P-09-60

Site investigation SFR

Geological single-hole interpretation of KFR102A

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October 2009

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Keywords: P-report SKBDoc id 1222920, Review statement, SKBDoc id 1222921, KFR102A, Geology, Bedrock, Borehole, Fractures, Forsmark, Geophysics, Hydrogeology, Radar, AP SFR-08-009, Project SFR extension.

Abstract

This report presents the geological single-hole interpretations of the cored borehole KFR102A at 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 KFR102A has been divided into six different rock units, RU1–RU6, of which RU2 and RU4 occur in two and three separate length intervals, respectively. The predominant rock type in RU2 and RU4 are moderately to strongly foliated metagranite-granodiorite (101057) with subordinate amounts of pegmatitic granite (101061) and fine- to medium-grained granite (111058). Rock unit 3 and RU6 include also considerable amount of amphibolite (102017), whereas RU1 generally consists of pegmatitic granite (101061). Minor intervals of quarts dissolution occur between 440 and 479 m.

Three possible deformation zones of brittle character have been interpreted in KFR102A (DZ1–DZ3), one with a medium degree of confidence and the other two with a high degree of confidence.

Sammanfattning

Denna rapport presenterar den geologiska enhålstolkningen från kärnborrhålet KFR102A i anslutning till 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 KFR102A har delats upp i sex litologiska enheter, RU1–RU6, av vilka RU2 och RU4 vardera förekommer i två respektive tre separata längdintervall. Den dominerande bergarten i RU2 och RU4 är måttligt till starkt folierad metagranit-granodiorit (101057) med underordnade mängder pegmatitisk granit (101061) och fin- till medelkornig granit (111058). RU4 och RU6 inkluderar också betydande mängder amfibolit (102017), medan RU1 uteslutande består av pegmatitisk granit (101061).

Tre möjliga deformationszoner av spröd karaktär har tolkats i KFR102A (DZ1–DZ3), en med medelhög grad av tillförlitlighet och de andra två 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 intermediate-level radioactive operational waste, SFR. An essential part in this project is the drilling of three percussion drilled and six core drilled boreholes. Each borehole should be thoroughly documented by means of geological mapping by the so-called Boremap system, as well as geophysical and radar borehole measurements. After storage in the SKB database Sicada, the data needs to be integrated and synthesized before they can be used 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 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 KFR102A. The horizontal projection of the borehole is shown in Figure 1-1.

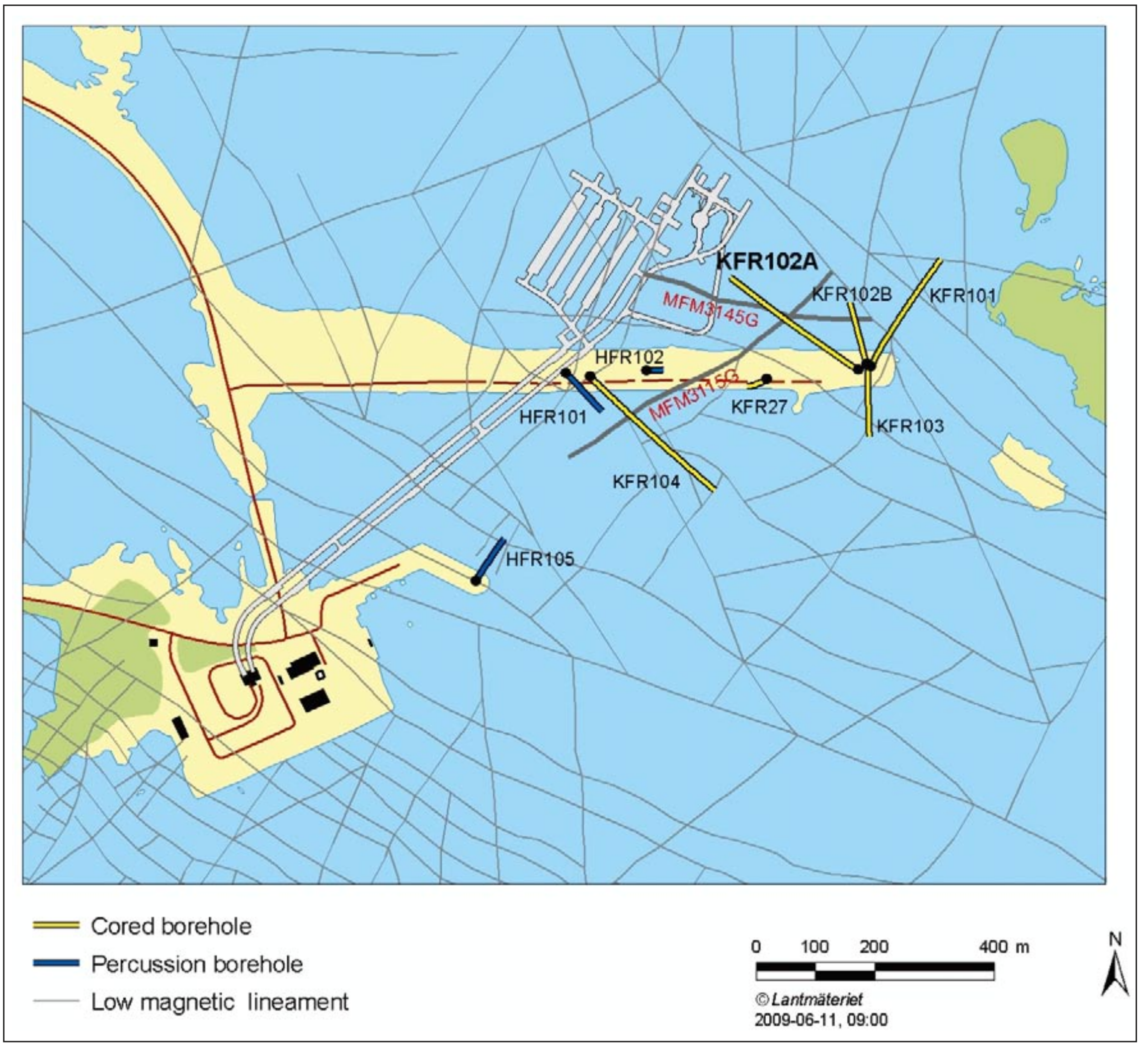


Figure 1-1. Map showing position and horizontal projection of the cored borehole KFR102A relative to SFR and other boreholes in the drilling programme.

The work was carried out in accordance with activity plan AP SFR-08-009. 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.

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

Activity plan	Number	Version
Geologisk enhålstolkning av hammarborrhål HFR101, HFR102, HFR105 samt kärnborrhål KFR27, KFR101, KFR102A, KFR102B, KFR103 och KFR104	AP SFR-08-009	1.0
Method description	**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 the 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 KFR102A:

- Boremap data (including BIPS-image and geological mapping) /Winell et al. 2009/.
- 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 /Hurmerinta and Väisäsvaara 2009/.

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. The latter was included after that the geological single-hole interpretation was performed, i.e. the rock units and the possible deformation zones were defined. 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.

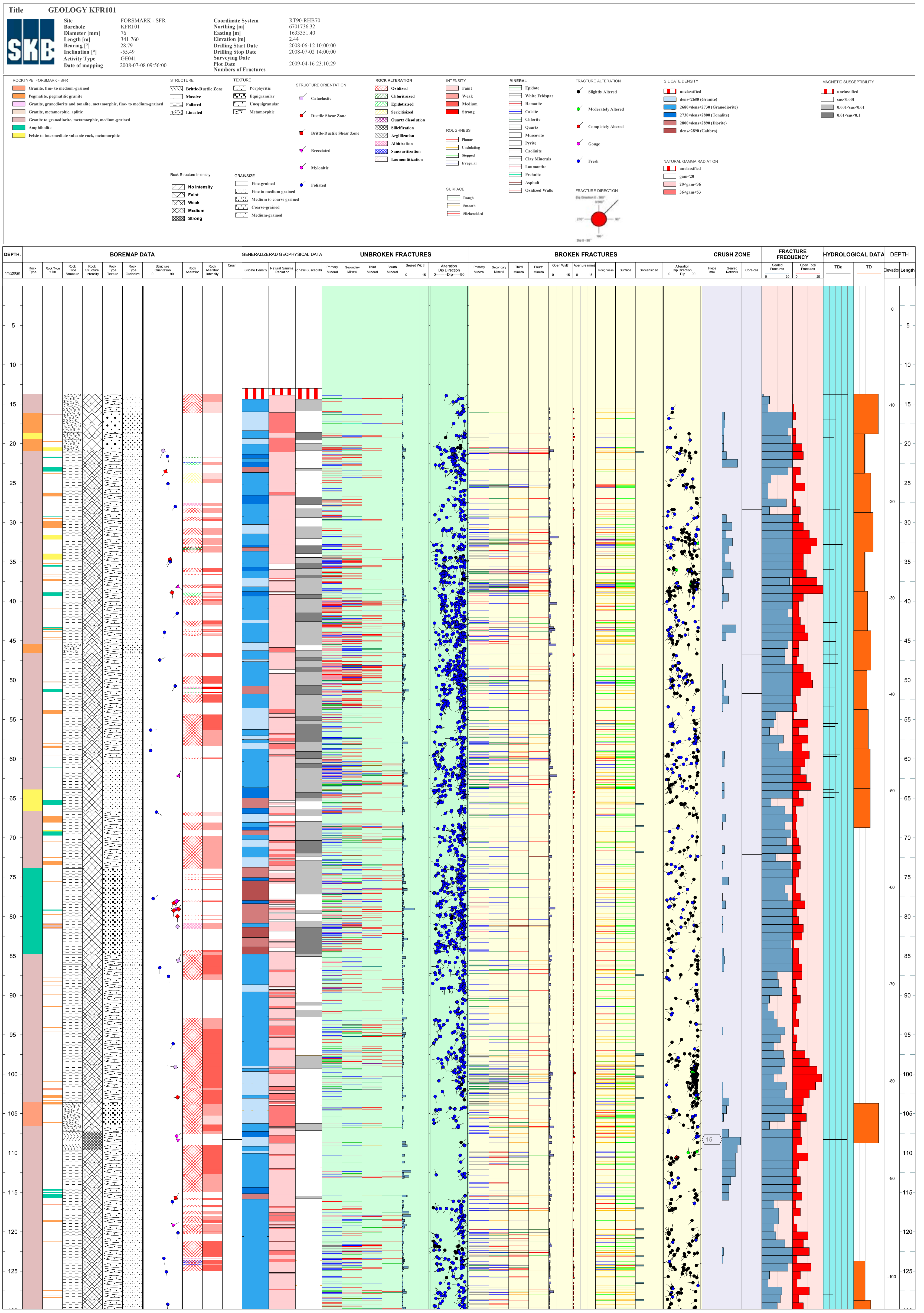


Figure 3-1. Example of WellCAD plot (from borehole KFR101) used as basis for the geological single-hole interpretation.

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 less. 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 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 eight 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.

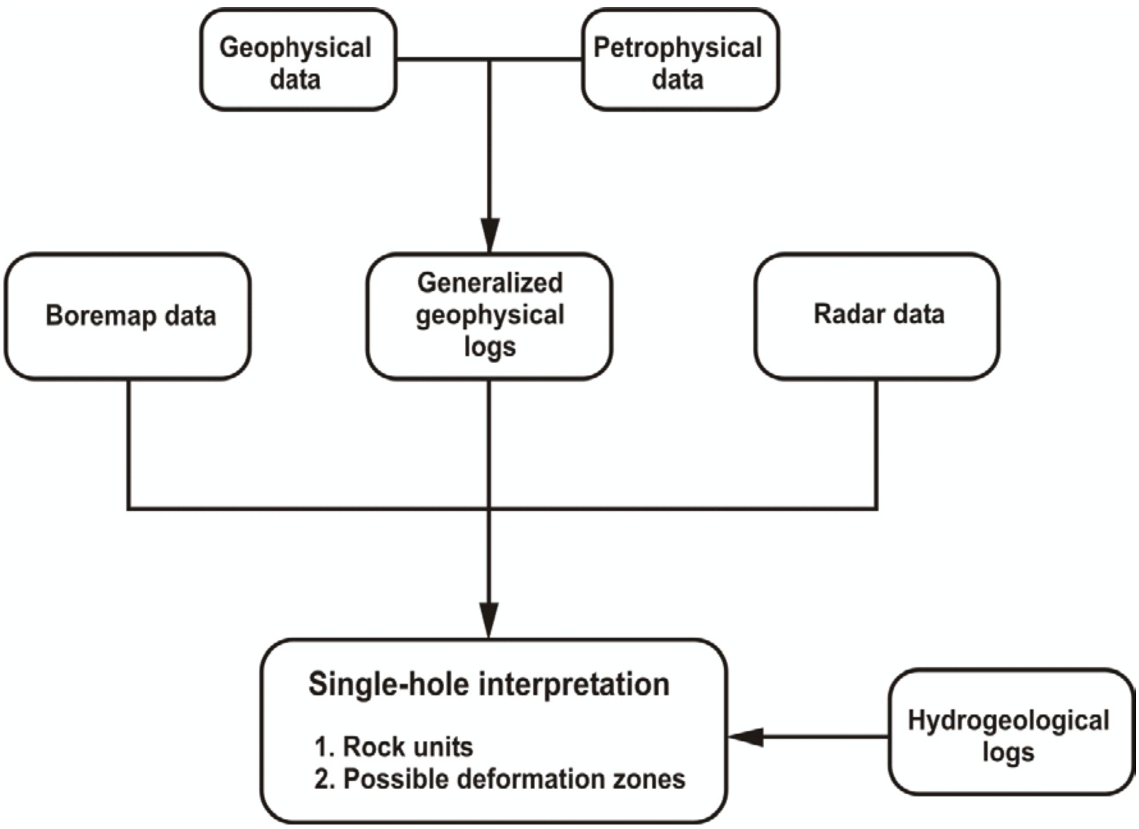


Figure 4-1. Schematic chart showing the procedure for the development of a geological single-hole interpretation.

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 transitional part, with a fracture frequency in the range 4–9 fractures/m, and the core 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, orientation of 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 KFR102A (Figure 4-3). A 5 m window and 1 m steps 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, based on 20 MHz dipole data, is presented in Figure 4-4. Along some intervals in the borehole, e.g. around 310 m and from 420 m to 500 m, the penetration is very limited due to relatively high electrical conductivity. The effect of attenuation varies between the different antenna frequencies (in this case 20 MHz dipole and 60 MHz directional antenna). 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.

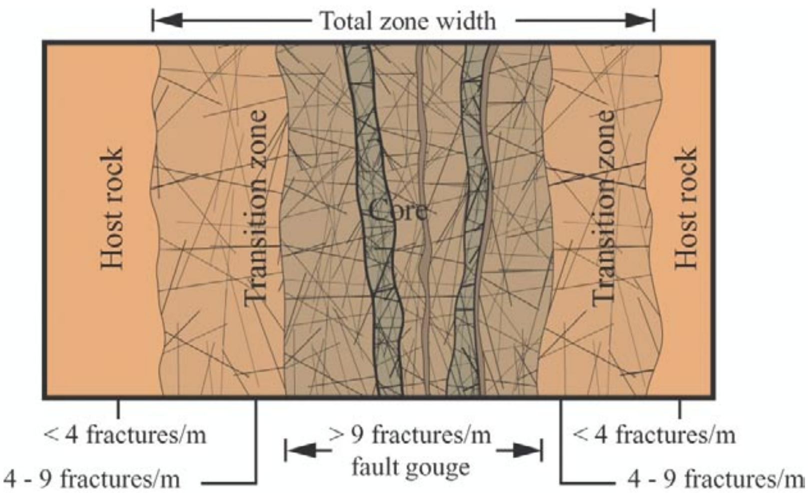


***Figure 4-2.** Schematic illustration of the structure of a brittle deformation zone. After /Munier et al. 2003/.*

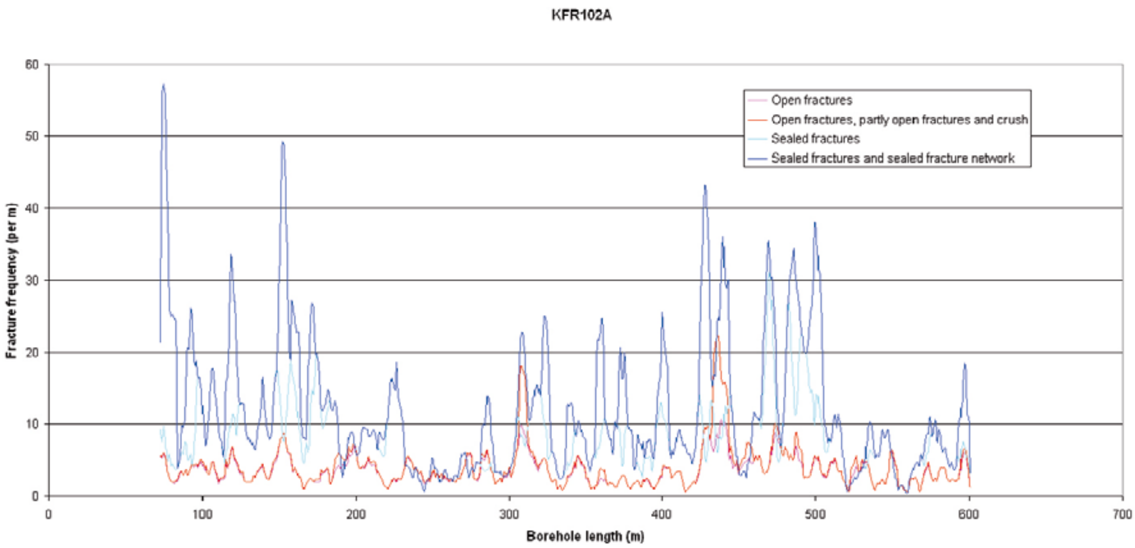


Figure 4-3. Fracture frequency plot for KFR102A. Moving average with a 5 m window and 1 m steps.

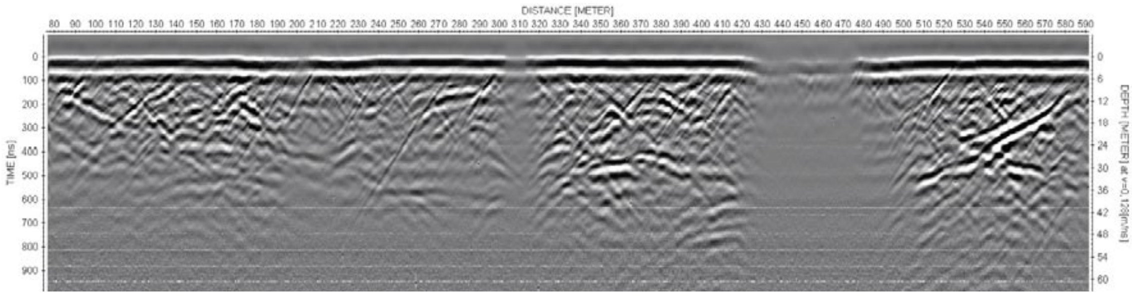


Figure 4-4. An overview (20 MHz data) of the radar data for the borehole KFR102A. Horisontal scale shows borehole length and vertical scale the distance from the borehole. Observe the sub-parallel structure, visible in the lower half of the borehole.

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.

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

The intervals 70.44–71.92 and 599.34–600.84 m of KFR102A was mapped without access to BIPS-image.

5 Results

The results of the geological single-hole interpretation of KFR102A are presented as print-outs from the software WellCAD in Appendix 1.

5.1 KFR102A

The orientation at the beginning of the borehole is 302.3°/–65.4°.

Rock Units

The borehole can be divided into six different rock units, RU1–RU6. Rock units 2 and 4 occur in two and three separate length intervals, respectively. All rock units have been interpreted with a high degree of confidence.

70.44–90.70 m

RU1: Pegmatitic granite (101061) and in the upper most part fine to medium-grained granite (111058). Confidence level = 3.

90.70–177.10 m

RU2a: Moderately foliated metagranite-granodiorite (101057) with subordinate pegmatitic granite (101061), fine- to medium-grained granite (111058) and very minor felsic to intermediate metavolcanic rock (103076) and amphibolite (102017). Confidence level = 3.

177.10–233.80 m

RU3: Moderately foliated metagranite-granodiorite (101057) and amphibolite (102017) in approximate equal proportions with subordinate pegmatitic granite (101061), felsic to intermediate metavolcanic rock (103076) and fine- to medium-grained granite (111058). Confidence level = 3.

233.80–287.04 m

RU4a: Moderately foliated metagranite-granodiorite (101057) with subordinate pegmatitic granite (101061) and fine- to medium-grained granite (111058). Confidence level = 3.

287.04–308.84 m

RU5: Fine- to medium-grained granite (111058) with subordinate pegmatitic granite (101061). Confidence level = 3.

308.84–346.06 m

RU4b: Moderately foliated metagranite-granodiorite (101057) with subordinate pegmatitic granite (101061) and in the lower most part fine- to medium-grained granite (111058). Confidence level = 3.

346.06–430.86 m

RU2b: Strongly foliated metagranite-granodiorite (101057) with subordinate pegmatitic granite (101061), fine- to medium-grained granite (111058), felsic to intermediate metavolcanic rock (103076) and very minor amphibolite (102017). Confidence level = 3.

430.86–497.72 m

RU6: Moderately to strongly foliated metagranite-granodiorite (101057), pegmatitic granite (101061) and amphibolite (102017) in approximate equal proportions. Five interval with quartz dissolution at 440.39–440.91, 441.64–441.76, 448.85–458.65, 473.15–474.14 and 478.35–478.42 m. In the interval 450–457 m the density is significantly decreased to c 2,570 kg/m^3. Confidence level = 3.

497.72–600.83 m

RU4c: Strongly foliated metagranite-granodiorite (101057) and pegmatitic granite (101061) in approximately equal proportions. Subordinate occurrence of fine- to medium-grained granite (111058) and one minor amphibolite (102017). Confidence level = 3.

Possible deformation zones

Three possible deformation zones of brittle character have been interpreted in KFR102A, one with a medium degree of confidence and the other two with a high degree of confidence.

149–161 m

DZ1: Increased frequency of open and particularly sealed fractures. No alteration. Fracture apertures 0.5 mm or less. Predominant minerals in sealed and open fractures are laumontite, adularia, calcite and chlorite. One oriented radar reflector at 154 m (315°/63° or 108°/63°). The magnetic susceptibility is decreased along the entire section. There are no other significant anomalies related to increased fracturing in the geophysical logging data. Metagranite-granodiorite (101057). Confidence level = 2.

Two flow anomalies and rather low transmissivity of the section ($T = 1\cdot10^{-8}$ m^2/s).

302–325 m

DZ2: Increased frequency of open and sealed fractures. Fractures aperture generally less than 0.5 mm. Locally faint to medium oxidation. Predominant minerals in open fractures are chlorite, calcite, hematite, clay minerals and laumontite and in sealed fractures calcite, laumontite, chlorite and adularia. The possible deformation zone core 308–310 m is characterized by two fractures with five mm aperture, three minor crushes, argillisation and clay minerals as predominant mineral in open fractures. Two radar reflectors without orientation at 302 and 311 m, and one oriented reflector at 325 m (033°/83° or 213°/32°). The magnetic susceptibility is decreased along the entire section. In the section 307–310 m the resistivity is significantly decreased and there is also a distinct caliper anomaly. There is another clear low resistivity anomaly in the interval 322–325 m. In the section 312–318 m there is a fluid temperature anomaly indicating the occurrence of a water bearing fracture. Metagranite-granodiorite (101057), fine- to medium-grained granite (111058) and pegmatitic granite (101061). Confidence level = 3.

One single medium-transmissive flow anomaly ($T = 2\cdot10^{-8}$ m^2/s) at 309 m, probably related to one, or both, of the 5 mm aperture fractures. Transmissivity below the measurement limit in the rest of the section.

422–503 m

DZ3: Increased frequency of open and sealed fractures in the intervals 422–444 and 461–503 m. Eight crushes with the most extensive at 434.65–435.90 m. Two slickensides. Fracture apertures generally up to 0.5 mm with a few ranging up to 2 mm and a local maximum up to 10 mm. Locally weak to strong oxidation, rarely argillisation, laumontitisation and carbonatitisation. Five intervals with quarts dissolution at 440.39–440.91, 441.64–441.76, 448.85–458.65, 473.15–474.14 and 478.35–478.42 m. Ductile deformation recorded at 466.46–466.09 m (019°/81°) and brittle ductile deformation recorded at 488.86–489.10 m (320°/41°). Predominant minerals in open fractures are chlorite, calcite, hematite, clay minerals, in sealed fractures calcite, quarts, adularia and chlorite and in sealed fracture networks calcite, quartz, chlorite and clay minerals. The entire possible deformation zone is characterised by poor radar penetration. The entire interval 422–503 m is characterized by significantly decreased bulk resistivity, several distinct caliper anomalies and decreased magnetic susceptibility. The most prominent low resistivity anomalies occur in the intervals 434–443, 451–458 and 471–475 m. In the section 450–457 m the density is significantly decreased, c 2,570 kg/m^3. Starting at 427 m the fluid temperature is characterized by several anomalies, and this pattern of anomalies continues through out the entire borehole length. Metagranite-granodiorite (101057), pegmatitic granite (101061) and amphibolite (102017). Confidence level = 3.

No flow anomalies above 427 m. Increased frequency of flow anomalies in the interval 427–458 m. No flow anomalies below 458 apart from one single flow anomaly at 474 m. The total transmissivity of the section is $2 \cdot 10^{-6}$ m^2/s, where the transmissivity is dominated by one single flow anomaly at 427 m ($T = 1 \cdot 10^{-6}$ m^2/s) and a number of flow anomalies at the section 435–441 m ($T = 8 \cdot 10^{-7}$ m^2/s). The character of the inflow indicates porous rock at 451–458 m.

References

Gustafsson J, Gustafsson C, 2009. Site investigation SFR. BIPS-logging in the core drilled boreholes KFR102A, KFR102B, KFR103, KFR104 and KFR27 (140–500 m) and radar logging in KFR27 (0–500 m), KFR102A and KFR104. SKB P-09-11, Svensk Kärnbränslehantering AB.

Hurmerinta E, Väisäsvaara J, 2009. Site investigation SFR. Difference flow logging in borehole KFR102A. SKB P-09-21, Svensk Kärnbränslehantering AB.

Mattsson H, Keisu M, 2009. Site investigation SFR. Interpretation of geophysical borehole measurements from KFR102A, KFR102B, KFR103, KFR104 and KFR27 (0–500 m). SKB P-09-26, Svensk Kärnbränslehantering AB.

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.

Winell S, Carlsten S, Stråhle A, 2009. Site investigation SFR. Boremap mapping of core drilled borehole KFR102A. SKB P-09-52, Svensk Kärnbränslehantering AB. In prep.

WellCAD image

Title SINGLE HOLE INTERPRETATION KFR102A

Site	FORSMARK - SFR	**Inclination [°]**	-65.63	**Elevation [m.a.s.l.]**	2.66	**Signed data**
Borehole	KFR102A	**Date of mapping**	2009-01-22 07:32:00	**Drilling Start Date**	2008-11-25 15:40:00	
Diameter [mm]	76	**Coordinate System**	RT90-RHB70	**Drilling Stop Date**	2008-12-12 18:00:00	
Length [m]	600.830	**Northing [m]**	6701730.30	**Surveying Date**		
Bearing [°]	302.26	**Easting [m]**	1633330.21	**Plot Date**	2009-07-02 23:01:23	

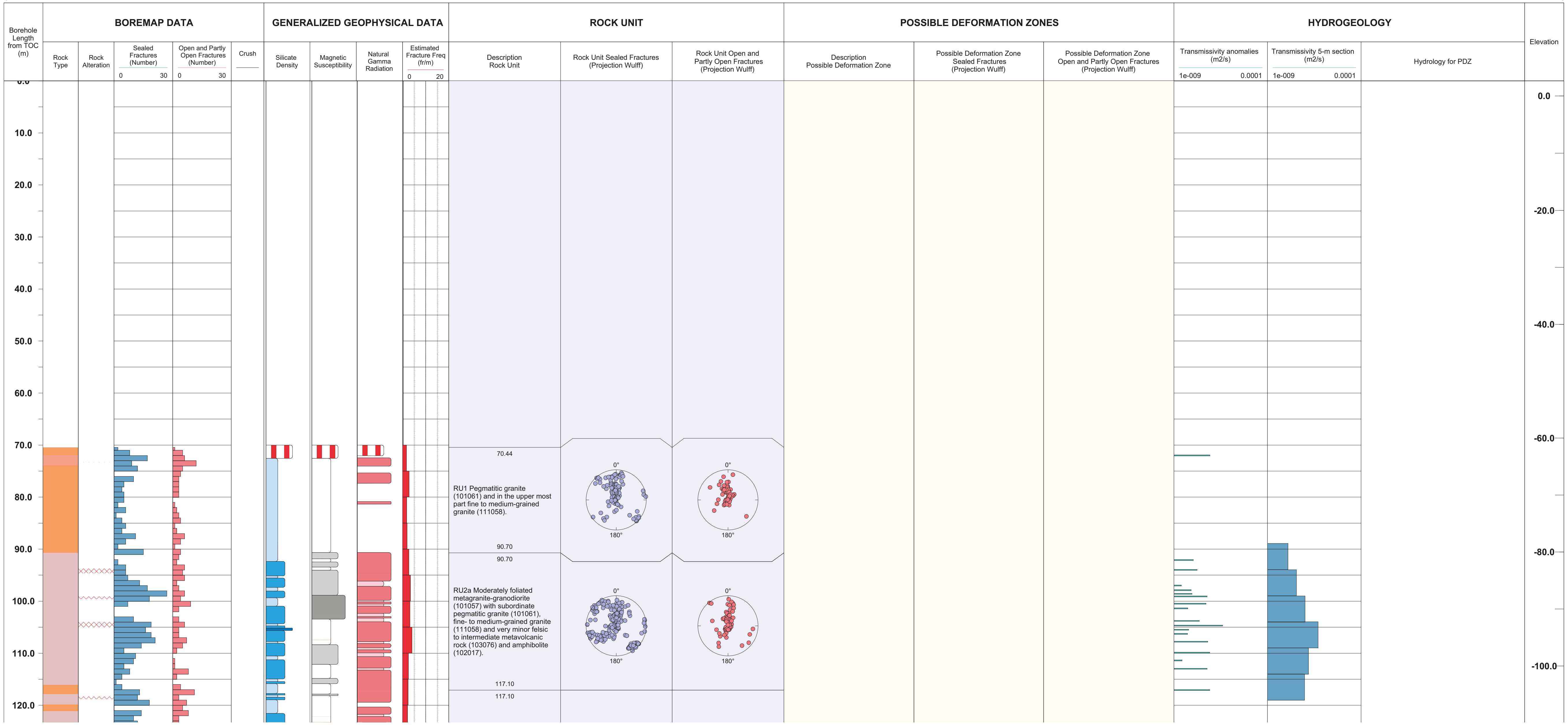
ROCKTYPE FORSMARK - SFR
- Granite, fine- to medium-grained
- Pegmatite, pegmatitic granite
- Granite to granodiorite, metamorphic, medium-grained
- Amphibolite
- Felsic to intermediate volcanic rock, metamorphic

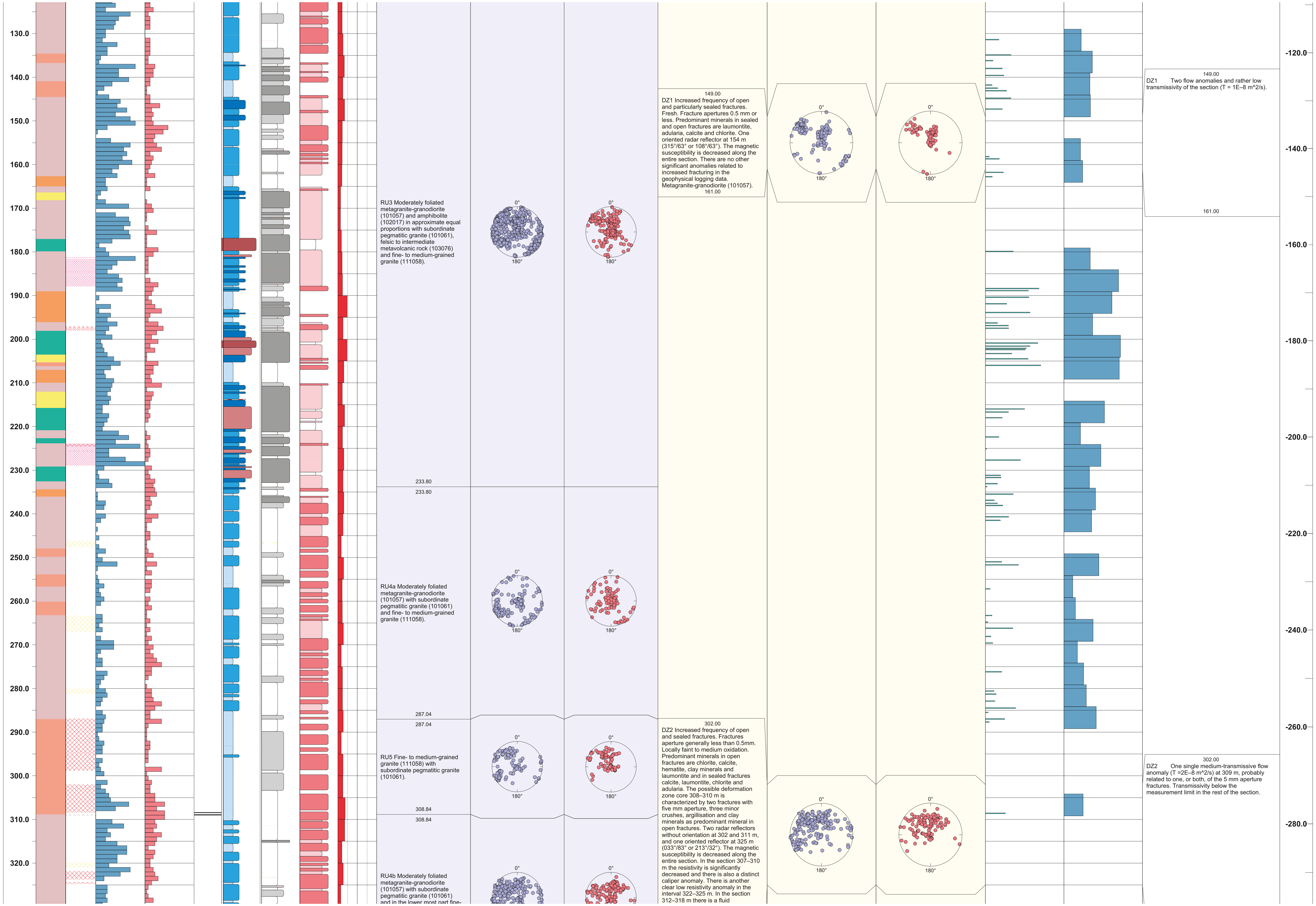
ROCK ALTERATION
- Oxidized
- Epidotisized
- Sericitisized
- Quartz dissolution
- Argillization
- Albitization
- Carbonatization
- Laumontitization

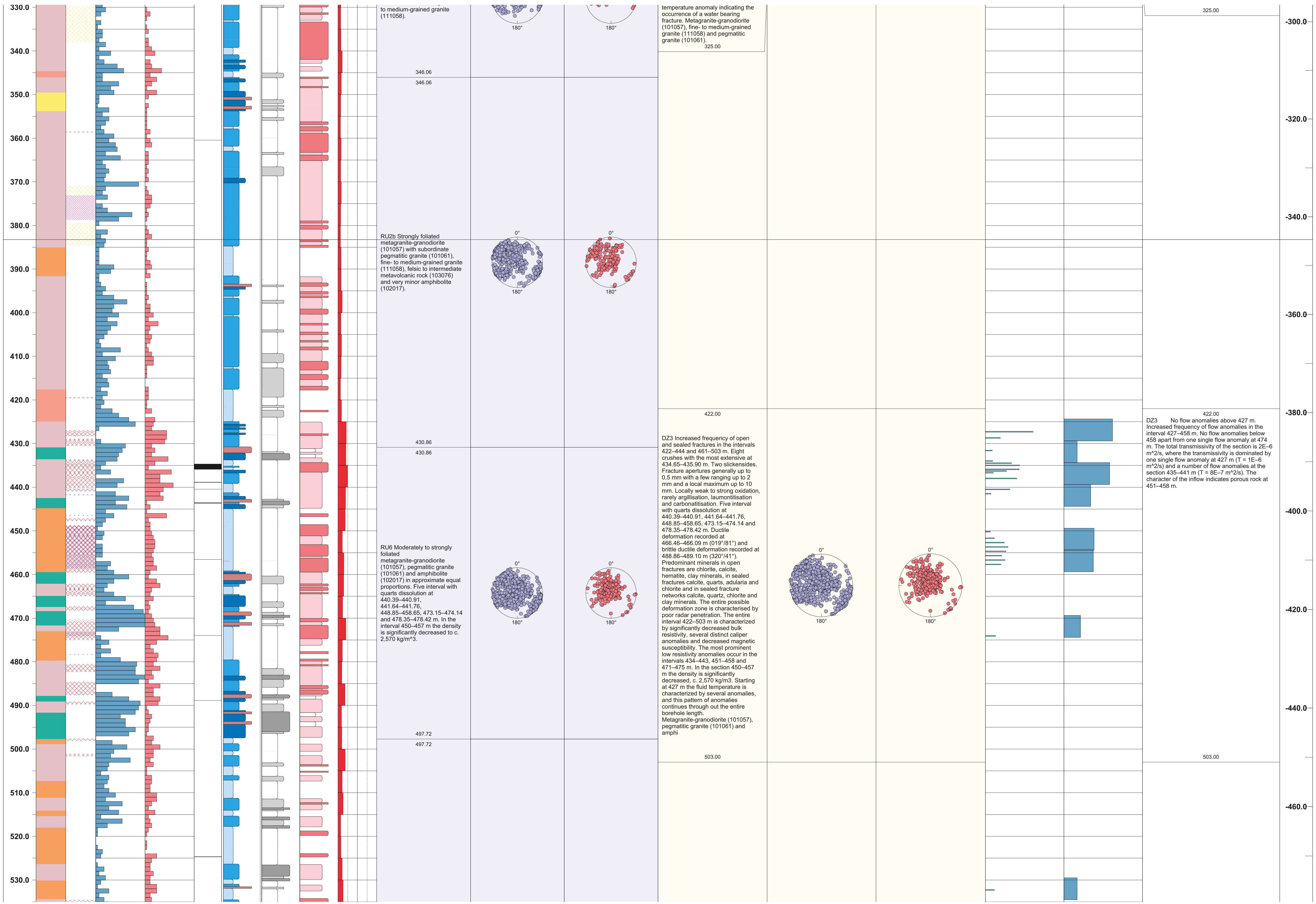
SILICATE DENSITY (kg/m³)
- unclassified
- dens<2680 (Granite)
- 2680<dens<2730 (Granodiorite)
- 2730<dens<2800 (Tonalite)
- 2800<dens<2890 (Diorite)
- dens>2890 (Gabbro)

SUSCEPTIBILITET (SI)
- unclassified
- sus<0.001
- 0.001<sus<0.01
- 0.01<sus<0.1

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




130.0
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
310.0
320.0
RU3 Moderately foliated metagranite-granodiorite (101057) and amphibolite (102017) in approximate equal proportions with subordinate pegmatitic granite (101061), felsic to intermediate metavolcanic rock (103076) and fine- to medium-grained granite (111058).
233.80
233.80
RU4a Moderately foliated metagranite-granodiorite (101057) with subordinate pegmatitic granite (101061) and fine- to medium-grained granite (111058).
287.04
287.04
RU5 Fine- to medium-grained granite (111058) with subordinate pegmatitic granite (101061).
308.84
308.84
RU4b Moderately foliated metagranite-granodiorite (101057) with subordinate pegmatitic granite (101061) and in the lower most part fine-
0°
180°
149.00
DZ1 Increased frequency of open and particularly sealed fractures. Fresh. Fracture apertures 0.5 mm or less. Predominant minerals in sealed and open fractures are laumontite, adularia, calcite and chlorite. One oriented radar reflector at 154 m (315°/63° or 108°/63°). The magnetic susceptibility is decreased along the entire section. There are no other significant anomalies related to increased fracturing in the geophysical logging data. Metagranite-granodiorite (101057).
161.00
302.00
DZ2 Increased frequency of open and sealed fractures. Fractures aperture generally less than 0.5mm. Locally faint to medium oxidation. Predominant minerals in open fractures are chlorite, calcite, hematite, clay minerals and laumontite and in sealed fractures calcite, laumontite, chlorite and adularia. The possible deformation zone core 308–310 m is characterized by two fractures with five mm aperture, three minor crushes, argillisation and clay minerals as predominant mineral in open fractures. Two radar reflectors without orientation at 302 and 311 m, and one oriented reflector at 325 m (033°/83° or 213°/32°). The magnetic susceptibility is decreased along the entire section. In the section 307–310 m the resistivity is significantly decreased and there is also a distinct caliper anomaly. There is another clear low resistivity anomaly in the interval 322–325 m. In the section 312–318 m there is a fluid
149.00
DZ1 Two flow anomalies and rather low transmissivity of the section (T = 1E–8 m^2/s).
161.00
302.00
DZ2 One single medium-transmissive flow anomaly (T =2E–8 m^2/s) at 309 m, probably related to one, or both, of the 5 mm aperture fractures. Transmissivity below the measurement limit in the rest of the section.
-120.0
-140.0
-160.0
-180.0
-200.0
-220.0
-240.0
-260.0
-280.0


330.0
340.0
350.0
360.0
370.0
380.0
390.0
400.0
410.0
420.0
430.0
440.0
450.0
460.0
470.0
480.0
490.0
500.0
510.0
520.0
530.0
to medium-grained granite (111058).
346.06
346.06
RU2b Strongly foliated metagranite-granodiorite (101057) with subordinate pegmatitic granite (101061), fine- to medium-grained granite (111058), felsic to intermediate metavolcanic rock (103076) and very minor amphibolite (102017).
430.86
430.86
RU6 Moderately to strongly foliated metagranite-granodiorite (101057), pegmatitic granite (101061) and amphibolite (102017) in approximate equal proportions. Five interval with quarts dissolution at 440.39–440.91, 441.64–441.76, 448.85–458.65, 473.15–474.14 and 478.35–478.42 m. In the interval 450–457 m the density is significantly decreased to c. 2,570 kg/m^3.
497.72
497.72
0°
180°
temperature anomaly indicating the occurrence of a water bearing fracture. Metagranite-granodiorite (101057), fine- to medium-grained granite (111058) and pegmatitic granite (101061).
325.00
422.00
DZ3 Increased frequency of open and sealed fractures in the intervals 422–444 and 461–503 m. Eight crushes with the most extensive at 434.65–435.90 m. Two slickensides. Fracture apertures generally up to 0.5 mm with a few ranging up to 2 mm and a local maximum up to 10 mm. Locally weak to strong oxidation, rarely argillisation, laumontitisation and carbonatitisation. Five interval with quarts dissolution at 440.39–440.91, 441.64–441.76, 448.85–458.65, 473.15–474.14 and 478.35–478.42 m. Ductile deformation recorded at 466.46–466.09 m (019°/81°) and brittle ductile deformation recorded at 488.86–489.10 m (320°/41°). Predominant minerals in open fractures are chlorite, calcite, hematite, clay minerals, in sealed fractures calcite, quarts, adularia and chlorite and in sealed fracture networks calcite, quartz, chlorite and clay minerals. The entire possible deformation zone is characterised by poor radar penetration. The entire interval 422–503 m is characterized by significantly decreased bulk resistivity, several distinct caliper anomalies and decreased magnetic susceptibility. The most prominent low resistivity anomalies occur in the intervals 434–443, 451–458 and 471–475 m. In the section 450–457 m the density is significantly decreased, c. 2,570 kg/m3. Starting at 427 m the fluid temperature is characterized by several anomalies, and this pattern of anomalies continues through out the entire borehole length. Metagranite-granodiorite (101057), pegmatitic granite (101061) and amphi
503.00
325.00
422.00
DZ3 No flow anomalies above 427 m. Increased frequency of flow anomalies in the interval 427–458 m. No flow anomalies below 458 apart from one single flow anomaly at 474 m. The total transmissivity of the section is 2E–6 m^2/s, where the transmissivity is dominated by one single flow anomaly at 427 m (T = 1E–6 m^2/s) and a number of flow anomalies at the section 435–441 m (T = 8E–7 m^2/s). The character of the inflow indicates porous rock at 451–458 m.
503.00
-300.0
-320.0
-340.0
-360.0
-380.0
-400.0
-420.0
-440.0
-460.0


540.0
550.0
560.0
570.0
580.0
590.0
600.0
RU4c Strongly foliated metagranite-granodiorite (101057) and pegmatitic granite (101061) in approximately equal proportions. Subordinate occurrence of fine- to medium-grained granite (111058) and one minor amphibolite (102017).
600.83
0°
180°
0°
180°
-480.0
-500.0
-520.0