Confidence level = 3.
245.00
260.00
DZ3
Increased frequency of sealed and to a less extent open fractures, with calcite and chlorite as the predominant infilling minerals. Also some epidote sealed fractures. Fractures are both gently dipping and strike NE and NS with steep dips. Apertures up to 3 mm. Two crush zones (2 and 4 cm wide). Faint to weak oxidation. Four radar reflectors, two of these are oriented: 217/09 (269.3 m) and 043/47 (269.4 m). A general decrease in the resistivity in the interval 267–276 m. One distinct sonic anomaly at 268 m. Confidence level = 3.
278.00
318.00
DZ4
Increased frequency of sealed and to a less extent open fractures with chlorite



and calcite as the main infilling minerals. Fractures strike NE, NS and EW with steep dips. Gently dipping fractures are also present. Apertures up to 3 mm. Faint to medium, and locally strong, oxidation. Vuggy metagranite associated with the stronger oxidation in the interval c 330–337 m. This interval also shows a low P-wave velocity. Twelve non-oriented and two oriented radar reflectors are present in the interval. The orientations are 209/26 or 034/89 (335.6 m) and 209/79 or 202/38 (354.0 m). A general decrease in the resistivity in the entire interval. Low magnetic susceptibility in the interval 343–358 m. Confidence level = 3.

358.00



582.42

582.42

RU2
Fine- to medium-grained metagranitoid (101051) of granodioritic to tonalitic composition consistent with increased magnetic susceptibility and silicate density (c. 2700-2740 kg/m³), and lower natural gamma radiation rate (10-20 µR/h). Subordinate occurrences of medium-grained metagranite-granodiorite (101057) and pegmatitic granite (101061). Confidence level = 3

634.77

634.77

RU3
Fine-grained and foliated metagranite (101058) with subordinate occurrences of pegmatitic granite (101061), fine- to medium-grained metagranitoid (101051), medium-grained metagranite-granodiorite (101057) and amphibolite (102017). Diffuse contacts between the fine-grained metagranite and medium-grained metagranite-granodiorite. Confidence level = 3

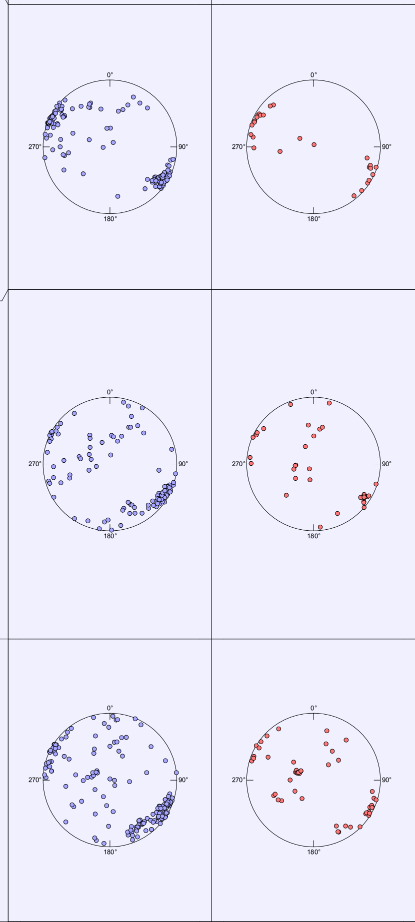
699.00

699.00

RU1b
Medium-grained metagranite-granodiorite (101057) with subordinate occurrences of pegmatitic granite (101061), amphibolite (102017), fine- to medium-grained metagranitoid (101051) and fine- to medium-grained leucocratic granite (111058). Confidence level = 3

750.97

750.97



619.00

DZ5
Increased frequency of steeply dipping sealed and open fractures that strike NE. Chlorite, calcite and quartz are the main infilling minerals. Apertures up to 4 mm. Locally weak oxidation. Two oriented radar reflectors occur: 209/81 (622.6 m) and 117/42 (624.0 m). Three distinct low resistivity anomalies at 620.3 m, 622.5 m and 624.5 m. Only minor anomalies in the P-wave velocity and caliper data. Confidence level = 2.

624.00

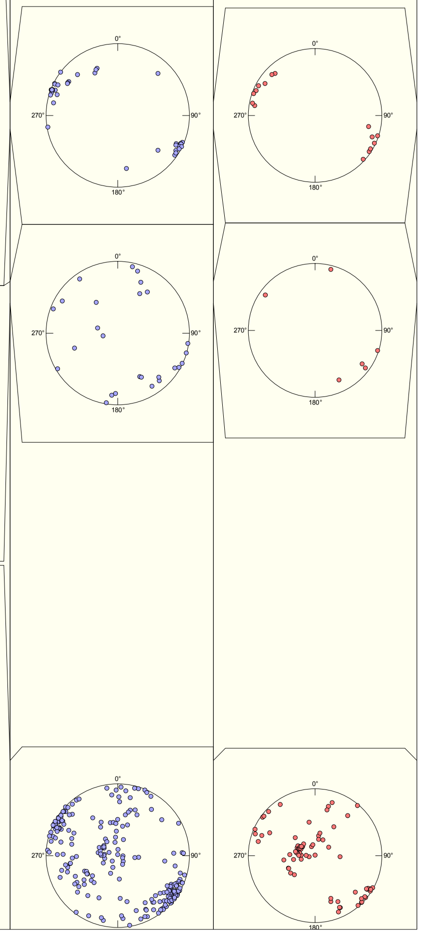
652.00

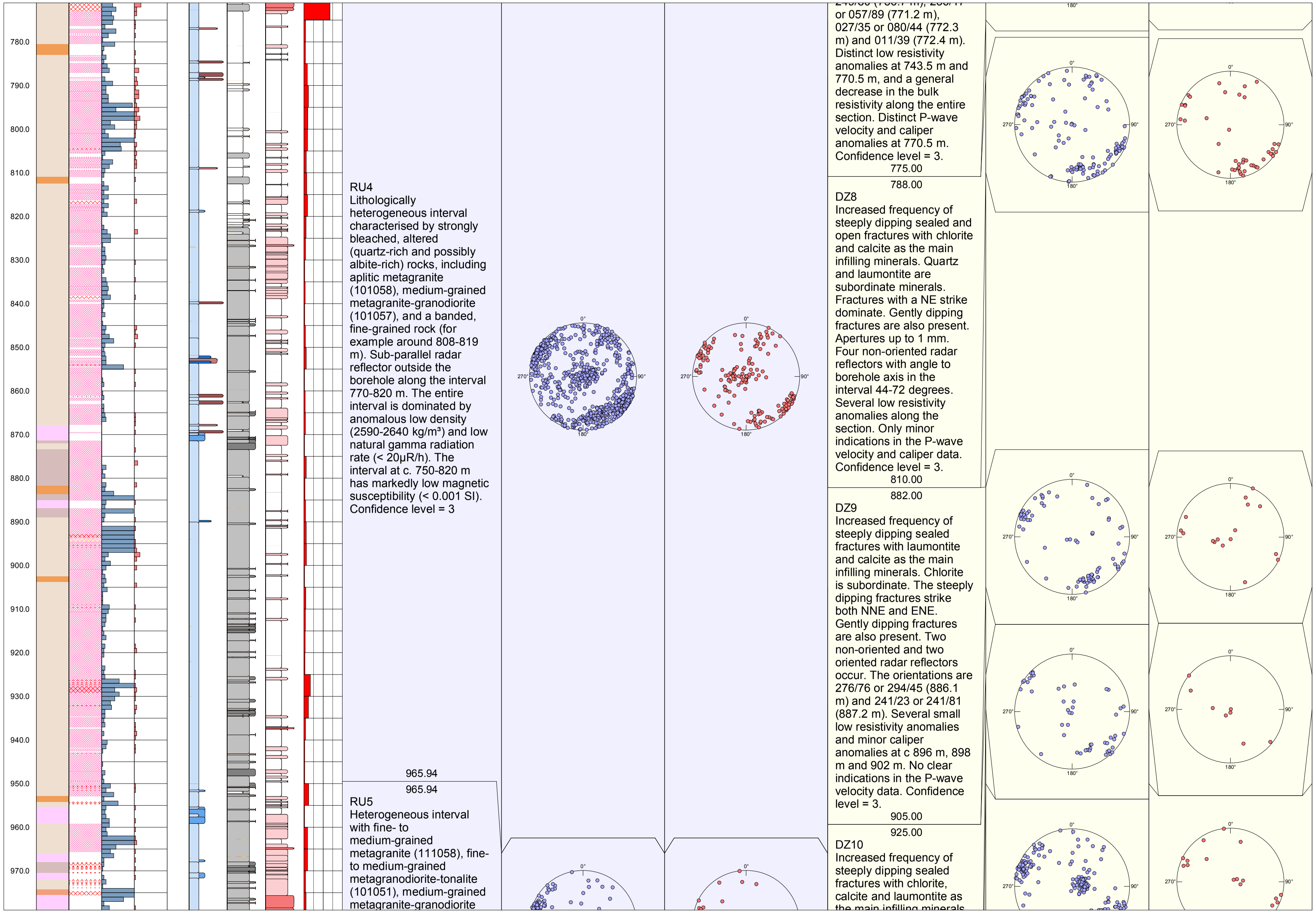
DZ6
Increased frequency of steeply dipping sealed fractures with chlorite and calcite as the main infilling minerals. Apertures up to 2 mm. In part faint to weak oxidation. One radar reflector with the orientation 047/88 (656.2 m). Low resistivity along the entire interval. No indications in the P-wave velocity or caliper data. Confidence level = 2.

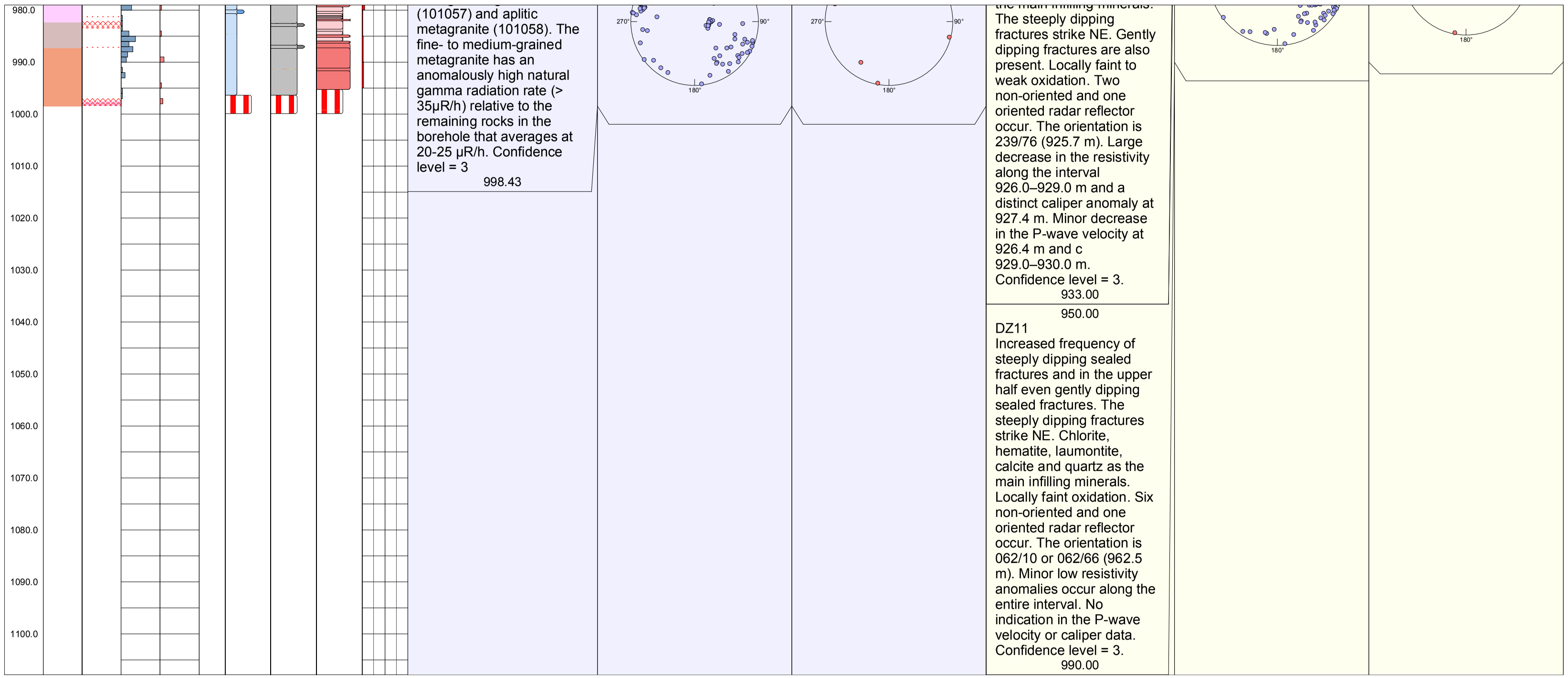
656.00

740.00

DZ7
Increased frequency of predominantly steeply dipping sealed fractures and both gently and steeply dipping open fractures. Steeply dipping fractures with a NE strike dominate. One 56 cm wide crush zone in the lower part of the interval. Chlorite, calcite and to some extent quartz as the main infilling minerals. Apertures up to 4 mm. Locally faint to weak oxidation. Seven non-oriented and five oriented radar reflectors occur. The orientations are: 168/25 (743.4 m), 249/80 (756.7 m), 236/17




780.0
790.0
800.0
810.0
820.0
830.0
840.0
850.0
860.0
870.0
880.0
890.0
900.0
910.0
920.0
930.0
940.0
950.0
960.0
970.0
RU4
Lithologically heterogeneous interval characterised by strongly bleached, altered (quartz-rich and possibly albite-rich) rocks, including aplitic metagranite (101058), medium-grained metagranite-granodiorite (101057), and a banded, fine-grained rock (for example around 808-819 m). Sub-parallel radar reflector outside the borehole along the interval 770-820 m. The entire interval is dominated by anomalous low density (2590-2640 kg/m³) and low natural gamma radiation rate (< 20μR/h). The interval at c. 750-820 m has markedly low magnetic susceptibility (< 0.001 SI). Confidence level = 3
965.94
965.94
RU5
Heterogeneous interval with fine- to medium-grained metagranite (111058), fine- to medium-grained metagranodiorite-tonalite (101051), medium-grained metagranite-granodiorite
or 057/89 (771.2 m), 027/35 or 080/44 (772.3 m) and 011/39 (772.4 m). Distinct low resistivity anomalies at 743.5 m and 770.5 m, and a general decrease in the bulk resistivity along the entire section. Distinct P-wave velocity and caliper anomalies at 770.5 m. Confidence level = 3.
775.00
788.00
DZ8
Increased frequency of steeply dipping sealed and open fractures with chlorite and calcite as the main infilling minerals. Quartz and laumontite are subordinate minerals. Fractures with a NE strike dominate. Gently dipping fractures are also present. Apertures up to 1 mm. Four non-oriented radar reflectors with angle to borehole axis in the interval 44-72 degrees. Several low resistivity anomalies along the section. Only minor indications in the P-wave velocity and caliper data. Confidence level = 3.
810.00
882.00
DZ9
Increased frequency of steeply dipping sealed fractures with laumontite and calcite as the main infilling minerals. Chlorite is subordinate. The steeply dipping fractures strike both NNE and ENE. Gently dipping fractures are also present. Two non-oriented and two oriented radar reflectors occur. The orientations are 276/76 or 294/45 (886.1 m) and 241/23 or 241/81 (887.2 m). Several small low resistivity anomalies and minor caliper anomalies at c 896 m, 898 m and 902 m. No clear indications in the P-wave velocity data. Confidence level = 3.
905.00
925.00
DZ10
Increased frequency of steeply dipping sealed fractures with chlorite, calcite and laumontite as the main infilling minerals
0°
90°
180°
270°


980.0
990.0
1000.0
1010.0
1020.0
1030.0
1040.0
1050.0
1060.0
1070.0
1080.0
1090.0
1100.0
(101057) and aplitic metagranite (101058). The fine- to medium-grained metagranite has an anomalously high natural gamma radiation rate (> 35µR/h) relative to the remaining rocks in the borehole that averages at 20-25 µR/h. Confidence level = 3
998.43
270°
90°
180°
270°
90°
180°
The steeply dipping fractures strike NE. Gently dipping fractures are also present. Locally faint to weak oxidation. Two non-oriented and one oriented radar reflector occur. The orientation is 239/76 (925.7 m). Large decrease in the resistivity along the interval 926.0–929.0 m and a distinct caliper anomaly at 927.4 m. Minor decrease in the P-wave velocity at 926.4 m and c 929.0–930.0 m. Confidence level = 3.
933.00
950.00
DZ11
Increased frequency of steeply dipping sealed fractures and in the upper half even gently dipping sealed fractures. The steeply dipping fractures strike NE. Chlorite, hematite, laumontite, calcite and quartz as the main infilling minerals. Locally faint oxidation. Six non-oriented and one oriented radar reflector occur. The orientation is 062/10 or 062/66 (962.5 m). Minor low resistivity anomalies occur along the entire interval. No indication in the P-wave velocity or caliper data. Confidence level = 3.
990.00
180°
180°

Appendix 2

Geological single-hole interpretation for KFM06B

Title SINGLE HOLE INTERPRETATION KFM06B

Site	FORSMARK	**Inclination [°]**	-83.51	**Elevation [m.a.s.l.]**	4.13	**Signed data**
Borehole	KFM06B	**Date of mapping**	2004-08-17 15:23:00	**Drilling Start Date**	2004-05-26 07:00:00	
Diameter [mm]	77	**Coordinate System**	RT90-RHB70	**Drilling Stop Date**	2005-02-08 14:00:00	
Length [m]	100.330	**Northing [m]**	6699732.24	**Surveying Date**		
Bearing [°]	296.96	**Easting [m]**	1632446.41	**Plot Date**	2006-09-20 21:10:12	

ROCKTYPE FORSMARK
- Pegmatite, pegmatitic granite
- Granite, granodiorite and tonalite, metamorphic, fine- to medium-grained
- Granite to granodiorite, metamorphic, medium-grained

ROCK ALTERATION
- Oxidized
- Chloritisized
- Quartz dissolution

SILICATE DENSITY

SUSCEPTIBILITET

NATURAL GAMMA