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Abstract

This report presents the geological single-hole interpretations of the core drilled borehole KFR106 and percussion drilled borehole HFR106, both drilled from an islet located ca 220 m south-east of the pier above SFR. The interpretation combines the geological mapping, generalized geophysical logs, borehole radar measurements and subsequently hydrogeological logs to identify where rock units and possible deformation zones occur in the boreholes. A brief description of each rock unit and possible deformation zone is provided.

Borehole KFR106 has been divided into three different rock units, RU1–RU3, of which RU2 occurs in two separate length intervals. Rock unit 1 consists of pegmatitic granite (101061), fine- to medium-grained granite (111058) and fine- to medium-grained metagranitoid (granodiorite to tonalite; 101051) in approximately equal proportions. The predominant rock type in RU2 is fine- to medium-grained metagranite-granodiorite (101057), locally with considerable amount of metamorphic muscovite. Subordinate rock types are pegmatitic granite (101061), felsic to intermediate metavolcanic rock (103076), fine- to medium-grained granite (111058) and amphibolite (102017). Rock unit 3 consists almost entirely of pegmatitic granite (101061). Seven possible deformation zones of brittle character have been interpreted in KFR106 (DZ1–DZ7), one with a medium degree of confidence and the other six with a high degree of confidence.

Borehole HFR106 has be divided into three different rock units, RU1–RU3, of which RU2 and RU3 occur each in two separate length intervals. Rock unit 1 is dominated by pegmatitic granite (101061), RU2 by fine- to medium-grained metagranite-granodiorite (101057) and RU3 by pegmatitic granite (101061) and metagranite-granodiorite (101057) in approximately equal proportions. Three possible deformation zones of brittle character have been interpreted in HFR106 (DZ1–DZ3), two with a low degree of confidence and the third with a high degree of confidence.

Sammanfattning

Denna rapport presenterar den geologiska enhålstolkningen från kärnborrhål KFR106 och hammarborrhål HFR106, borrade från en kobbe ca 220 m sydost om piren över SFR. Tolkningen kombinerar den geologiska karteringen, generaliserade geofysiska loggar, data från borrhålsradar och därefter hydrogeologisk data för att identifiera litologiska enheter och möjliga deformationszoner i borrhålen. En översiktlig beskrivning av varje litologisk enhet och möjlig deformationszon presenteras.

Kärnborrhål KFR106 har delats in i tre litologiska enheter, RU1–RU3, av vilka RU2 förekommer i två separata längdintervall. RU1 består av pegmatitisk granit (101061), fin- till medelkornig granit (111058) och fin- till medelkornig metagranitoid (granodiorit-tonalit; 101051) i ungefär lika stora delar. Den dominerande bergarten i RU2 är fin- till medelkornig metagranit-granodiorit (101057), lokalt med betydande mängder metamorf muskovit. Underordnade bergarter är pegmatitisk granit (101061), felsisk till intermediär metavulkanisk bergart (103076), fin- till medelkornig granit (111058) och amfibolit (102017). RU5 består nästan uteslutande av pegmatitisk granit (101061). Sju möjliga deformationszoner av spröd karaktär har tolkats i KFR106 (DZ1–DZ7), en med medelhög grad av tillförlitlighet och de andra sex med en hög grad av tillförlitlighet.

Hammarborrhål HFR106 har delats in i tre olika litologiska enheter, RU1–RU3, av vilka RU2 och RU3 vardera förekommer i två separata längdintervall. RU1 domineras av pegmatitisk granit (101061), RU2 av fin- till medelkornig metagranit-granodiorit (101057) och RU3 av pegmatitisk granit (101061) och metagranit-granodiorit (101057) i ungefär lika stora delar. Tre möjliga deformationszoner av spröd karaktär har tolkats i HFR106 (DZ1–DZ3), två med en låg grad av tillförlitlighet och den sista med en hög grad av tillförlitlighet.

Contents

1 Introduction

During 2008, SKB has initiated an investigation programme for the future expansion of the final repository for low and middle level radioactive operational waste, SFR. An essential part in this project is the drilling of four percussion and eight core drilled boreholes. Each borehole is thoroughly documented by means of geological mapping by the so-called Boremap system, as well as geophysical and radar borehole measurements. After import to the SKB database Sicada, the data is used as input for modelling in the 3D-CAD Rock Visualization System (RVS). This procedure follows SKB's established methodology of geological single-hole interpretation, which is based on an integrated series of different logs and accompanying descriptive documents. However, a difference in the methodology compared to that applied during the Forsmark site investigation programme (i.e. SKB MD 810.003) is the incorporation of hydrogeological borehole data in the interpretation process.

This document outlines the results of the geological single-hole interpretation of borehole KFR106 and HFR106. The horizontal projections of the boreholes are shown in Figure 1-1.

The work was carried out in accordance with activity plan AP SFR-09-026. In Table 1-1 controlling documents for performing this activity are listed. Both activity plan and method descriptions are SKB's internal controlling documents.

Original data from the reported activity are stored in the primary database Sicada. Only data in SKB's databases are accepted for further interpretation and modelling. The data presented in this report are regarded as copies of the original data. Data in the databases may be revised, if needed. Such revisions will not necessarily result in a revision of the associated P-report, although the normal procedure is that major data revisions entail a revision of the P-report. Minor data revisions are normally presented as supplements, available at www.skb.se.

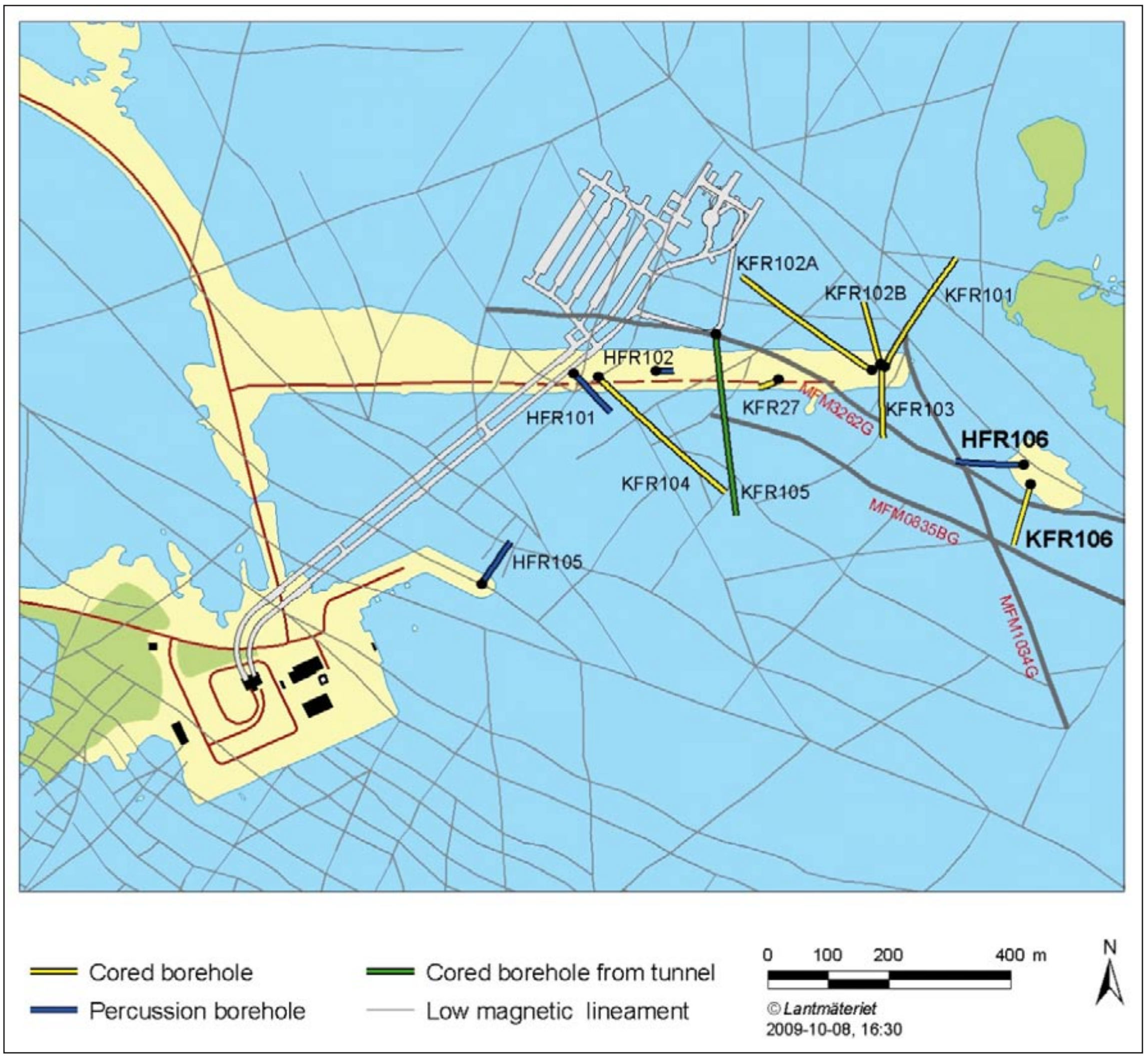

Figure 1-1. Map showing position and horizontal projection of the cored borehole KFR106 and HFR106 relative to SFR and other boreholes in the drilling programme.

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

Activity plan	Number	Version
Geohydrologisk enhålstolkning av kärnborrhål KFR105, KFR106 samt hammarborrhål HFR106	AP SFR-09-026	1.0
Method descriptions	**Number**	**Version**
Metodbeskrivning för geologisk enhålstolkning	SKB MD 810.003	3.0

2 Objective and scope

A geological single-hole interpretation is carried out in order to identify and to describe the general 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 a drill core. Hydrogeological borehole data were used to identify flow anomalies and transmissive sections of the borehole.

The result from the geological single-hole interpretation is presented in a WellCAD plot. A detailed description of the technique is provided in the Method Description (SKB MD 810.003). The work reported here concerns stage 1 in the single-hole interpretation, as defined in the Method Description.

3 Data used for the geological single-hole interpretation

The following data have been used for the single-hole interpretation of the borehole HFR106 and KFR106:

- Boremap data (including BIPS-image and geological mapping /Winell 2010a, b/).
- Generalized geophysical logs and their interpretation /Mattsson and Keisu 2009/.
- Radar data and their interpretation /Gustafsson and Gustafsson 2009/.
- Borehole flow logging data and their interpretation /Kristiansson et al. 2010, Thur et al. 2010/.

The geological mapping of the borehole involves documentation of the drill core in combination with inspection of the oriented image of the borehole walls, obtained by a Borehole Image Processing System (BIPS).

The basis for the geological single-hole interpretation was a WellCAD plot consisting of parameters from the geological mapping, as well as geophysical, radar and hydrogeological data. Hydrogeological data were included after the geological single-hole interpretation was performed, i.e. the rock units and the possible deformation zones were defined first. An example of a WellCAD plot used during geological single-hole interpretation is shown in Figure 3-1. The plot consists of eight main columns and several subordinate columns. These include:

1: Length along the borehole

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

3: Geophysics
  3.1: Silicate density
  3.2: Natural gamma radiation
  3.3: Magnetic susceptibility
  3.4: Estimated fracture frequency

4: Unbroken fractures
  4.1: Primary mineral
  4.2: Secondary mineral
  4.3: Third mineral
  4.4: Fourth mineral
  4.5: Width
  4.6: Alteration, dip direction

5: Broken fractures
  5.1: Primary mineral
  5.2: Secondary mineral
  5.3: Third mineral
  5.4: Fourth mineral
  5.5: Width
  5.6: Aperture
  5.7: Roughness
  5.8: Surface

   5.9: Slickenside
   5.10: Alteration, dip direction

6: Crush zones
   6.1: Piece (mm)
   6.2: Sealed network
   6.3: Core loss

7: Fracture frequency
   7.1: Open fractures
   7.2: Sealed fractures

8: Hydrogeology
   8.1: Transmissivity flow anomalies
   8.2: Transmissivity 5-m sections

The use of the geophysical, radar and hydrogeological parameters during the single-hole interpretation is as follows:

Silicate density: Indicates the density of the rock after subtraction of the magnetic component of the rock. It provides general information on the mineral composition of the rock and serves as a support for rock classification.

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 (111058) or pegmatitic granite (101061).

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 of the rock.

Radar data: 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.

Transmissivity: The transmissivity from flow logging is related to the transmissivity of individual fractures and to the connectivity of the water-bearing fracture network.

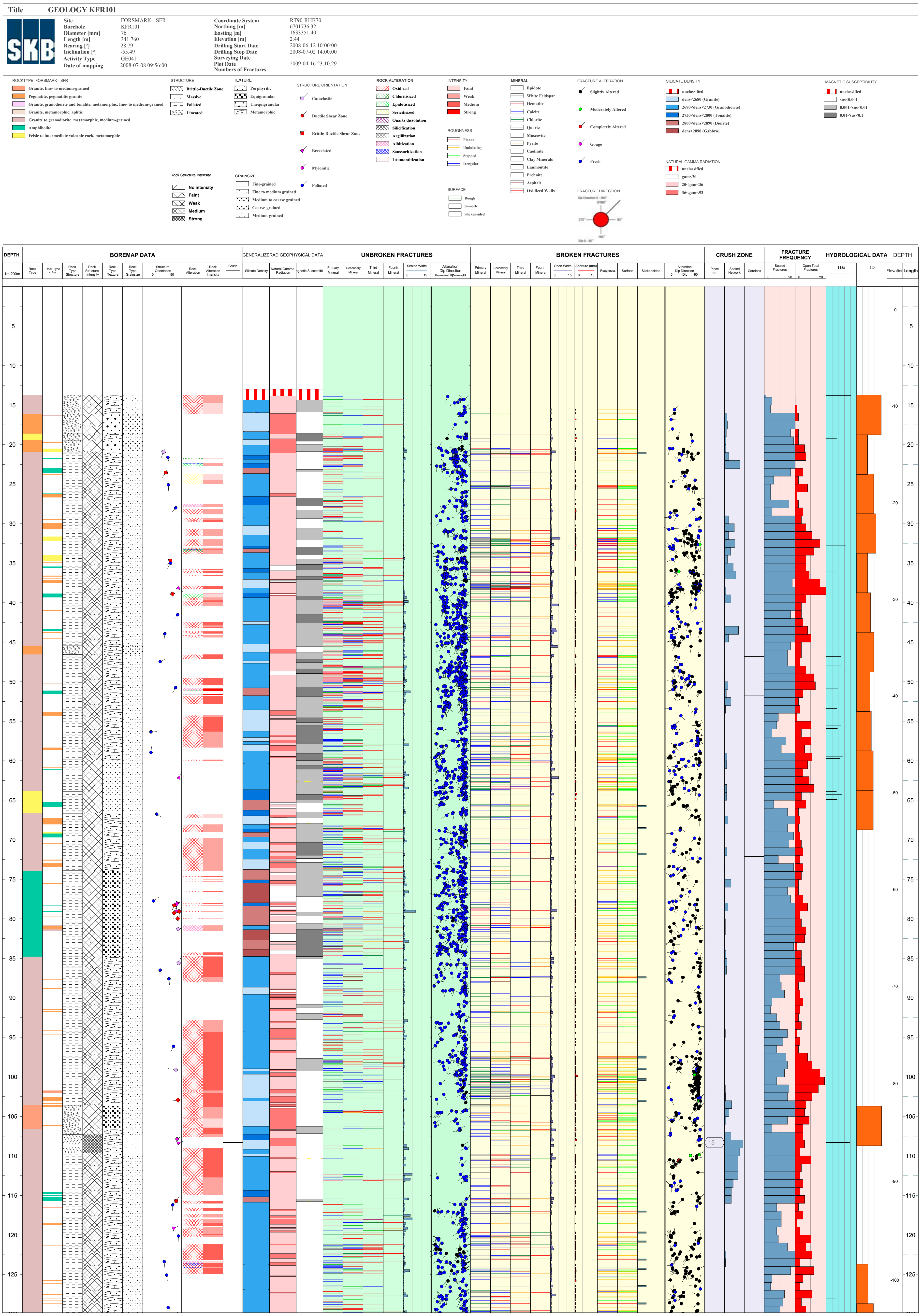

Figure 3-1. *Example of WellCAD plot (from borehole KFR101) used as basis for the geological single-hole interpretation.*

4 Execution

4.1 Geological single-hole interpretation

The geological single-hole interpretation has been carried out by a group of geoscientists, consisting of geologists, geophysicists and hydrogeologists. Several of them previously participated in the development of the source material. All data to be used (see Chapter 3) are presented 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.

The first step in the working procedure is to study all types of data 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. A minimum length of about 5 m was used for the single-hole interpretations during the site investigation. This minimum length was generally also used during this work, but not consistently, since the SFR model volume is considerably smaller. 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 assigned according to three classes: 3 = high, 2 = medium and 1 = low. The use of low or medium degree of confidence is generally restricted to percussion drilled boreholes, where no drill core is available.

The second step in the working procedure is to identify possible deformation zones by visual inspection of the results of the geological mapping (fracture frequency, fracture mineral, alteration, etc.) in combination with available geophysical 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. This includes a brief description of the rock types affected by the possible deformation zone. Mineral fillings registered in at least 10% of the open/sealed fractures in the interval or ten individual fractures are noted. The confidence in the interpretation of a possible deformation zone is assigned according to three classes: 3 = high, 2 = medium and 1 = low.

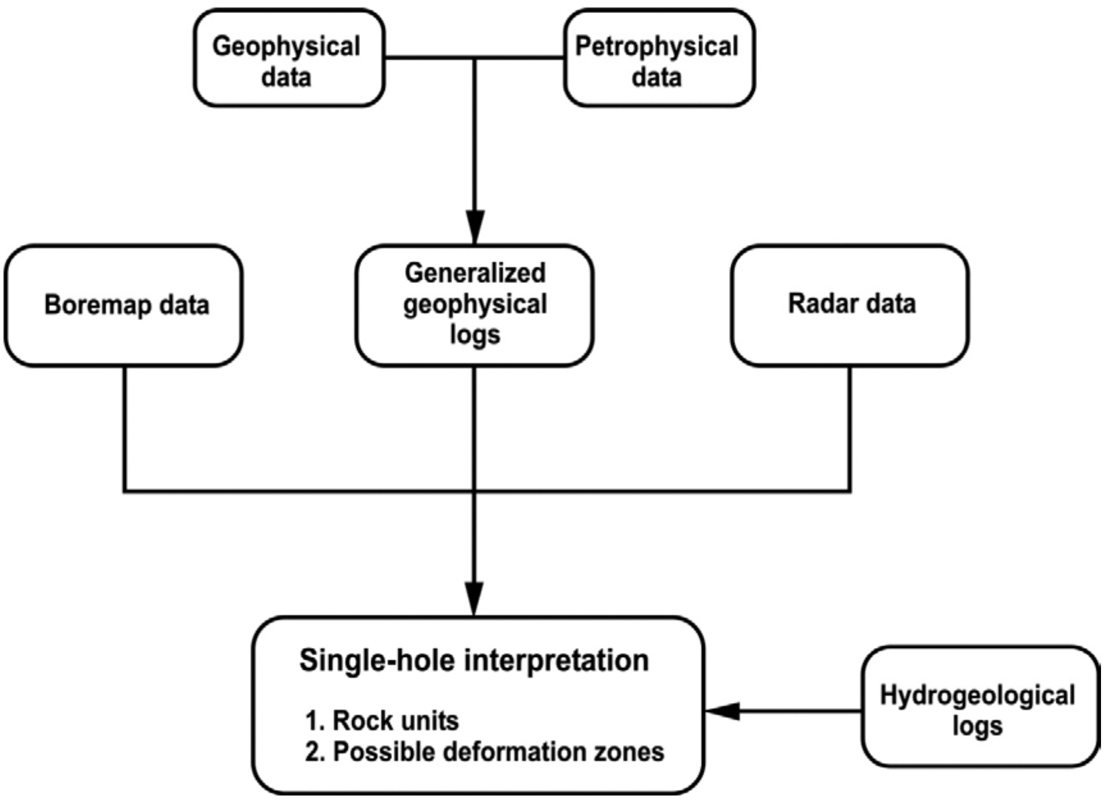

Figure 4-1. Schematic chart showing the procedure for the development of a geological single-hole interpretation.

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

Possible deformation zones that are brittle in character have been identified primarily on the basis of the frequency of fractures, according to the concept presented in /Munier et al. 2003/. Brittle deformation zones defined by an increased frequency of extensional fractures (joints) or shear fractures (faults) are not distinguished. Both the damage zone part, with a fracture frequency in the range 4–9 fractures/m, and the core zone 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 orientation of any radar reflectors, the resistivity, SPR, caliper and magnetic susceptibility logs have all assisted in the identification of the zones. The anomalies in these parameters that assist with the interpretation are presented in the short description.

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 the cored borehole KFR106 and percussion drilled HFR106 (Figure 4-3 and Figure 4-4). A 5 m window and 1 m step length have been used in the calculation procedure. The moving average for open fractures alone; the total number of open (including open, partly open and crush); the sealed fractures alone and the total number of sealed fractures (including sealed and sealed fracture networks) are shown in the diagram.

The occurrence and orientation of radar anomalies within the possible deformation zones are used during the identification of these zones. Overview of the borehole radar measurements from KFR106, based on 20 MHz dipole data, is presented in Figure 4-5. Along some intervals in the borehole, e.g. from approximately 150 m to 160 m and around 257 m the penetration is affected, probably due to the presence of fractures. The effect of attenuation varies between the different antenna frequencies (in this case 20 MHz dipole and 60 MHz directional antenna). As seen, some very prominent radar reflectors are observed. In some cases, alternative orientations for oriented radar reflectors are presented, and a decision concerning which of the alternatives that represent the true orientation cannot be made. Orientations from the directional radar are presented as strike/dip using the right-hand-rule method.

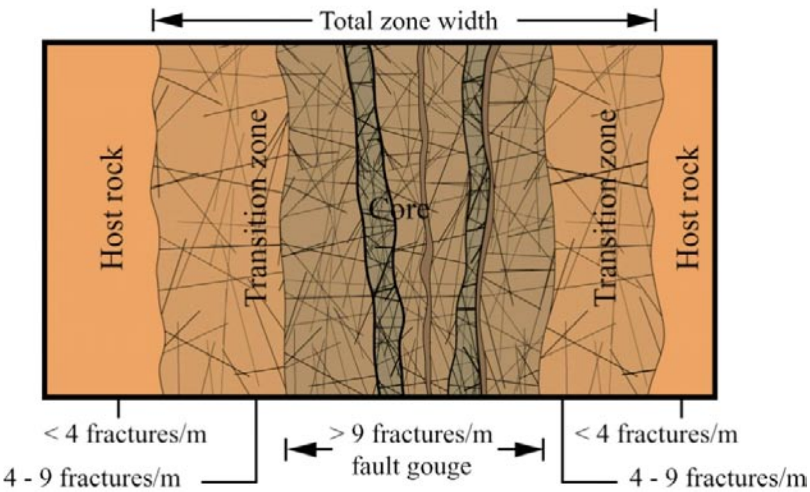

Figure 4-2. *Schematic illustration of the structure of a brittle deformation zone. After /Munier et al. 2003/. Note that the marked 'transition zone' corresponds to damage zone.*

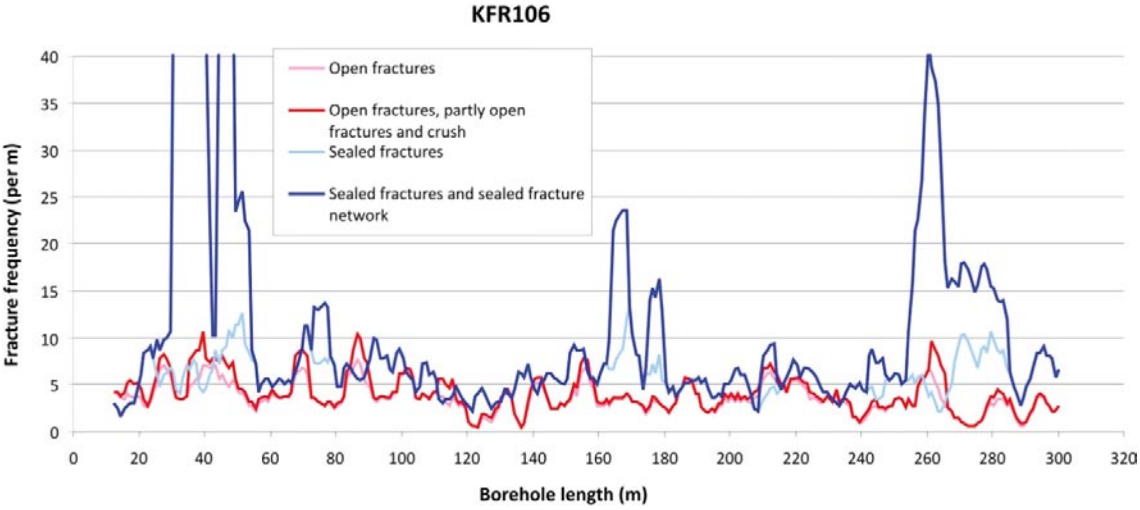

Figure 4-3. *Fracture frequency plot for KFR106. Moving average with a 5 m window and 1 m step length.*

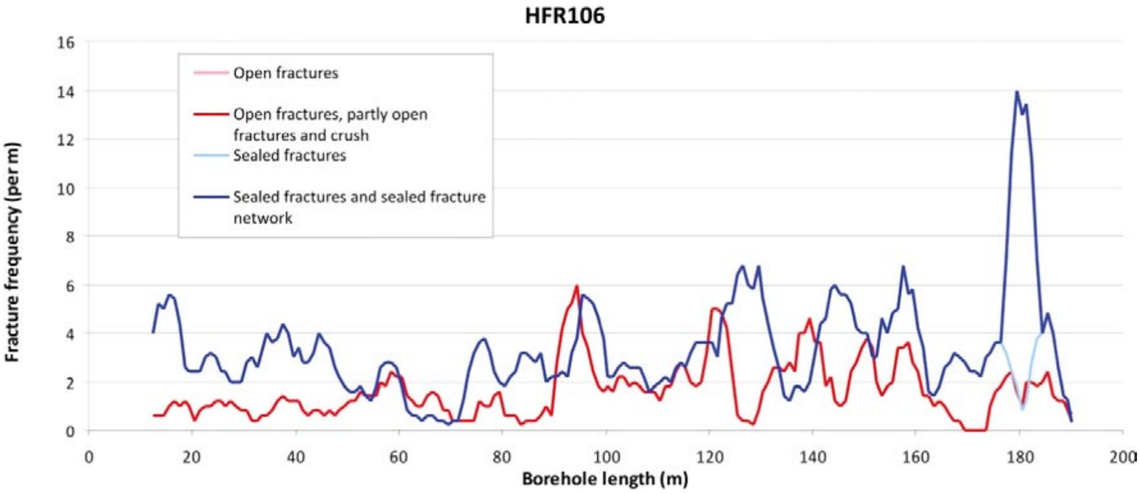

Figure 4-4. *Fracture frequency plot for HFR106. Moving average with a 5 m window and 1 m step length.*

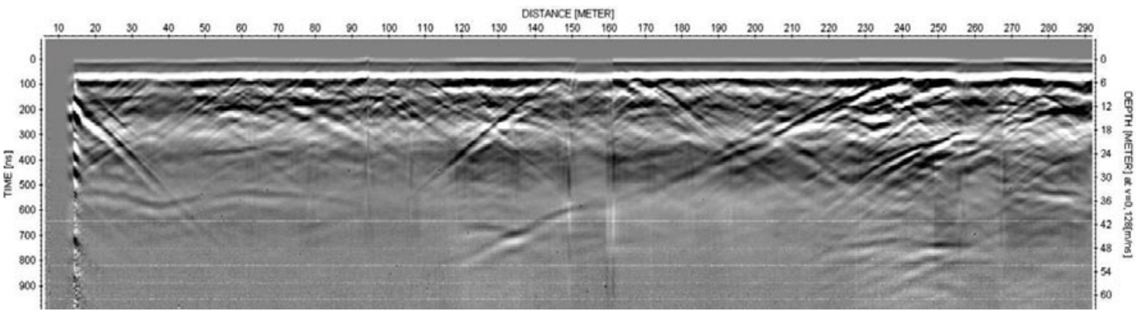

Figure 4-5. *An overview (20 MHz data) of the radar data for the borehole KFR106. The horizontal axis shows the borehole length and the vertical axis the distance from the borehole.*

4.2 Hydrogeological single-hole interpretation

The hydrogeological single-hole interpretation has been carried out by a hydrogeologist as a second step after, but in immediate connection to, the geological single-hole interpretation. All data to be used are presented side by side in the same borehole document as the geological and geophysical data. The hydrogeological columns were however not accessible at the geological interpretation stage.

In this particular case the single-hole interpretation concerned one cored borehole with differential flow logging data and one percussion-drilled borehole with spinner flow logging data.

The methodology of the hydrogeological single-hole interpretation was to study the hydrogeological data for the identified possible deformation zones. The flow anomalies and hydraulic properties of each zone were then evaluated and described in comparison to the properties of the whole borehole.

4.3 Nonconformities

A difference in the current applied methodology compared to earlier single-hole interpretations (SKB MD 810.003) is that hydrogeological single-hole interpretation was performed after the definition of rock units and possible deformation zones in the boreholes.

The last 1.99 m (297.97–299.96 m) of KFR106 was mapped without access to BIPS-image.

5 Results

The results of the geological single-hole interpretation of HFR106 and KFR106 are presented as print-outs from the software WellCAD in Appendix 1.

5.1 KFR106

The coordinates at T.O.C is 6701541 N, 1633592 E and the direction is 195.1°/–69.9° (RT 90 2.5 gon V 0:-15). The elevation is 1.1 m (RHB70).

Rock Units

The borehole can be divided into three different rock units, RU1–RU3. Rock unit 2 occurs in two separate length intervals. All rock units have been interpreted with a high degree of confidence.

9.11–36.50 m

RU1: Pegmatitic granite (101061), fine- to medium-grained granite (111058) and fine- to medium-grained metagranitoid (101051) in approximate equal proportions. Subordinate occurrence of metagranite-granodiorite (101057) and one minor occurrence of amphibolite and one of felsic to intermediate metavolcanic rock (103076). Confidence level = 3.

36.50–116.12 m

RU2a: Metagranite-granodiorite (101057) locally with a considerable amount of muscovite. Subordinate occurrences of felsic to intermediate metavolcanic rock (103076), pegmatitic granite (101061) and amphibolite (102017). One minor occurrence of fine- to medium-grained granite (111058). Confidence level = 3.

116.12–139.28 m

RU3: Pegmatitic granite (101061). Confidence level = 3.

139.28–299.96 m

RU2b: Metagranite-granodiorite (101057) generally with a considerable amount of muscovite. Subordinate occurrences of pegmatitic granite (101061), fine- to medium-grained granite (111058), amphibolite (102017) and felsic to intermediate metavolcanic rock (103076). One occurrence of quartz dissolution at 285.59–289.74 m, which partly corresponds to decreased density. However, there are no anomalies in the resistivity data. Confidence level = 3.

Possible deformation zones

Seven possible deformation zones of brittle character have been interpreted in KFR106, one with a medium degree of confidence and the other six with a high degree of confidence.

15–20 m

DZ1: There are a few distinct open fractures with apertures up to 10 mm. Breccia at a very low alpha angle, parallel to the borehole axis between 16.68 m (218°/88°) –17.41 m (055°/70°), 18.60 m (062°/79°) –19.38 m (066°/87°) and 19.40 m (068°/85°) –19.53 m (081/85). Generally faint oxidation and locally weak argillization. Predominant minerals in sealed and open fractures are calcite and chlorite. Distinct decrease in the bulk resistivity and significant caliper anomalies. The density is also significantly decreased. Pegmatitic granite (101061). Confidence level = 3.

Diffuse flow in a zone at about 16–19 m. The transmissivity of the section is moderate, about $5 \cdot 10^{-7}$ m^2/s.

36.5–52 m

DZ2: Increased frequency of open and especially sealed fractures. Two minor crush intervals at 37.51–37.54 and 46.05–46.08 m. Fracture apertures generally 0.5 mm or less, locally up to 4 mm. Locally faint to medium oxidation. Predominant minerals in open fractures are chlorite, calcite, clay minerals, oxidized walls, laumontite and hematite; in sealed fractures calcite, laumontite, chlorite, oxidized walls and adularia. Three radar reflectors occur of which one is oriented at 41 m borehole length (239°/20°). There are no major anomalies in the geophysical logging data. However, in the Section 39–45 m there are minor caliper and a few narrow low resistivity anomalies. Metagranite-granodiorite (101057), felsic to intermediate metavolcanic rock (103076), pegmatitic granite (101061) and amphibolite (102017). Confidence level = 2.

High transmissivity of the interval 37–42 m, the most significant flow anomaly at 37.6 m. The total transmissivity of the section is $3 \cdot 10^{-6}$ m^2/s.

67–73 m

DZ3: Locally increased frequency of open and sealed fractures. One minor crush at 69.38–69.42 m and one ductile shear zone at 69.25–69.99 m (256°/44°). Fracture apertures generally between 0.5 and 1.5 mm with one example up to 12 mm. No alteration. Predominant minerals in open fractures are calcite, chlorite, clay minerals, laumontite and oxidized walls. In sealed fractures calcite, oxidized walls, laumontite and chlorite. One radar reflector interpreted without orientation at 72 m. A few narrow low resistivity anomalies and one distinct fluid temperature anomaly, that in combination indicate the occurrence of water bearing fractures. Metagranite-granodiorite (101057), felsic to intermediate metavolcanic rock (103076) and pegmatitic granite (101061). Confidence level = 3.

Very high transmissivity of the interval 68–73 m. A number of flow anomalies, with the dominating anomaly at 68.3 m. The total transmissivity of the section is $3 \cdot 10^{-5}$ m^2/s.

84.5–86.0 m

DZ4: Increased frequency of open fractures. Fractures apertures generally between 0.5 and 1 mm, one example up to 6 mm. No alteration. Dominating minerals in the open fractures are chlorite, calcite and clay minerals. One radar reflector at 85 m (089°/13° or 280°/53°). One narrow low resistivity anomaly and one distinct fluid temperature anomaly, which in combination indicate the occurrence of water bearing fractures. Metagranite-granodiorite (101057) and pegmatitic granite (101061). Confidence level = 3.

Two flow anomalies, with the dominating anomaly at 85.4 m. The total transmissivity of the section is very high, $2 \cdot 10^{-5}$ m^2/s.

100.5–101 m

DZ5: Increased frequency of open fractures. Fractures apertures generally between 0.5 and 5 mm. No alteration. Dominating minerals in the open fractures are clay minerals, oxidized walls and chlorite. One narrow low resistivity anomaly, one caliper anomaly and a distinct fluid temperature anomaly, which in combination indicate the occurrence of water bearing fractures. Metagranite-granodiorite (101057). Confidence level = 3.

One very high-transmissive flow anomaly at 100.7 m. The transmissivity of the section is $2 \cdot 10^{-5}$ m^2/s.

153–157 m

DZ6: Local increased frequency of open fractures. Crushed interval at 156.08–156.24 m. Fracture apertures between 0.5 and 6 mm. No alteration. Dominating minerals in open fractures are calcite, clay minerals and chlorite. There are also a few fractures with pyrite and unidentified sulfides. One oriented radar reflector at 157 m (292°/61° or 122°/20°). Two narrow low resistivity anomalies, two caliper anomalies and a distinct fluid temperature anomaly, which in combination indicate the occurrence of water bearing fractures. Metagranite-granodiorite (101057), felsic to intermediate metavolcanic rock (103076) and amphibolite (102017). Confidence level = 3.

Very high transmissivity. A number of flow anomalies, with the dominating anomaly at 156.0 m. The total transmissivity of the section is $>2 \cdot 10^{-5}$ m^2/s.

256–266 m

DZ7: Increased frequency of sealed and locally open fractures. One crush at 262.68–262.83 m, and one breccia at 262.81 m (294°/55°) – 263.43 m (327°/70°). Fracture apertures generally 0.5 mm or less, locally up to 3 mm. Locally faint to weak oxidation, faint argillization and faint epidotization. Dominating minerals in sealed fractures are calcite, chlorite, clay minerals, oxidized walls, quartz, epidote and hematite; in open fractures clay minerals, calcite, chlorite and hematite. Three radar reflectors of which one is oriented at 262 m (330°/81°). Significantly decreased bulk resistivity, one significant caliper anomaly and a minor, but distinct fluid temperature anomaly. Metagranite-granodiorite (101057) and pegmatitic granite (101061). Confidence level = 3.

One high-transmissive flow anomaly at 262.7 m. The transmissivity of the section is $8 \cdot 10^{-6}$ m^2/s.

5.2 HFR106

The coordinates at T.O.C is 6701574 N, 1633580 E and the direction is 269.4°/–60.9° (RT 90 2.5 gon V 0:-15). The elevation is 1.3 m (RHB70).

Rock Units

The borehole can be divided into three different rock units, RU1–RU3. Rock units 2 and 3 both occur in two separate length intervals. One section of these rock units has been interpreted with a medium degree of confidence and the other four with a high degree of confidence.

9.03–25.13 m

RU1: Pegmatitic granite (101061). Confidence level = 3.

25.13–63.92 m

RU2a: Metagranite-granodiorite (101057). Subordinate occurrences of felsic to intermediate metavolcanic rock (103076) and pegmatitic granite (101061). Confidence level = 3.

63.92–110.74 m

RU3a: Metagranite-granodiorite (101057) and pegmatitic granite (101061) in approximate equal proportions. Subordinate occurrences of felsic to intermediate metavolcanic rock (103076), one occurrence of fine- to medium-grained granite (111058) and one of amphibolite (102017). Confidence level = 3.

110.74–161.01 m

RU2b: Metagranite-granodiorite (101057) with subordinate occurrences of felsic to intermediate metavolcanic rock (103076) and pegmatitic granite (101061). Confidence level = 3.

161.01–190.10 m

RU3b: Metagranite-granodiorite (101057) and pegmatitic granite (101061) in approximate equal proportions. Confidence level = 2.

Possible deformation zones

Three possible deformation zones of brittle character have been interpreted in HFR106, two with a low degree of confidence and the third with a high degree of confidence.

38–40 m

DZ1: Notable open fractures with apertures up to 6 mm. No alteration. One non-oriented radar reflector at 38 m. Distinct decrease in the bulk resistivity and significant caliper anomalies. Metagranite-granodiorite (101057). Confidence level = 1.

One flow anomaly at 38.0–40.0 m. The transmissivity of the section is very high, $3 \cdot 10^{-5}$ m^2/s.

158–162 m

DZ2: No clear indications in the BIPS-image. However, there is a distinct decrease in the bulk resistivity and there are significant caliper anomalies. Metagranite-granodiorite (101057), pegmatitic granite (101061) and felsic to intermediate metavolcanic rock (103076). Confidence level = 1.

No flow anomaly observed in this section (however, there may be flow below the lower measurement limit which was relatively high in this case).

177–182 m

DZ3: Distinct increase in fracture frequency. One brittle-ductile shear zone at 178.05 m (322°/88°) –178.27 m (331°/84°) and one breccias at 178.39 m (332°/82°) –178.74 m (326°/82°). Fracture apertures generally 0.5 to 2 mm, with one example of 8 mm. Locally weak oxidation. At 179.0 m borehole length there is one narrow low resistivity anomaly, one caliper anomaly and a minor but distinct fluid temperature anomaly, that in combination indicate the occurrence of water bearing fractures. Metagranite-granodiorite (101057), pegmatitic granite (101061). Confidence level = 3.

One flow anomaly at 177.3–178.5 m. The transmissivity of the section is very high, $2 \cdot 10^{-5}$ m^2/s.

References

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Winell S, 2010b. Site investigation SFR. Boremap mapping of percussion drilled borehole HFR106. SKB P-10-10 (in progress), Svensk Kärnbränslehantering AB.

WellCAD image

Title	SINGLE HOLE INTERPRETATION HFR106					
Site	FORSMARK - SFR	Inclination [°]	-60.9	Elevation [m.a.s.l.]	1.3	Signed data
Borehole	HFR106	Date of mapping	2009-11-11 14:24:00	Drilling Start Date	2009-06-24 07:45:00	
Diameter [mm]	139	Coordinate System	RT90-RHB70	Drilling Stop Date	2009-07-02 10:00:00	
Length [m]	190.400	Northing [m]	6701574	Surveying Date		
Bearing [°]	269.4	Easting [m]	1633580	Plot Date	2010-04-07 23:01:32	

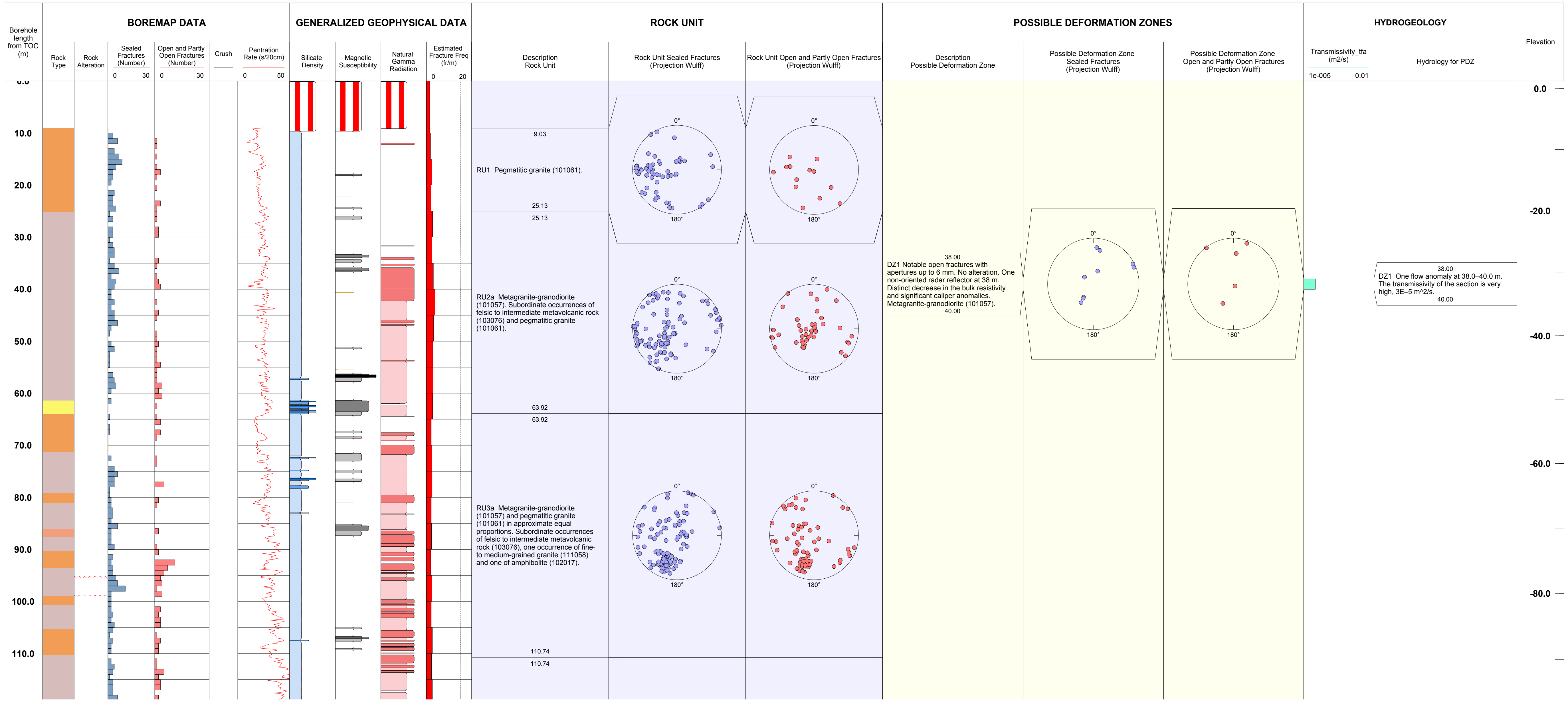
ROCKTYPE FORSMARK - SFR
- Granite, fine- to medium-grained
- Pegmatite, pegmatitic granite
- Granite to granodiorite, metamorphic, medium-grained
- Felsic to intermediate volcanic rock, metamorphic

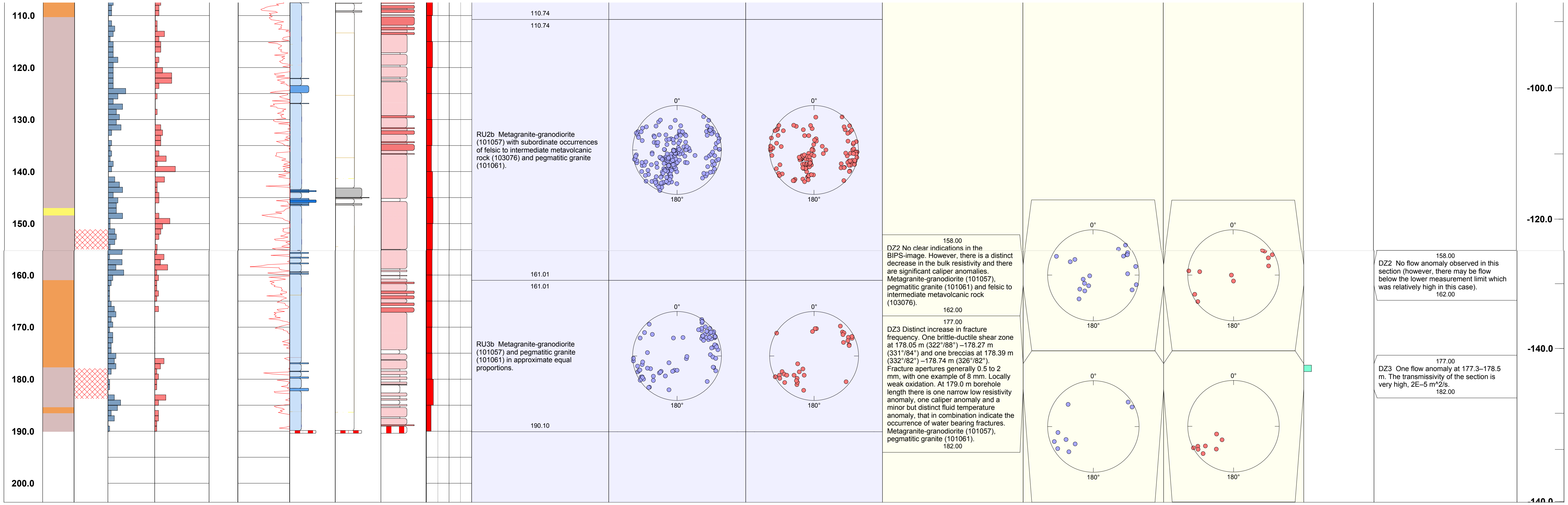
ROCK ALTERATION
- Oxidized
- Albitization

SILICATE DENSITY (kg/m³)
- unclassified
- dens<2680 (Granite)
- 2680<dens<2730 (Granodiorite)
- 2730<dens<2800 (Tonalite)

SUSCEPTIBILITY (SI)
- unclassified
- sus<0.001
- 0.001<sus<0.01
- 0.01<sus<0.1
- sus>0.1

NATURAL GAMMA (μR/h)
- unclassified
- gam<20
- 20<gam<36
- 36<gam<53




110.0
120.0
130.0
140.0
150.0
160.0
170.0
180.0
190.0
200.0
110.74
110.74
RU2b Metagranite-granodiorite (101057) with subordinate occurrences of felsic to intermediate metavolcanic rock (103076) and pegmatitic granite (101061).
161.01
161.01
RU3b Metagranite-granodiorite (101057) and pegmatitic granite (101061) in approximate equal proportions.
190.10
0°
180°
158.00
DZ2 No clear indications in the BIPS-image. However, there is a distinct decrease in the bulk resistivity and there are significant caliper anomalies. Metagranite-granodiorite (101057), pegmatitic granite (101061) and felsic to intermediate metavolcanic rock (103076).
162.00
177.00
DZ3 Distinct increase in fracture frequency. One brittle-ductile shear zone at 178.05 m (322°/88°) –178.27 m (331°/84°) and one breccias at 178.39 m (332°/82°) –178.74 m (326°/82°). Fracture apertures generally 0.5 to 2 mm, with one example of 8 mm. Locally weak oxidation. At 179.0 m borehole length there is one narrow low resistivity anomaly, one caliper anomaly and a minor but distinct fluid temperature anomaly, that in combination indicate the occurrence of water bearing fractures. Metagranite-granodiorite (101057), pegmatitic granite (101061).
182.00
158.00
DZ2 No flow anomaly observed in this section (however, there may be flow below the lower measurement limit which was relatively high in this case).
162.00
177.00
DZ3 One flow anomaly at 177.3–178.5 m. The transmissivity of the section is very high, 2E–5 m^2/s.
182.00
-100.0
-120.0
-140.0

Title	SINGLE HOLE INTERPRETATION KFR106					
Site	FORSMARK - SFR	Inclination [°]	-69.9	Elevation [m.a.s.l.]	1.06	Signed data
Borehole	KFR106	Date of mapping	2009-09-28 10:49:00	Drilling Start Date	2009-06-23 08:04:00	
Diameter [mm]	76	Coordinate System	RT90-RHB70	Drilling Stop Date	2009-06-23 10:56:00	
Length [m]	300.130	Northing [m]	6701541	Surveying Date		
Bearing [°]	195.1	Easting [m]	1633592	Plot Date	2010-04-07 23:01:32	

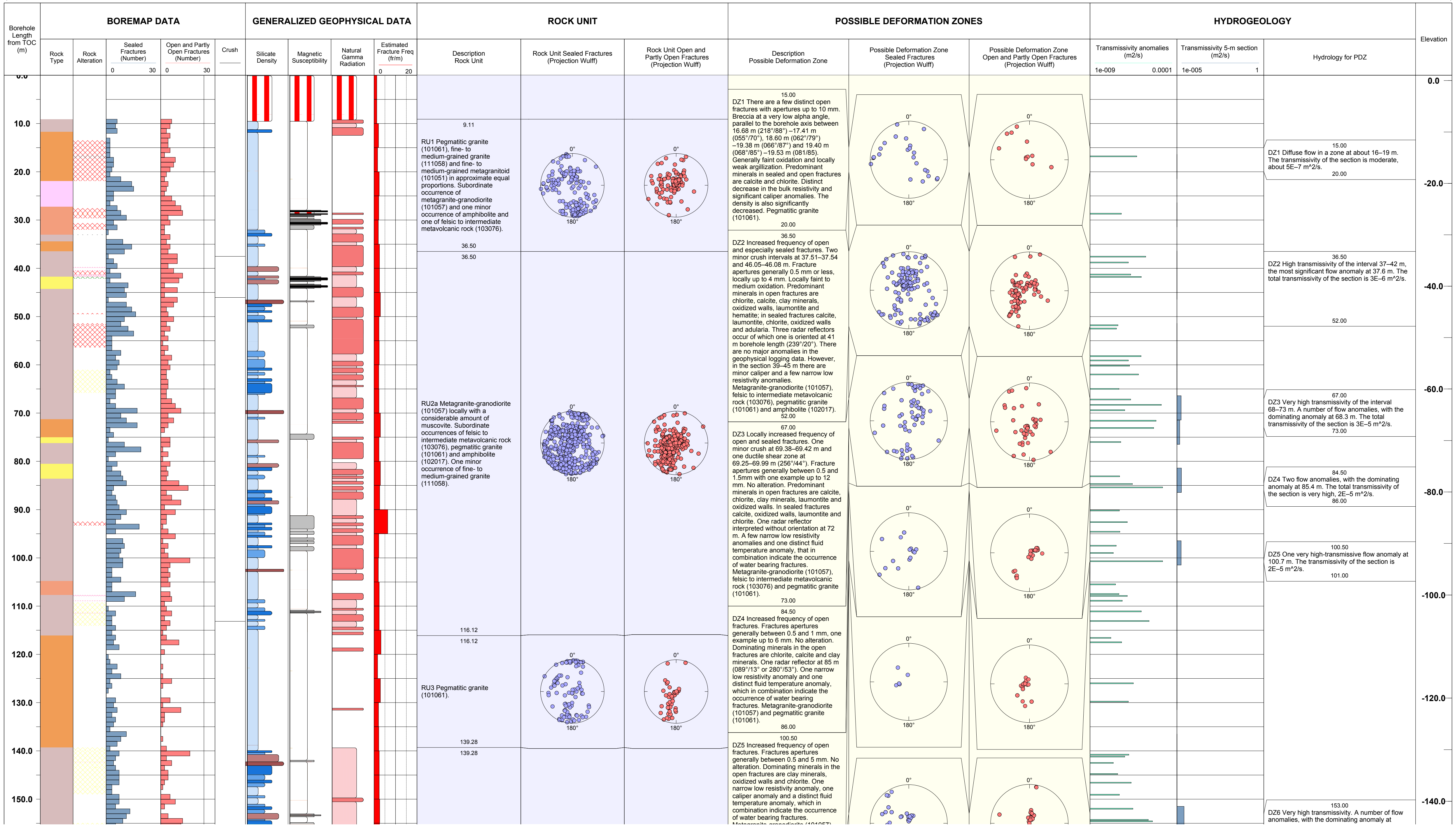
ROCKTYPE FORSMARK - SFR
- Granite, fine- to medium-grained
- Pegmatite, pegmatitic granite
- Granite, granodiorite and tonalite, metamorphic, fine- to medium-grained
- Granite to granodiorite, metamorphic, medium-grained
- Amphibolite
- Felsic to intermediate volcanic rock, metamorphic

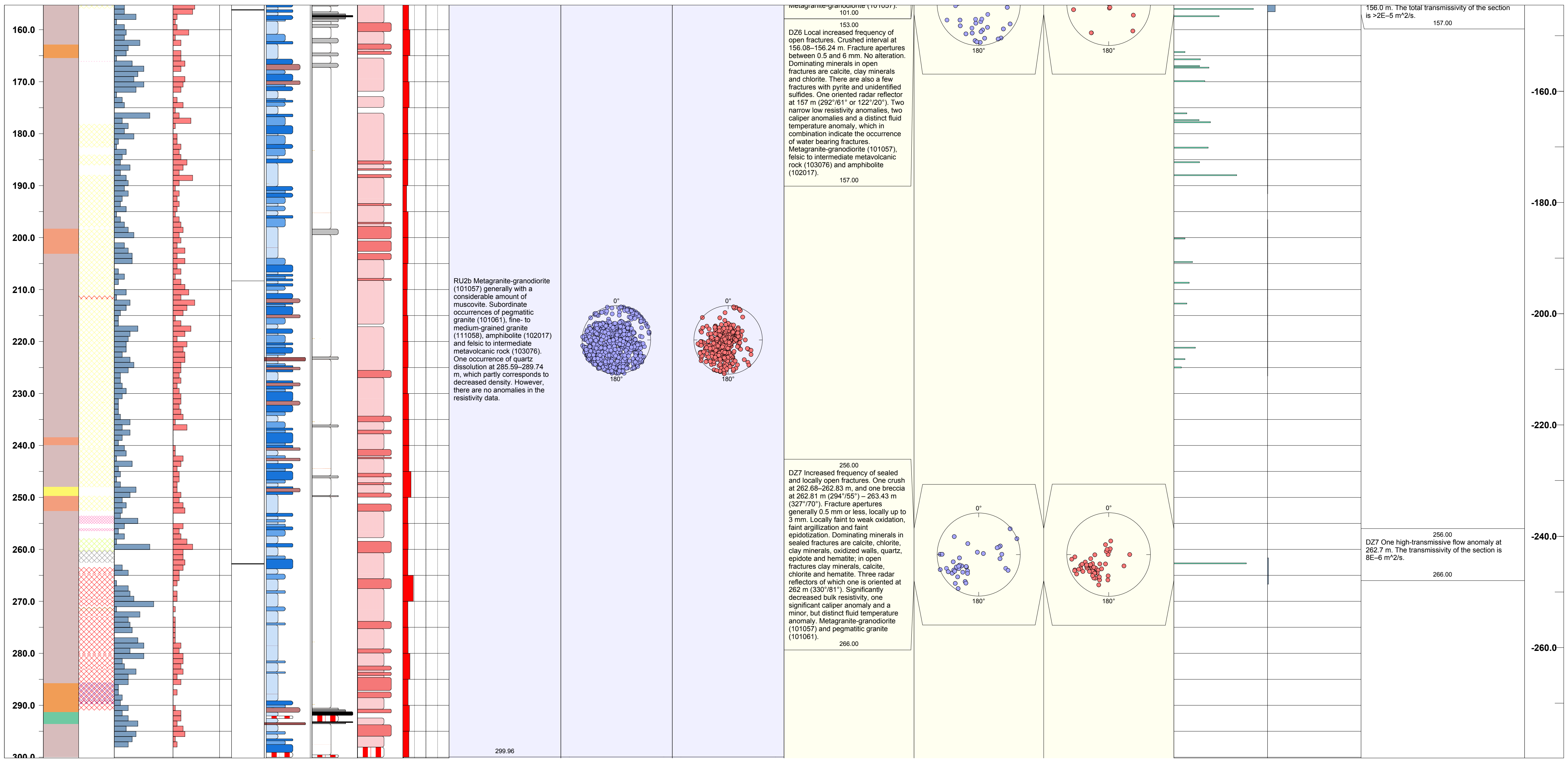
ROCK ALTERATION
- Oxidized
- Chloritisized
- Epidotisized
- Sericitisized
- Quartz dissolution
- Argillization
- Albitization
- Carbonatization
- Laumontitization

SILICATE DENSITY (kg/m³)
- unclassified
- dens<2680 (Granite)
- 2680<dens<2730 (Granodiorite)
- 2730<dens<2800 (Tonalite)
- 2800<dens<2890 (Diorite)
- dens>2890 (Gabbro)

SUSCEPTIBILITY (SI)
- unclassified
- sus<0.001
- 0.001<sus<0.01
- 0.01<sus<0.1
- sus>0.1

NATURAL GAMMA (μR/h)
- unclassified
- 20<gam<36
- 36<gam<53




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
RU2b Metagranite-granodiorite (101057) generally with a considerable amount of muscovite. Subordinate occurrences of pegmatitic granite (101061), fine- to medium-grained granite (111058), amphibolite (102017) and felsic to intermediate metavolcanic rock (103076). One occurrence of quartz dissolution at 285.59–289.74 m, which partly corresponds to decreased density. However, there are no anomalies in the resistivity data.
299.96
0°
180°
0°
180°
Metagranite-granodiorite (101057).
101.00
153.00
DZ6 Local increased frequency of open fractures. Crushed interval at 156.08–156.24 m. Fracture apertures between 0.5 and 6 mm. No alteration. Dominating minerals in open fractures are calcite, clay minerals and chlorite. There are also a few fractures with pyrite and unidentified sulfides. One oriented radar reflector at 157 m (292°/61° or 122°/20°). Two narrow low resistivity anomalies, two caliper anomalies and a distinct fluid temperature anomaly, which in combination indicate the occurrence of water bearing fractures. Metagranite-granodiorite (101057), felsic to intermediate metavolcanic rock (103076) and amphibolite (102017).
157.00
256.00
DZ7 Increased frequency of sealed and locally open fractures. One crush at 262.68–262.83 m, and one breccia at 262.81 m (294°/55°) – 263.43 m (327°/70°). Fracture apertures generally 0.5 mm or less, locally up to 3 mm. Locally faint to weak oxidation, faint argillization and faint epidotization. Dominating minerals in sealed fractures are calcite, chlorite, clay minerals, oxidized walls, quartz, epidote and hematite; in open fractures clay minerals, calcite, chlorite and hematite. Three radar reflectors of which one is oriented at 262 m (330°/81°). Significantly decreased bulk resistivity, one significant caliper anomaly and a minor, but distinct fluid temperature anomaly. Metagranite-granodiorite (101057) and pegmatitic granite (101061).
266.00
180°
180°
0°
180°
0°
180°
156.0 m. The total transmissivity of the section is >2E–5 m^2/s.
157.00
256.00
DZ7 One high-transmissive flow anomaly at 262.7 m. The transmissivity of the section is 8E–6 m^2/s.
266.00
-160.0
-180.0
-200.0
-220.0
-240.0
-260.0