P-09-32

Site investigation SFR

Geological single-hole interpretation of KFR04, KFR08, KFR09, KFR13, KFR35, KFR36, KFR54, KFR55, KFR7A, KFR7B and KFR7C

Jesper Petersson, Vattenfall Power Consultant AB
Philip Curtis, Niclas Bockgård, Golder Associates AB
Assen Simeonov, Svensk Kärnbränlehantering AB

August 2009

Svensk Kärnbränslehantering AB
Swedish Nuclear Fuel
and Waste Management Co

Box 250, SE-101 24 Stockholm
Phone +46 8 459 84 00

ISSN 1651-4416
SKB P-09-32

Site investigation SFR

Geological single-hole interpretation of KFR04, KFR08, KFR09, KFR13, KFR35, KFR36, KFR54, KFR55, KFR7A, KFR7B and KFR7C

Jesper Petersson, Vattenfall Power Consultant AB
Philip Curtis, Niclas Bockgård, Golder Associates AB
Assen Simeonov, Svensk Kärnbränlehantering AB

August 2009

Keywords: P-report SKBDoc id 1216011, Review statement SKBDoc id 1216010 KFR04, KFR08, KFR09, KFR13, KFR35, KFR36, KFR54, KFR55, KFR7A, KFR7B, KFR7C, Geology, Bedrock, Boremap, Borehole, Fractures, Forsmark, Geophysics, Hydrogeolog, Project SFR extension.

Abstract

This report presents the geological single-hole interpretations of eleven cored boreholes obtained during the construction of SFR: KFR04, KFR08, KFR09, KFR13, KFR35, KFR36, KFR54, KFR55, KFR7A, KFR7B and KFR7C. The interpretation follows SKB's established methodology that combines the various variables of the geological drill core mapping with available geophysical borehole data to identify rock units and possible deformation zones in the boreholes. However, geophysical logging was performed only in one borehole, KFR04. In addition, it was decided to include data from hydrogeological borehole tests after that the geological single-hole interpretation was performed.

All drill cores have undergone renewed mapping according to the so-called Boremap system. The prime criterion for the selection of the drill cores was their crosscutting relationship with inferred deformation zones in the original deformation zone model for SFR.

Individual drill core has been separated in up to five different rock units. The main component is a fine- to finely medium-grained metagranite, which clearly appears to be a high-strain variety of the typically medium-grained metagranite-granodiorite (101057) that prevails further south, within the candidate area for site investigation Forsmark. Other volumetrically important rock types are pegmatitic granite (101061), finely medium-grained granite (111058) and metagranodiorite-tonalite (101051), aplitic metagranite (101058), amphibolites (102017) and slightly coarser metagabbros (101033).

Mainly based on the occurrence of rock alterations and anomalously high fracture frequencies, up to four possible deformation zones of brittle character have been interpreted in each drill core. The drill core length of individual zones ranges between 3 and 70 m, though the general length is some twenty to thirty meters. Two of the possible zones, one in each of KFR08 and KFR7A, have locally a brittle-ductile component. Most of the possible zones coincide with intervals affected by varying degrees of oxidation. Predominant fracture filling minerals are calcite, clay minerals, chlorite, adularia and laumontite; the latter two typically discoloured by hematite/Fe-hydroxide.

Sammanfattning

Föreliggande rapport behandlar geologisk enhålstolkning av elva kärnborrhål från byggnationen av SFR: KFR04, KFR08, KFR09, KFR13, KFR35, KFR36, KFR54, KFR55, KFR7A, KFR7B and KFR7C. Tolkningen följer en av SKB etablerad metodik som kombinerar de olika variablerna från den geologiska borrkärnekarteringen med tillgänglig geofysisk borrhålsdata för att urskilja läge och utbredning för olika litologiska enheter och möjliga deformationszoner. Geofysisk borrhålsloggning har dock endast gjorts i ett av borrhålen, KFR04. Dessutom bestämdes att data från hydrogeologiska borrhålstester skulle inkluderas, efter att den geologiska enhålstolkningen genomförts.

Alla borrhål har genomgått förnyad kartering med det s.k. Boremap-systemet. Det främsta urvalskriteriet för borrkärnorna var att de skulle klippa deformationszoner som tolkats in i den ursprungliga modellen för SFR.

Enskilda borrkärnor har indelats i upp till fem olika litologiska enheter. Den huvudsakliga komponenten är en fin- till fint medelkorning metagranit, som uppenbarligen tycks vara en mer kraftigt deformerad variant av den typiskt medelkorniga metagranit-granodiorit (101057) som dominerar längre söderut, inom kandidatområdet för platsundersökning Forsmark. Andra volymmässigt viktiga bergarter är pegmatitisk granit (101061), fint medelkornig granit (111058) och metagranodiorit-tonalit (101051), aplitisk metagranit (101058), amfiboliter (102017) och något grövre metagabbro (101033).

Huvudsakligen baserat på förekomsten av bergartsomvandlingar och anomalt förhöjda sprickfrekvenser har upp till fyra möjliga deformationszoner som är spröda tolkats in i varje borrkärna. Längden längs borrkärnan för enskilda zoner varierar mellan 3 och 70 m, men den generella längden är några tiotal meter. Två av de möjliga deformationszonerna, en i vardera, har lokalt en spröd-plastisk komponent. De flesta möjliga zonerna sammanfaller med intervall som påverkats av olika grader av oxidation. Dominerande sprickfyllnadsmineral är kalcit, olika lermineral, klorit, adularia och laumontit; de två senare är generellt missfärgade av hematit/Fe-hydroxid.

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 of the preparations for this work is to update the geological model for the SFR. This necessitates a reassessment of existing geological data from the construction of the SFR, at the basis of the experiences from the preceding site investigation.

For this purpose, it was decided that eleven (11) drill cores obtained between 1983 and 1986 in SFR should undergo renewed mapping according to the so-called Boremap system. The prime criteria for the selection of these drill cores was their crosscutting relationship with inferred deformation zones in the original deformation zone model for SFR /cf. Axelsson and Hansen 1989/.

This activity generally follows SKB's established methodology for geological single-hole interpretation and is based on an integrated series of different logs and accompanying descriptive documents. There are, however, deficiencies in the available data, which have enforced deviations from the established methodology. An additional difference in the currently applied methodology compared to earlier SHI work is the incorporation of hydrogeological borehole data in the interpretation process. Furthermore, geophysical logging was performed only in one borehole, meaning that no generalized geophysical loggs were used for the single-hole interpretations.

This document outlines the results of the geological single-hole interpretation of the following 11 drill cores obtained during the construction of SFR: KFR04, KFR08, KFR09, KFR13, KFR35, KFR36, KFR54, KFR55, KFR7A, KFR7B and KFR7C. The horizontal projections of the boreholes are shown in Figure 1-1.

The work was carried out in accordance with activity plan AP SFR-07-005. 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 KFR04, KFR08, KFR09, KFR13, KFR35, KFR36, KFR54, KFR55, KFR7A, KFR7B och KFR7C	AP SFR-07-005	1.0
Method descriptions	**Number**	**Version**
Metodbeskrivning för geologisk enhålstolkning	SKB MD 810.003	3.0

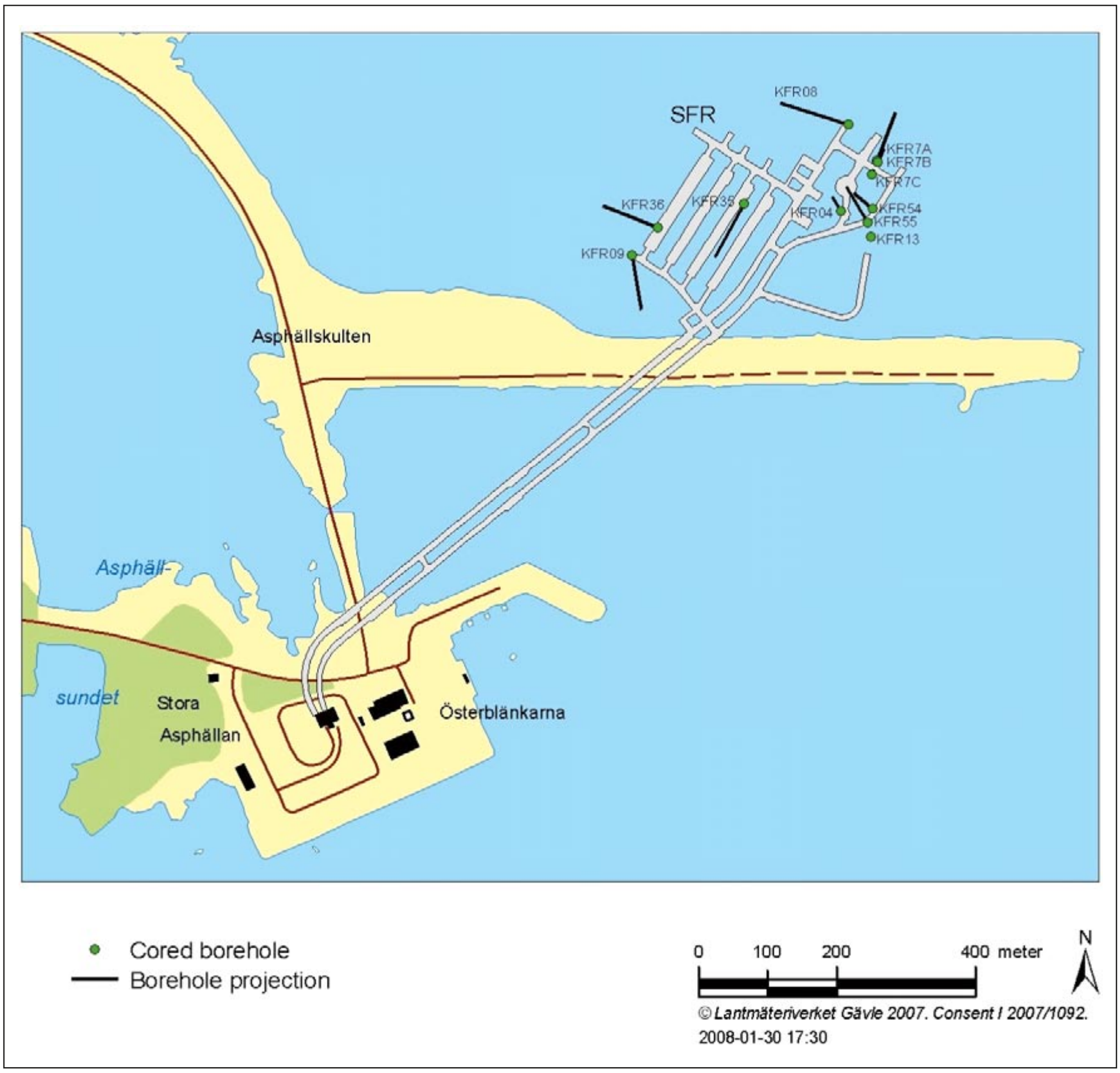


Figure 1-1. *Map showing position and horizontal projection of the cored boreholes KFR04, KFR08, KFR09, KFR13, KFR35, KFR36, KFR54, KFR55, KFR7A, KFR7B and KFR7C relative to SFR.*

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. Geophysical logging data was available only from one borehole. Hydrogeological borehole data from hydraulic tests from all eleven boreholes was used to identify transmissive sections of the boreholes.

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 SFR-boreholes KFR04, KFR08, KFR09, KFR13, KFR35, KFR36, KFR54, KFR55, KFR7A, KFR7B and KFR7C:

- Updated geological mapping (i.e. Boremap data) /Petersson and Andersson 2008/.
- Fracture frequency registered during the original mapping /Carlsson et al. 1986, Christiansson 1986, Christiansson and Magnusson 1985ab/.
- Geophysical borehole logs for KFR04A /Christiansson and Magnusson 1985a/.
- Hydrogeological borehole data /Carlsson et al. 1986 for KFR35 and KFR36; SKB's database Sicada for the other boreholes/.

The basis for the geological mapping by the Boremap-system is generally an oriented image of the borehole walls that is obtained by a Borehole Image Processing *S*ystem (BIPS). However, no such images were available for the SFR boreholes. Thus, in contrast to the regular BIPS-based mapping, the data from this mapping are rather limited and include the following parameters: (1) lithological units that exceed 1 m in drill core length, (2) type and degree of alteration, (3) the exact position along the drill core of broken and unbroken fractures, (4) fracture mineralogy, (5) α-angles (i.e. the angle of deviation between a fracture plane and the drill core length axis) for the predominant fracture sets, (6) crush zones, (7) breccias, (8) sealed fracture networks, and (9) ductile shear zones.

Table 3-1 gives the lengths of individual drill cores, as well as the various deformation zones they are inferred to penetrate according to the original SFR model (cf. /Axelsson and Hansen 1989/) and the site descriptive model of the PLU (cf. /Stephens et al. 2007/).

Geophysical borehole data, including density, magnetic susceptibility, natural gamma and single point resistivity (SPR), are only available for one of the boreholes, KFR04. None of these data were transformed into geological parameters (e.g. fracture frequency or silica density) according to the methodology for single-hole interpretation.

In contrast to the methodology for single-hole interpretation, it was decided to include data from hydrogeological borehole tests after that the geological single-hole interpretation was performed, i.e. the rock units and the possible deformation zones were defined. Such data are available for all eleven boreholes and include interference tests, steady state and transient injection tests, as well as pressure build up tests (Table 3-2).

Table 3-1. Boreholes from the SFR selected for geological single-hole interpretation

New borehole ID-code	Original borehole ID-code	Total logged drill core length (m)	Penetrated deformation zones (SFR model)	Penetrated deformation zones (PLU model)
KFR04	HK4	100.50	Zone H2	ZFM871
KFR08	HK8	104.40	Zone 8	ZFMNW0805
KFR09	HK9	80.24	Zone 3	ZFMNNE869
KFR13	HK13	76.60	Zone H2	ZFM871
KFR35	KB15	18.00–140.17	Zone 6	ZFMNNW1209
KFR36	KB16	16.00–123.90	Zone 3	ZFMNNE0869
KFR54	KB24	53.30	Zone 9	ZFMNE0870
KFR55	KB25	61.89	Zone 9	ZFMNE0870
KFR7A	HK7A	74.45	Zone H2 and 8	ZFM871 and ZFMNW0805
KFR7B	HK7B	21.10	Zone H2	ZFM871
KFR7C	HK7C	34.00	Zone H2	ZFM871

Table 3-2. Hydrogeological borehole data used in the geological single-hole interpretation.

Borehole ID-code	Test	Borehole section [m]	Test length [m]
KFR04	Pressure build up test	5–101	~20
KFR08	Pressure build up test	6–104	~30–40
KFR09	Pressure build up test	7–80	~20
KFR13	Transient injection tes	4–74	10
	Pressure build up test	4–77	~20–30
KFR35	Steady state injection test	30–102	3
	Steady state injection test	99-140	41
KFR36	Steady state injection test	27–117	3
	Steady state injection test	117–123	6
KFR54	Pressure build up test	5–53	~10–25
KFR55	Pressure build up test	2–48	~10–15
	Transient injection test *	40–58	2
KFR7A	Pressure build up test	2–75	~15–25
KFR7B	Pressure build up test	4–21	~3–13
KFR7C	Pressure build up test	6–34	28

* Two separate tests in the same section

The material used as a basis for the geological single-hole interpretation was a WellCAD plot consisting of parameters from the updated geological mapping by the Boremap system, with the limitations mentioned above, the original fracture frequencies as well as available geophysical and hydrogeological borehole logs where available. An example of a WellCAD plot used during geological single-hole interpretation is shown in Figure 3-1. The plot consists of nine 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 structure intensity
- 2.4: Rock type texture
- 2.5: Rock type grain size
- 2.6: Rock alteration
- 2.7: Rock alteration intensity

3: Unbroken fractures
- 3.1: Primary mineral
- 3.2: Secondary mineral
- 3.3: Third mineral
- 3.4: Fourth mineral
- 3.5: α-angle

4: Broken fractures
- 4.1: Primary mineral
- 4.2: Secondary mineral
- 4.3: Third mineral
- 4.4: Fourth mineral
- 4.5: α-angle

5: Crush zones
- 5.1: Crush
- 5.2: Piece (mm)
- 5.3: Sealed network
- 5.4: Core loss
- 6: Fracture frequency
- 6.1: Unbroken fractures
- 6.2: Broken fractures

7: Data from protocol tables
- 7.1: Open protocol
- 7.2: Protocol fractures along drill core
- 7.3. Protocol crush

8: Geophysics
- 8.1: Density
- 8.2: Magnetic susceptibility
- 8.3: Natural gamma
- 8.4: SPR

9: Hydrogeology
- 9.1: Pressure build up
- 9.2: Transient injection
- 9.3: Steady state injection

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

Density: provides general information on the mineral composition of the rock and serves as a support for rock classification.

Magnetic susceptibility: the susceptibility measurement is strongly connected to the magnetite content of the rock.

Natural gamma radiation: low radiation may indicate mafic rock types and high radiation may indicate younger, fine-grained granite (111058) or pegmatitic granite (101061).

SPR (Single Point Resistivity): In general, low resistivity provides an indication of water-bearing fractures, and hence the frequency of broken fractures.

Pressure build up: The transient pressure build-up after a pressure disturbance in a closed borehole section is measured. All hydraulic tests provide information on the hydraulic conductivity or transmissivity of the tested section. These properties are related to the transmissivity, frequency, and connectivity of water-bearing fractures. Pressure build up tests give information on the transmissivity of the connected fracture network on a larger scale than information from short-term injection tests that may represent the local trasmissivity.

Transient injection: Injection test with transient evaluation. Transient evaluation of injections tests is generally more reliable than steady-state evaluation as these are short-term tests.

Steady-state injection: Injection test with steady-state evaluation. Gives an order-of-magnitude indication of the hydraulic properties.

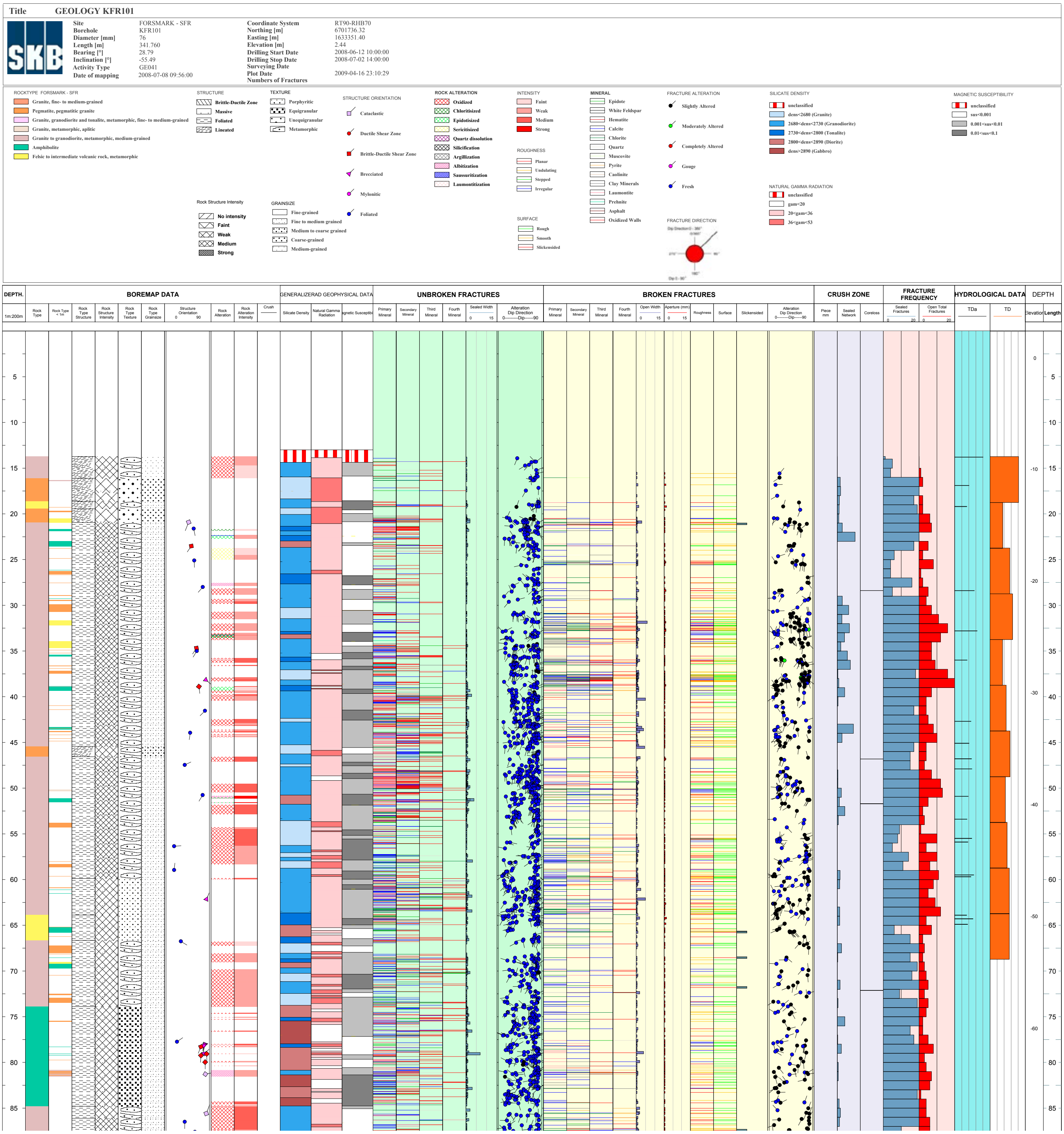


Figure 3-1. Example of WellCAD plot (from borehole KFR101) used as basis for the geological single-hole interpretation.

4 Execution

4.1 Geological single-hole interpretation

The geological single-hole interpretation has been carried out by a group of geoscientists. One of them participated in the geological mapping of the drill core. 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 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 and hydrogeological 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. The confidence in the interpretation of a possible deformation zone is assigned according to three classes: 3 = high, 2 = medium and 1 = low.

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 broken and unbroken fractures have been assessed in the

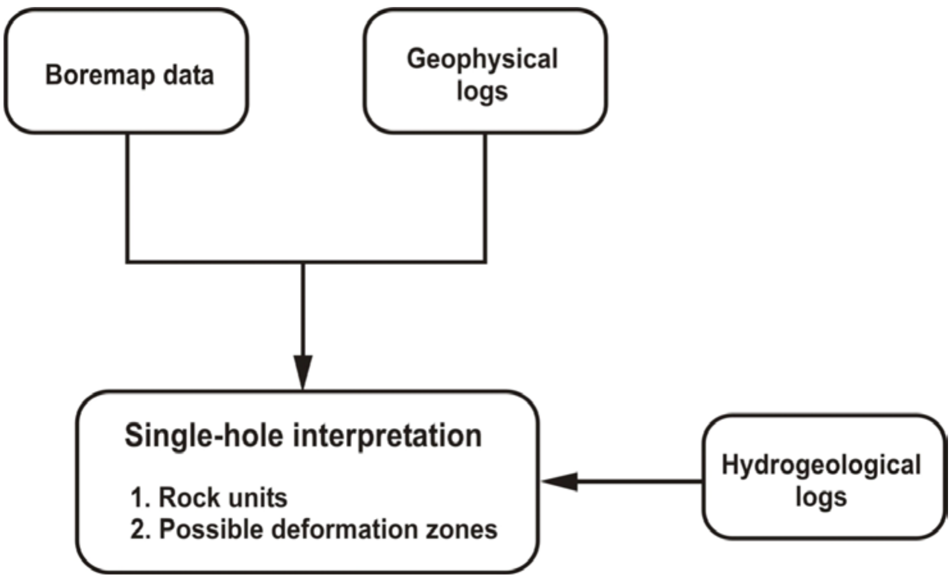


Figure 4-1. Schematic chart showing the procedure for the development of a geological single-hole interpretation.

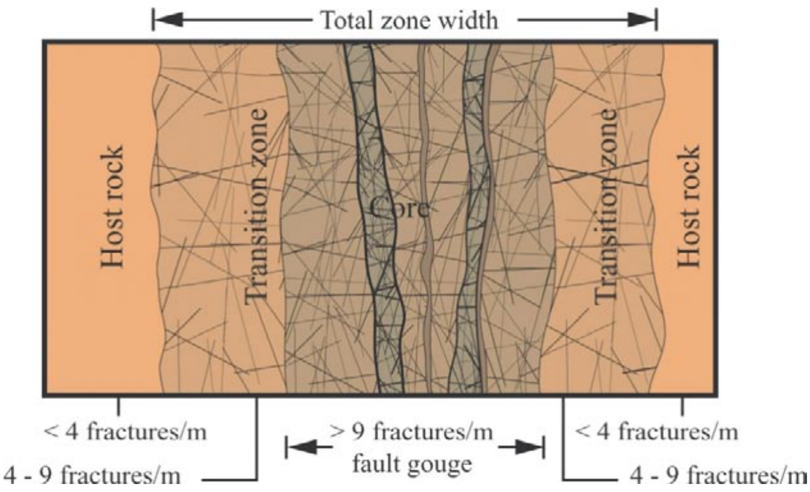


***Figure 4-2.** Schematic illustration of the structure of a brittle deformation zone. After /Munier et al. 2003/.*

identification procedure, and the character of the zone has been described accordingly. The presence of bedrock alteration and anomalies in the geophysical and hydrogeological 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 all the boreholes (Figure 4-3 to Figure 4-13). A 5 m window and 1 m steps have been used in the calculation procedure. The moving average for broken fractures alone, the total number of broken fractures (including crush zones), the unbroken fractures alone, and the total number of unbroken fractures (including sealed fracture networks) are shown in each diagram.

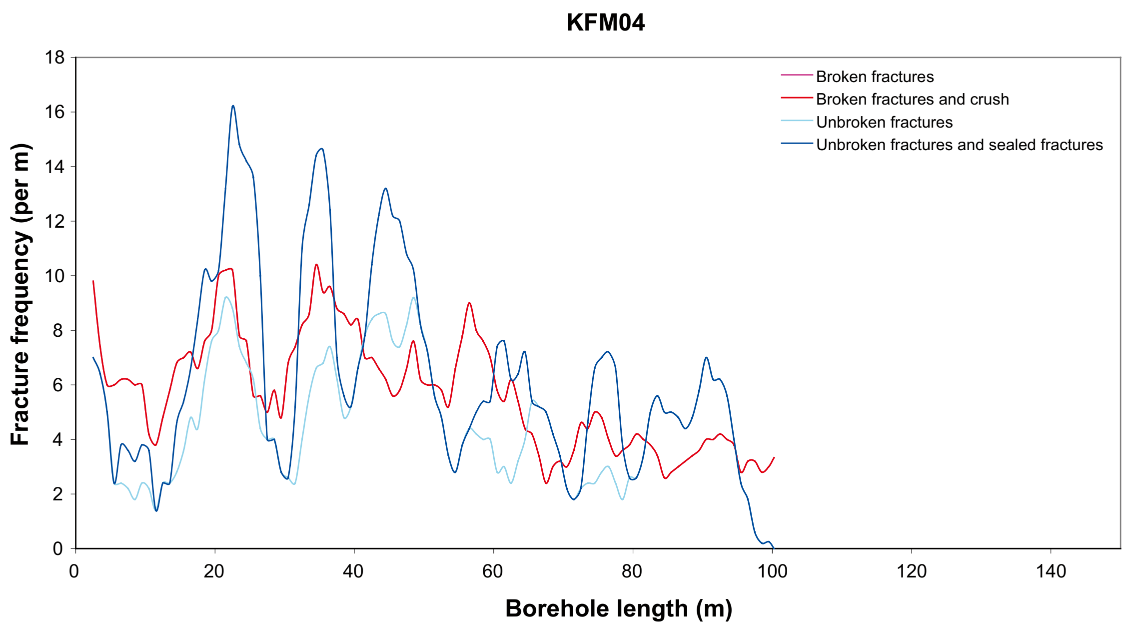


***Figure 4-3.** Fracture frequency plot for KFR04. Moving average with a 5 m window and 1 m steps.*

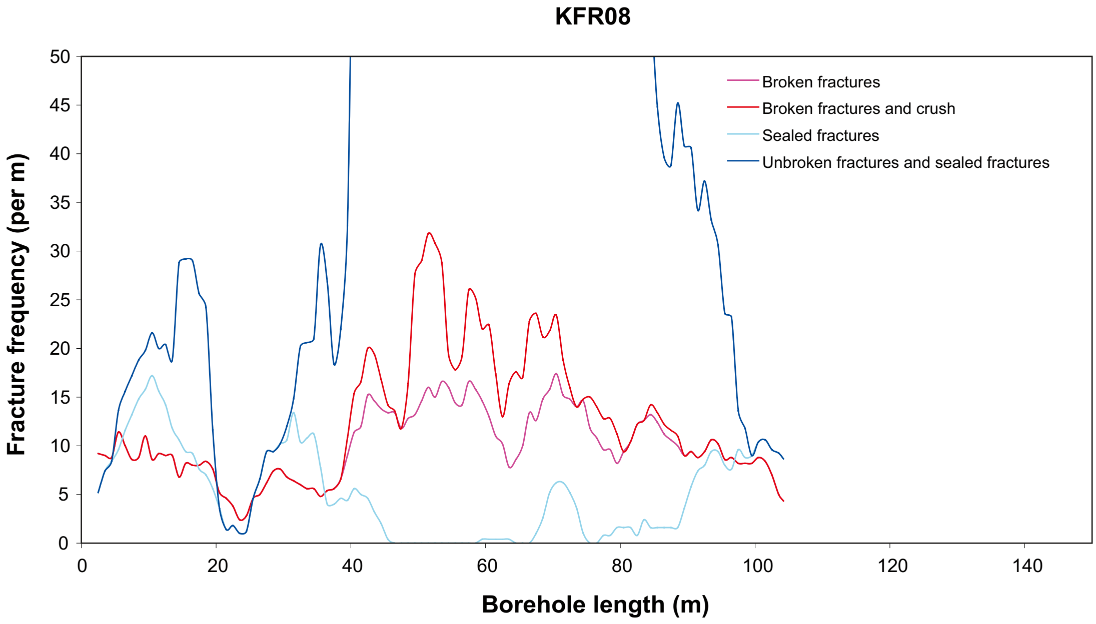


Figure 4-4. *Fracture frequency plot for KFR08. Moving average with a 5 m window and 1 m steps.*

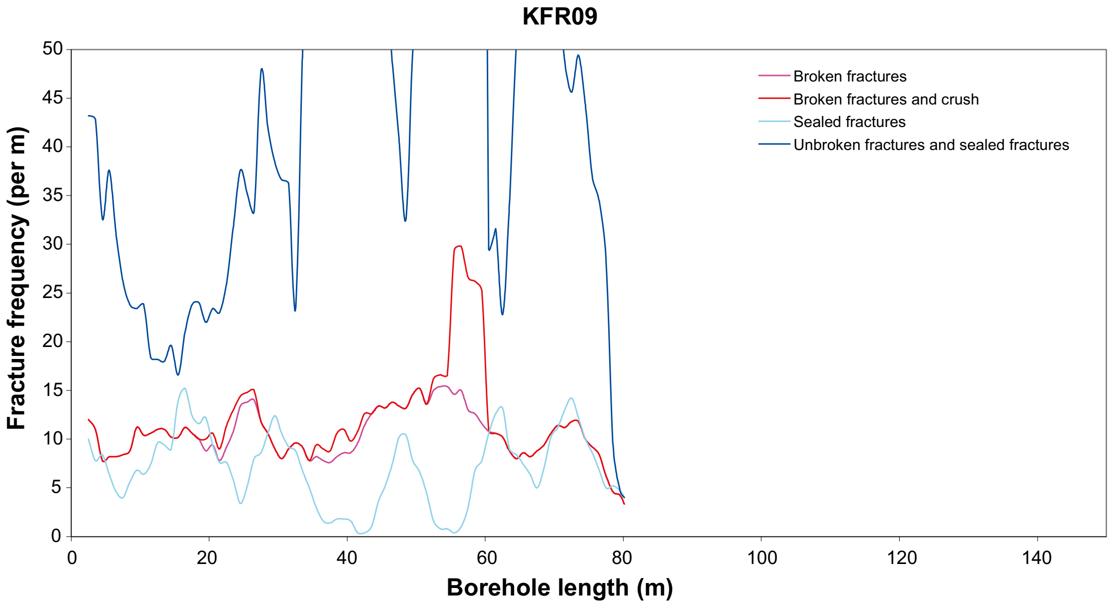


Figure 4-5. *Fracture frequency plot for KFR09. Moving average with a 5 m window and 1 m steps.*

In contrast to the Boremap data used during previous single-hole interpretations, the only available information regarding fracture orientations are α-angles for predominant fracture sets. Together with the fracture mineralogy and experiences from the site investigation, this may yield rough orientations of possible deformation zones. In addition, it can be used to facilitate separation of overlapping zones. Therefore, frequency histograms of the predominant fracture minerals were used to support the characterization of individual possible deformation zones.

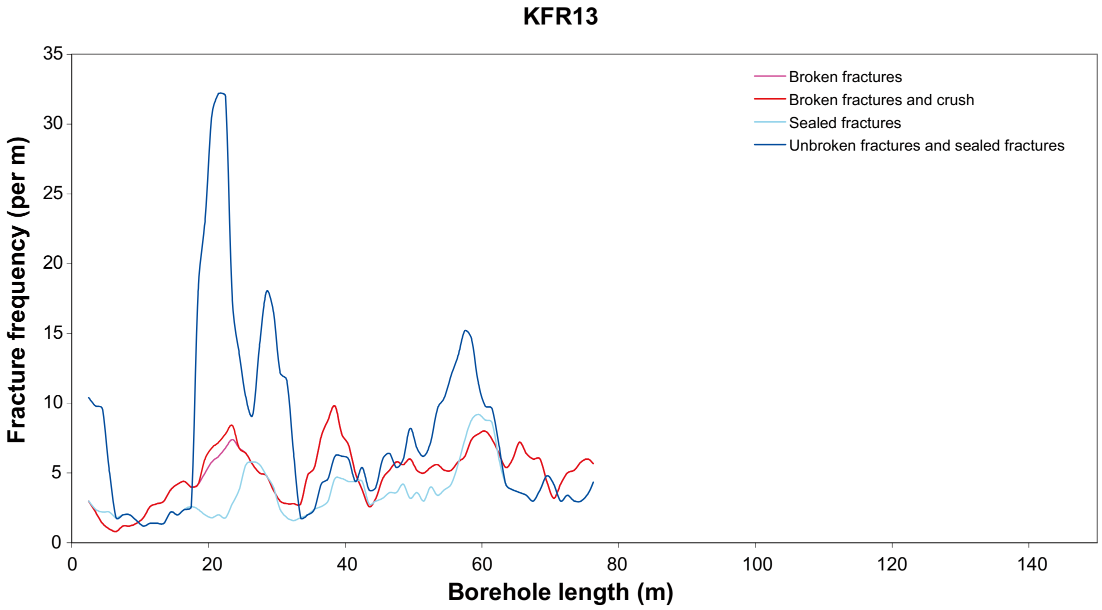


Figure 4-6. *Fracture frequency plot for KFR13. Moving average with a 5 m window and 1 m steps.*

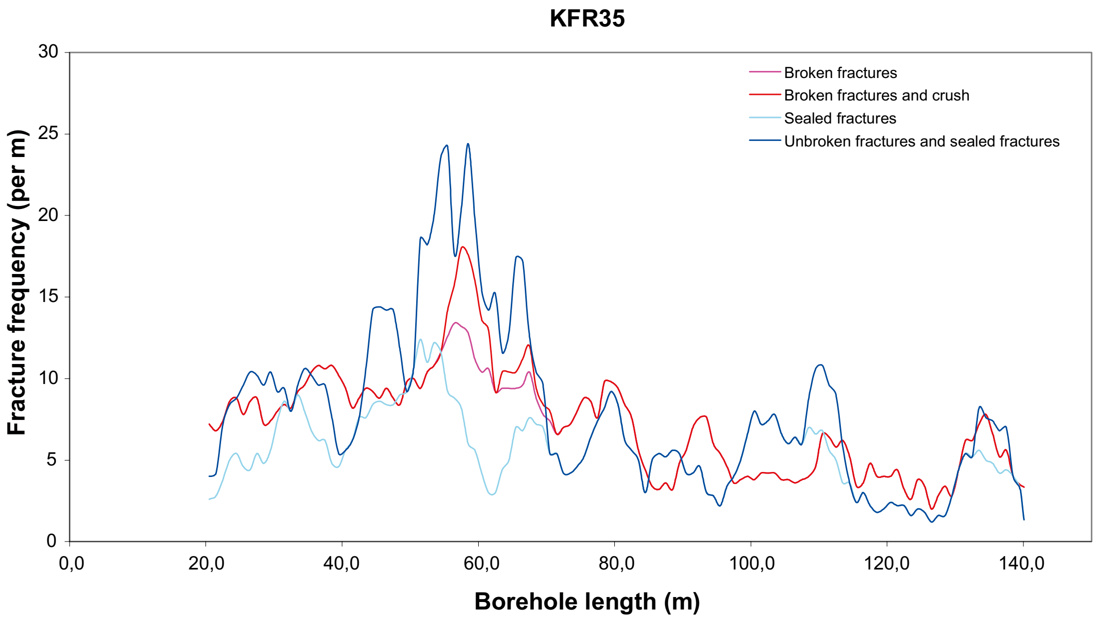


Figure 4-7. *Fracture frequency plot for KFR35. Moving average with a 5 m window and 1 m steps.*

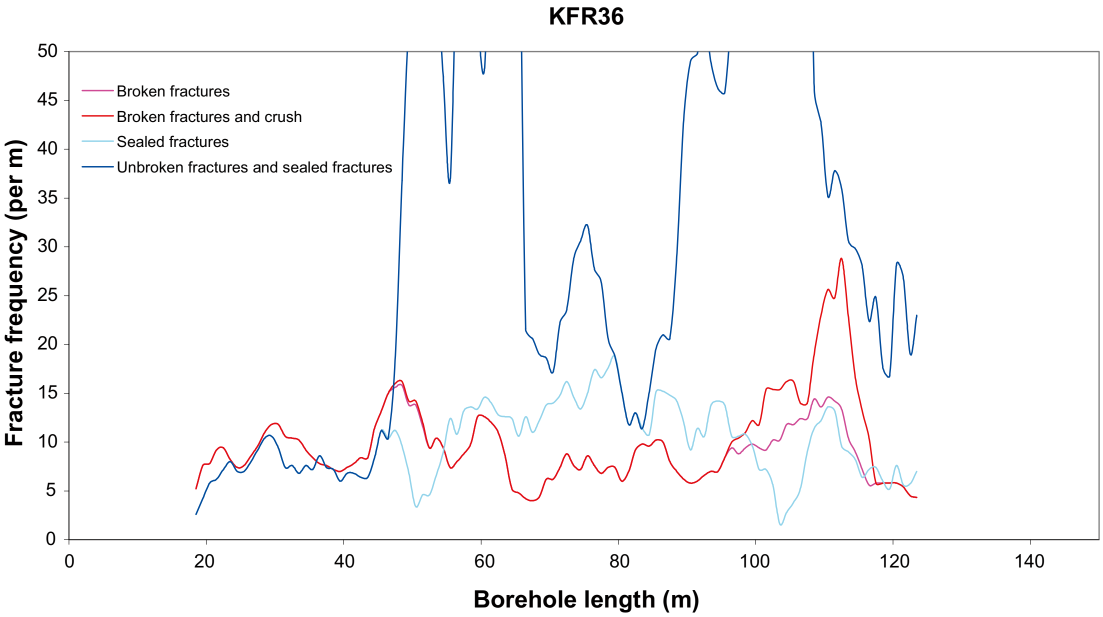


Figure 4-8. *Fracture frequency plot for KFR36. Moving average with a 5 m window and 1 m steps.*

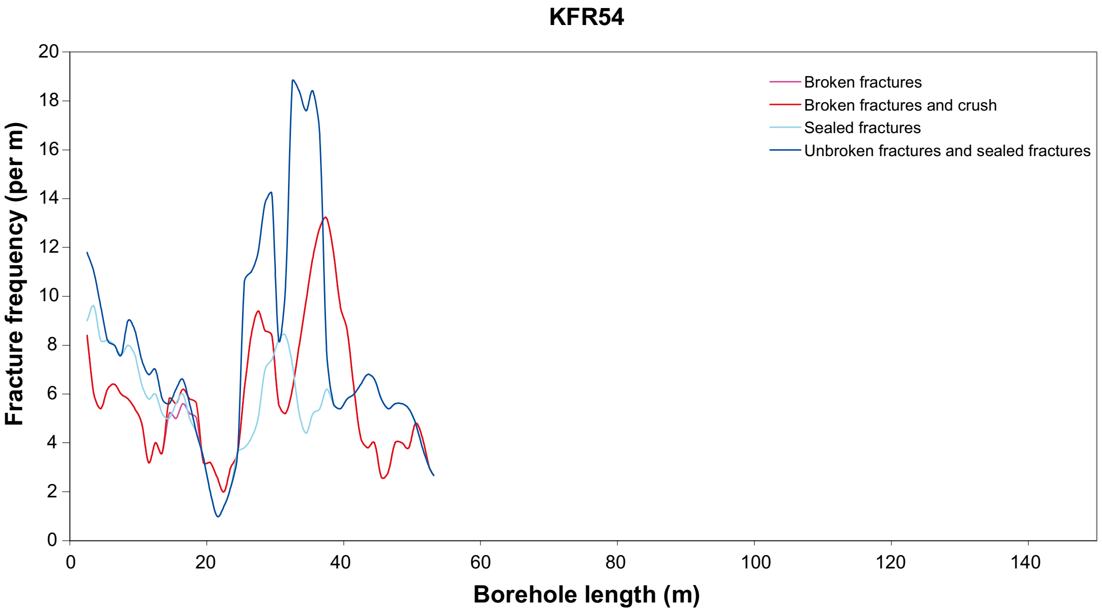


Figure 4-9. *Fracture frequency plot for KFR54. Moving average with a 5 m window and 1 m steps.*

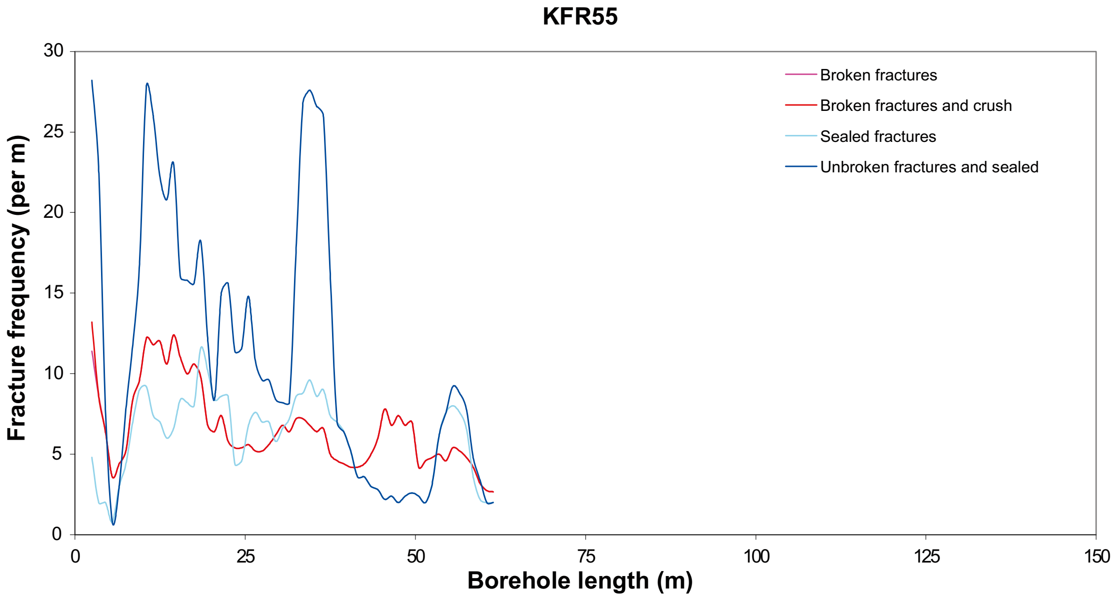


Figure 4-10. *Fracture frequency plot for KFR55. Moving average with a 5 m window and 1 m steps.*

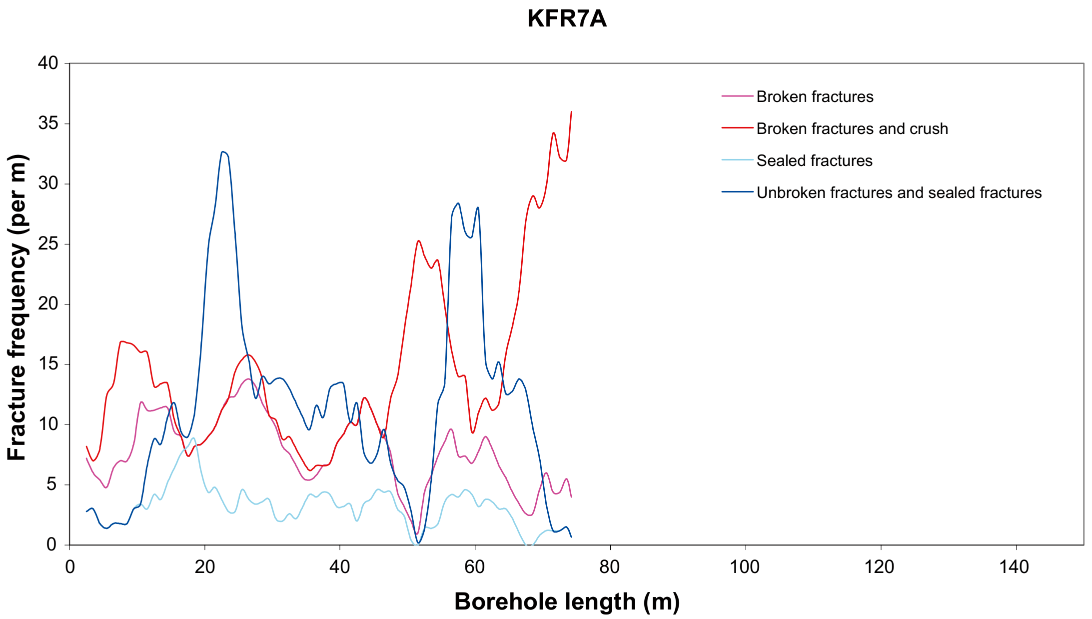


Figure 4-11. *Fracture frequency plot for KFR7A. Moving average with a 5 m window and 1 m steps.*

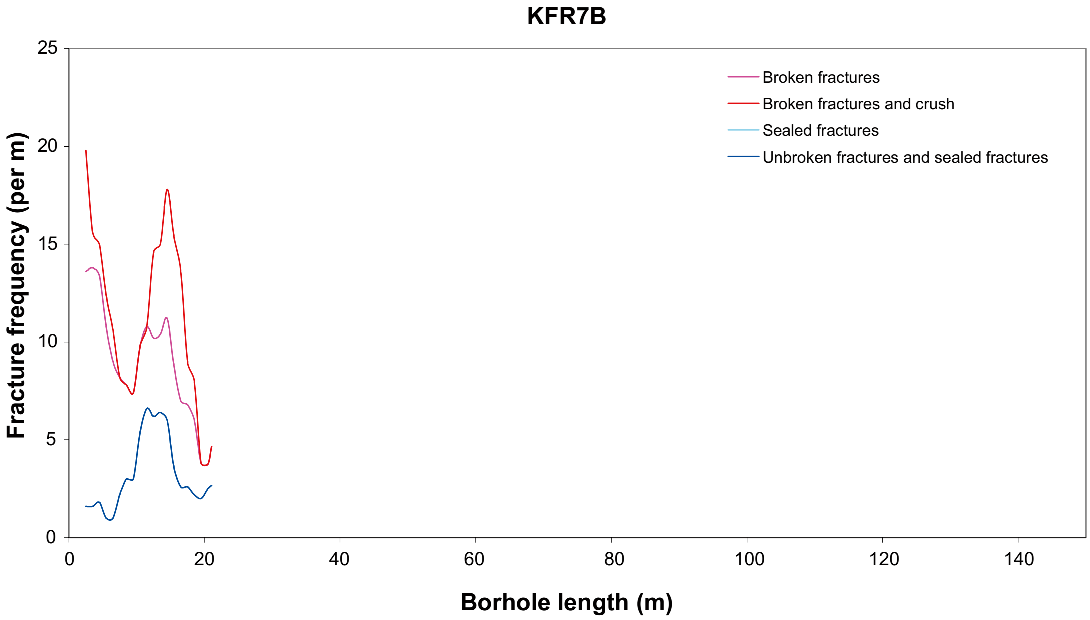


Figure 4-12. *Fracture frequency plot for KFR7B. Moving average with a 5 m window and 1 m steps.*

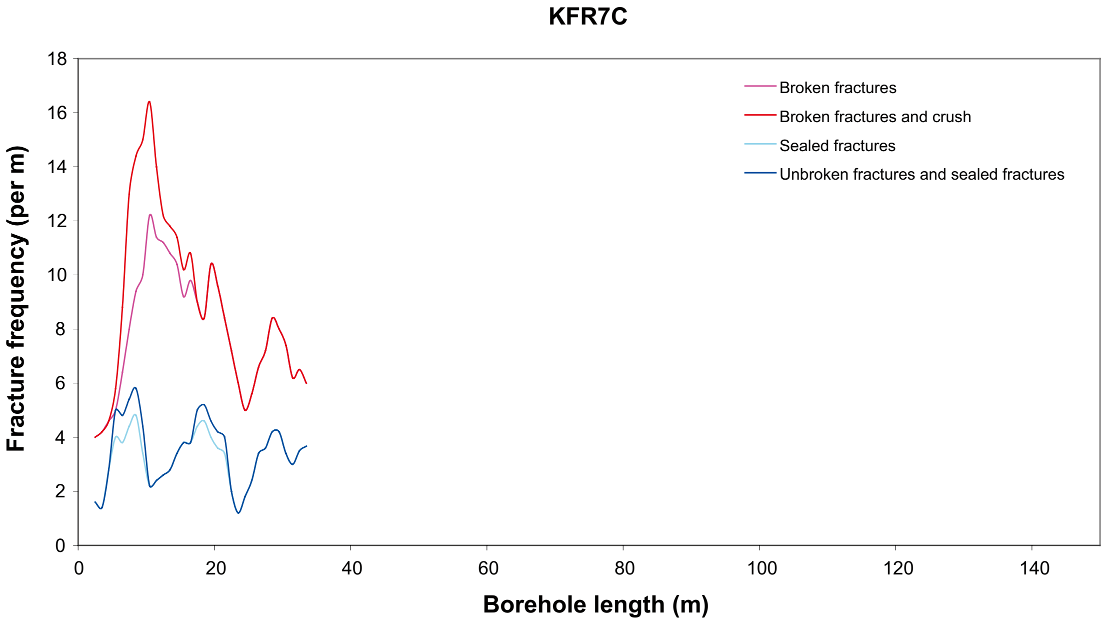


Figure 4-13. *Fracture frequency plot for KFR7C. Moving average with a 5 m window and 1 m steps.*

4.2 Hydrogeological single-hole interpretation

The hydrogeological single-hole interpretation has been carried out by a hydrogeologist 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 old boreholes without BIPS and geophysical data and with only very crude hydrogeological date available. There was therefore no possibility to study hydrogeological anomalies at fracture level. This will however be possible in new boreholes with modern types of hydrogeological data available.

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

4.3 Nonconformities

There are deviations from the established methodology for geological single-hole interpretation (SKB MD 810.003) during the present work, enforced by the deficiencies in the available data.

Regular geological mapping of cored boreholes 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). Such images were not available for the eleven re-logged boreholes. To obtain an approximate orientation of fractures and structures in the rock, the angle between the core axis and the geological feature (α-angle) was documented. A rough estimation of the in-situ orientation of the geological features can then be made by combine the α-angle with the orientation of the borehole.

Regarding the geophysical logging, it was performed only in borehole KFR04. None of these data were transformed into geological parameters (e.g. fracture frequency or silica density).

An additional difference in the currently applied methodology compared to earlier single-hole interpretations is that hydrogeological single-hole interpretation was performed after that the rock units and the possible deformation zones were defined for each borehole.

5 Results

The results of the geological single-hole interpretations of KFR04, KFR08, KFR09, KFR13, KFR35, KFR36, KFR54, KFR55, KFR7A, KFR7B and KFR7C are presented as print-outs from the software WellCAD in Appendices 1–11.

5.1 KFR04

The orientation at the beginning of the borehole is 098°/–75°.

Rock Units

The borehole can be divided into four different rock units, RU1–RU4. Rock unit 2 occurs in two separate length intervals. All rock units have been interpreted with a high degree of confidence.

0–9.34 m

RU1: Moderately foliated metagranite-granodiorite (101057) with one occurrence of metagabbro-diorite (101033) in the uppermost part. Confidence level = 3.

9.34–42.22 m

RU2a: Fine- to medium-grained granite (111058). Confidence level = 3.

42.22–57.63 m

RU3: Amphibolite (102017) and felsic to intermediate metavolcanic rock (103076). Confidence level = 3.

57.63–65.08 m

RU2b: Fine- to medium-grained granite (111058) with one minor occurrence of pegmatitic granite (101061). Confidence level = 3.

65.08–100.5 m

RU4: Moderately to strongly foliated metagranite-granodiorite (101057) and felsic to intermediate metavolcanic rock (103076). Confidence level = 3.

Possible deformation zones

Two possible deformation zones of brittle character have been interpreted in KFR04, one with a low degree of confidence and one with a medium degree of confidence.

0–3 m

DZ1: Increased frequency of broken and unbroken fractures. Predominant fracture minerals are chlorite with subordinate calcite, epidote and laumontite. Partly moderately oxidized. Moderately foliated metagranite-granodiorite (101057) and metagabbro-diorite (101033). Confidence level = 1.

No hydrogeological investigation data from this interval.

14 – 63 m

DZ2: Increased frequency of broken and unbroken fractures. One crush at 32.60–32.77 m and one breccia at 33.00–33.22 m. Predominant fracture minerals are laumontite and calcite. Registered α–angles for laumontite-bearing fractures in the interval are generally gently to moderately dipping (< 53°). The occurrence of clay minerals is mainly concentrated to two short sections at 20–23 and 32–36 m length, which corresponds to low single point resistivity anomalies (SPR). The α–angles of these clay filled fractures are moderately to steeply dipping. Generally weak to moderately oxidized. Fine to medium grained granite (111058), amphibolite (102017) and felsic to intermediate metavolcanic rock (103076). Confidence level = 2.

The hydraulic conductivity (measured in sections of about 20–40 m) is low in the whole interval (about $1 \cdot 10^{-8}$ m/s).

5.2 KFR08

The orientation at the beginning of the borehole is 056°/–05°.

Rock Units

The borehole consists of three rock units, RU1–RU3, of which all have been interpreted with a high degree of confidence.

0–16.00 m

RU1: Moderately to strongly foliated metagranite-granodiorite (101057). Confidence level = 3.

16.00–74.90 m

RU2: Pegmatitic granite (101061) with one minor occurrences of metagabbro-diorite (101033), two of fine- to medium-grained granite (111058), one of moderately foliated metagranite-granodiorite (101057) and one of felsic to intermediate metavolcanic rock (103076). Confidence level = 3.

74.90–104.4 m

RU3: Fine- to medium-grained granite (111058) with one subordinate occurrence of moderately foliated metagranite-granodiorite (101057) in the lower most part. Confidence level = 3.

Possible deformation zones

Two possible deformation zones have been interpreted in KFR08 with brittle and locally brittle-ductile character, one has been classed as low confidence and one as high confidence.

3–19 m

DZ1: Increased frequency of broken fractures, sealed networks and especially unbroken fractures. Predominant fracture fillings are chlorite, calcite and laumontite. Registered α–angles are highly variable between 10 and 81°. Minor weak chloritization and faint oxidation occurs. Moderately to strongly foliated metagranite-granodiorite (101057) and pegmatitic granite (101061). Confidence level = 1.

No hydrogeological investigation data from the upper 6 m of the borehole. Moderate hydraulic conductivity of $2 \cdot 10^{-8}$ m/s in the section 6–19 m.

41–104.4 m

DZ2: Very high frequency of sealed networks and broken fractures. Nineteen crushed sections. Brittle- to ductile section characterised by fault breccias and cataclasite at 42.25–49.80, 53.83–59.1 and 76–80 m. The predominant fracture filling minerals are calcite, chlorite, laumontite and adularia, typically discoloured by hematite. Registered α–angles for fractures in this interval are variable, but generally moderately dipping. Generally weakly to moderately oxidized with two short sections of quartz dissolution (vuggy rock) at 72.55–73.30 and 77.95–79.55 m. Pegmatitic granite (101061), fine- to medium-grained granite (111058) and moderately foliated metagranite-granodiorite (101057). Confidence level = 3.

Moderate hydraulic conductivity (measured in sections of about 20–40 m) of $2–5 \cdot 10^{-7}$ m/s throughout the interval.

5.3 KFR09

The orientation at the beginning of the borehole is 300°/–05°.

Rock Units

The borehole consists of three rock units, RU1–RU3, of which all have been interpreted with a high degree of confidence.

0–54.27 m

RU1: Felsic to intermediate metavolcanic (103076) with minor occurrence of pegmatitic granite (101061) and one of amphibolite (102017). Confidence level = 3.

54.27–75.32 m

RU2: Pegmatitic granite (101061) with two minor occurrences of fine- to medium-grained granite (111058) and one of felsic to intermediate volcanic rock (103076). Confidence level = 3.

75.32–80.24 m

RU3: Moderately foliated metagranite-granodiorite (101057) with one occurrences of pegmatitic granite (101061) in the uppermost part. Confidence level = 3.

Possible deformation zones

Two possible deformation zones are present in KFR09, both are of brittle character and have been interpreted with a high degree of confidence.

0–58.7 m

DZ1: Increased frequency of broken and unbroken fractures and sealed networks. Most intensely fractured between 16–58.7 m. Seven minor intervals of crush. Calcite, chlorite, adularia and laumontite, variably discoloured by microscopic hematite, are the most frequent fracture filling minerals. The occurrence of laumontite is, generally restricted to two distinct sections at 0–24 and 40–45 m, and their α–angles are typically dipping moderately (57–78°). None of the other major mineral phases exhibit such a distinct distribution pattern. Numerous asphalt-bearing fractures have been registered in the length interval 26–61 m. The occurrence of clay mineral fillings is rather scarce. Generally faint to weak oxidation. Felsic to intermediate volcanic rock (103076) with minor occurrences of pegmatitic granite (101061), fine- to medium-grained granite (111058) and amphibolite (102017). Confidence level = 3.

No hydrogeological investigation data from the upper 7 m of the borehole. The hydraulic conductivity (measured in sections of about 20 m) is moderate to high in the whole interval (above $4 \cdot 10^{-8}$ m/s). The maximum measured hydraulic conductivity is $2 \cdot 10^{-6}$ m/s in the interval 43–62 m.

69–74.3 m

DZ2: Increased frequency of broken and unbroken fractures and sealed networks. Minor core losses at 70.55–70.62 and 71.50–71.54 m. Calcite, chlorite, adularia and laumontite, variably discoloured by microscopic hematite, are the most frequent fracture filling minerals. Generally faint oxidation. Pegmatitic granite (101061), fine- to medium-grained granite (111058) and felsic to intermediate metavolcanic rock (103076). Confidence level = 3.

The hydraulic conductivity (measured in one section from 63 m to the end of the borehole) is moderate ($2 \cdot 10^{-7}$ m/s).

5.4 KFR13

The orientation at the beginning of the borehole is 0°/–90°.

Rock Units

The borehole consists of two rock units, RU1–RU2, of which all have been interpreted with a high degree of confidence.

0–13.70 m

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

13.70–76.6 m

RU2: Moderately foliated metagranite-granodiorite (101057) with subordinate occurrences of fine- to medium-grained granite (111058), pegmatitic granite, one occurrence of fine- to medium-grained metagranodiorite-tonalite (101051) and one of amphibolite (102017). Confidence level = 3.

Possible deformation zones

Four possible deformation zones of brittle character are present in KFR13. One has been interpreted with a high degree of confidence, one with medium and two with a low degree of confidence.

20–30 m

DZ1: Increased frequency of broken and unbroken fractures and sealed networks. One crushed interval at 21.45–21.52 m and two breccias at 28.00–28.13 and 28.18–28.21 m. Predominant fracture filling minerals are laumontite and calcite. α–angles for the laumontite-bearing fractures are generally small to moderate between 3 and 43°. Generally faintly to moderately oxidized. Moderately foliated metagranite-granodiorite (101057) and pegmatitic granite (101061). Confidence level = 3.

The hydraulic conductivity is low to very low (10^{-9}–10^{-11} m/s) throughout the interval.

36–41 m

DZ2: Increased frequency of unbroken and especially broken fractures. Predominant fracture filling minerals are laumontite, chlorite and calcite. α–angles are generally small. Locally weak to moderate oxidation. Strongly foliated metagranite-granodiorite (101057) and amphibolite (102017). Confidence level = 1.

The hydraulic conductivity is low ($3 \cdot 10^{-9}$ m/s) throughout the interval.

47.5–61 m

DZ3: Increased frequency of broken and unbroken fractures and sealed networks. Predominant fracture filling minerals are laumontite, chlorite and calcite. α–angles are generally small. Locally faint to moderate oxidation. Moderately foliated metagranite-granodiorite (101057) and fine- to medium-grained granite (111058). Confidence level = 2.

Increased hydraulic conductivity ($1 \cdot 10^{-7}$ m/s) in the interval 54–61 m.

61–68 m

DZ4: 61–68 m. Increased frequency of unbroken and especially broken fractures. Predominant fracture filling minerals are laumontite, chlorite and calcite. A number of broken fractures with clay minerals are concentrated along the section 60.1–64.5 m length. Their α–angles range between 42 and 78°. Moderately foliated metagranite-granodiorite (101057) and fine- to medium-grained metagranodiorite-tonalite (101051). Confidence level = 1.

Increased hydraulic conductivity ($1–2 \cdot 10^{-7}$ m/s) throughout the interval.

5.5 KFR35

The orientation at the beginning of the borehole is 208°/–52°.

Rock Units

The borehole consists of five rock units, RU1–RU5, of which all have been interpreted with a high degree of confidence.

18.00–43.44 m

RU1: Pegmatitic granite (101061) with a minor occurrence of metagranite-granodiorite (101057). Confidence level = 3.

43.44–82.03 m

RU2: Felsic to intermediate metavolcanic rock (103076) with occurrences of fine- to medium-grained granite (111058), strongly foliated metagranite-granodiorite (101057), pegmatitic granite (101061) and one occurrence of fine- to medium-grained metagranodiorite-tonalite (101051). Confidence level = 3.

82.03–115.35 m

RU3: Moderately foliated metagranite-granodiorite (101057) with two minor occurrences of pegmatitic granite (101061) and one occurrence of felsic to intermediate metavolcanic rock (103076). Confidence level = 3.

115.35–126.68 m

RU4: Amphibolite with (102017) with one occurrence of moderately foliated metagranite-granodiorite (101057). Confidence level = 3.

126.68–140.17 m

RU5: Generally strongly foliated metagranite-granodiorite (101057) with two occurrences of pegmatitic granite (101061). Confidence level = 3.

Possible deformation zones

One possible deformation zone of brittle character has been interpreted with a high degree of confidence in KFR35.

32.7–70 m

DZ1: Increased frequency of broken and unbroken fractures and sealed networks. Six crushed intervals in the lower part of the section (57.37–68.15 m). Three intervals at 44.83–46.07, 55.92–56.01 and 60.37–61.60 m include fault breccias and cataclasite. Predominant fracture minerals are adularia, calcite and quartz. α–angles are generally small to moderate (21–61°). Asphaltite, typically associated with calcite, is more or less limited to this section. Occurrence of a black unknown mineral that resembles asphaltite is registered in the interval between 20.1 and 71.6 m. Locally faint to weak oxidation. One minor core loss at 63.84–64.15 m. Pegmatitic granite (101061) with occurrences of felsic to intermediate metavolcanic rock (103076), fine- to medium-grained granite (111058) and strongly foliated metagranite-granodiorite (101057). Confidence level = 3.

Hydraulic conductivity (measured in 3-m sections) above the lower measurement limit ($1.7 \cdot 10^{-8}$) in the intervals 36–39 and 54–63 m. Hydraulic conductivity slightly above $1 \cdot 10^{-6}$ m/s at 54–60 m.

5.6 KFR36

The orientation at the beginning of the borehole is 292°/–46°.

Rock Units

The borehole consists of two rock units, RU1–RU2, of which both have been interpreted with a high degree of confidence.

16.10–70.00 m

RU1: Fine- to medium-grained granite (111058) with subordinate occurrences of pegmatitic granite (101061), intermediate metavolcanic rock (103046) and one minor occurrence of strongly foliated metagranite-granodiorite (101057). Confidence level = 3.

70.00–123.90 m

RU2: Generally strongly foliated metagranite-granodiorite (101057) with two occurrences of amphibolites (102017), one of metagabbro-diorite (101033) and one of fine- to medium-grained granite (111058). Confidence level = 3.

Possible deformation zones

One possible deformation zone of brittle character has been interpreted with a high degree of confidence in KFR36.

45–115.5 m

DZ1: Increased frequency of broken and unbroken fractures and sealed networks. Decreased frequency of broken fractures between 63.5–70 m, which corresponds to the occurrence of pegmatitic granite. The section between 98–115.5 m is the most highly fractured part, with nine crushed sections. The primary infilling minerals in the interval are adularia, calcite and laumontite, together with trace amounts of hematite. Three breccias at 57.09–57.10, 104.81–105.56 and 107.95–108.04 m occur in the interval. α–angles are generally small to moderate (<67°). In the intensely fractured interval at 44–53 m length, there is a majority of fractures filled by calcite and chlorite, with subordinate amounts of hematite. The interval includes one minor crush zone at 49.11–49.15 m. A distinct peak of broken fractures with adularia and chlorite together with a white unidentifiable mineral that might be kaolinite or a zeolite occurs at 60–62 m. Two α–angles at 12 and 30° are registered in the interval. Asphaltite-bearing fractures, concentrated to the interval between 105–114 m. Generally faint to weak oxidation through out the possible zone. Strongly foliated metagranite-granodiorite (101057) with occurrences of fine- to medium-grained granite (111058), intermediate metavolcanic rock (103076), pegmatitic granite (101061), amphibolites (102017) and metagabbro-diorite (101033). Confidence level = 3.

The hydraulic conductivity (measured in 3-m sections) is quite high in the whole interval ($6 \cdot 10^{-6}$–$5 \cdot 10^{-8}$ m/s). Hydraulic conductivity above $1 \cdot 10^{-6}$ m/s at 48–51, 54–57, 96–99 and 102–108 m.

5.7 KFR54

The orientation at the beginning of the borehole is 310°/–48°.

Rock Units

The borehole consists of one rock unit, RU1, which has been interpreted with a high degree of confidence.

0–53.3 m

RU1: Generally strongly foliated metagranite-granodiorite (101057) with two occurrences of pegmatitic granite (101061), two of fine- to medium-grained granite (111058) and one of amphibolite (102017). Confidence level = 3.

Possible deformation zones

Two possible deformation zones of brittle character, of which both have been interpreted with a high degree of confidence, are present in KFR54.

0–2.5 m

DZ1: Increased frequency of broken and unbroken fractures and sealed networks. Predominant fracture minerals are chlorite, calcite and laumontite. Strongly foliated metagranite-granodiorite (101057). Confidence level = 3.

No hydrogeological investigation data from this interval.

27–40 m

DZ2: Increased frequency of broken and to a lesser extent unbroken fractures and sealed networks. Decreased frequency of broken fractures between 28.6–33.7 m. Hematite stained clay minerals are restricted to two intervals of anomalously high fracture frequencies at 26.9–28.2 and 31.1–37.4 m, whereas laumontite mainly is restricted to 28.0–31.2 and 37.3–39.1 m. Both assemblages often include calcite. The chlorite content, on the other hand, is very low relative to that in other parts of the drill core. The α–angles of the clay-bearing fractures are typically dipping gently to moderately (30, 37, 60 and 71°). Generally weak to medium oxidation. Generally strongly foliated metagranite-granodiorite (101057) and one occurrence of pegmatitic granite (101061) in the lower most part of the section. Confidence level = 3.

The hydraulic conductivity is low to very low (10^{-9}–10^{-10} m/s).

5.8 KFR55

The orientation at the beginning of the borehole is 329°/–11°.

Rock Units

The borehole consists of one rock unit, RU1, which has been interpreted with a high degree of confidence.

0–61.89 m

RU1: Generally strongly foliated metagranite-granodiorite (101057) with two occurrences of pegmatitic granite (101061), one of fine- to medium-grained granite (111058) and one of intermediate metavolcanic rock (103076). Confidence level = 3.

Possible deformation zones

Two possible deformation zones of brittle character are present in KFR55. One has been classed as medium confidence and one as high confidence.

0–3.3 m

DZ1: Increased frequency of broken and unbroken fractures and sealed networks. One minor crush at 0.39–0.52 m and one minor core loss at 1.77–1.91 m. Predominant fracture minerals are laumontite, calcite, chlorite and hematite. Generally weakly oxidized. Strongly foliated metagranite-granodiorite (101057). Confidence level = 2.

No hydrogeological investigation data from this interval.

8–38 m

DZ2: Increased frequency of broken and unbroken fractures and sealed networks, especially in the intervals 8–21 m and 32–38 m. Core loss at 17.86–18.51, 19.13–19.37, 33.48–33.60 and 34.89–35.33 m. The most frequent fracture filling minerals, which occur throughout the interval, are calcite, and to some extent chlorite. Fractures with clay minerals as the primary infilling are generally restricted to the interval at 16.8–19.5 m, with α–angles of 69°. Laumontite ± calcite filled fractures, on the other hand, occur along three intervals at 8.0–12.6, 16.0–16.5 and 20.4–28.1 m length. Two α–angles are registered in the uppermost (68 and 77°) and three in the lowermost (50, 57 and 65°) intervals. Locally faint to medium oxidation. Strongly foliated metagranite-granodiorite (101057) and one occurrence of fine- to medium-grained granite (111058). Confidence level = 3.

No hydrogeological investigation data from the upper 22 m of the borehole. The hydraulic conductivity is low in the measured section 22–38 m (10^{-8} m/s).

5.9 KFR7A

The orientation at the beginning of the borehole is 021°/–02°.

Rock Units

The borehole consists of three rock units, RU1–RU3, of which all have been interpreted with a high degree of confidence.

0–12.68 m

RU1: Moderately to strongly foliated metagranite-granodiorite (101057). Confidence level = 3.

12.68–41.52 m

RU2: Pegmatitic granite (101061) and aplitic metagranite (101058). Confidence level = 3.

41.52–74.45 m

RU3: Moderately to strongly foliated metagranite-granodiorite (101057) with one minor occurrence of fine to medium grained granite (111058), one of pegmatitic granite (101061) and one of amphibolite (102017). Confidence level = 3.

Possible deformation zones

One possible deformation zone of brittle and locally brittle-ductile character has been interpreted with a high degree of confidence in KFR7A.

3.5–74.45 m

DZ1: Increased frequency of unbroken fractures, sealed networks and especially broken fractures. Nineteen crushes with the most extensive sections at 49.09–74.45 m. Brittle-ductile section characterised by fault breccias and cataclasite at 21–24 m and 64.83–71.29 m. Predominant fracture minerals are clay minerals, calcite and Fe-hydroxide/hematite. The registered α–angles of clay filled fractures are highly variable, ranging from 0 to 85°. Fractures filled with laumontite form swarms throughout the drill core, with the most extensive occurrence at 56.9–64.8 m length. Most of these fractures have gently dipping α–angles less than 25°, with a few ranging up to 55° towards the drill core length axis. Moderately to strongly foliated metagranite-granodiorite (101057), pegmatitic granite (101061), aplitic metagranite (101058), fine- to medium-grained granite (111058) and amphibolite (102017). Confidence level = 3.

Low hydraulic conductivity $6 \cdot 10^{-9}$ m/s in the interval 3.5–19 m. Moderate hydraulic conductivity of $5 \cdot 10^{-7}$ m/s in the interval 20–47 m. High hydraulic conductivity of $3 \cdot 10^{-6}$ m/s in the interval 48–74.45 m.

5.10 KFR7B

The orientation at the beginning of the borehole is 012°/–75°.

Rock Units

The borehole consists of one rock unit, RU1, which has been interpreted with a high degree of confidence.

0–21.1 m

RU1: Moderately foliated metagranite-granodiorite (101057) with subordinate occurrences of pegmatitic granite (101061). Confidence level = 3.

Possible deformation zones

One possible deformation zone of brittle character has been interpreted with a high degree of confidence in KFR7B.

0–17 m

DZ1: Increased frequency of unbroken and especially broken fractures. Four crushed sections at 0.67–1.01, 4.14–4.33, 14.34–14.88 and 15.98–16.25 m and two core losses at 14.48–14.88 and 15.98–16.25 m. Predominant fracture minerals are calcite, chlorite and clay minerals, locally with hematite/Fe-hydroxide staining. α–angles are ranging between 43 and 72°. Moderately foliated metagranite-granodiorite (101057) and pegmatitic granite (101061). Confidence level = 3.

No hydrogeological investigation data from the upper 4 m of the borehole. Moderate hydraulic conductivity of $1 \cdot 10^{-8}$ m/s in the interval 4–7 m. High hydraulic conductivity of $2 \cdot 10^{-6}$ m/s in the interval 8–17 m.

5.11 KFR7C

The orientation at the beginning of the borehole is 196°/–70°.

Rock Units

The borehole consists of two rock units, RU1–RU2, of which both have been interpreted with a high degree of confidence.

0–14.43 m

RU1: Fine to medium grained granite (111058) with subordinate occurrence of pegmatitic granite (101061) and strongly foliated metagranite-granodiorite (101057). Confidence level = 3.

14.43–34 m

RU2: Strongly foliated metagranite-granodiorite (101057) with one minor occurrence of pegmatitic granite (101061). Confidence level = 3.

Possible deformation zones

One possible deformation zone of brittle character has been interpreted with a high degree of confidence in KFR7C.

6–32 m

DZ1: Increased frequency of unbroken and especially broken fractures. Five crushes in the intervals 7.89–7.95, 8.11–8.19, 8.47–8.50, 9.25–9.40 and 14.67–14.77 m. Predominant fracture minerals are clay minerals, locally accompanied by Fe-hydroxide/hematite discolouration, chlorite and calcite. Most fractures have α–angles that are moderate (29–74°). Virtually all laumontite-bearing fractures are concentrated in a zone with low α–angles (9 and 10° for individual fractures) at 6.24–7.15 m length. Locally faint oxidation and minor argillization. Strongly foliated metagranite-granodiorite (101057), fine- to medium-grained granite (111058) and pegmatitic granite (101061). Confidence level = 3.

Moderate hydraulic conductivity $2 \cdot 10^{-8}$ m/s throughout the interval.

6 Summary and discussions

Initially, it was thought that the updated mapping and subsequent single-hole interpretation of the 11 SFR boreholes should shed at least some light over the obscurities in the methodology of the original fracture mapping. A calibration between the fracture mappings from the two occasions was planned with the aim of facilitating geological single-hole interpretation of the remaining, pre-existing drill cores from the construction of SFR, based solely on the original logs.

However, a comparison between the new and the original frequencies for broken fractures in all 11 boreholes did not show the expected concordance; both higher and lower frequencies were registered. This is probably due to handling and transportation of the drill cores between the two mapping occasions and the fact that drilling induced fractures were recorded during the original mapping. The planned calibration between the new and the original fracture frequencies was, therefore, not possible to carry out. Consequently, it was concluded that the original geological data, even together with geophysical and/or hydrogeological borehole data are alone insufficient for single-hole interpretation.

References

Axelsson C-L, Hansen L M, 1989. Update of structural models at SFR nuclear waste repository, Forsmark, Sweden SKB R-98-05, Svensk Kärnbränslehantering AB.

Carlsson L, Winberg A, Arnefors J, 1986. Hydraulic modeling of the final repository for reactor waste (SFR). Compilation and Conceptualization of Available Geological an Hydrogeological Data. SKB SFR 86-03, Svensk Kärnbränslehantering AB.

Christiansson R, Magnusson K-Å, 1985a. Hydrogeologiskt program. Beskrivning av den geologiska miljön kring kärnborrhålen HK1–4. SKB SFR 85-03, Svensk Kärnbränslehantering AB.

Christiansson R, Magnusson K-Å, 1986b. Geologisk miljö kring silo 1. SKB SFR 85-07, Svensk Kärnbränslehantering AB.

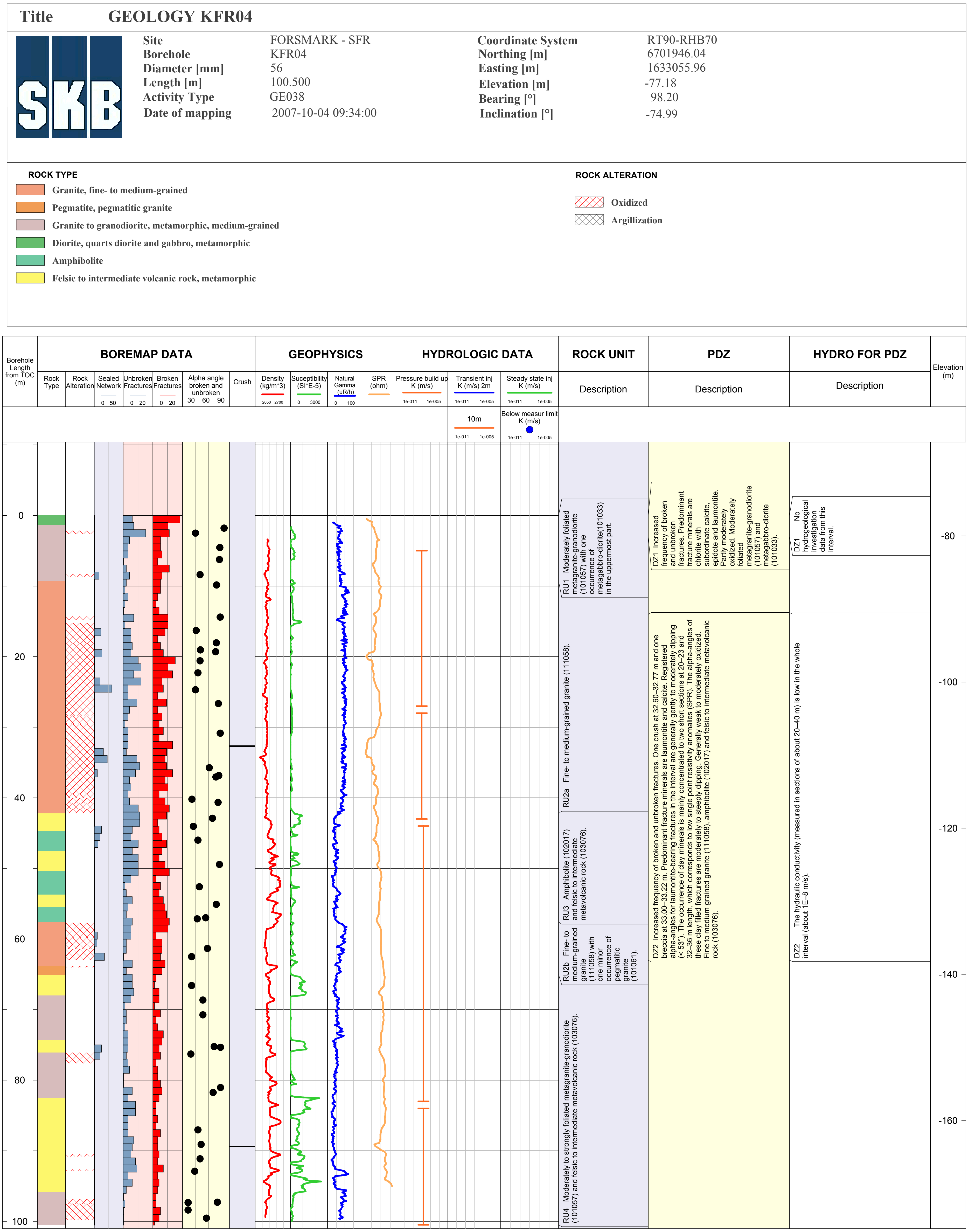
Christiansson R, 1986. Geologisk beskrivning av zoner kring SFR. SKB SFR 86-02, Svensk Kärnbränslehantering AB.

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.

Petersson J, Andersson U B, 2008. Investigations SFR3. Overview Boremap mapping of drill cores from KFR04, KFR08, KFR09, KFR13, KFR35, KFR36, KFR54, KFR55, KFR7A, KFR7B and KFR7C. In press, Svensk Kärnbränslehantering AB.

Stephens M B, Fox A, Pointe P L, Simeonov A, Isaksson H, Hermanson J, Öhman J, 2007. Geology Forsmark. Site descriptive modelling. Forsmark stage 2.2. SKB R-07-45, Svensk Kärnbränslehantering AB.

WellCAD images



Title GEOLOGY KFR08

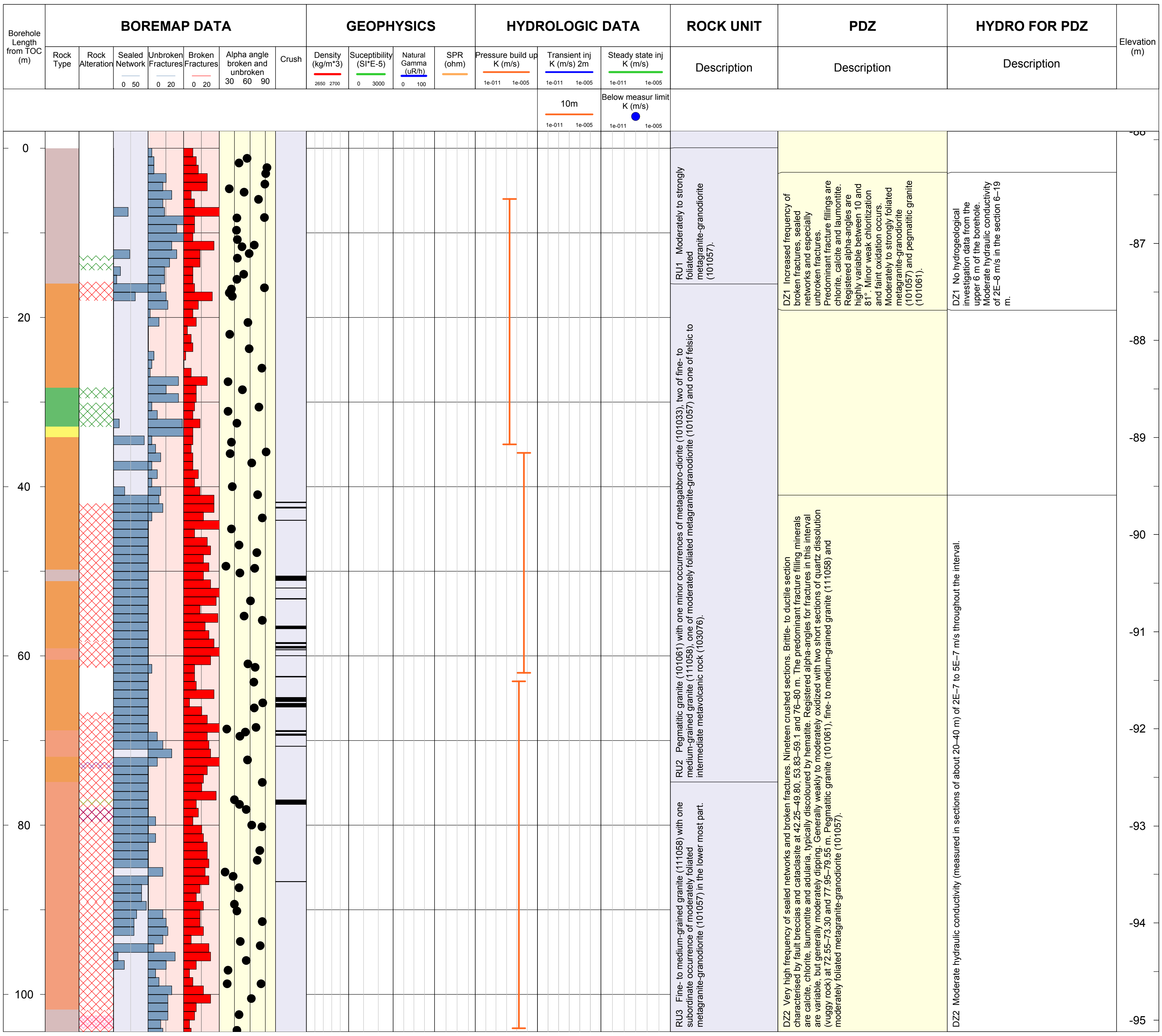
Site	FORSMARK - SFR	**Coordinate System**	RT90-RHB70
Borehole	KFR08	**Northing [m]**	6702071.23
Diameter [mm]	56	**Easting [m]**	1633066.45
Length [m]	104.400	**Elevation [m]**	-86.01
Activity Type	GE038	**Bearing [°]**	56.40
Date of mapping	2007-10-04 09:34:00	**Inclination [°]**	-4.99

ROCK TYPE

- Granite, fine- to medium-grained
- Pegmatite, pegmatitic granite
- Granite to granodiorite, metamorphic, medium-grained
- Diorite, quarts diorite and gabbro, metamorphic
- Felsic to intermediate volcanic rock, metamorphic

ROCK ALTERATION

- Oxidized
- Chloritisized
- Epidotisized
- Quartz dissolution
- Albitization
- Laumontitization



Title GEOLOGY KFR09

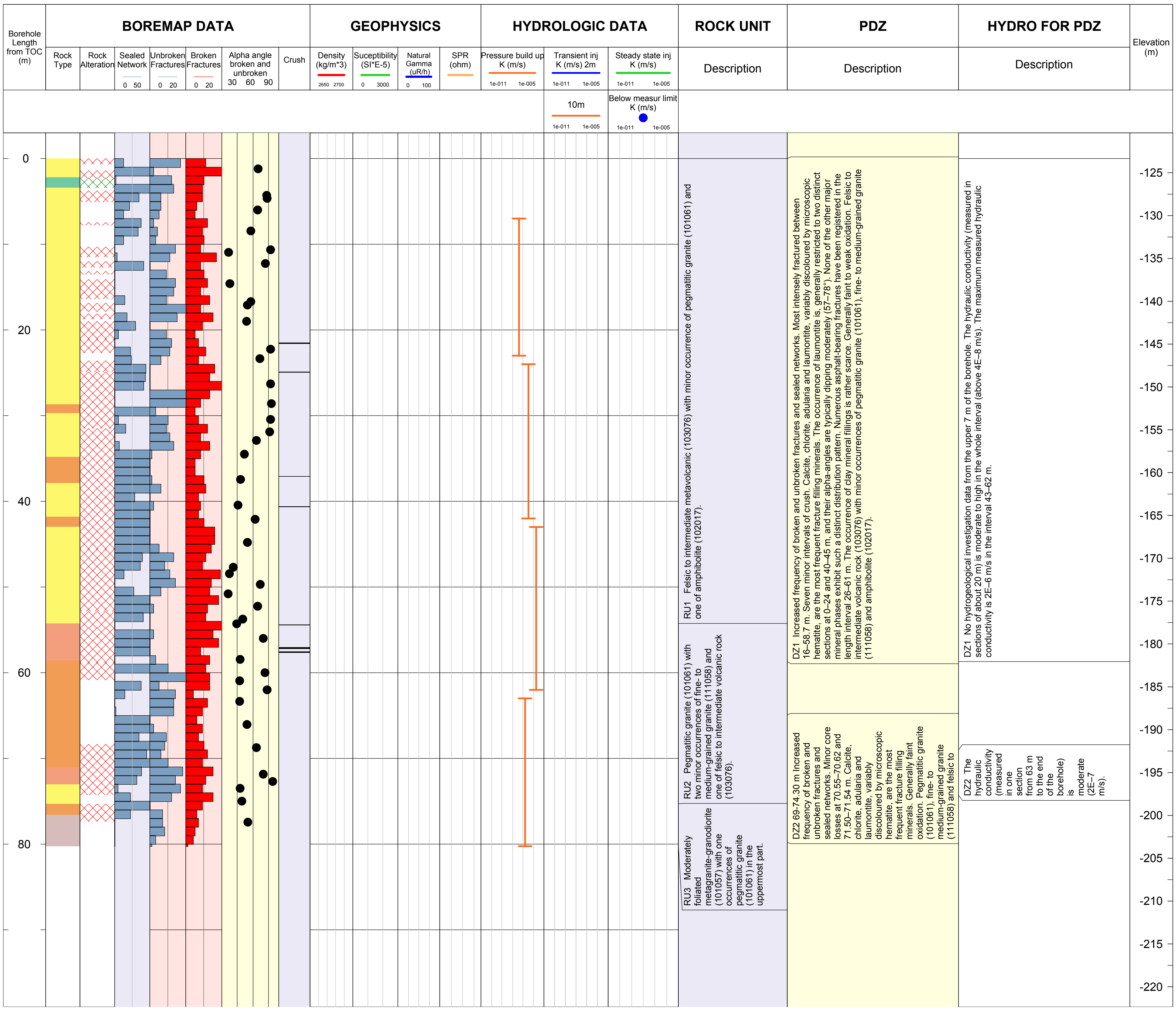
Site	FORSMARK - SFR	**Coordinate System**	RT90-RHB70
Borehole	KFR09	**Northing [m]**	6701881.84
Diameter [mm]	56	**Easting [m]**	1632755.38
Length [m]	80.240	**Elevation [m]**	-77.43
Activity Type	GE038	**Bearing [°]**	299.90
Date of mapping	2007-10-04 09:34:00	**Inclination [°]**	-4.99

ROCK TYPE

- 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



Title	**GEOLOGY KFR13**

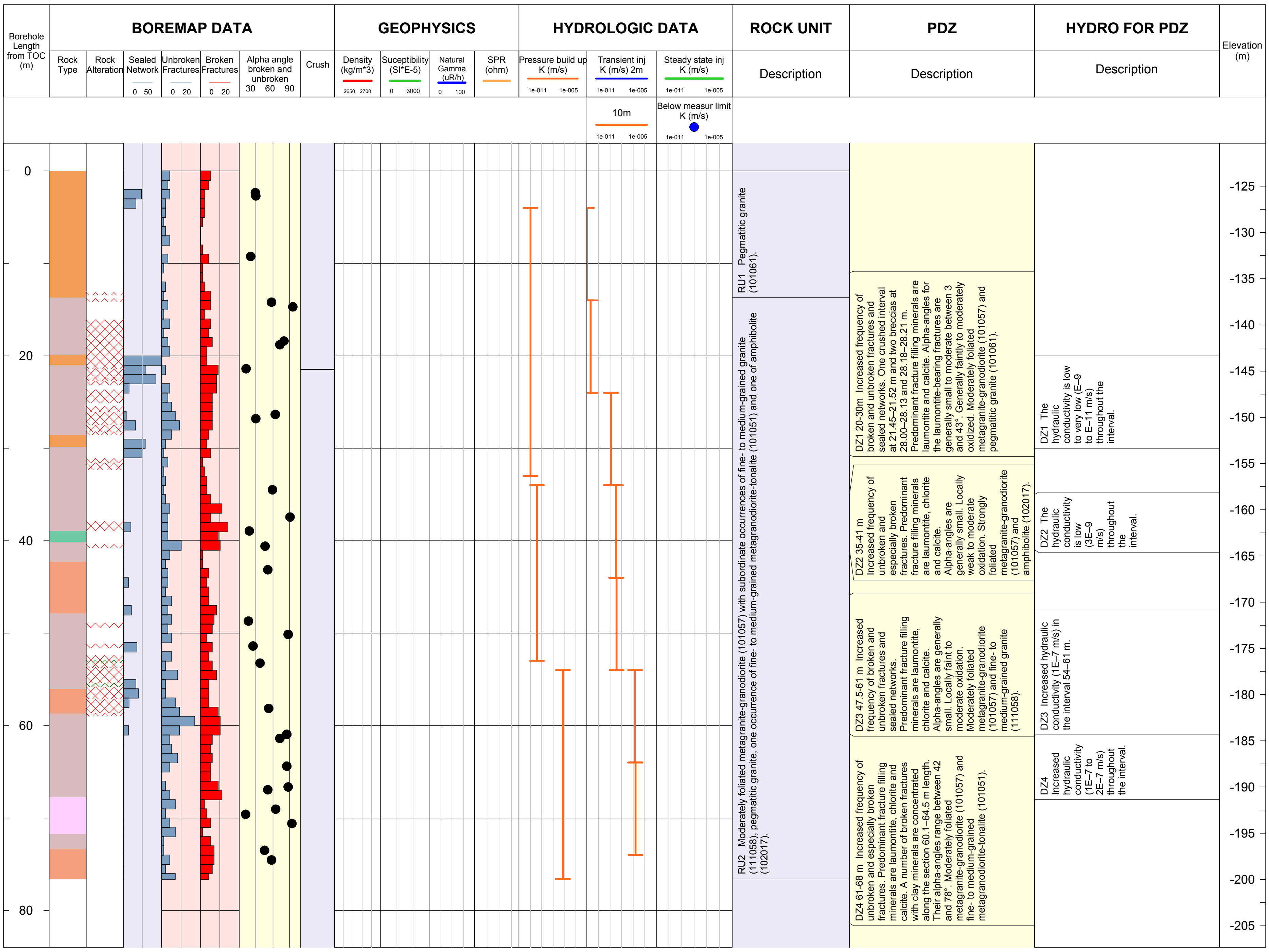
Site	FORSMARK - SFR	**Coordinate System**	RT90-RHB70
Borehole	KFR13	**Northing [m]**	6701910.29
Diameter [mm]	56	**Easting [m]**	1633092.89
Length [m]	76.600	**Elevation [m]**	-123.33
Activity Type	GE038	**Bearing [°]**	0.00
Date of mapping	2007-10-04 09:34:00	**Inclination [°]**	-89.99

ROCK TYPE

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

ROCK ALTERATION

- Oxidized
- Chloritisized
- Laumontitization



Title GEOLOGY KFR35

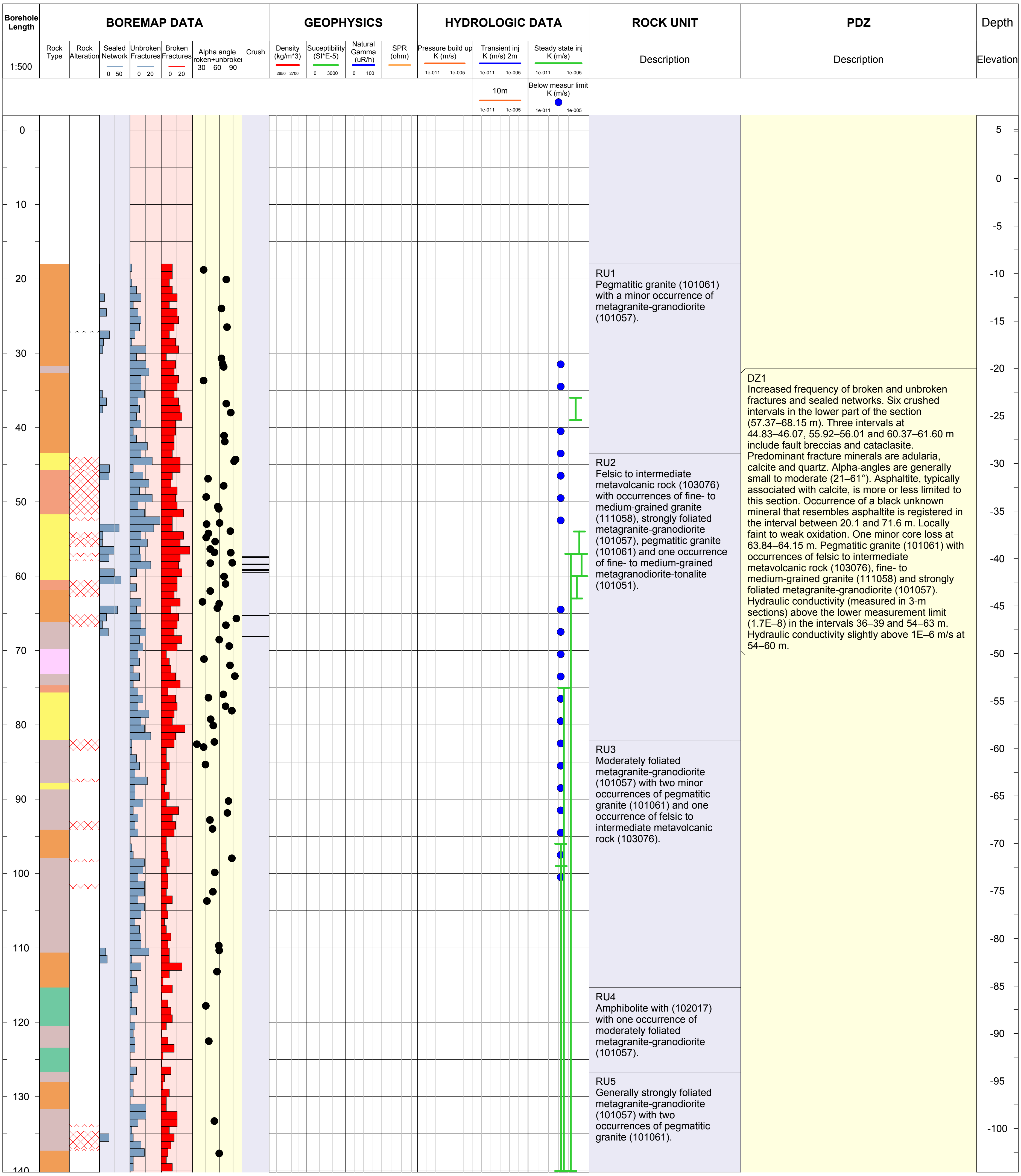
Site	FORSMARK - SFR	**Coordinate System**	RT90-RHB70
Borehole	KFR35	**Northing [m]**	6701956.28
Diameter [mm]	56	**Easting [m]**	1632915.93
Length [m]	140.200	**Elevation [m]**	5.10
Activity Type	GE038	**Bearing [°]**	208.11
Date of mapping	2007-10-04 09:34:00	**Inclination [°]**	-51.49

ROCK TYPE

- 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
- Carbonatization



Title GEOLOGY KFR36

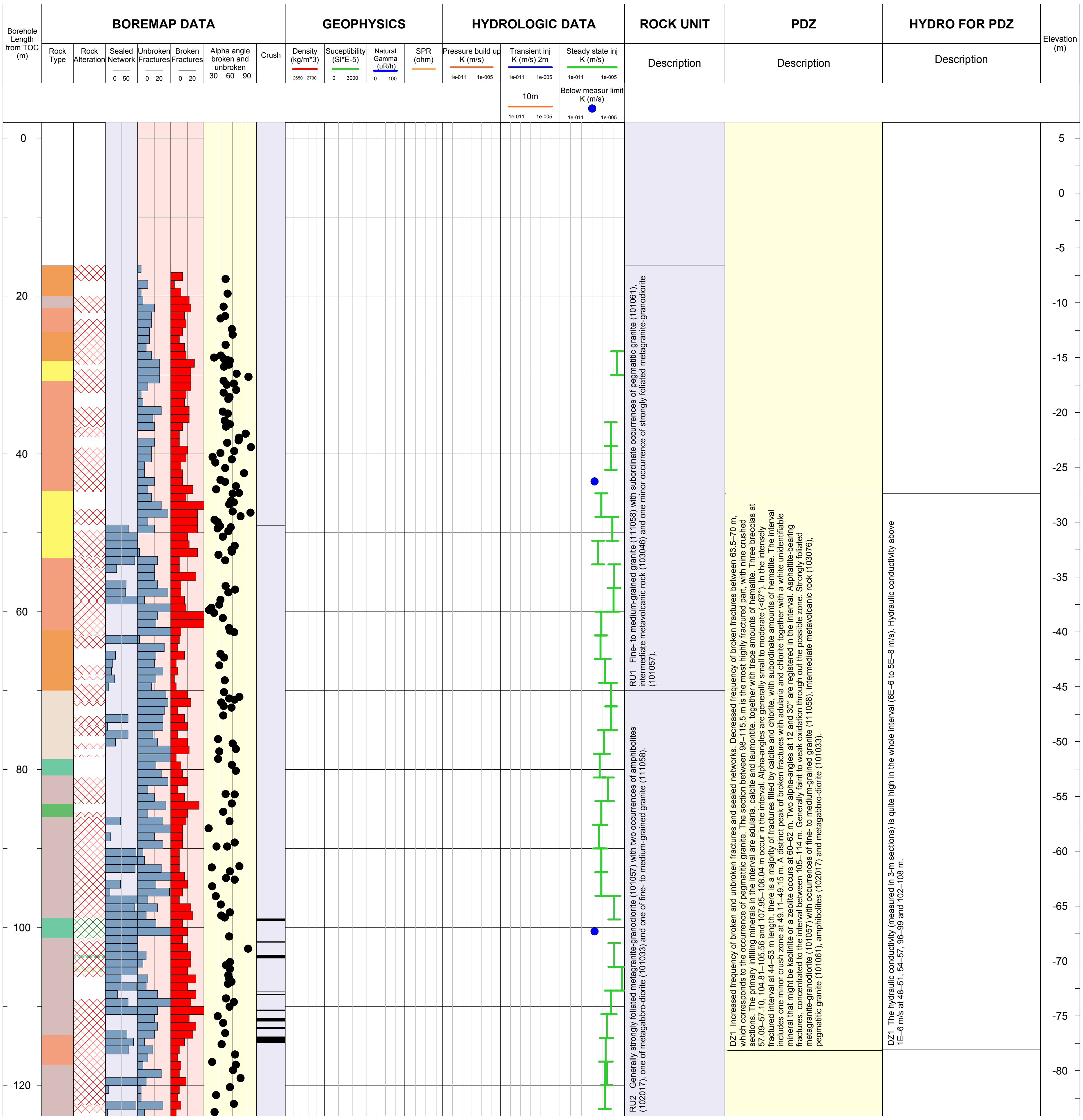
Site	FORSMARK - SFR	**Coordinate System**	RT90-RHB70
Borehole	KFR36	**Northing [m]**	6701922.23
Diameter [mm]	56	**Easting [m]**	1632792.99
Length [m]	123.900	**Elevation [m]**	5.00
Activity Type	GE038	**Bearing [°]**	291.71
Date of mapping	2007-10-04 09:34:00	**Inclination [°]**	-45.99

ROCK TYPE

- Granite, fine- to medium-grained
- Pegmatite, pegmatitic granite
- Granite, metamorphic, aplitic
- Granite to granodiorite, metamorphic, medium-grained
- Diorite, quarts diorite and gabbro, metamorphic
- Amphibolite
- Felsic to intermediate volcanic rock, metamorphic

ROCK ALTERATION

- Oxidized
- Chloritisized
- Epidotisized
- Steatitization
- Laumontitization



Title GEOLOGY KFR54

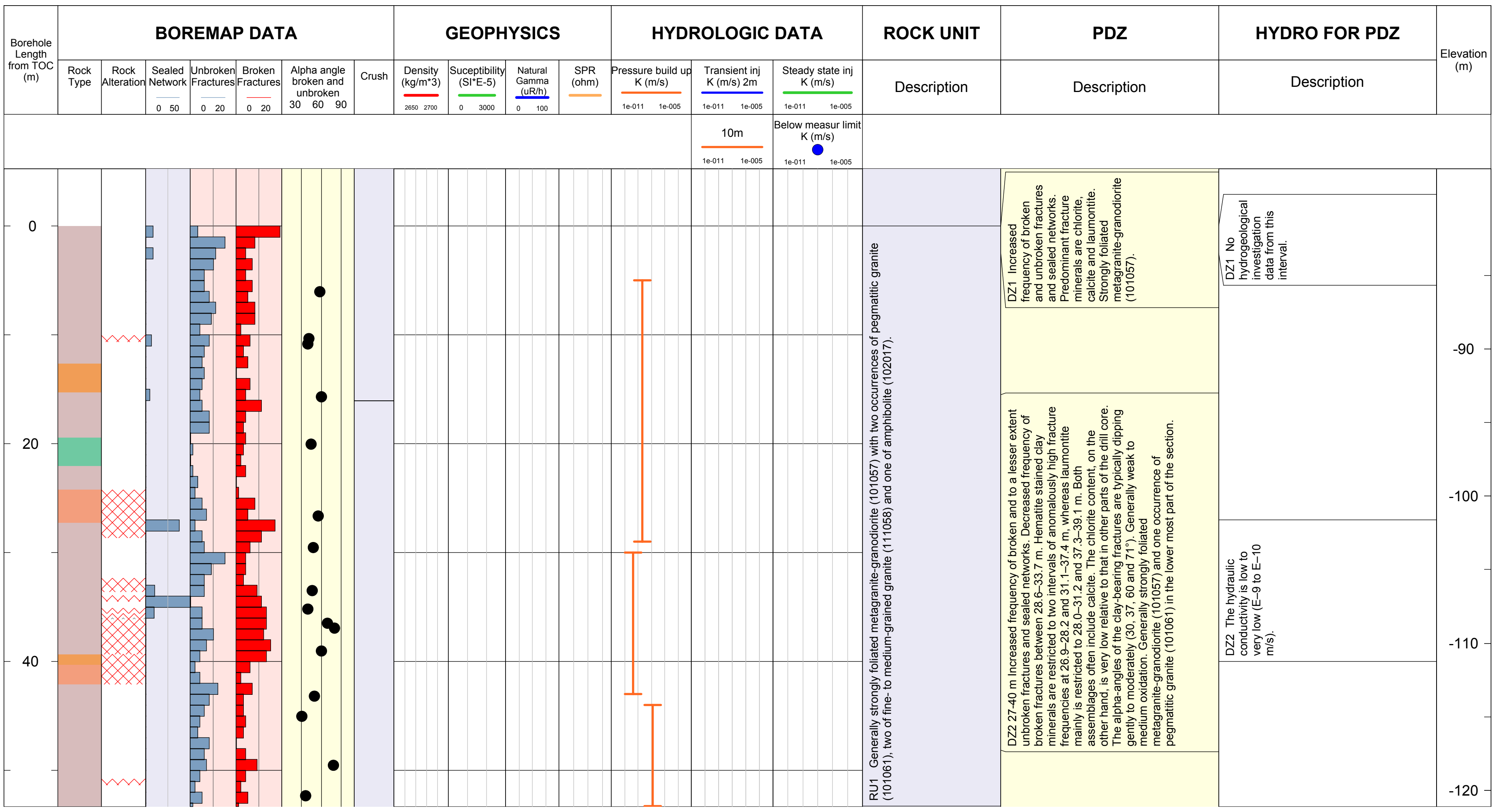
Site	FORSMARK - SFR	Coordinate System	RT90-RHB70
Borehole	KFR54	Northing [m]	6701949.71
Diameter [mm]	56	Easting [m]	1633102.00
Length [m]	53.300	Elevation [m]	-81.64
Activity Type	GE038	Bearing [°]	309.97
Date of mapping	2007-10-04 09:34:00	Inclination [°]	-47.69

ROCK TYPE

- Granite, fine- to medium-grained
- Pegmatite, pegmatitic granite
- Granite to granodiorite, metamorphic, medium-grained
- Amphibolite

ROCK ALTERATION

- Oxidized
- Argillization



Title GEOLOGY KFR55

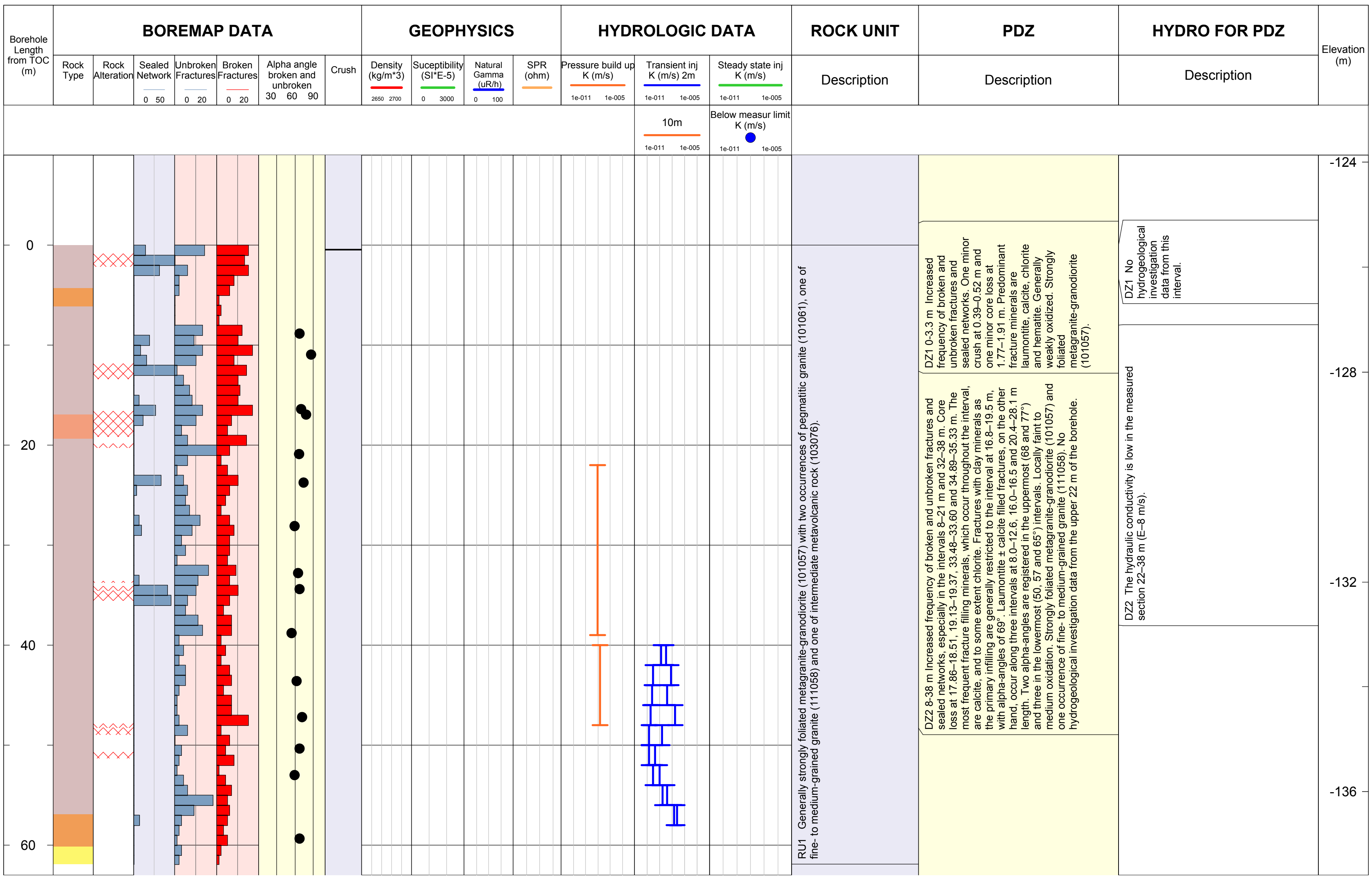
Site	FORSMARK - SFR	**Coordinate System**	RT90-RHB70
Borehole	KFR55	**Northing [m]**	6701930.05
Diameter [mm]	56	**Easting [m]**	1633094.49
Length [m]	61.890	**Elevation [m]**	-125.57
Activity Type	GE038	**Bearing [°]**	328.98
Date of mapping	2007-10-04 09:34:00	**Inclination [°]**	-10.99

ROCK TYPE

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

ROCK ALTERATION

- Oxidized



Title GEOLOGY KFR7A

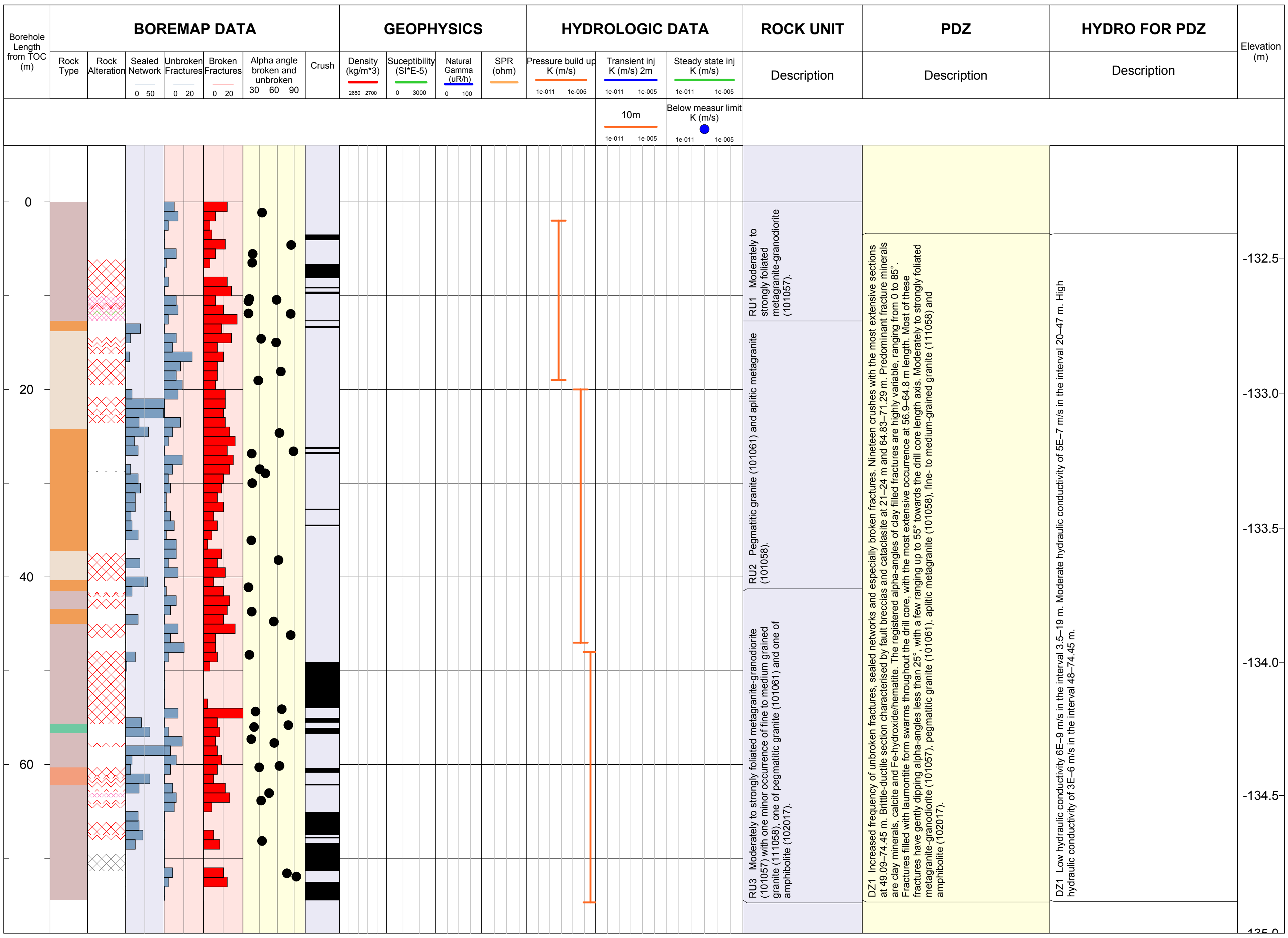
Site	FORSMARK - SFR	**Coordinate System**	RT90-RHB70
Borehole	KFR7A	**Northing [m]**	6702020.20
Diameter [mm]	56	**Easting [m]**	1633107.36
Length [m]	74.700	**Elevation [m]**	-132.28
Activity Type	GE038	**Bearing [°]**	20.80
Date of mapping	2007-10-04 09:34:00	**Inclination [°]**	-1.99

ROCK TYPE

- Granite, fine- to medium-grained
- Pegmatite, pegmatitic granite
- Granite, metamorphic, aplitic
- Granite to granodiorite, metamorphic, medium-grained
- Amphibolite

ROCK ALTERATION

- Oxidized
- Epidotisized
- Argillization
- Albitization

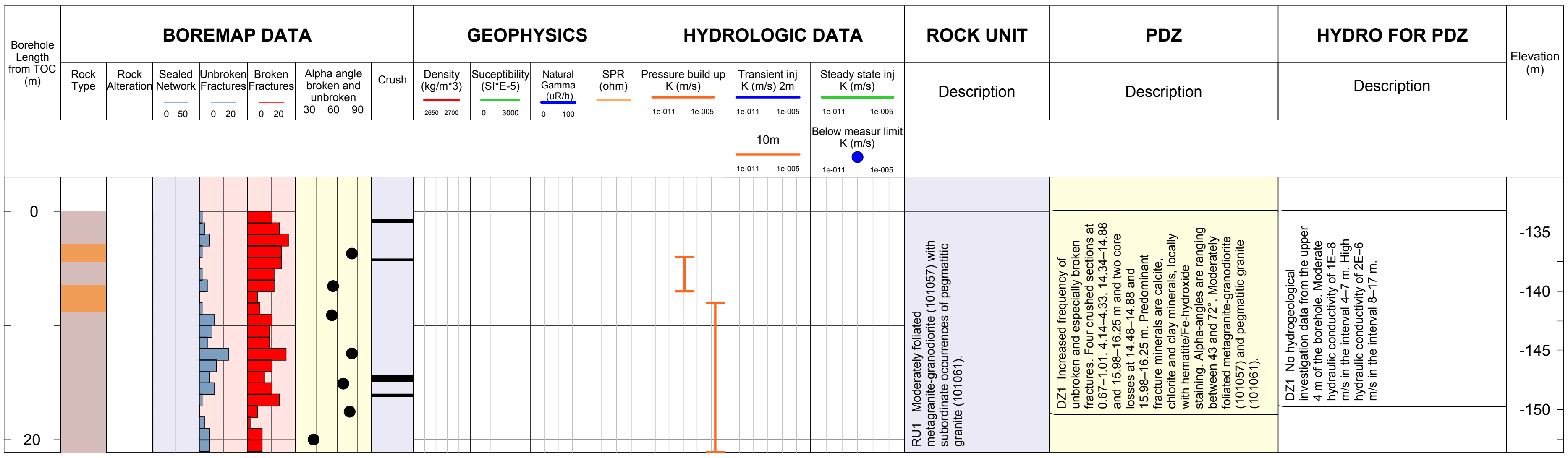


Title	GEOLOGY KFR7B		
Site	FORSMARK - SFR	Coordinate System	RT90-RHB70
Borehole	KFR7B	Northing [m]	6702017.62
Diameter [mm]	56	Easting [m]	1633109.54
Length [m]	21.100	Elevation [m]	-133.24
Activity Type	GE038	Bearing [°]	11.50
Date of mapping	2007-10-04 09:34:00	Inclination [°]	-74.99

ROCK TYPE

- Pegmatite, pegmatitic granite
- Granite to granodiorite, metamorphic, medium-grained

ROCK ALTERATION



Title	GEOLOGY KFR7C		
Site	FORSMARK - SFR	Coordinate System	RT90-RHB70
Borehole	KFR7C	Northing [m]	6701999.29
Diameter [mm]	56	Easting [m]	1633100.63
Length [m]	34.000	Elevation [m]	-133.39
Activity Type	GE038	Bearing [°]	196.00
Date of mapping	2007-10-04 09:34:00	Inclination [°]	-69.99

ROCK TYPE

- Granite, fine- to medium-grained
- Pegmatite, pegmatitic granite
- Granite to granodiorite, metamorphic, medium-grained

ROCK ALTERATION

- Oxidized
- Argillization
- Albitization