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Revised October 2006

Forsmark site investigation

Geological single-hole interpretation of KFM07A and HFM20–21 (DS7)

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March 2005

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Keywords: Forsmark, Geophysics, Geology, Borehole, Bedrock, Fractures, AP-PF 400-05-027.

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 as well as in Appendix 1.

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.

Appendix 1, 2 and 3 are updated.

Abstract

This report contains geological single-hole interpretations of the cored borehole KFM07A and the percussion boreholes HFM20 and HFM21 at Forsmark. Each interpretation combines the geological core mapping, interpreted geophysical logs and borehole radar measurements to interpret where rock units and possible deformation zones occur in the boreholes.

The geological single-hole interpretation shows that three rock units (RU1–RU3) occur in KFM07A. However, the borehole can be divided into six separate sections due to the occurrence of sections in rock unit RU1 that show either a somewhat higher frequency of sealed fractures or, locally, an early-stage alteration, and also due to the occurrence of rock unit RU2 along two separate borehole sections. Foliated, medium-grained or strongly foliated, fine- to medium-grained metagranite-granodiorite (101057) dominates the borehole. The latter corresponds to a more intense ductile deformation. Pegmatitic granite (101061), amphibolite (102017), and fine- to medium-grained metagranitoid (101051) occur in shorter sections. Four possible deformation zones that are brittle in character have been identified in KFM07A (DZ1–DZ4).

The geological single-hole interpretation shows that two rock units (RU1–RU2) occur in the percussion borehole HFM20. The borehole can be divided into three separate sections along the borehole length due to the repetition of rock unit RU1. Medium-grained metagranite-granodiorite (101057) dominates the borehole. A wide section of amphibolite (102017) occurs in the middle part of the borehole. Pegmatitic granite (101061) and amphibolite (102017) occur in shorter sections. No deformation zone has been identified in HFM20.

The percussion borehole HFM21 is dominated by medium-grained metagranite-granodiorite (101057), which constitutes one rock unit (RU1). Amphibolite (102017), pegmatitic granite (101061), and fine- to medium-grained metagranitoid (101051) occur in shorter sections. Two possible deformation zones have been identified in HFM21 (DZ1–DZ2).

Sammanfattning

Denna rapport behandlar geologisk enhålstolkning av kärnborrhål KFM07A och hammarborrhålen HFM20 och HFM21 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 KFM07A finns tre litologiska enheter (RU1–RU3). Baserat på förekomsten av en sektion i enheten RU1 med en något högre frekvens av läkta sprickor, en sektion i enheten RU1 som lokalt visar en tidig omvandling, samt en repetition av enheten RU2, kan borrhålet delas in i sex sektioner. Folierad medelkornig eller starkt folierad fin- till medelkornig metagranit-granodiorit (101057) förekommer i större delen av borrhålet. Den senare indikerar en kraftig plastisk deformation. I mindre omfattning förekommer dessutom pegmatitisk granit (101061), amfibolit (102017) och fin- till medelkornig metagranitoid (101051). Fyra möjliga deformationszoner som är spröda har identifierats i KFM07A (DZ1–DZ4).

I hammarborrhål HFM20 finns två litologiska enheter (RU1–RU2). Baserat på en repetition av enheten RU1 kan borrhålet delas in i tre sektioner. Borrhålet domineras av medelkorning metagranit-granodiorit (101057). Ett omfattande parti med amfibolit (102017) finns i borrhålets mellersta del. I mindre omfattning förekommer pegmatitisk granit (101061) och även amfibolit (102017). Inga deformationszoner har identifierats i HFM20.

Hammarborrhål HFM21 domineras av medelkornig metagranit-granodiorit (101057), vilket utgör en enhet (RU1). I mindre omfattning förekommer amfibolit (102017), pegmatitisk granit (101061) och fin- till medelkorning metagranitoid (101051). Två möjliga deformationszoner har identifierats i HFM21 (DZ1–DZ2).

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 400-05-027 (SKB internal controlling document)

This document reports the geological single-hole interpretations of boreholes KFM07A, HFM20 and HFM21 at and close to drill site 7 (DS7) in the Forsmark area (Figure 1-1). The horizontal projection of the boreholes in the candidate area is shown in Figure 1-2.

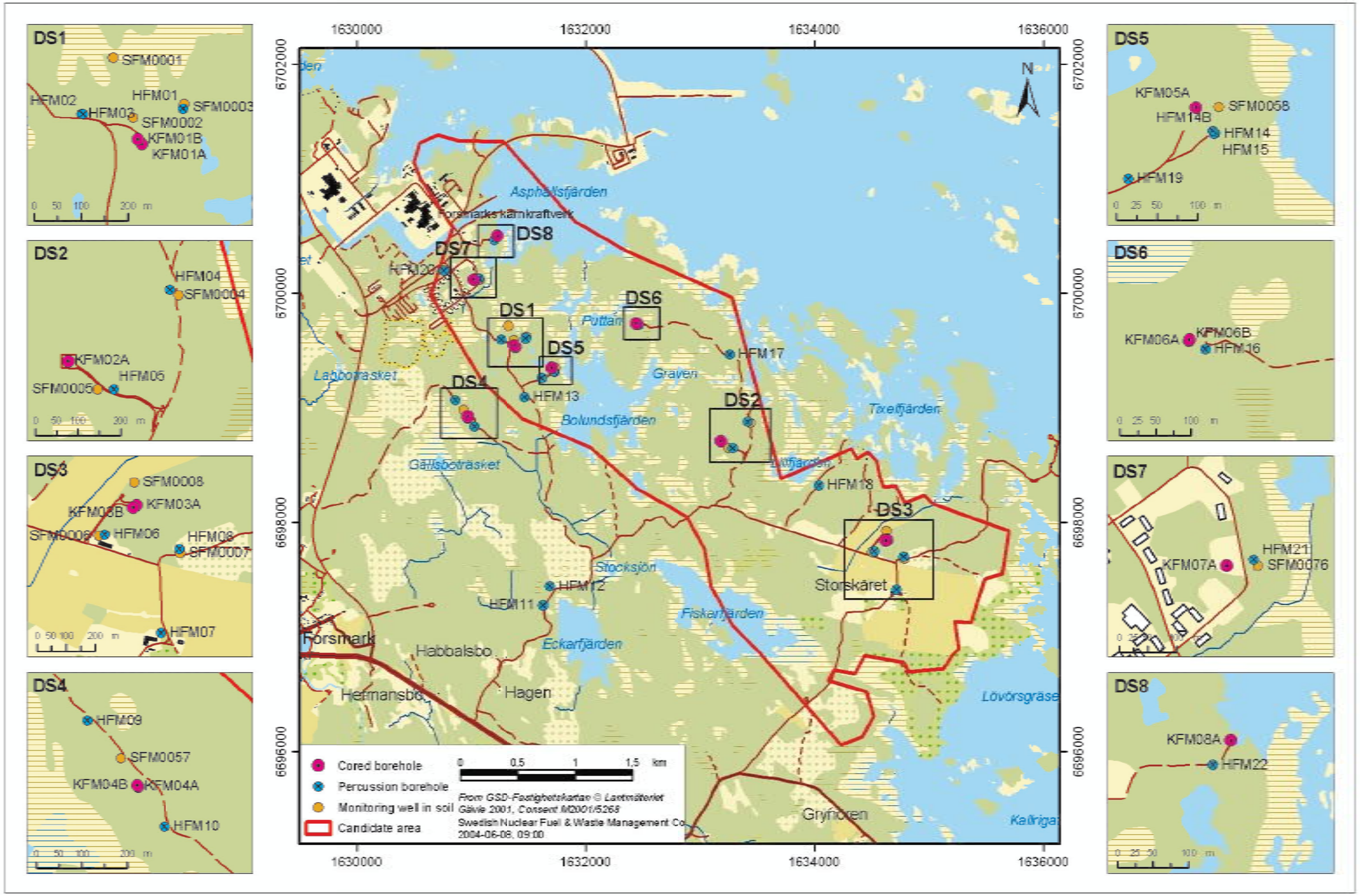

Figure 1-1. *Map showing drill site 7 (DS7) and the position of the cored borehole KFM07A and the percussion drilled boreholes HFM20 and HFM21.*

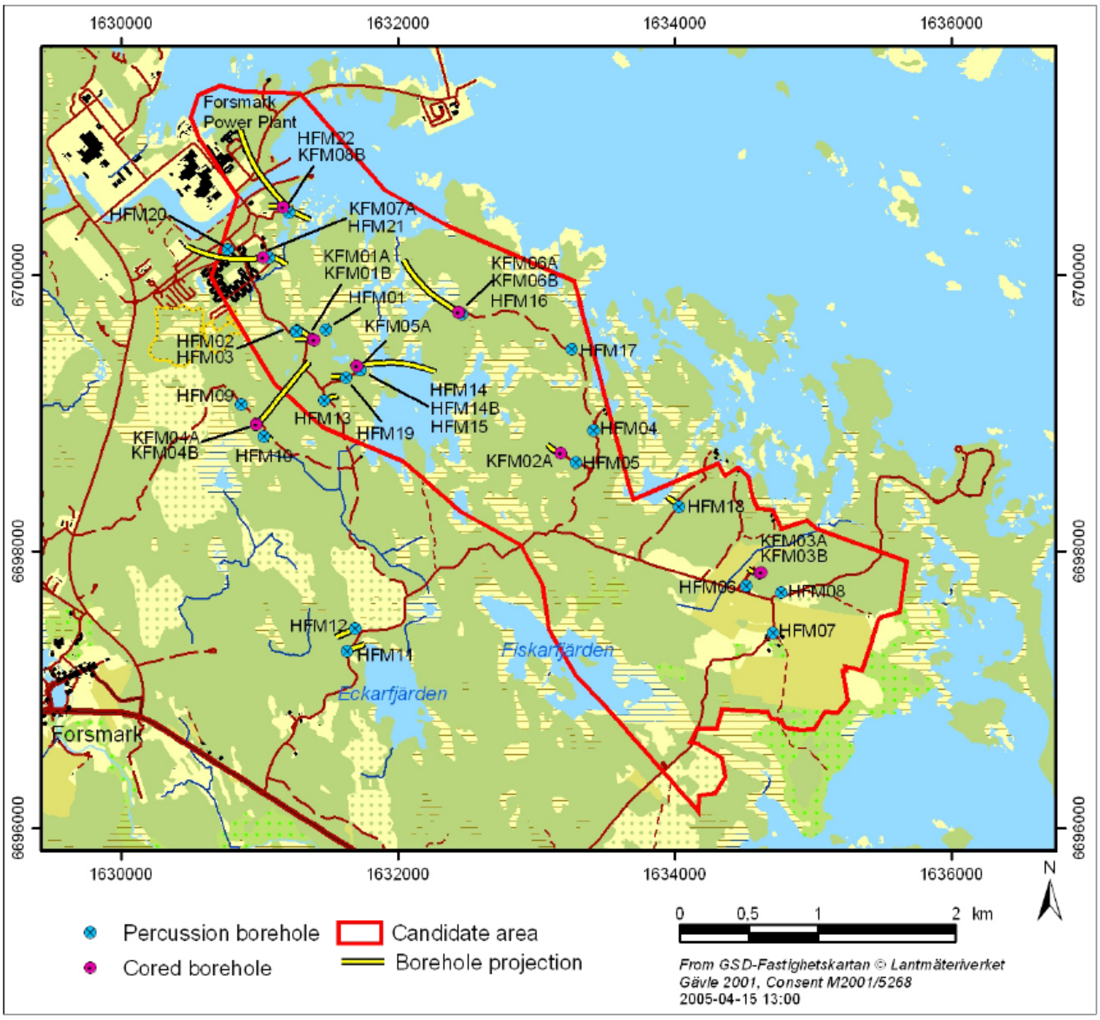

Figure 1-2. Map showing horizontal projection of the boreholes in the candidate area.

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 (MD 810.003, SKB internal controlling 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 boreholes KFM07A, HFM20 and HFM21:

- Boremap data (including BIPS and geological mapping data) /1, 2/.
- Generalized geophysical logs and their interpretation /3, 4, 5, 6/.
- Radar data and their interpretation /7, 8/.

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 /9/.

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.

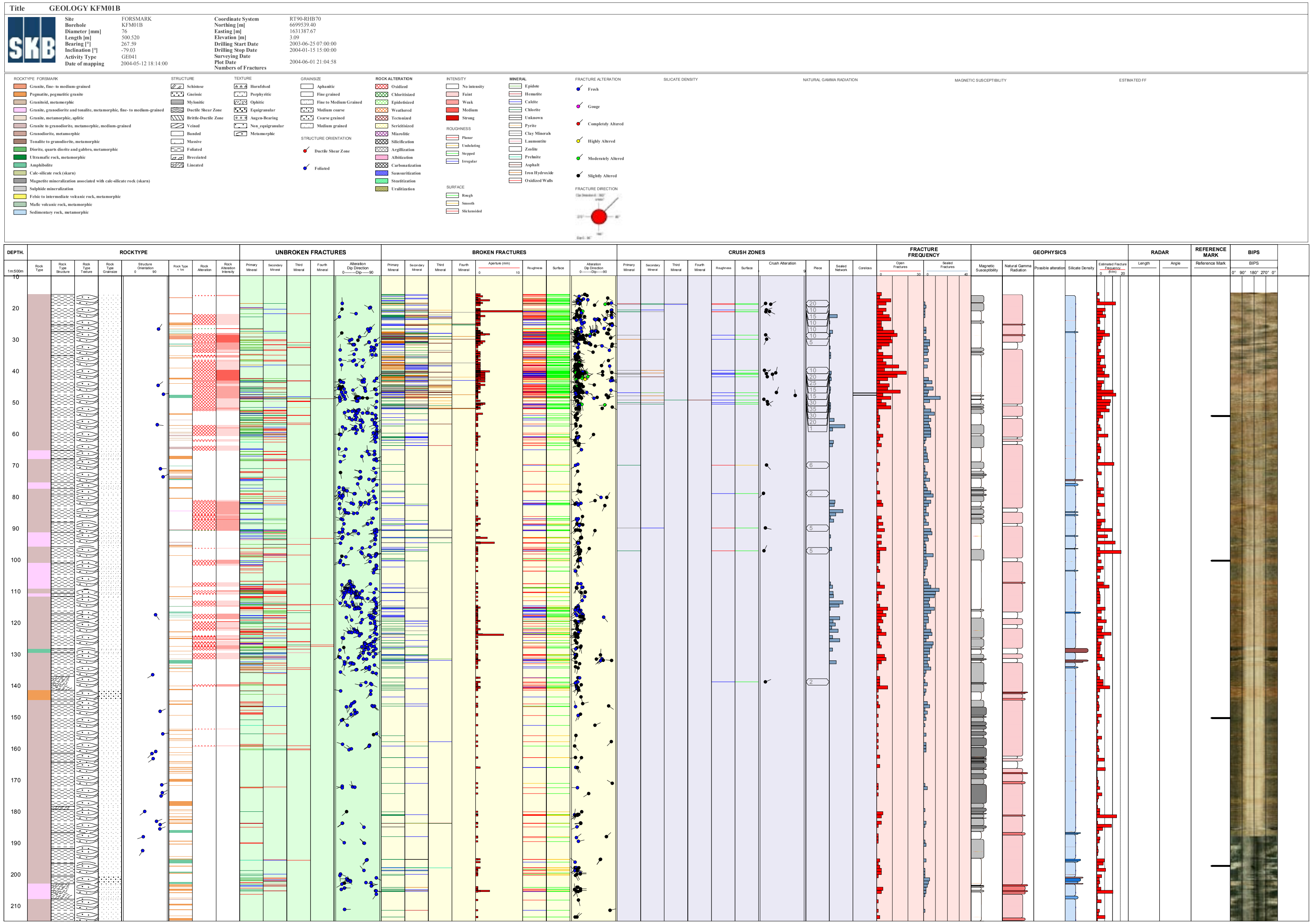

Figure 3-1. Example of WellCad plot (from borehole KFM01B) used as a basis for the single-hole interpretation.

4 Execution of the geological single-hole interpretation

4.1 General

The geological single-hole interpretation has been carried out by a group of geoscientists consisting of both geologists and geophysicists. 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 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 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.

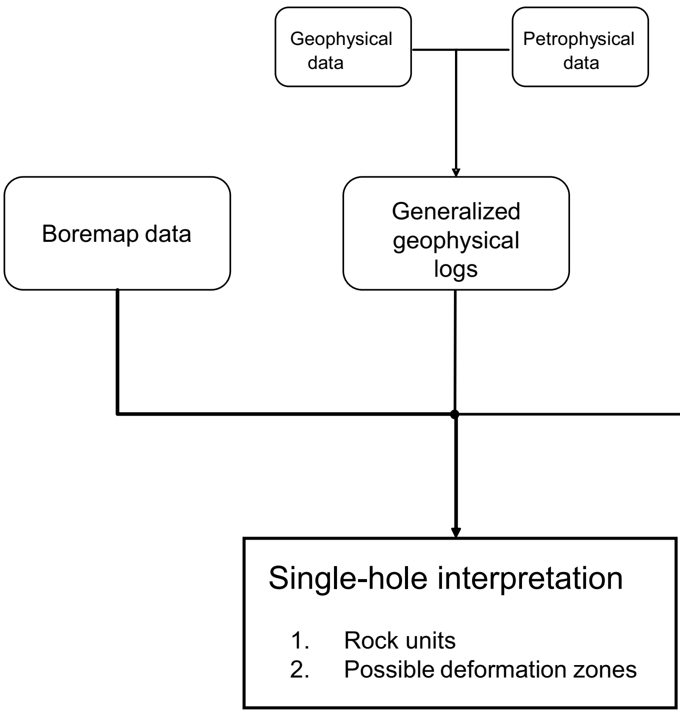

Figure 4-1. *Schematic chart that shows the procedure for the development of a geological single-hole interpretation.*

Inspection of BIPS images is carried out wherever it is judged necessary during the working procedure. Furthermore, following definition of rock units and deformation zones, with their respective confidence estimates, 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 /10/. 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, a moving average plot for this parameter is shown for the cored borehole KFM07A (Figure 4-3). A 5 m window and 1 m steps have been used in the calculation procedure. 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 in this diagram.

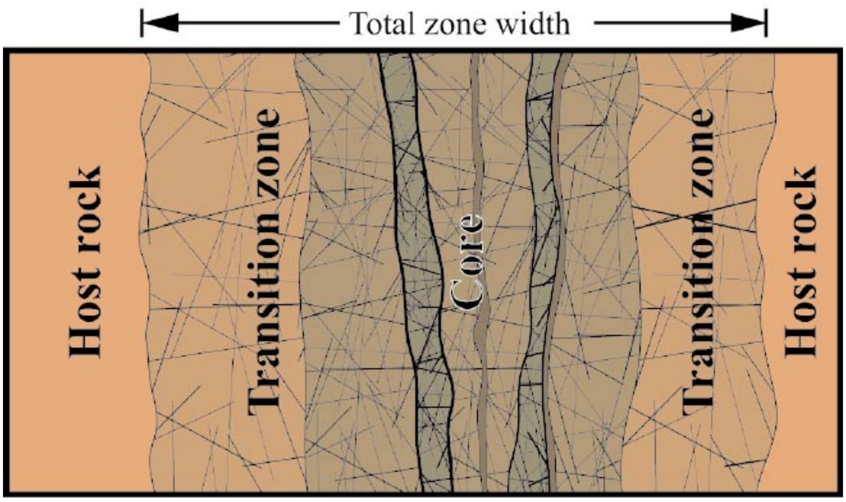

***Figure 4-2.** Terminology for brittle deformation zones (after /10/).*

4.2 Nonconformities

The percussion drilled borehole HFM21 was remapped after the execution of the single-hole interpretation. Inspection of the new mapping shows that it strengthens the result from the single-hole interpretation. The new mapping is presented in /2/.

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.

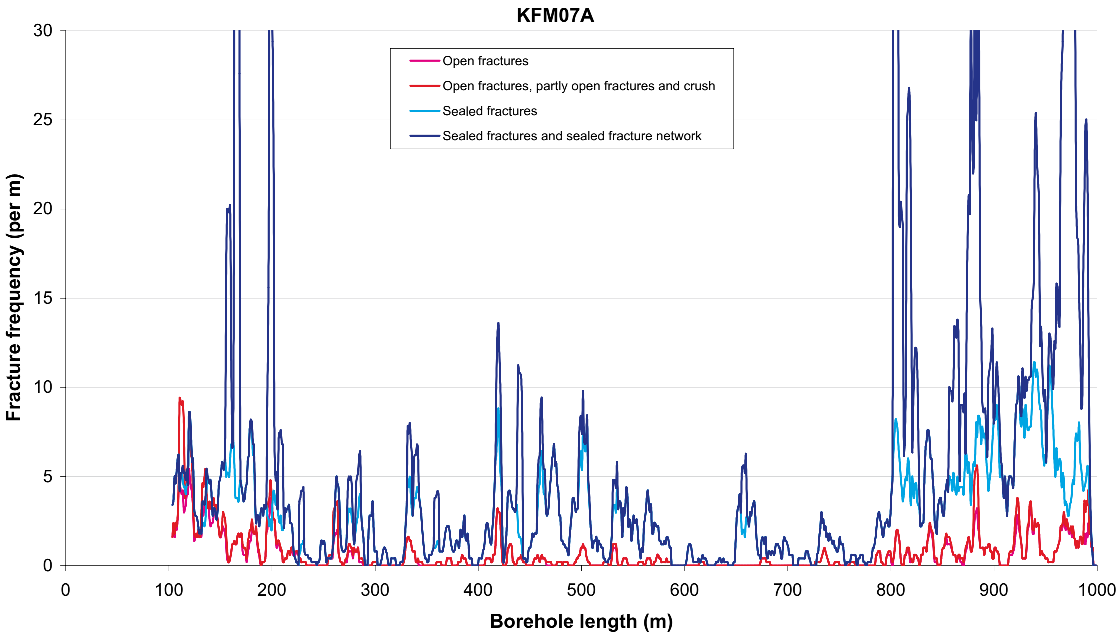

Figure 4-3. *Fracture frequency plot for KFM07A. Moving average with a 5 m window and 1 m steps.*

5 Results

The results of the geological single-hole interpretations are presented as print-outs from the software WellCad (Appendix 1 for KFM07A, Appendix 2 for HFM20 and Appendix 3 for HFM21). The data is stored at SKB under field note Forsmark 493.

5.1 KFM07A

The borehole direction at the start is 261.5/–59.2. The borehole can be divided into three different rock units, RU1–RU3. A somewhat higher frequency of sealed fractures along one borehole section as well as the local occurrence of an early-stage alteration along another borehole section motivates a division of rock unit RU1 into three separate sections. Furthermore, rock unit RU2 occurs along two separate borehole sections. For these reasons, the borehole is divided into six rock sections:

101.95–418.84 m	RU1: Foliated, medium-grained metagranite-granodiorite (101057) with subordinate occurrences of pegmatitic granite (101061), amphibolite (102017) and a few minor occurrences of fine- to medium-grained metagranitoid (101051). Confidence level = 3.
418.84–506.68 m	RU2: Foliated, medium-grained metagranite-granodiorite (101057) with subordinate occurrences of pegmatitic granite (101061), amphibolite (102017) and one about 2 m wide occurrence of fine-grained, felsic meta-igneous rock (103076). Distinguished from the section above on the basis of a somewhat higher frequency of sealed fractures. Only the uppermost part between 417 m and 422 m consists of a deformation zone (see below). Confidence level = 3.
506.68–793.12 m	RU3: Foliated, medium-grained metagranite-granodiorite (101057) with subordinate occurrences of pegmatitic granite (101061), amphibolite (102017) and a few minor occurrences of fine- to medium-grained metagranitoid (101051). The metagranite-granodiorite (101057) is greyer relative to the upper half of the borehole. Several, minor occurrences of bleached (albitized?) meta-igneous rocks occur beneath 600 m. Variable magnetic susceptibility and several intervals with low natural gamma radiation. Confidence level = 3.
793.12–942.04 m	RU4a: Foliated, fine- to medium-grained metagranite-granodiorite (101057) with up to 9 m wide occurrences of pegmatitic granite (101061), especially in the upper part, and subordinate occurrences of amphibolite (102017). Generally more intense ductile deformation and more heterogeneous relative to the upper part of the borehole. Locally mica-rich relative to the typical metagranite-granodiorite (101057) in the borehole. Variable magnetic susceptibility and several intervals with low natural gamma radiation. Confidence level = 3.
942.04–966.19 m	RU5: Pegmatitic granite (101061) with subordinate occurrences of metagranite-granodiorite (101057). Confidence level = 3.

966.19–999.22 m RU4b: Foliated, fine- to medium-grained metagranite-granodiorite (101057) with subordinate occurrences of pegmatitic granite (101061) and amphibolite (102017). Generally more intense ductile deformation and more heterogeneous relative to the upper part of the borehole. Locally mica-rich relative to the typical metagranite-granodiorite (101057) in the borehole. Confidence level = 3.

Four deformation zones that are brittle in character and that have been recognised with a variable degree of confidence are present in KFM07A:

108–183 m DZ1: Increased frequency of open and sealed fractures, except in a minor interval at 135–143 m. Open fractures are especially conspicuous in the upper part of the zone. The open/partly open fractures are predominantly gently dipping. The sealed fractures are both gently and steeply dipping. Fracture apertures up to 4 mm and the predominant fracture filling minerals are chlorite, calcite, laumontite and clay minerals. Locally faint to medium oxidation. Six crush zones in the upper half and one close to the base of the zone. Seventeen radar reflectors, eight oriented (133/82, 326/18 or 001/45, 343/55, 250/10 or 002/63, 161/73, 342/82, 148/80 and 303/15). Numerous low resistivity anomalies, especially in the upper part, as well as intervals with low P-wave velocity and caliper anomalies. Confidence level = 3.

196–205 m DZ2: Increased frequency of open and sealed fractures. Gently dipping fractures dominate. Steeply dipping fractures that strike ENE are also present. Fracture apertures up to 2 mm and the predominant fracture filling minerals are chlorite and calcite. Faint to medium oxidation. One oriented radar reflector at 203.0 m (343/87) and one non-oriented at 198.2 m with the angle 39 degrees to borehole axis. General decrease in the resistivity and a minor decrease in the P-wave velocity. No caliper anomalies. Confidence level = 3.

417–422 m DZ3: Increased frequency of open and especially steeply dipping, sealed fractures. This zone occurs at the top of the borehole section in RU1 that was distinguished on the basis of a somewhat increased frequency of sealed fractures (418.84–506.68 m). The steeply dipping fractures strike NS. Gently dipping fractures are also present. Fracture apertures up to 2 mm and the predominant fracture filling minerals are chlorite and calcite. Faint to medium oxidation. One oriented radar reflector at 419.9 m (175/89) and one non-oriented at 418.7 m with the angle 48 degrees to borehole axis. Distinct low resistivity anomaly and low P-wave velocity. Minor indication in the caliper log. Confidence level = 3.

803–999.22 m DZ4: Increased frequency of steeply dipping open and especially sealed fractures, except in two shorter intervals at 843–857 m and 900–920 m. The steeply dipping sealed fractures show a variable strike between NNW and ENE. The steeply dipping open/partly open fractures strike predominantly NNW. Gently dipping fractures are also present. Fracture apertures are typically less than 1 mm, a few range up to 4 mm and one is over 10 mm. The most frequent fracture filling minerals in order of decreasing abundance include chlorite, calcite, laumontite, adularia and hematite. Also some minor intervals of adularia sealed breccia in the lower part of the zone. Two crush zones at 882.80–882.84 m and 989.51–989.55 m. Locally faint to medium oxidation. Thirty-nine radar reflectors of which one oriented at 827.1 m (208/85). Numerous low resistivity and caliper anomalies, as well as intervals with low P-wave velocity. The geophysical anomalies are mainly concentrated along the sections 873–900 m and 932–977 m. Confidence level = 3.

5.2 HFM20

The borehole direction at the start is 354.4/–85.4. The borehole can be divided into two rock units, one of which is recurrent in the borehole. For this reason, the borehole is divided into three rock sections:

12.04–136.19 m RU1a: Medium-grained metagranite-granodiorite (101057) with subordinate occurrences of amphibolite (102017) and pegmatitic granite (101061). Three crush zones and four radar reflectors, as well as caliper and resistivity anomalies occur in the interval 22–29 m. Indications of sub-parallel radar reflectors along the whole borehole length, 10–30 m from the borehole. Confidence level = 2.

136.19–147.83 m RU2: Amphibolite (102017). Corresponds to a borehole section with low magnetic susceptibility and low natural gamma radiation. Indications of sub-parallel radar reflectors along the whole borehole length, 10–30 m from the borehole. Confidence level = 3.

147.83–301.34 m RU1b: Medium-grained metagranite-granodiorite (101057) with subordinate occurrences of amphibolite (102017) and pegmatitic granite (101061). Slightly increased silica density relative to the upper part of the borehole. Indications of sub-parallel radar reflectors along the whole borehole length, 10–30 m from the borehole. Confidence level = 2.

No indications of possible deformation zones are present in HFM20.

5.3 HFM21

The borehole direction at the start is 088.8/–58.4. The borehole is composed of one rock unit:

12.05–201.9 m RU1: Medium-grained metagranite-granodiorite (101057) with subordinate occurrences of amphibolite (102017) and pegmatitic granite (101061), as well as a few occurrences of fine- to medium-grained metagranitoid (101051) in the upper part of the borehole. Confidence level = 2.

Two possible deformation zones are indicated in HFM21:

94–102 m DZ1: Increased frequency of sealed fractures. The sealed fractures are predominantly gently dipping. The open/partly open fracture is striking NNW and steeply dipping. Two crush zones. Three radar reflectors 45, 51 and 65 degrees to the borehole axis. Distinct low resistivity and caliper anomalies, as well as a decrease in the P-wave velocity. Confidence level = 2.

160–177 m DZ2: No anomaly in fracture frequency observed. The sealed fractures are both gently dipping and predominantly striking ENE with steep dips. Eight radar reflectors, 34–61 degrees to the borehole axis. Several distinct low resistivity anomalies and minor indications in the sonic and caliper loggings. Confidence level = 1.

6 Comments

The results from the geological single-hole interpretations of KFM07A, HFM20 and HFM21 are presented in WellCad plots (Appendix 1–3). The WellCad plots consist of the following columns:

1: Depth (Length along the borehole)

2: Rock type

3: Rock alteration

4: Sealed fractures

5: Open and partly open fractures

6: Crush zones

7: Silicate density

8: Magnetic susceptibility

9: Natural gamma radiation

10: Estimated fracture frequency

11: Description: Rock unit

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

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

14: Description: Possible deformation zone

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

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

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Geological single-hole interpretation for KFM07A

Appendix 1

Site	FORSMARK	**Inclination [°]**	-59.21	**Elevation [m.a.s.l.]**	3.33
Borehole	KFM07A	**Date of mapping**	2005-01-17 15:59:00	**Drilling Start Date**	2004-06-07 11:40:00
Diameter [mm]	77	**Coordinate System**	RT90-RHB70	**Drilling Stop Date**	2004-06-16 14:30:00
Length [m]	1001.550	**Northing [m]**	6700127.08	**Surveying Date**	
Bearing [°]	261.47	**Easting [m]**	1631031.57	**Plot Date**	2006-09-20 21:10:12

Signed data

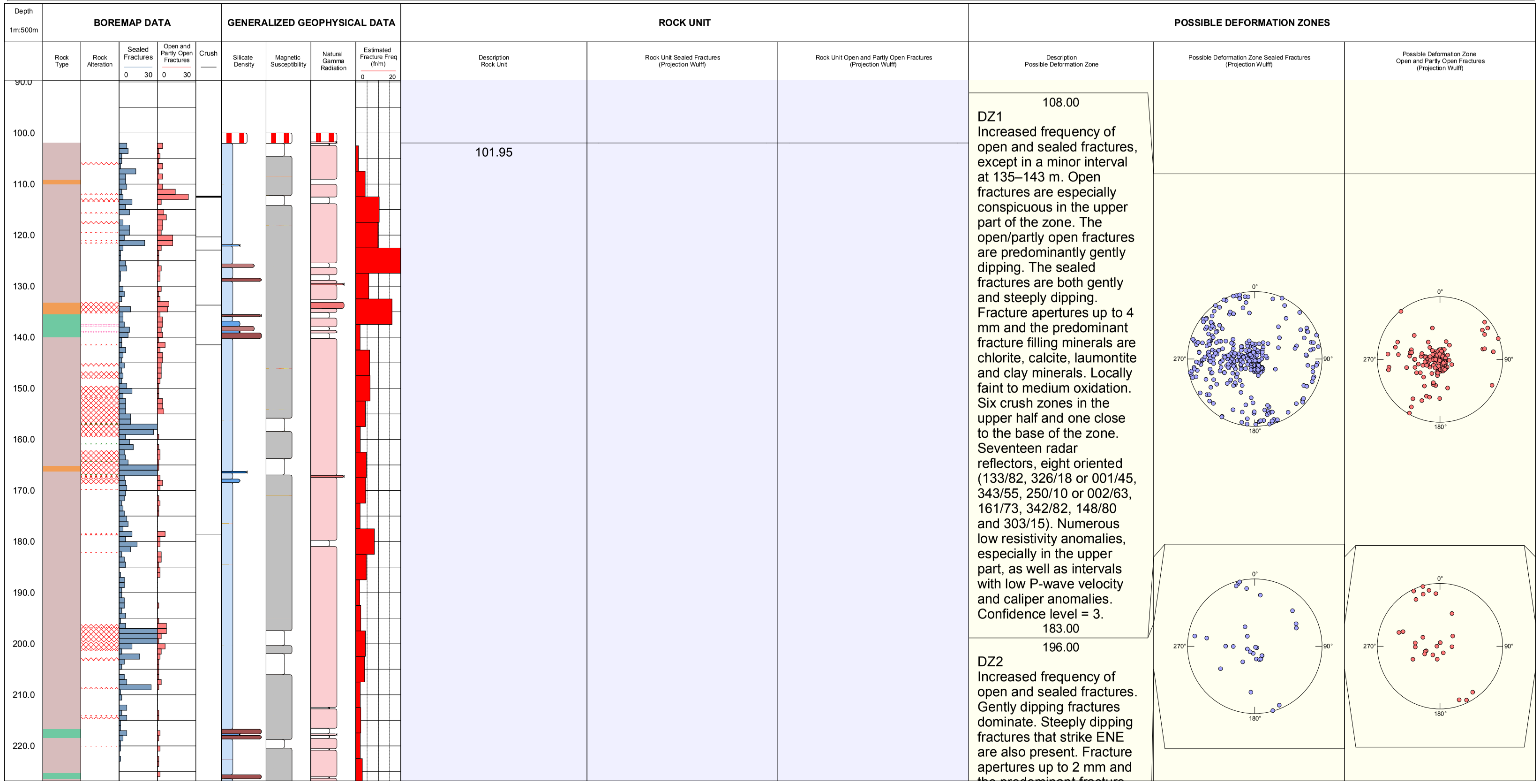
ROCKTYPE FORSMARK
- Granite, fine- to medium-grained
- Pegmatite, pegmatitic granite
- Granite to granodiorite, metamorphic, medium-grained
- Amphibolite
- Felsic to intermediate volcanic rock, metamorphic

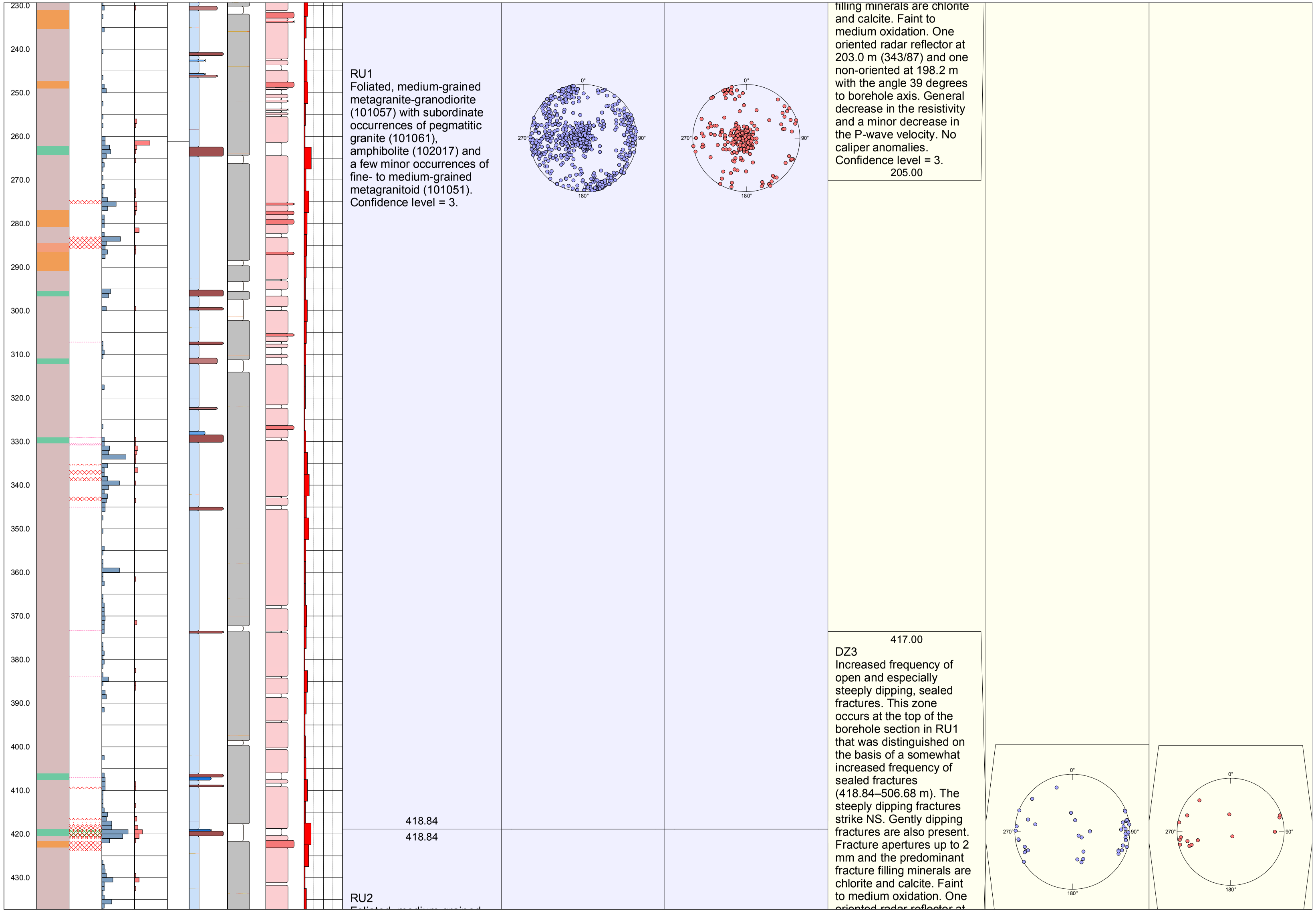
ROCK ALTERATION
- Oxidized
- Chloritisized
- Epidotisized
- Sericitisized
- Argillization
- Albitization
- Carbonatization
- Saussuritization

SILICATE DENSITY
- unclassified
- dens<2680 (Granite)
- 2680<dens<2730 (Granodiorite)
- 2730<dens<2800 (Tonalite)
- 2800<dens<2890 (Diorite)
- dens>2890 (Gabbro)

SUSCEPTIBILITET
- unclassified
- sus<0.001
- 0.001<sus<0.01
- 0.01<sus<0.1

NATURAL GAMMA
- unclassified
- gam<20
- 20<gam<36
- 36<gam<53

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240.0
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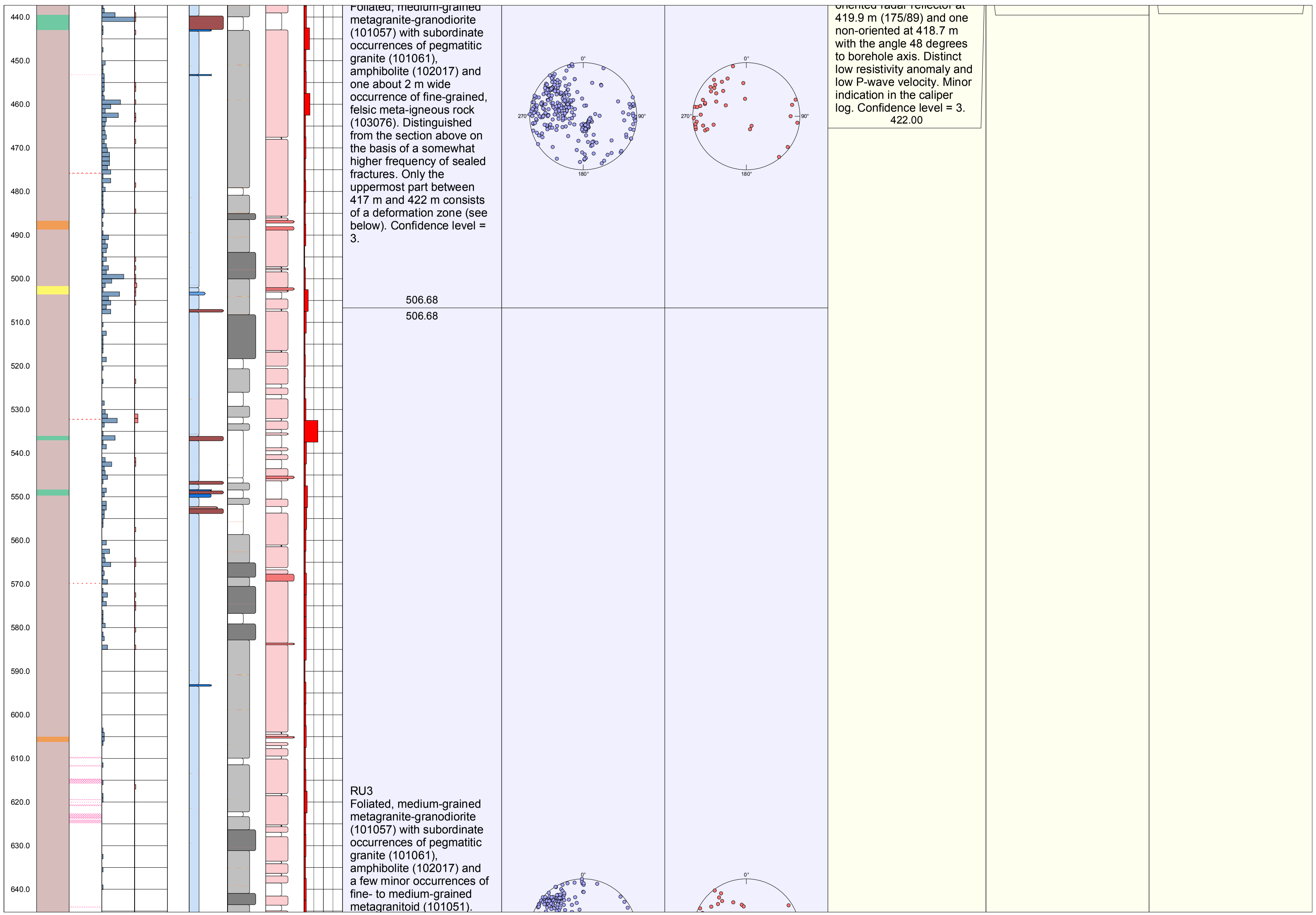
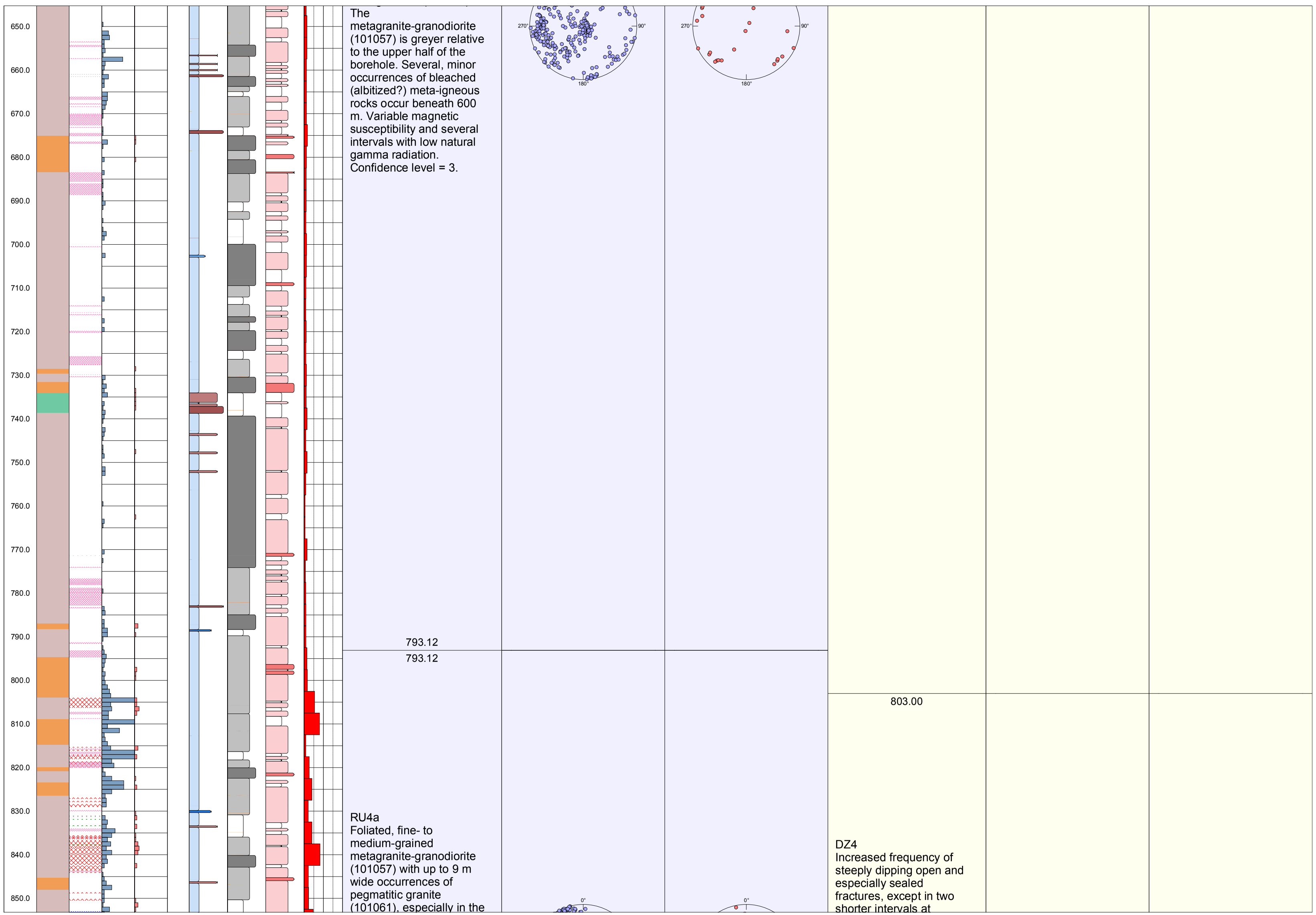
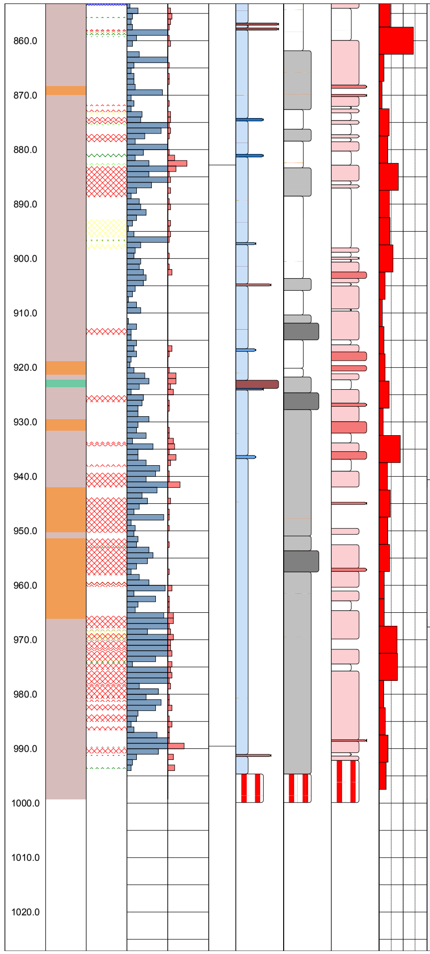
320.0
330.0
340.0
350.0
360.0
370.0
380.0
390.0
400.0
410.0
420.0
430.0
RU1
Foliated, medium-grained metagranite-granodiorite (101057) with subordinate occurrences of pegmatitic granite (101061), amphibolite (102017) and a few minor occurrences of fine- to medium-grained metagranitoid (101051).
Confidence level = 3.
418.84
418.84
RU2
0°
90°
180°
270°
filling minerals are chlorite and calcite. Faint to medium oxidation. One oriented radar reflector at 203.0 m (343/87) and one non-oriented at 198.2 m with the angle 39 degrees to borehole axis. General decrease in the resistivity and a minor decrease in the P-wave velocity. No caliper anomalies.
Confidence level = 3.
205.00
417.00
DZ3
Increased frequency of open and especially steeply dipping, sealed fractures. This zone occurs at the top of the borehole section in RU1 that was distinguished on the basis of a somewhat increased frequency of sealed fractures (418.84–506.68 m). The steeply dipping fractures strike NS. Gently dipping fractures are also present. Fracture apertures up to 2 mm and the predominant fracture filling minerals are chlorite and calcite. Faint to medium oxidation. One


440.0
450.0
460.0
470.0
480.0
490.0
500.0
510.0
520.0
530.0
540.0
550.0
560.0
570.0
580.0
590.0
600.0
610.0
620.0
630.0
640.0
Foliated, medium-grained metagranite-granodiorite (101057) with subordinate occurrences of pegmatitic granite (101061), amphibolite (102017) and one about 2 m wide occurrence of fine-grained, felsic meta-igneous rock (103076). Distinguished from the section above on the basis of a somewhat higher frequency of sealed fractures. Only the uppermost part between 417 m and 422 m consists of a deformation zone (see below). Confidence level = 3.
506.68
506.68
RU3
Foliated, medium-grained metagranite-granodiorite (101057) with subordinate occurrences of pegmatitic granite (101061), amphibolite (102017) and a few minor occurrences of fine- to medium-grained metagranitoid (101051).
0°
90°
180°
270°
419.9 m (175/89) and one non-oriented at 418.7 m with the angle 48 degrees to borehole axis. Distinct low resistivity anomaly and low P-wave velocity. Minor indication in the caliper log. Confidence level = 3.
422.00



650.0
660.0
670.0
680.0
690.0
700.0
710.0
720.0
730.0
740.0
750.0
760.0
770.0
780.0
790.0
800.0
810.0
820.0
830.0
840.0
850.0
The metagranite-granodiorite (101057) is greyer relative to the upper half of the borehole. Several, minor occurrences of bleached (albitized?) meta-igneous rocks occur beneath 600 m. Variable magnetic susceptibility and several intervals with low natural gamma radiation. Confidence level = 3.
793.12
793.12
RU4a
Foliated, fine- to medium-grained metagranite-granodiorite (101057) with up to 9 m wide occurrences of pegmatitic granite (101061), especially in the
270°
90°
180°
0°
803.00
DZ4
Increased frequency of steeply dipping open and especially sealed fractures, except in two shorter intervals at



upper part, and subordinate occurrences of amphibolite (102017). Generally more intense ductile deformation and more heterogeneous relative to the upper part of the borehole. Locally mica-rich relative to the typical metagranite-granodiorite (101057) in the borehole. Variable magnetic susceptibility and several intervals with low natural gamma radiation. Confidence level = 3.

942.04

942.04

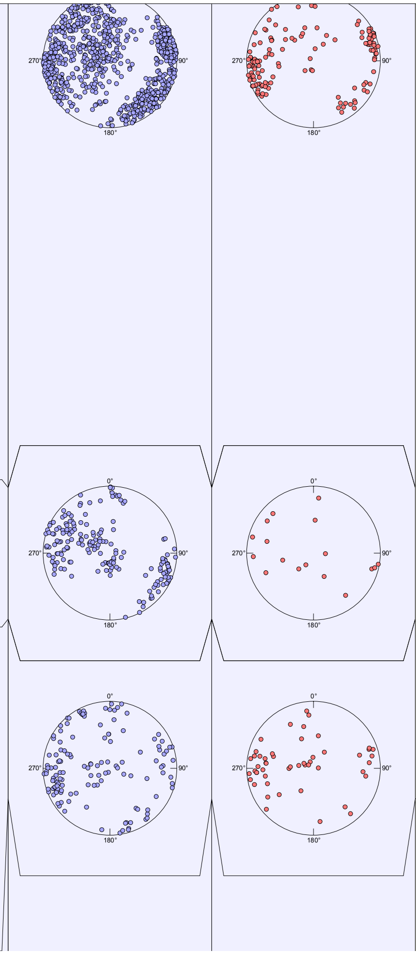
RU5
Pegmatitic granite (101061) with subordinate occurrences of metagranite-granodiorite (101057). Confidence level = 3.

966.19

966.19

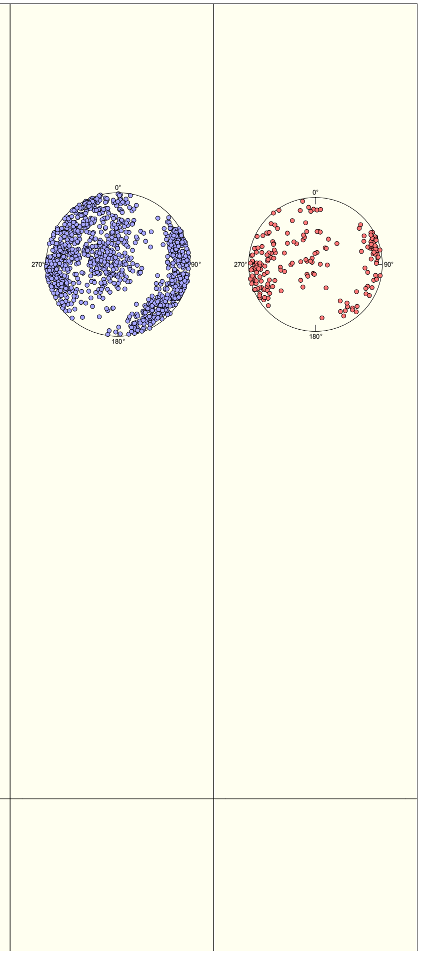
RU4b
Foliated, fine- to medium-grained metagranite-granodiorite (101057) with subordinate occurrences of pegmatitic granite (101061) and amphibolite (102017). Generally more intense ductile deformation and more heterogeneous relative to the upper part of the borehole. Locally mica-rich relative to the typical metagranite-granodiorite (101057) in the borehole. Confidence level = 3.

999.22



843–857 m and 900–920 m. The steeply dipping sealed fractures show a variable strike between NNW and ENE. The steeply dipping open/partly open fractures strike predominantly NNW. Gently dipping fractures are also present. Fracture apertures are typically less than 1 mm, a few range up to 4 mm and one is over 10 mm. The most frequent fracture filling minerals in order of decreasing abundance include chlorite, calcite, laumontite, adularia and hematite. Also some minor intervals of adularia sealed breccia in the lower part of the zone. Two crush zones at 882.80–882.84 m and 989.51–989.55 m. Locally faint to medium oxidation. Thirty-nine radar reflectors of which one oriented at 827.1 m (208/85). Numerous low resistivity and caliper anomalies, as well as intervals with low P-wave velocity. The geophysical anomalies are mainly concentrated along the sections 873–900 m and 932–977 m. Confidence level = 3.

999.22



Geological single-hole interpretation for HFM20

Appendix 2

Title SINGLE HOLE INTERPRETATION HFM20

Site	FORSMARK	**Inclination [°]**	-85.44	**Elevation [m.a.s.l.]**	2.97	**Signed data**
Borehole	HFM20	**Date of mapping**	2005-01-24 00:00:00	**Drilling Start Date**	2004-05-18 15:20:00	
Diameter [mm]	135	**Coordinate System**	RT90-RHB70	**Drilling Stop Date**	2004-06-01 20:00:00	
Length [m]	301.000	**Northing [m]**	6700187.50	**Surveying Date**		
Bearing [°]	354.41	**Easting [m]**	1630776.68	**Plot Date**	2006-09-20 21:10:12	

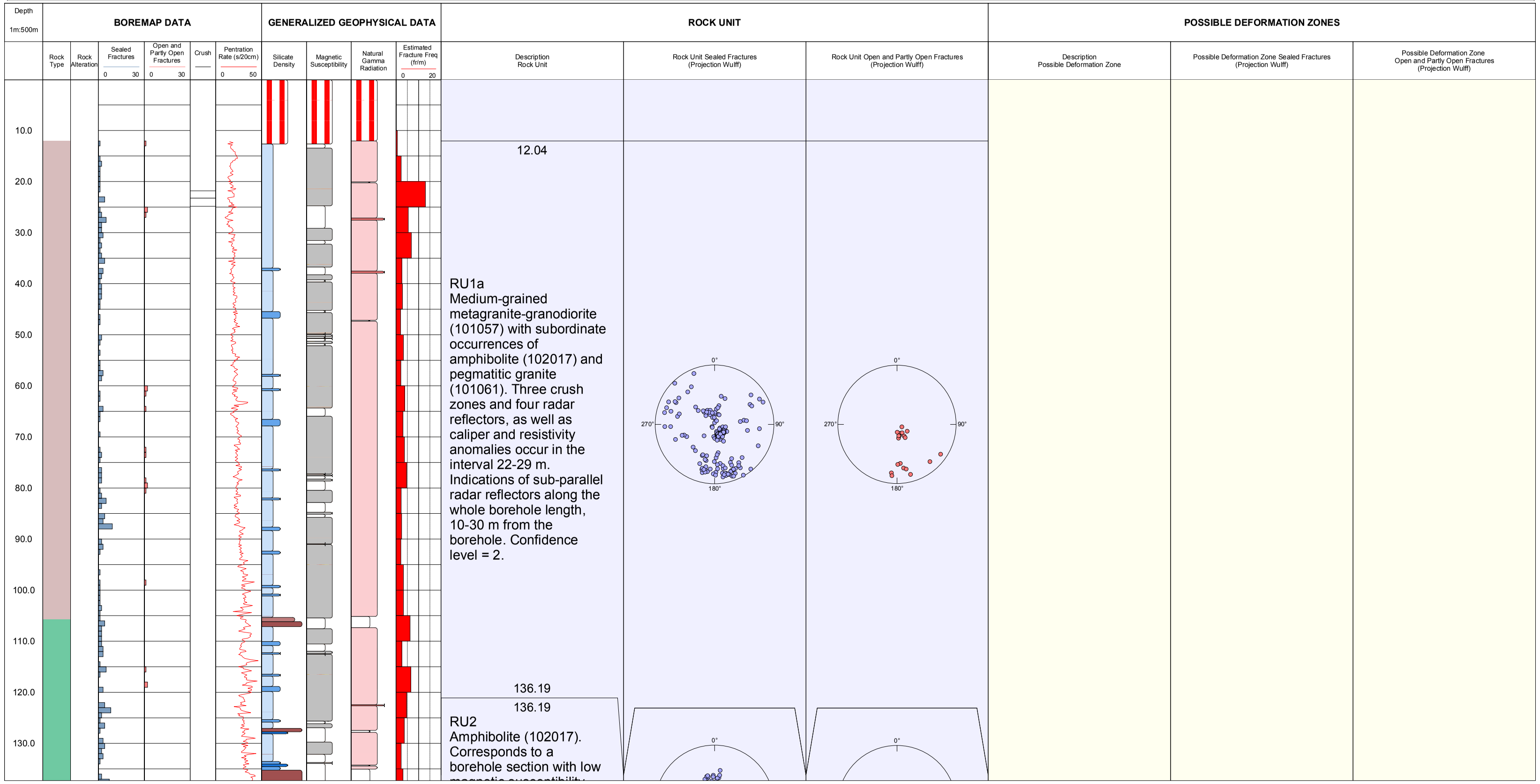
ROCKTYPE FORSMARK
- Granite to granodiorite, metamorphic, medium-grained
- Amphibolite

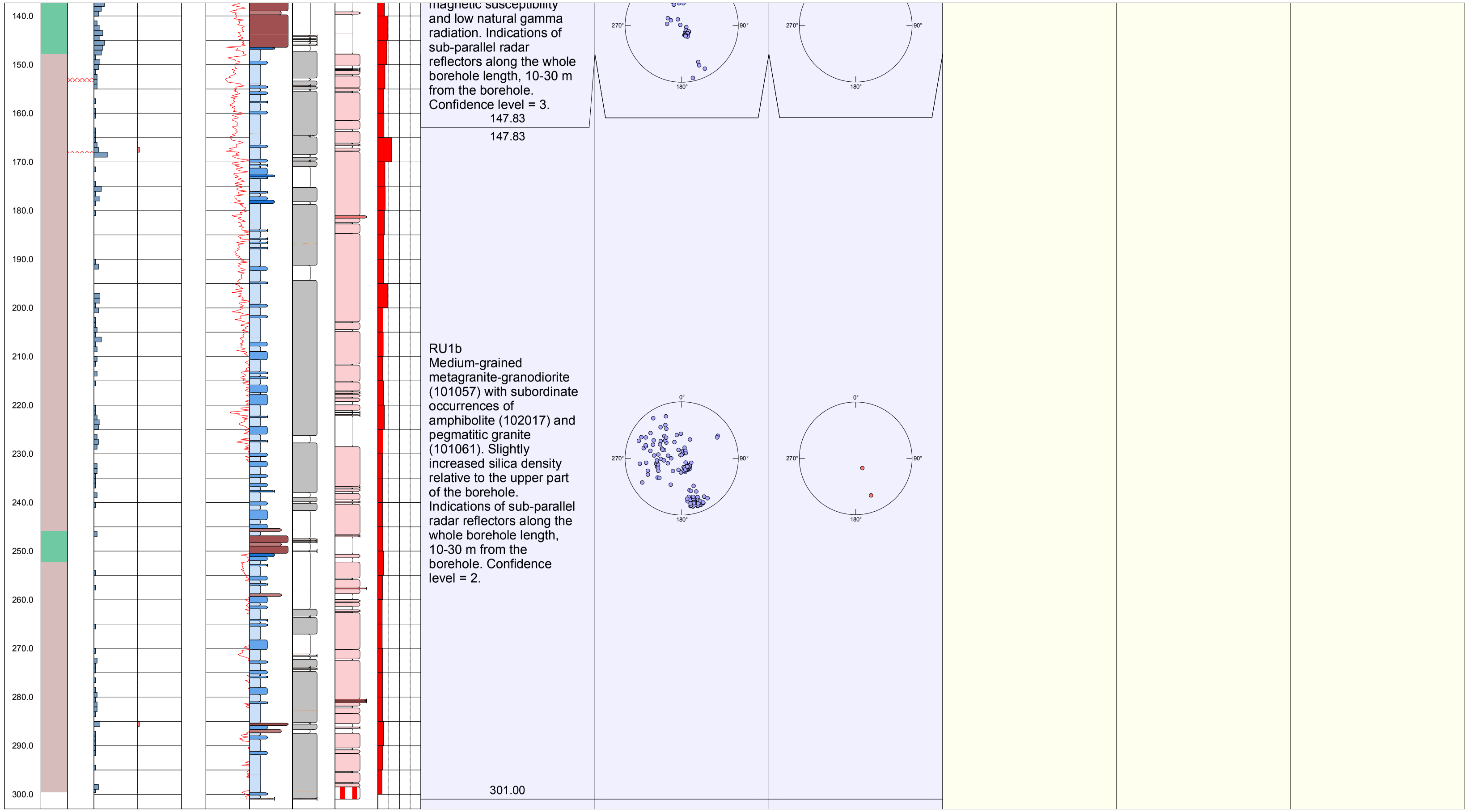
ROCK ALTERATION
- Oxidized

SILICATE DENSITY
- unclassified
- dens<2680 (Granite)
- 2680<dens<2730 (Granodiorite)
- 2730<dens<2800 (Tonalite)
- 2800<dens<2890 (Diorite)
- dens>2890 (Gabbro)

SUSCEPTIBILITET
- unclassified
- sus<0.001
- 0.001<sus<0.01

NATURAL GAMMA
- unclassified
- gam<20
- 20<gam<36
- 36<gam<53




140.0
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
magnetic susceptibility and low natural gamma radiation. Indications of sub-parallel radar reflectors along the whole borehole length, 10-30 m from the borehole. Confidence level = 3.
147.83
147.83
RU1b
Medium-grained metagranite-granodiorite (101057) with subordinate occurrences of amphibolite (102017) and pegmatitic granite (101061). Slightly increased silica density relative to the upper part of the borehole. Indications of sub-parallel radar reflectors along the whole borehole length, 10-30 m from the borehole. Confidence level = 2.
301.00
0°
90°
180°
270°

Geological single-hole interpretation for HFM21

Appendix 3

Title	SINGLE HOLE INTERPRETATION HFM21					
Site	FORSMARK	Inclination [°]	-58.47	Elevation [m.a.s.l.]	3.98	Signed data
Borehole	HFM21	Date of mapping	2005-01-27 13:28:00	Drilling Start Date	2004-06-02 09:00:00	
Diameter [mm]	137	Coordinate System	RT90-RHB70	Drilling Stop Date	2004-06-07 11:40:00	
Length [m]	202.000	Northing [m]	6700125.57	Surveying Date		
Bearing [°]	88.81	Easting [m]	1631074.05	Plot Date	2006-09-20 21:10:12	

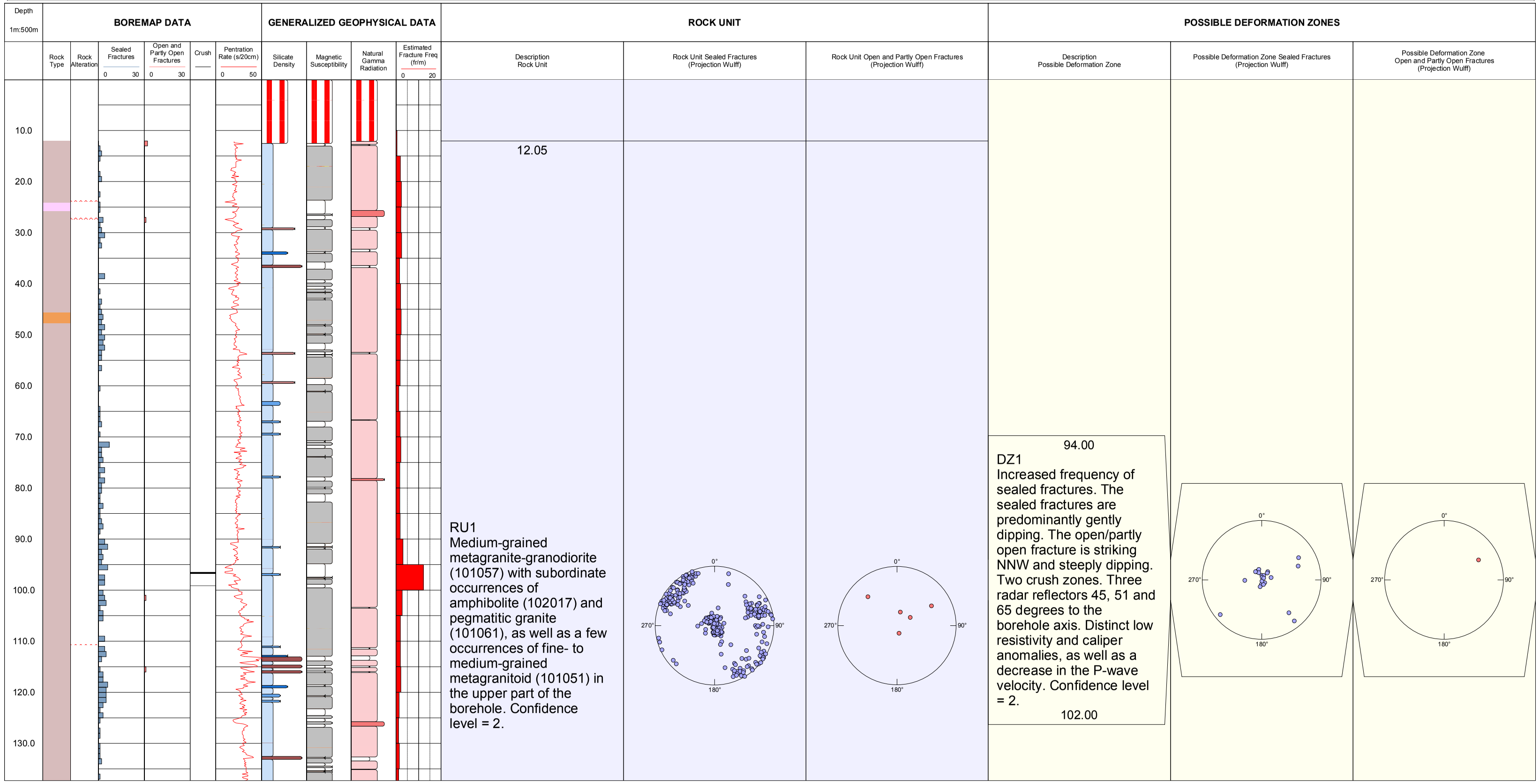
ROCKTYPE FORSMARK
- Pegmatite, pegmatitic granite
- Granite, granodiorite and tonalite, metamorphic, fine- to medium-grained
- Granite to granodiorite, metamorphic, medium-grained
- Amphibolite

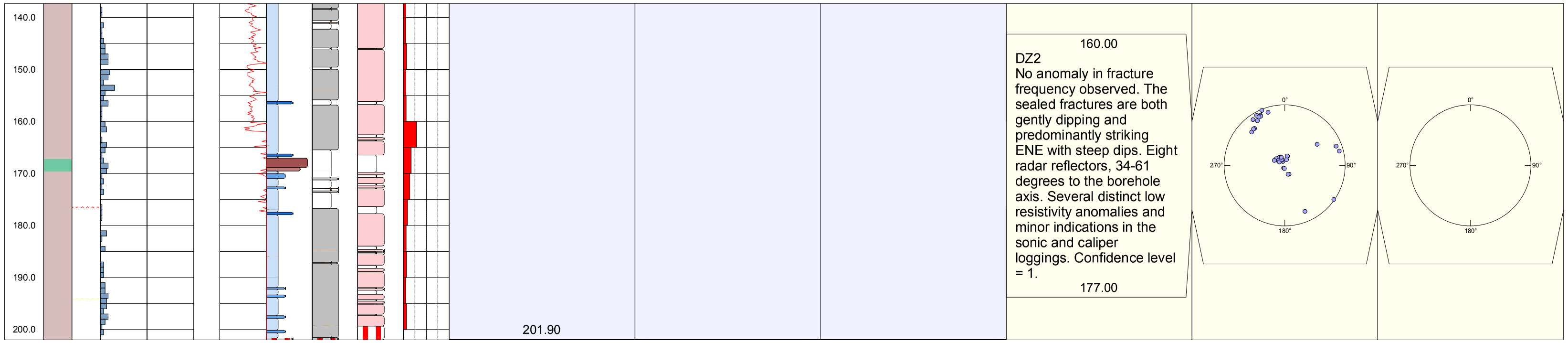
ROCK ALTERATION
- Oxidized
- Sericitisized

SILICATE DENSITY
- unclassified
- dens<2680 (Granite)
- 2680<dens<2730 (Granodiorite)
- 2730<dens<2800 (Tonalite)
- 2800<dens<2890 (Diorite)
- dens>2890 (Gabbro)

SUSCEPTIBILITET
- unclassified
- sus<0.001
- 0.001<sus<0.01

NATURAL GAMMA
- unclassified
- gam<20
- 20<gam<36
- 36<gam<53




140.0
150.0
160.0
170.0
180.0
190.0
200.0
201.90
160.00
DZ2
No anomaly in fracture frequency observed. The sealed fractures are both gently dipping and predominantly striking ENE with steep dips. Eight radar reflectors, 34-61 degrees to the borehole axis. Several distinct low resistivity anomalies and minor indications in the sonic and caliper loggings. Confidence level = 1.
177.00
0°
90°
180°
270°