P-09-37

Site investigation SFR

Boremap mapping of percussion drilled boreholes HFR101, HFR102 and HFR105 and core drilled borehole KFR27 (down to 147.4 m length)

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Abstract

This report presents the result from the Boremap mapping of the percussion drilled boreholes HFR101, HFR102 and HFR105 and core drilled borehole KFR27 (downto 147.4 m borehole length) which are situated on the pier outside Forsmark nuclear power plant adjacent to the existing repository for low- and intermediate-level waste (SFR). The percussion drilled boreholes were drilled during spring 2008 with the aim to gather information about the geological and hydrogeological properties of the near surface bedrock as well as to investigate one deterministic deformation zone and four low magnetic lineaments. KFR27 was drilled in the 1980's during the building of the present SFR in order to measure the rock stress in the area.

The geological mapping of the boreholes began in May 2008 and was finished in October 2008. The mapping is based on the borehole image (BIPS) and on generalized, as well as more detailed geophysical logs. In some cases the drill cuttings were investigated to support the mapping. No such support was possible for the mapping of KFR27, since the drill core was not available.

The dominating rock type in HFR101, HFR102, HFR105 and KFR27 is a mostly foliated, somewhat folded metagranite-granodiorite. The deformation is stronger in HFR105, which is situated closer to the Singö deformation zone, and in places the foliation grades into a gneissic structure. Younger pegmatite to pegmatitic granite and fine- to medium-grained granite are also frequent in the percussion drilled boreholes. These rock types are usually massive or have a linear fabric. Also a felsic to intermediate metavolcanic rock is interpreted to appear in the boreholes, except for in HFR102. This rock type is difficult to separate from the metagranite-granodiorite in the BIPS-image, but is discerned in the geophysical logs by a higher magnetic susceptibility. Subordinate rock types are amphibolite, fine- to medium-grained metagranitoid and thin quartz-dominated hydrothermal veins.

Oxidation of the rock occurs in certain intervals in all boreholes, but the alteration is more intense in HFR105 relative to HFR101, HFR102 and KFR27. Only in HFR105 has other types of alterations been observed, namely sporadic epidotization and albitization.

The boreholes show following interpreted open fracture frequencies: HFR101 has 2.4 fractures/m, HFR102 has 3.6 fractures/m, HFR105 has 4.1 fractures/m, while KFR27 has only 1.2 open fractures/m. The interpretation of open contra sealed fractures is somewhat different in BIPS-images from percussion drilled boreholes versus the core drilled boreholes, and therefore the frequency of open fractures in KFR27 is probably underestimated relative to the frequencies in percussion drilled boreholes.

When it comes to interpreted sealed and partly open fractures, KFR27 and HFR105 exhibits the highest fracture frequencies, 5.7 sealed fractures/m and 0.4 partly open fractures for KFR27 and 4.6 sealed fractures/m and 0.4 partly open fractures/m for HFR105. The corresponding frequencies for HFR101 are 2.1 sealed fractures/m and 0.3 partly open fractures/m and for HFR102 it is 2.5 sealed fractures/m and 0.3 partly open fractures/m. Fractures in sealed networks and in crush are excluded in the frequencies.

Also, other types of deformation are frequently occurring in HFR105 relative to the other boreholes. In HFR105 there are 5 crushed sections, 22 sealed fracture networks, 4 breccias, 4 cataclasites, 1 brittle-ductile deformation band and 12 fault planes. In HFR101 no crushed section is observed, but there is a sealed fracture network and three ductile deformation bands. In HFR102 the pegmatite looks cataclastic in an almost 1 m long interval, but no other signs on either crush or sealed fracture networks can be found. In KFR27 one thin interpreted ductile shear zone, one possible brittle-ductile shear zone and one possible cataclasite is observed, as well as 15 sealed fracture networks.

Sammanfattning

Denna rapport redovisar resultatet från Boremapkartering av de hammarborrade borrhålen HFR101, HFR102 och HFR105, samt det kärnborrade borrhålet KFR27 (ner till 147,4 m), vilka alla är belägna vid piren utanför Forsmark kärnkraftverk i anslutning till det befintliga slutförvaret för låg- och medelaktivt avfall, benämnt SFR. Hammarborrhålen borrades under våren 2008 med syfte att ge information om ytbergets geologiska och hydrogeologiska egenskaper, samt att undersöka en modellerad deformationszon och fyra lågmagnetiska lineament. KFR27 borrades under 1980-talet med syftet att mäta bergspänningarna i området.

Den geologiska karteringen av borrhålen påbörjades i maj 2008 och avslutades i oktober 2008. Karteringarna är baserade på borrhålsbilden (BIPS) och generaliserade samt mer detaljerade geofysiska loggar. I några fall har borrkaxet undersökts för att ge stöd åt karteringen. Inget sådant extra stöd fanns att tillgå vid karteringen av KFR27.

Den dominerande bergarten i HFR101, HFR102, HFR105 och KFR27 är en mestadels folierad och något veckad metagranit-granodiorit. HFR105, som ligger närmare Singö-zonen uppvisar en starkare deformation, och där övergår foliationen ställvis till gnejsighet. Yngre pegmatit till pegmatitisk granit och fin- till medelkornig granit är också vanligt förekommande i hammarborrhålen. Dessa bergarter är vanligen massiva eller uppvisar en stänglighet. Även felsiska till intermediära metavulkaniter antas förekomma i borrhålen, med undantag av HFR102. Dessa är svåra att separera från metagranit-granodioriten i BIPS-bilden, men utmärker sig i de geofysiska loggarna med en högre magnetisk susceptibilitet. Underordnade bergarter är amfibolit, fin- till medelkornig metagranitoid och tunna kvartsgångar.

Oxidation av berget förekommer i vissa intervall i alla borrhål, men omvandlingen är mer intensiv i HFR105 jämfört med HFR101, HFR102 och KFR27. Det är enbart i HFR105 annan typ av omvandling har påträffats, nämligen enstaka sektioner med epidotisering och albitisering.

Borrhålen uppvisar följande sprickfrekvenser: HFR101 har 2,4, HFR102 har 3,6 och HFR105 har 4,1 tolkade öppna sprickor/m, medan KFR27 endast har 1.2 tolkade öppna sprickor/m. Bedömningen huruvida sprickorna är öppna eller inte i BIPS-bilder från hammarborrhål respektive kärnborrhål är något olika, varför de öppna sprickorna sannolikt är underskattade i KFR27 jämfört med de hammarborrade hålen.

När det gäller tolkade läkta och delvis öppna sprickor uppvisar HFR105 och KFR27 de högsta sprickfrekvenserna, nämligen 5,7 läkta sprickor/m och 0,4 delvis öppna sprickor/m i KFR27 och 4,6 läkta sprickor/m och 0,4 delvis öppna sprickor/m i HFR105. Motsvarande frekvenser för HFR101 är 2,1 läkta sprickor/m och 0,3 delvis öppna sprickor/m och för HFR102 är det 2,5 läkta sprickor/m och 0,3 delvis öppna sprickor/m.

Även andra typer av deformation är frekvent förekommande i HFR105 jämfört med de övriga borrhålen. I HFR105 återfinns 5 krossade sektioner, 22 läkta spricknätverk, 4 breccior, 4 kataklasiter, 1 sprött till plastiskt deformationsband och 12 förkastningsplan. I HFR101 återfinns ingen kross, men däremot ett läkt spricknätverk och tre plastiska deformationsband. I HFR102 ser pegmatiten kataklastisk ut i ett nästan 1 m långt intervall, men i övrigt förekommer inga tecken på vare sig kross eller läkta spricknätverk. I KFR27 återfinns en tolkad plastisk skjuvzon, en möjlig spröd-plastisk skjuvzon och en möjlig kataklasit. Därtill har 15 läkta spricknätverk dokumenterats.

Contents

1 Introduction

SKB intends to enlarge the repository for low- and intermediate-level waste in Forsmark (SFR) which was completed and ready for operation in 1988. Protection clothing, trash and filters that are used to clean the reactor water are examples of radioactive waste that are stored in SFR. In the future, SFR is also going to host the waste that arises from the demolishing of the nuclear plants. An extension of SFR is therefore planned and it is estimated to be ready in 2020.

A lot of information about the bedrock and groundwater has already been gathered during the building of SFR, but some complementary studies are needed. This document reports the data gained by the Boremap mapping of three percussion drilled boreholes and one core drilled borehole, which is one of the activities performed within the site investigation SFR. Locations of the boreholes are presented in Figure 1-1. The work was carried out in accordance with activity plan AP SFR-08-006. In Table 1-1 controlling documents for performing this activity are listed. Both activity plan and method descriptions are SKB's internal controlling documents.

The percussion drilled and core drilled boreholes were, after completion of drilling, investigated with several logging methods, such as conventional geophysical logging and TV-logging. The latter method implies logging with a colour TV-camera to produce images of the borehole wall, so called BIPS-images (Borehole Image Processing System).

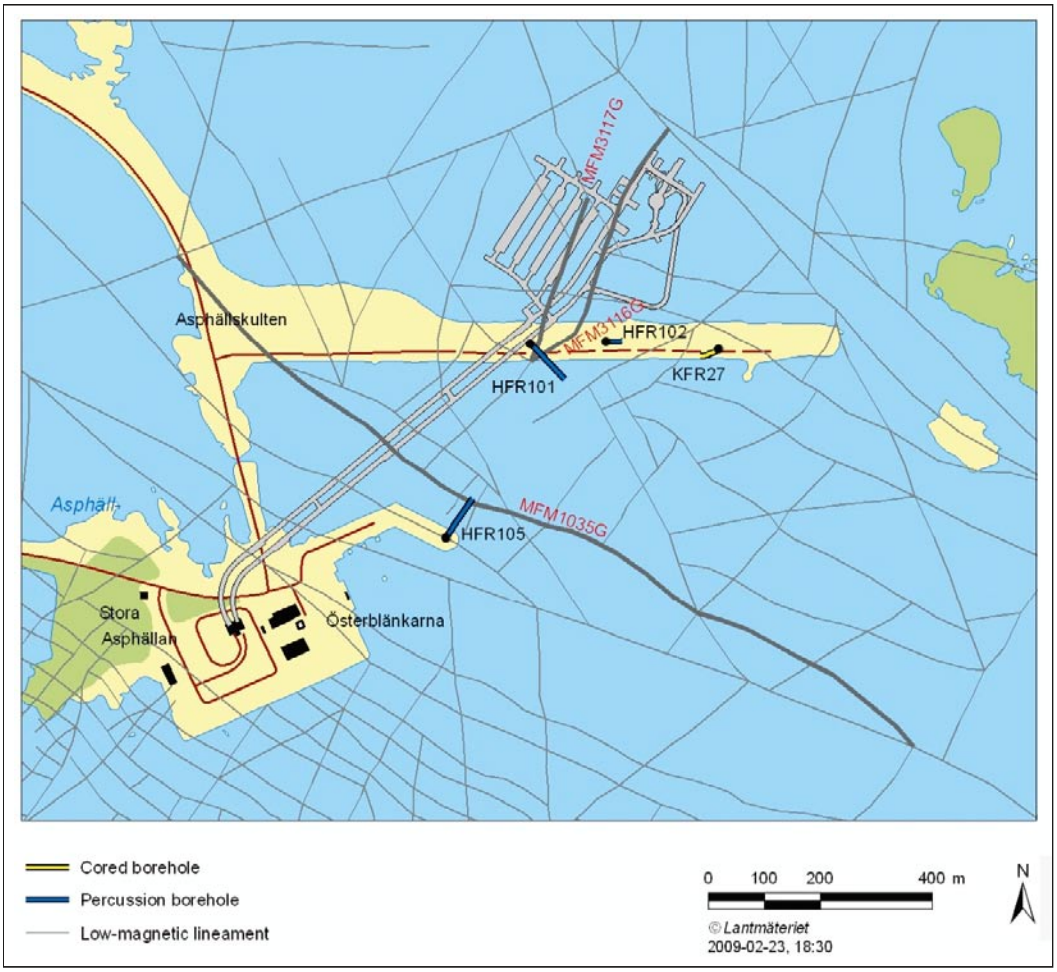

Figure 1-1. Location of percussion drilled boreholes HFR101, HFR102, HFR105 as well as core drilled borehole KFR27 in relation to SFR. Three lineaments with low magnetic intensity, expected to be intersected by the boreholes, are highlighted.

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

Activity plan	Number	Version
Boremapkartering av hammarborrhål HFR101–102, HFR105, kärnborrhål KFR101 samt borrhål KFR27.	AP SFR-08-006	1.0
Method descriptions	**Number**	**Version**
Metodbeskrivning för Boremapkartering	SKB MD 143.006	2.0
Mätsystembeskrivning för Boremap	SKB MD 146.005	1.0
Instruktion: Regler för bergarters benämningar vid platsundersökningen i Forsmark	SKB MD 132.005	1.0

The boreholes were mapped during the period May 2008–October 2008. Mapping of percussion boreholes according to the Boremap method is based on the use of BIPS-images of the borehole wall supported by study of drill cuttings (Appendix 5) and generalized geophysical logs (Appendix 3). KFR27 is a core drilled borehole from the 1980's. The borehole could not be mapped by simultaneous study of the drill core and the BIPS-image, since there was no access to the drill core. The mapping of KFR27 is therefore based on the BIPS-image and the mapping resembles the mapping of a percussion drilled boreholes. KFR27 was extended during the ongoing investigation programme and the old part of the borehole was reamed with the purpose to receive a fresh borehole wall for the BIPS-logging. The Boremap mapping of the extended part of the borehole is presented in a separate P-report /1/.

The BIPS-images enable the study of the distribution of fractures along the borehole. Fracture characteristics like aperture, colour of fracture minerals, etc are possible to study as well. Furthermore, since the BIPS software has the potential of calculating strike and dip of planar structures such as foliations, rock contacts and fractures intersecting the borehole, also the orientation of each planar structure is documented with the Boremap method.

Original data from the reported activity are stored in the primary database Sicada where they are traceable by the Activity Plan number (AP SFR 08-006). Only data in SKB's databases are accepted for further interpretation and modelling.

2 Objective and scope

The aim of this activity was to document lithologies, ductile structures and the occurrence and character of fractures in the bedrock penetrated by the percussion drilled boreholes HFR101, HFR102 and HFR105 as well as core drilled borehole KFR27. The deterministically modelled deformation zone ZFM871 (also called H2-zone) is expected to be intersected by HFR101. The boreholes also intersect three other lineaments with low magnetic intensity that are possible deformation zones. The purpose of the boreholes was also to reveal information about the character of these lineaments and of ZFM871. Borehole KFR27, which was drilled during the building of the SFR in the 1980's, was drilled in order to measure the rock stress in the area.

Other data obtained from the percussion drilled boreholes, such as thickness of soil cover, soil stratigraphy, groundwater level and groundwater flow, will not be treated in this report.

3 Equipment

3.1 Description of equipment/interpretation tools

Mapping of the boreholes based on BIPS-images was performed with the software Boremap v.3.9.6.4. The Boremap software is loaded with the rock types and mineral standard used for surface mapping at the Forsmark investigation site, in order to enable correlation with the surface geology. Inclination, bearing and diameter of the borehole are used as in-data for the calculations (Table 4-2). The BIPS-image lengths were calibrated (Table 4-1).

Schematic presentations of the boreholes are presented in WellCAD-diagrams (Appendix 1).

When investigating the drill cuttings, tap water, an ordinary kitchen strainer, a hand lens and 10% hydrochloric acid was used.

3.2 BIPS-image

3.2.1 Used BIPS-images

The BIPS-images that have been used in the mappings are listed in Table 3-1.

3.2.2 BIPS-image quality

The BIPS-image qualities of the boreholes are listed in Table 3-2. The results from the BIPS-loggings are presented in a P-report /2/.

Table 3-1. Used BIPS-files.

Borehole	BIPS-image	Logging date	Logging time	From (m)	To (m)
HFR101	HFR101.BIP	2008-05-20	08:47	8.000	207.299
HFR102	HFR102.BIP	2008-05-20	13:10	9.000	54.723
HFR105	HFR105.BIP	2008-05-19	13:00	20.000	199.090
KFR27	KFR27_11_147_20080709.BIP	2008-07-09	22:35	11.000	147.457

Table 3-2 BIPS-image quality.

Borehole	From	To	% visible	Comment
HFR101	8.00	27.91	100	Poor image quality. Light reflection from dry borehole wall aggravates the interpretation.
	27.91	207.63	100	Good image quality.
	207.63	208.32	40–60	Acceptable image quality. Coating on the edges of the image.
HFR102	9.00	54.74	100	Good image quality.
HFR105	20.00	125	100	Good image quality.
	125	200.09	80–100	Relatively good image quality. Semitransparent coating on the edges of the image. Image interval seems overexposed relative to the first image interval.
KFR27	10.09	148.09	100	Good image quality.

4 Execution

4.1 General

Boremap mapping of the percussion drilled boreholes HFR101, HFR102 and HFR105 and core drilled borehole KFR27 was performed and documented according to activity plan AP SFR 08-006 (SKB, internal document). Geophysical logs of the boreholes supported the mapping and the drill cuttings were investigated when considered necessary. The mapping was performed in accordance with the SKB method description for Boremap mapping SKB MD 143.006, as well as SKB MD 146.001 (SKB internal controlling documents) and /3/. Information from earlier performed investigations in the area were also helpful in the interpretations /4, 5, 6, 7, 8 and 9/.

4.2 Preparations

Length adjustments of the BIPS-images were made for all the boreholes. However, groove marks are not available in percussion borehole or in older boreholes such as KFR27. Due to this, length adjustments were made based on known experience from core drilled boreholes with groove marks. This implies that the registered length in the BIPS-images can deviate up to approximately 0.5 m per 100 m from the real borehole length (SKB MD 143.006, SKB internal controlling document). The last 30 cm of the boreholes cannot be logged with BIPS due to the position of the battery package below the camera lens. The applied length adjustments are listed in Table 4-1.

Background data collected from Sicada prior to the Boremap mapping included:

- Borehole diameter (Appendix 2).
- Total borehole length (automatic import routine from Sicada to Boremap, Appendix 2).
- Borehole deviation data (automatic import routine from Sicada to Boremap).

Resampled and calibrated geophysical logging data as well as generalized geophysical logs from Geovista AB were used as supporting data for the mapping of all boreholes (Appendix 3).

General information about the boreholes is listed in Table 4-2.

Table 4-1 Length adjustments for BIPS-images.

Borehole	Recorded length (m)	Adjusted length (m)	Difference (m)
HFR101	8.05	8.04	–0.01
	207.290	208.327	1.037
HFR102	9.045	9.04	–0.005
	54.69	54.74	0.05
HFR105	21.114	21.12	0.006
	199.09	200.085	0.995
KFR27	11.914	11.82	–0.094
	147.444	147.484	0.040

Table 4-2. Borehole data for HFR101, HFR102, HFR105 and KFR27.

ID-code	Northing	Easting	Bearing (degrees)	Inclination (degrees)	Diameter (mm)	Borehole length (m)	Mapping interval (m)	End of casing
HFR101	6701725.15	1632838.91	150.0	–60.0	138	209.30	8.04–208.32	8.04
HFR102	6701728.55	1632974.54	085.0	–59.1	138	55.04	9.04–54.74	9.04
HFR105	6701376.55	1632686.82	034.5	–63.0	140	200.50	21.12–200.09	21.12
KFR27	6701714.42	1633175.52	248.2	–87.4	76	148.51	11.82–147.49	11.82

4.3 Execution of measurements

Available geological information is more limited for percussion drilled boreholes than core drilled boreholes, where the drill core can be directly compared with BIPS-images of the borehole wall. Since no drill core was available for KFR27 the borehole is mapped with the same method as percussion drilled boreholes. During mapping of percussion boreholes, fractures and rock types can only be seen in the BIPS-images. Since solid rock samples are not accessible, certain assumptions and simplifications have to be made during mapping. These are described below.

4.3.1 Fractures

As fractures could be studied only in the BIPS-image they could not be confidently classified as rough, smooth or slickensided, nor could their mineralogy or alteration be determined. The following assumptions were made:

- Width of very thin fractures (< 1.5 mm) were impossible to measure accurately and was therefore, as a rule, interpreted as 1 mm thick or, if only partly or vaguely observed, as 0.7 mm thick (0.5 mm thick for KFR27).
- Fractures were assumed to be open, if not clearly observed to be sealed.
- Fractures only indicated by shadows were mapped as open with a possible aperture of 0.7 mm. This applies on percussion drilled boreholes.
- Fractures with reddish rims were mapped as "oxidized walls". No other fracture mineral was generally documented.
- Mapped fracture alteration only counts for visible fracture wall alteration, which is mainly red staining, i.e. it should not be mixed with ISRM´s classification of fracture alteration, which cannot be applied on this mapping.

Comparing fractures in KFR27 with other boreholes.

The mapping of fractures in KFR27 are not fully comparable to the mapping of fractures in percussion drilled boreholes, since fractures have a slightly different appearance in BIPS-images from core drilled and percussion drilled boreholes. This is due to the better resolution of BIPS-images from core drilled boreholes because of the smaller borehole diameter (which is 76 mm, resulting in a resolution of ~ 0.7 mm/pixel) relative to BIPS-images from percussion drilled boreholes (140 mm borehole diameter, resulting in a resolution of ~ 1.2 mm/pixel), but also to the difference in drilling technique.

All fractures indicated by an intense shadow in the central part of the fracture, thus indicating an aperture, are mapped as open. Since the image resolution is better in KFR27 relative to the percussion drilled boreholes, it could be expected that more open fractures would be documented in KFR27. However, such fractures was rarely observed in KFR27 as well as in other core drilled boreholes, but are common in percussion drilled boreholes.

Open fractures in KFR27 are underestimated relative to other core drilled boreholes. Since no drill core was available for KFR27, judgements whether fractures with no visible aperture in BIPS have a probable or a possible aperture could not be made according to method description (SKB MD 143.008). Instead these fractures are mapped as sealed fractures.

In order to compare fracture frequencies in KFR27 with other core drilled fractures, only fractures with certain aperture in the other core drilled boreholes should be counted.

4.3.2 Rock colour and alteration

Colours in the BIPS-images appear somewhat altered and bleached relative to the actual rock colour, and the classifications of the rock colours are therefore likely to be less accurate. The varying exposure of the BIPS-image as well as drill cutting in suspension in the borehole water complicates the interpretation of oxidized sections. Sections with higher exposure are less reddish than sections with lower exposure, and sections rich in suspension looks more brownish/reddish in the BIPS-image than sections with no or less suspension.

Albitization is relatively easy to recognize when it occurs adjacent to amphibolitic rock, but if not, this type of alteration is hard to distinguish from metamorphic pegmatites /10/. Other rock alterations are usually not distinguishable in the BIPS image.

4.3.3 Rock contacts

Orientation of irregular or diffuse rock contacts may be difficult to observe and measure with the Boremap method, since only planar and discrete features can be accurately measured.

4.3.4 Lithologies and correlation with geophysical data

Classification of lithology was sometimes difficult since some of the rock types appear rather similar in terms of texture, structure and colour. The classification of the granitic rocks is usually based on relative age, which is displayed in different structural and textural appearance (massive, lineated or foliated) and in crosscutting relationships. Unfortunately structures are not always discernible in the BIPS-image and due to the fine grain-size of the drill cuttings, these are not always helpful in determining the structure of the rock.

Generalized geophysical logs /9, 11/ are very useful for interpreting rock occurrences > 20 cm wide, but the difference in geophysical properties is rarely shown in the log for rock occurrences < 20 cm wide. Therefore, more detailed plots of the geophysical properties, denoted litho-logs, have been used in the interpretation (Appendix 3). The silica density log shows the composition of the rock; whether it is granitic, granodioritic, tonalitic, dioritic or gabbroic in composition. The natural gamma radiation log can be used to separate the younger granitic rocks, fine- to medium-grained granite (111058), and some pegmatite (101061) from the others. The geophysical characteristic of pegmatite and granite is low silica density (~ 2,600 kg/m^3) and relatively high gamma radiation (> 36 μR/h, sometimes > 200 μR/h). The magnetic susceptibility of a rock type is affected by oxidation and metamorphism and can therefore vary within the same rock type. With this in mind, it can be used to separate different rock types from each other.

Drill cuttings were investigated to classify the rock types and/or alterations only when considered necessary.

4.3.5 Grain-size

Classification of grain-size can be difficult, especially for minor rock occurrences of fine or medium grain-size. This is due to the pixel resolution of the BIPS-image and the difficulty to measure the width of grains less than 2 mm. For rocks composed of minerals of similar colours, the grain-size can be overestimated when relying too much on the BIPS-images.

4.3.6 Foliation and lineation

Foliation and lineation are difficult to separate from each other in the BIPS-image, unless the structure is clearly developed. Intersection angle of the structures also affects the possibility to distinguish foliation from lineation. In the mapping of percussion drilled boreholes during the site investigation Forsmark, steep or vertical structures could be interpreted as foliation while sub-horizontal and gently dipping structures could be interpreted as lineation. The SFR area shows generally a greater strain compared to the lens of the candidate area and gently dipping foliation also occurs. Therefore, most visible structures in the mappings of HFR101, HFR102 and HFR105 are considered to be foliation and not lineation. However, lineation is well developed in rocks penetrated by KFR27 and is clearly visible in the BIPS-image. Due to the difficulty in separating the structures from each other in the BIPS-image, some misinterpretations may occur.

4.4 Data handling/post processing

The Boremap mappings of HFR101, HFR102, HFR105 and KFR27 were performed on a local computer disk, while a backup of the Boremap mapping was saved on Geosigma's computer network before each break exceeding 15 minutes. When the mappings were finished and quality checked by the author and by a routine in Boremap, the data was submitted to SKB for exportation to Sicada.

All data are stored in the SKB Sicada database, and it is only these data that should be used for further interpretation.

4.5 Nonconformities

4.5.1 Length adjustments

The applied length adjustment (about +0.5 m/100 m borehole) showed to be incorrect for borehole KFR27. KFR27 was extended after the execution of this activity whereupon reference slots were cut into the borehole wall, and the borehole was filmed again with BIPS-camera. By comparing an overlapping section of this new, correctly adjusted BIPS-image it was noticed that the original adjusted end length of the mapping should not be 148.09 m but 147.484 m instead. This will be corrected for when the mappings of the first part (this report) and the extended part are connected.

4.5.2 Drilling penetration rate

Drilling penetration rate has not been used in the interpretation of the mappings.

5 Results

The Boremap mappings of HFR101, HFR102, HFR105 and KFR27 are stored in Sicada, and it is only these data that shall be used for further interpretation and modelling. The user of these data should be aware of the assumptions mentioned in Section 4. The graphical presentations of the data are given as WellCAD-diagrams in Appendix 1. Summaries of rock types and fracture frequency in the boreholes are presented in Tables 5-1 and 5-2, respectively.

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 P-report, although the normal procedure is that major revisions entail a revision of the P-report. Minor revisions are normally presented as supplements, available at www.skb.se.

5.1 General lithology

The boreholes show a similar lithology (Table 5-1), since they are drilled in a small restricted area. The boreholes are dominated by foliated metagranite-granodiorite (101057) followed by massive or lineated pegmatites (101061) and lineated fine- to medium-grained granites (111058). Less frequent rock types include minor occurrences of felsic to intermediate metavolcanic rock (103076), fine- to medium-grained metagranite-granodiorite-tonalite (101051), as well as quartz dominated hydrothermal veins (8021).

5.2 HFR101

The dominating rock type in HFR101 is pegmatite to pegmatitic granite (101061) followed by metagranite-granodiorite (101057), fine- to medium-grained granite (111058) and felsic to intermediate metavolcanic rock (103076). Minor rock types are amphibolite (102017), and quartz-dominated hydrothermal vein (8021) (Table 5-1 and Appendix 1).

Most of the pegmatites have a relatively high gamma radiation and exhibit often a weak lineation. Similar to the pegmatites, the fine- to medium grained granite seems to be either lineated or massive. These two rock types dominate the intervals 8.0–36 m and 84–188 m borehole lengths. The metagranite-granodiorite dominates the interval 36–84 m and 188–208 m and it is interpreted to be foliated with a sub-horizontal orientation. However, the structure is only vaguely observable in BIPS and the orientation is uncertain.

The felsic to intermediate metavolcanic rock is uncertain. The contacts are not always clearly visible in the BIPS-image but the intervals are clearly separated by higher magnetic susceptibility (0.01 SI) relative to the interpreted metagranite-granodiorite. Also a drill cutting sample (69 m) indicates felsic to intermediate metavolcanic rock.

Three bands which may be thin ductile shear zones occur in the following intervals (orientations in parenthesis): 48.85–49.20 m (~ 290°/30°), 127.07–127.51 m (~ 060°/55°) and 175.04–175.78 m (~ 060°/10°).

Shorter oxidized intervals occur throughout the borehole. No albitization was confidently observed.

In the mapped interval of HFR101 a number of 955 fractures were documented. Of them are 479 considered open, 63 partly open and 413 sealed, resulting in the following fracture frequencies: 2.4 open fractures/m, 0.3 partly open fractures/m and 2.1 sealed fractures/m (Table 5-2). There are quite many fractures that are parallel or sub-parallel to the borehole and these may be drill induced. The interval 14.1–19.9 m is relatively rich in fractures inferred to be open. Three dominating sets with open fractures oriented 220°/90°, 225°/50° and 225°/20° can be distinguished (Figure 5-1a). Subordinate fracture sets are oriented 335°/70° and 120°/20°. The interval 55.4–59.0 is relatively rich in sealed fractures. There are two dominating sets of sealed fractures with the orientation 200°/15° and 220°/90° (Figure 5-1b). A subordinate sealed fracture set is oriented 330°/70°.

No crushed sections were observed. One sealed fracture network is documented at 190.11–190.24 m length.

Table 5-1. Distribution of rock types in percent (rock occurrences excluded).

Rock type	HFR101	HFR102	HFR105	KFR27
Metagranite-granodiorite (101057)	27.0	38.1	49.3	42.4
Pegmatite and pegmatitic granite (101061)	50.2	42.6	23.9	45.8
Felsic to intermediate metavolcanic rock (103076)	9.5	0.0	5.0	2.8
Fine- to medium-grained granite (111058)	13.3	19.3	15.6	9.0
Amphibolite (102017)	–	–	5.0	–
Fine- to medium-grained metagranitoid (101051)	–	–	1.3	–

Table 5-2. Frequencies of interpreted fracture types (number of fractures/m).

Fracture type	HFR101	HFR102	HFR105	KFR27
Open	2.4	3.5	4.1	1.2
Partly open	0.3	0.3	0.4	0.4
Sealed	2.1	2.4	4.6	5.7

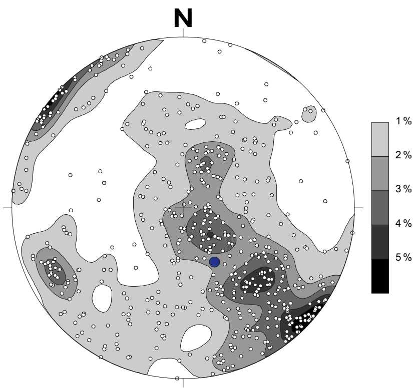

Figure 5-1a. *Contoured equal area stereographic projection showing interpreted open and partly open fractures (n=542) in HFR101. Blue dot represents borehole projection.*

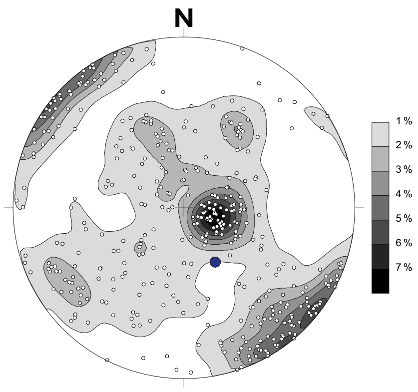

Figure 5-1b. *Contoured equal area stereographic projection showing interpreted sealed fractures (n=413) in HFR101. Blue dot represents borehole projection.*

5.3 HFR102

Pegmatite to pegmatitic granite (101061), metagranite-granodiorite (101057) and fine- to medium-grained granite (111058) are the dominating rock types in HFR102, while amphibolite (102017) is observed occasionally and only as rock occurrences (Table 5-1, Appendix 1).

The pegmatite occurs in the first 28 m and as thinner dykes below 28 m in the borehole. The pegmatite seems relatively massive and has a moderate gamma radiation (~ 36 μR/h). In the interval 25.12–26.06 m the pegmatite seems cataclastic. The orientation of the deformed section is roughly 090°/80°. The metagranite-granodiorite occurs in the intervals 28–39 m and 48–55 m. As in HFR101, the metagranite-granodiorite seems to have a sub-horizontal foliation, but the observations are uncertain. Fine- to medium-grained granite (111058) is observed in the interval 39–48 m, and minor occurrences of amphibolite (102017) occur in the upper half of the borehole. Oxidation occurs in a small, restricted interval.

In HFR102 289 fractures were observed. Of these are 165 interpreted to be open, 12 partly open and 112 are interpreted to be sealed. The frequency of open fractures is 3.6 fractures/m, while it is 0.3 fractures/m for partly open fractures and 2.5 fractures/m for sealed fractures (Table 5-2). No densely fractured interval is observed in the borehole. There is only one dominating set of open fractures and this is oriented 164°/85° (Figure 5-2a). There is also only one dominating set of sealed fractures which is oriented 174°/85° (Figure 5-2b). Subordinate sealed fracture sets are oriented 083°/30°, 120°/10° and 140°/90°.

Neither crushed sections nor sealed fracture networks were observed.

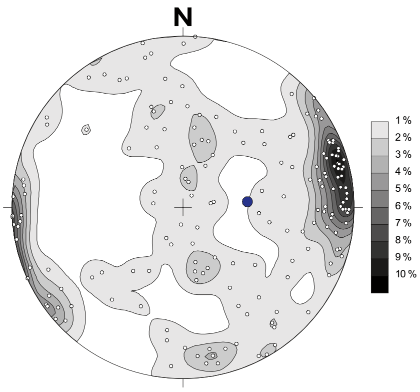

Figure 5-2a. Contoured equal area stereographic projection showing interpreted open and partly open fractures (n=177) in HFR102. Blue dot represents borehole projection.

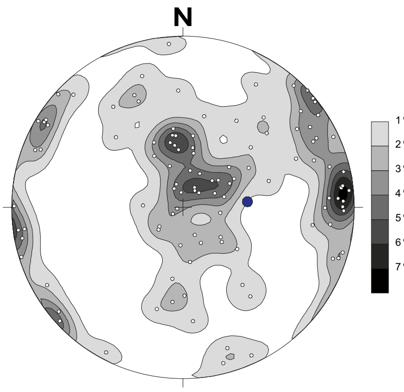

Figure 5-2b. Contoured equal area stereographic projection showing interpreted sealed fractures (n=112) in HFR102. Blue dot represents borehole projection.

5.4 HFR105

The borehole is dominated by moderately to strongly foliated metagranite-granodiorite (101057, Table 5-1), which in sections appears gneissic or "veined" (Appendix 1). Sections denoted "veined" are extremely rich in thin pegmatitic occurrences. The rock type is relatively dark in colour due to the moderate to strong foliation. Pegmatite to pegmatitic granite (101061) and fine- to medium-grained granite (111058) are the following most frequent rock types. The pegmatite and fine- to medium-grained granite look massive or lineated in BIPS and they are also characterized by higher gamma radiation in the borehole (> 36 μR/h, with some extremes ranging > 150 μR/h). Interpreted felsic to intermediate metavolcanic rock (103076) occurs in the intervals 33–42 m and 66–71 m borehole length and is separated from the metagranite-granodiorite by somewhat darker colour and higher magnetic susceptibility. Minor occurrences of amphibolite (102017) occur throughout the borehole but rarely in pegmatites and fine- to medium-grained granites.

The foliation and banding of the felsic to intermediate metavolcanic rock is subvertical and SW-trending (Figure 5-5a) reflecting the Singö deformation zone. Several displacements of veins or rock contacts have also been observed. The position (adjusted borehole length) and orientation of the faults are listed in Table 5-3. The roughly ENE striking sub-horizontal to moderately dipping faulting (Figure 5-5b) may reflect the influence of the H2-zone (ZFM871).

The closeness to the Singö deformation zone is also reflected in both the high amount of fractures that are observed: 1,622 fractures in total, and by the fracture orientations. Of these observed fractures, 737 are considered open (4.1 fractures/m), 66 partly open (0.4 fractures/m) and 821 sealed (4.6 fractures/m, Table 5-2). To that 11 crushed sections and 22 sealed networks have also been documented. There are two dominating sets of open fractures: 118°/75° and 060°/10° (Figure 5-3a), of which the first is

Table 5-3. Position and orientation of probable fault planes in HFR105.

Adjusted borehole length (m)	Orientation
35.036 m	076°/46°
63.813 m	059°/54°
65.198 m	065°/42°
73.152 m	128°/88°
74.707 m	040°/75°
110.874 m	053°/30°
124.750 m	050°/35°
125.742 m	337°/43°
129.083m	052°/49°
129.735 m	097°/56°
129.904 m	102°/38°
159.079 m	069°/78°

parallel to the Singö deformation zone. Also the sealed fractures are affected by the Singö deformation zone. The by far most dominating fracture set of sealed fractures is oriented 122°/80° (Figure 5-3b). In addition there is a subordinate set of sealed fractures oriented 270°/10°.

The borehole contains the following clearly deformed sections:

- 20–31 m: Increased frequency of open fractures and three crushed sections. The interval is oxidized. One sealed fracture network. One open fracture with aperture = 3 mm. Two thin deformation bands, interpreted as a brittle-ductile shear zone and a breccia both striking roughly 120˚ and dipping 80˚.
- 31–48 m: Relatively rich in sealed fractures with oxidized walls. Two thin sealed fracture networks.
- 66–72 m: Relatively rich in sealed fractures with oxidized walls. One thin sealed fracture network. In the end of the interval there is a crushed section.
- 88–94 m: Relatively rich in open fractures, two crushed sections, interpreted cataclastic rock with two sealed fracture networks (Figure 5-5a). Oxidation of medium to strong intensity.
- 116–123 m: Upper part shows increased frequency of open fractures. Central part (120.35–121.13 m) is interpreted to be cataclastic (Figure 5-5b). Lower part is oxidized with increased frequency of open fractures and two crushed sections. One calcite sealed fracture network.
- 140–160 m: Relatively rich in sealed fractures and four sealed fracture networks. One brecciated section (142.46–142.64 m) oriented roughly 085°/50°. One crushed section and one fracture with 5 mm aperture.
- 193–198 m: few thin sealed networks, one thin breccia which is oriented apprximately 115°/90°.

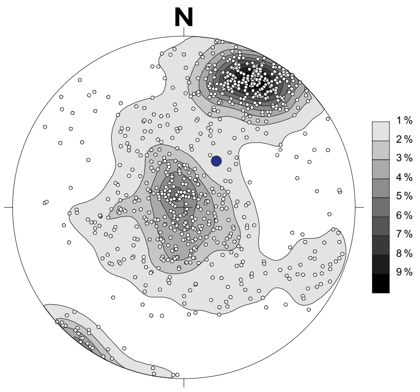

Figure 5-3a. Contoured equal area stereographic projection showing interpreted open and partly open fractures (n=801) in HFR105. Blue dot represents borehole projection.

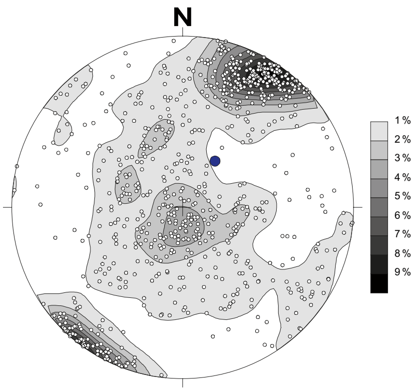

Figure 5-3b. Contoured equal area stereographic projection showing interpreted sealed fractures (n=821) in HFR105. Blue dot represents borehole projection.

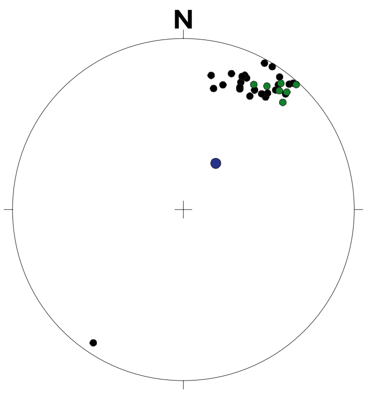

Figure 5-4a. Equal area stereographic projection showing foliation (black, n=24) and banding (green, n=7) in HFR105. Blue dot = borehole projection.

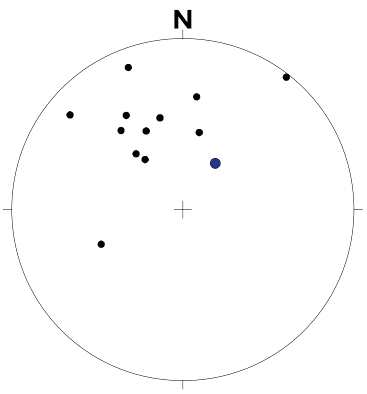

Figure 5-4b. Equal area stereographic projection showing possible faults (n=12) in HFR105. Blue dot = borehole projection.

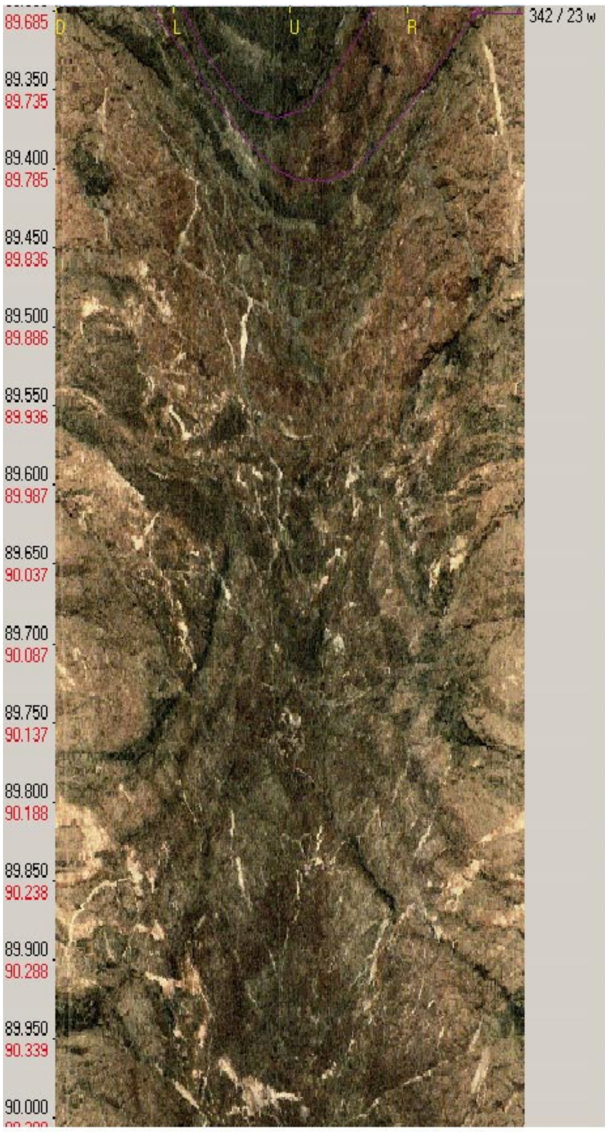

Figure 5-5a. Strongly deformed and fractured rock in HFR105, 89.68–90.39 m adjusted borehole length.

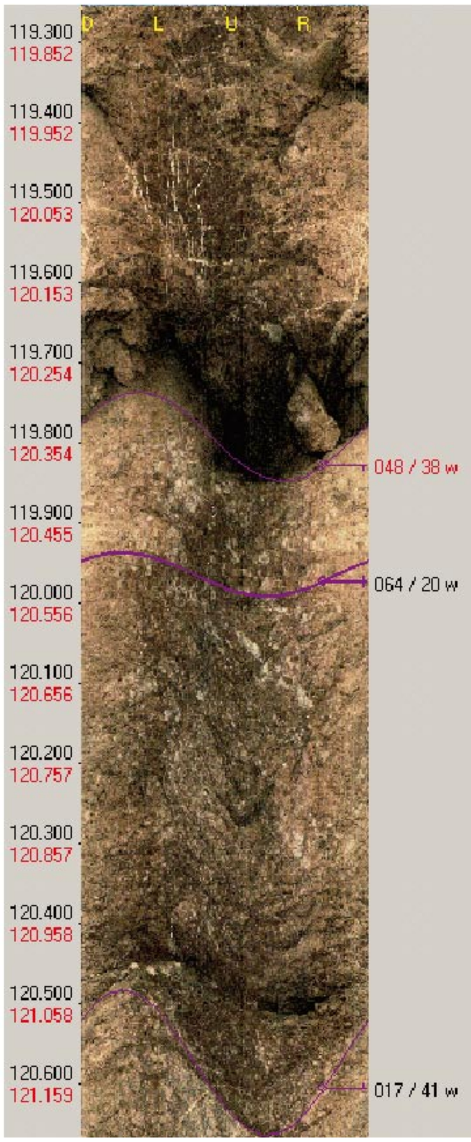

Figure 5-5b. Strongly deformed and crushed bedrock in HFR105, 119.83–121.63 m adjusted borehole length.

KFR27

KFR27 is dominated by pegmatite to pegmatitic granite (101061) and metagranite-granodiorite (101057, Table 5-1, Appendix 1). The pegmatite is mostly massive, medium- to coarse-grained and high anomalous gamma radiation at 40–230 μR/h. The metagranite-granodiorite seems to be mostly lineated in the BIPS-image, but looks veined in the beginning of the borehole, and foliated in the end of the borehole. The orientation of the interpreted foliation varies, but is mostly NW-striking with a moderate dip, while the interpreted lineation is trending mostly E with a moderate plunge (Figure 5-6).

Lineated fine- to medium-grained granite (111058) is also observed, as well as felsic to intermediate metavolcanic rock (103076). The felsic to intermediate metavolcanic rock in the interval 79–82 m is interpreted only on the basis of geophysics, but clear contacts can be observed in the interval 142–143 m.

Subordinate rock types are amphibolite (102017), aplitic granite (101058), quartz-dominated hydrothermal vein (8021) and cataclastic rock.

The only recognized alteration type in the BIPS-image of KFR27 is oxidation or red staining. Approximately 25% of the borehole shows weak to moderate oxidation. The intensity may be somewhat over-estimated in red coloured rock types, such as fine- to medium-grained granite and pegmatitic granite.

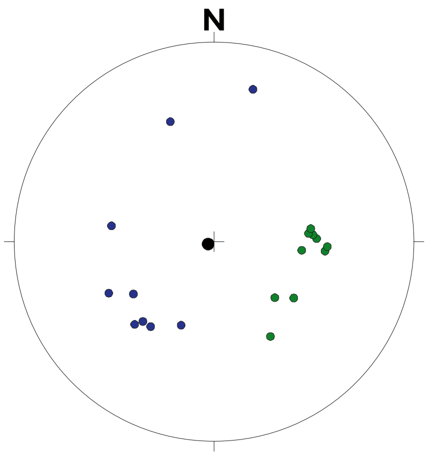

Figure 5-6. *Equal area projection showing poles to foliation planes (blue dots, n=9) and lineation (green dots, n=10) in KFR27. Black dot is borehole projection.*

Totally 979 fractures were observed in KFR27. Of these 156 are considered open, 55 partly open and 768 sealed fractures, resulting in the following fracture frequencies: 1.2 open fractures/m, 0.4 partly open fractures/m and 5.7 sealed fractures/m (fractures in crush and sealed fracture networks excluded). No sections are observed to be rich in interpreted open fractures. This may be due to reasons explained in chapter 4.3.1, but also due to the fact that the borehole intersects rock of good quality.

Many sealed fractures are light red to red, which infers the occurrence of laumontite. Fifteen sealed fracture networks are also present. The width of most sealed networks is 10–40 cm along the borehole, and they are most frequently occurring in the interval 100–118 m. There are two dominating sets of open fractures: 000°/00° and 075°/90° (Figure 5-7a). There is one dominating set of sealed fractures (080°/40°) and two subordinate sealed fracture sets (315°/70° and 200°/15°, Figure 5-7b).

Three deformed bands have been observed. One is considered a ductile shear zone, one a brittle-ductile shear zone and one a cataclasite.

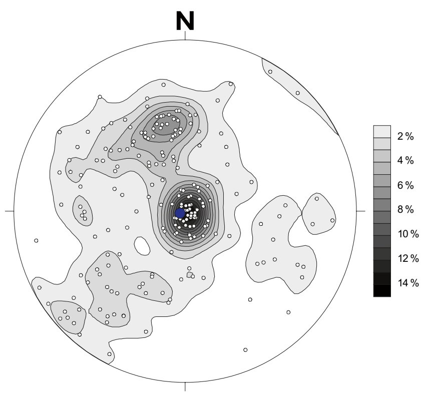

Figure 5-7a. *Contoured equal area projection showing contoured diagrams of poles to open and partly open fractures (n=210) in KFR27. Blue dot is borehole projection.*

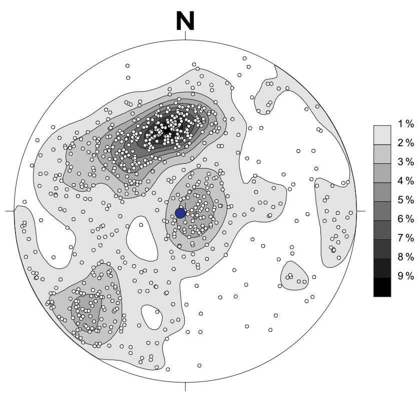

Figure 5-7b. *Contoured equal area projection showing contoured diagrams of poles to sealed fractures (n=766) in KFR27. Blue dot is borehole projection.*

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WellCAD diagrams

Title	SIMPLIFIED GEOLOGY HFR101	Appendix 1

Site	FORSMARK - SFR	Coordinate System	RT90-RHB70
Borehole	HFR101	Northing [m]	6701725.15
Diameter [mm]	137	Easting [m]	1632838.91
Length [m]	209.300	Elevation [m.a.s.l.]	2.63
Bearing [°]	133.55	Drilling Start Date	2008-04-23 10:10:00
Inclination [°]	-70.03	Drilling Stop Date	2008-04-28 17:30:00
Date of mapping	2008-09-24 16:00:00	Plot Date	2009-04-21 23:10:54
		Signed data	

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

ROCK OCCURRENCE
- Granite, fine- to medium-grained
- Pegmatite, pegmatitic granite
- Granite to granodiorite, metamorphi
- Amphibolite

ROCK STRUCTURE
- Massive
- Foliated
- Lineated

FRACTURE ALTERATION
- Slightly Altered
- Fresh

ROCK ALTERATION
- Oxidized

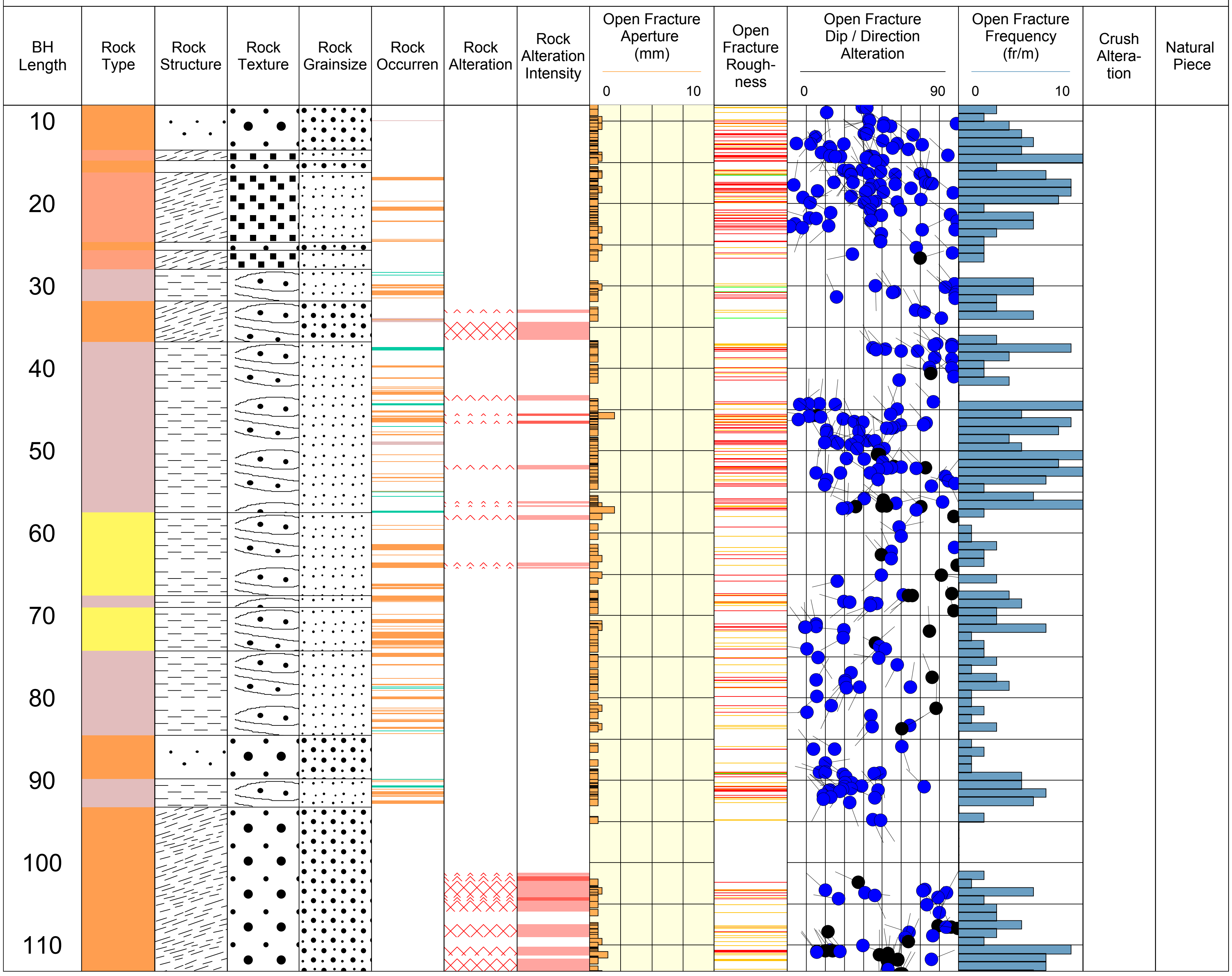
ROCK TEXTURE
- Equigranular
- Unequigranular
- Metamorphic

ROCK GRAINSIZE
- Fine to medium grained
- Medium to coarse grained

INTENSITY
- Weak
- Medium

ROUGHNESS
- Planar
- Undulating
- Stepped
- Irregular

SIMPLIFIED BOREMAP MAPPING



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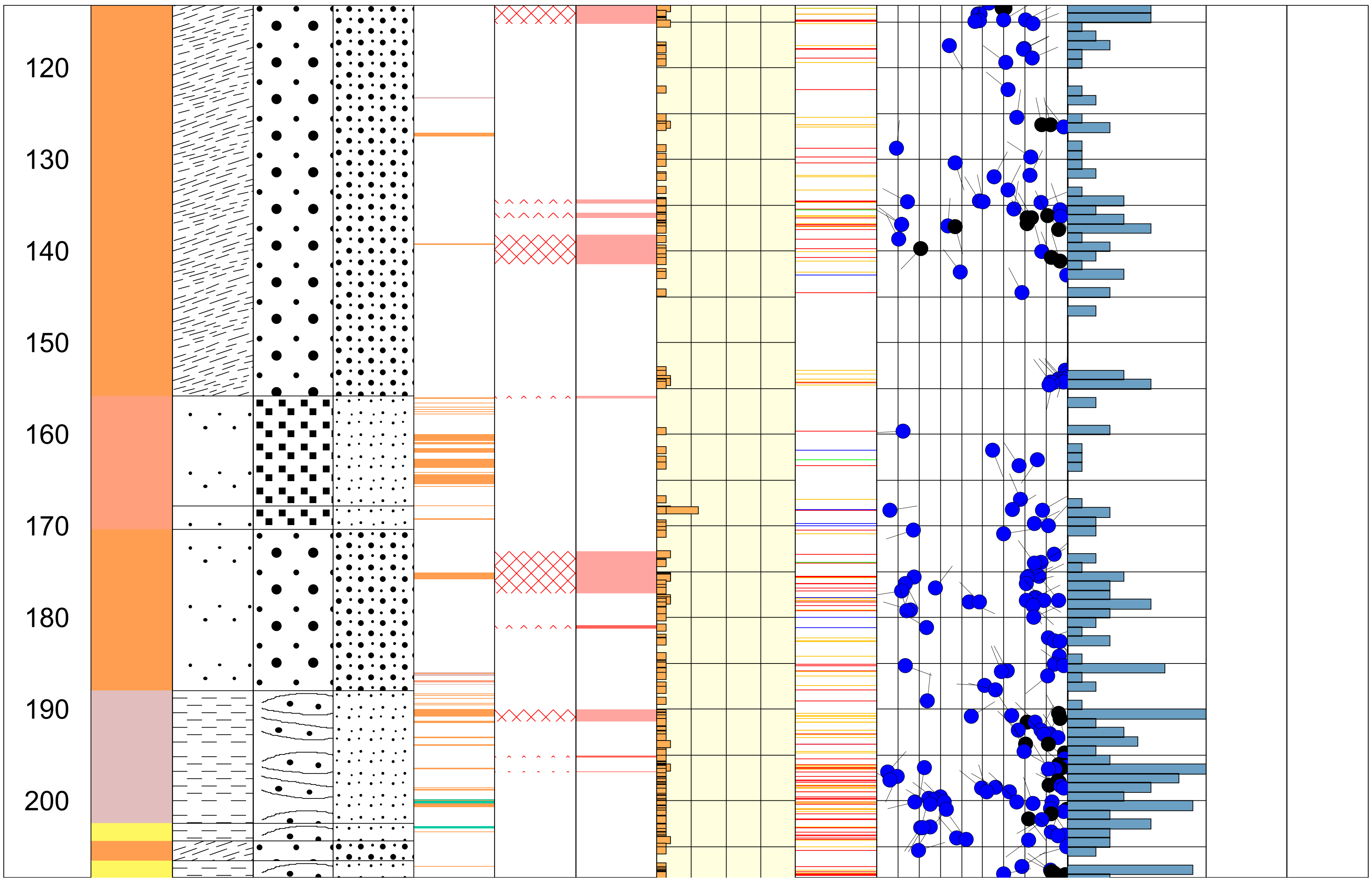


Title SIMPLIFIED GEOLOGY HFR102 Appendix 1

Site	FORSMARK - SFR	**Coordinate System**	RT90-RHB70
Borehole	HFR102	**Northing [m]**	6701728.55
Diameter [mm]	138	**Easting [m]**	1632974.54
Length [m]	55.040	**Elevation [m.a.s.l.]**	2.32
Bearing [°]	85.00	**Drilling Start Date**	2008-04-29 13:00:00
Inclination [°]	-59.13	**Drilling Stop Date**	2008-05-05 15:00:00
Date of mapping	2008-06-26 19:41:00	**Plot Date**	2009-04-21 23:10:54
		Signed data	

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

ROCK STRUCTURE
- Massive
- Foliated
- Lineated

ROCK ALTERATION
- Oxidized

INTENSITY
- Medium

ROCK TEXTURE
- Equigranular
- Unequigranular
- Metamorphic

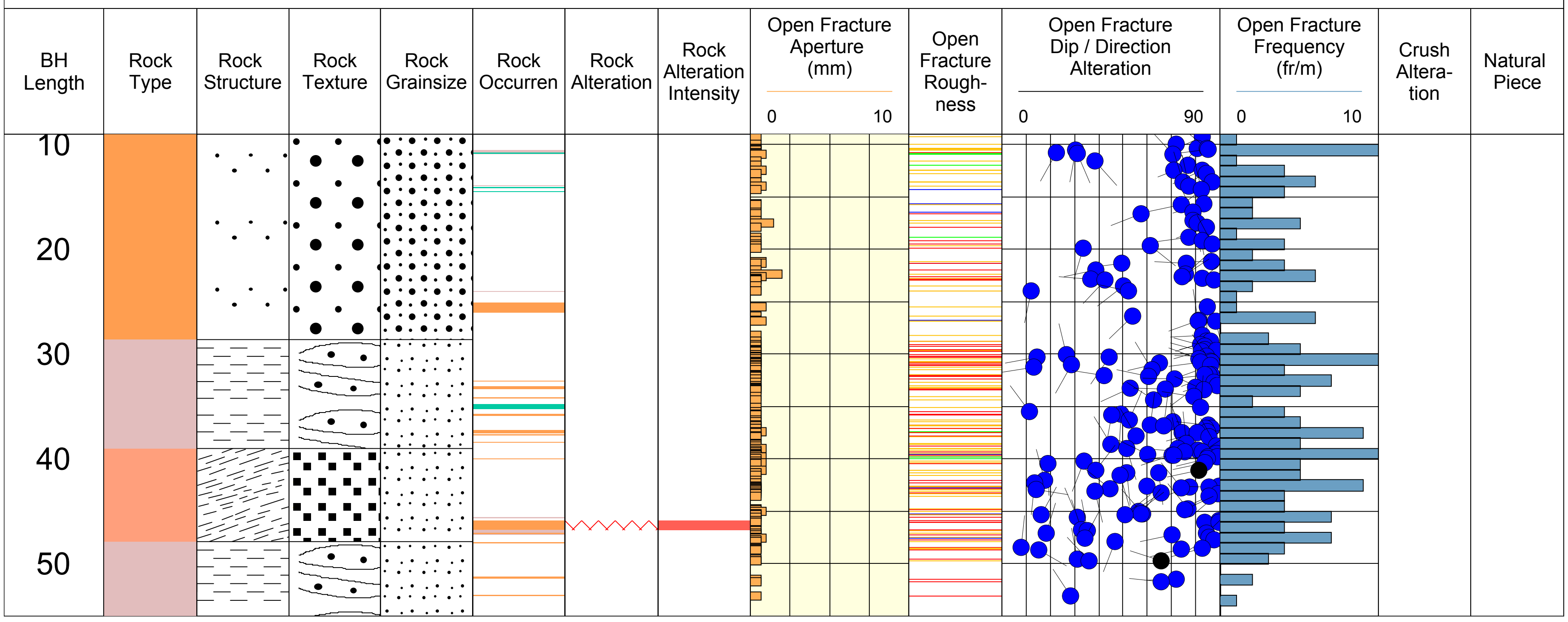
ROCK GRAINSIZE
- Fine to medium grained
- Medium to coarse grained

FRACTURE ALTERATION
- Slightly Altered
- Fresh

ROUGHNESS
- Planar
- Undulating
- Stepped
- Irregular

ROCK OCCURRENCE
- Pegmatite, pegmatitic granite
- Granite to granodiorite, metamorphic
- Amphibolite

SIMPLIFIED BOREMAP MAPPING



Title SIMPLIFIED GEOLOGY HFR105 Appendix 1

Site	FORSMARK - SFR	**Coordinate System**	RT90-RHB70
Borehole	HFR105	**Northing [m]**	6701376.55
Diameter [mm]	140	**Easting [m]**	1632686.82
Length [m]	200.500	**Elevation [m.a.s.l.]**	3.27
Bearing [°]	35.43	**Drilling Start Date**	2008-04-16 08:45:00
Inclination [°]	-61.90	**Drilling Stop Date**	2008-04-22 10:45:00
Date of mapping	2008-05-21 11:07:00	**Plot Date**	2009-04-21 23:10:54
		Signed data	

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

ROCK OCCURRENCE
- Granite, fine- to medium-grained
- Pegmatite, pegmatitic granite
- Granite, granodiorite and tonalite, m
- Granite, metamorphic, aplitic
- Granite to granodiorite, metamorphi
- Amphibolite

ROCK STRUCTURE
- Cataclastic
- Gneissic
- Veined
- Banded
- Massive

FRACTURE ALTERATION
- Slightly Altered
- Moderately Altered
- Fresh

ROCK ALTERATION
- Oxidized
- Epidotisized
- Albitization

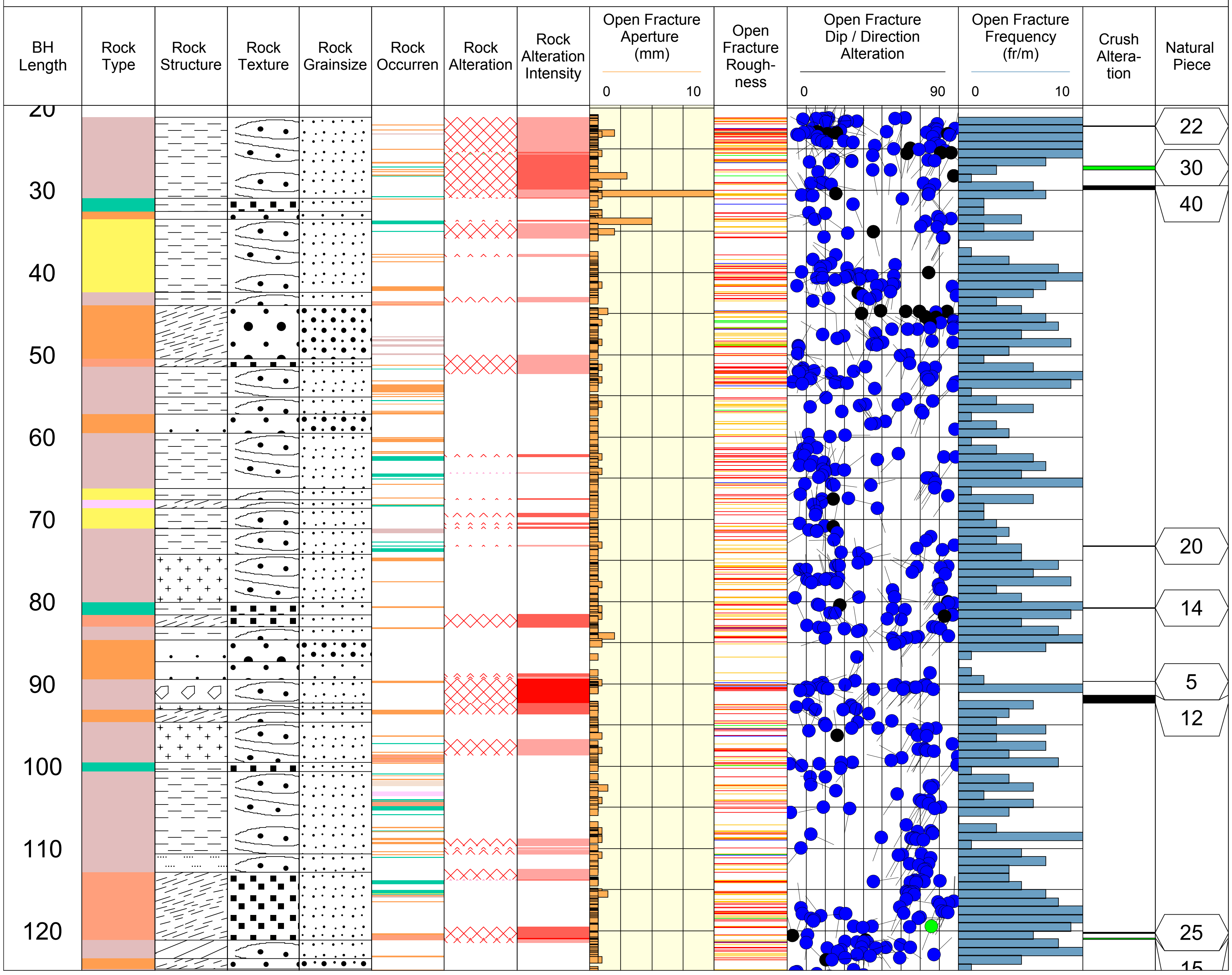
ROCK TEXTURE
- Equigranular
- Unequigranular
- Metamorphic

ROCK GRAINSIZE
- Fine to medium grained
- Medium to coarse grained
- Medium-grained

INTENSITY
- Weak
- Medium
- Strong

ROUGHNESS
- Planar
- Undulating
- Stepped
- Irregular

SIMPLIFIED BOREMAP MAPPING



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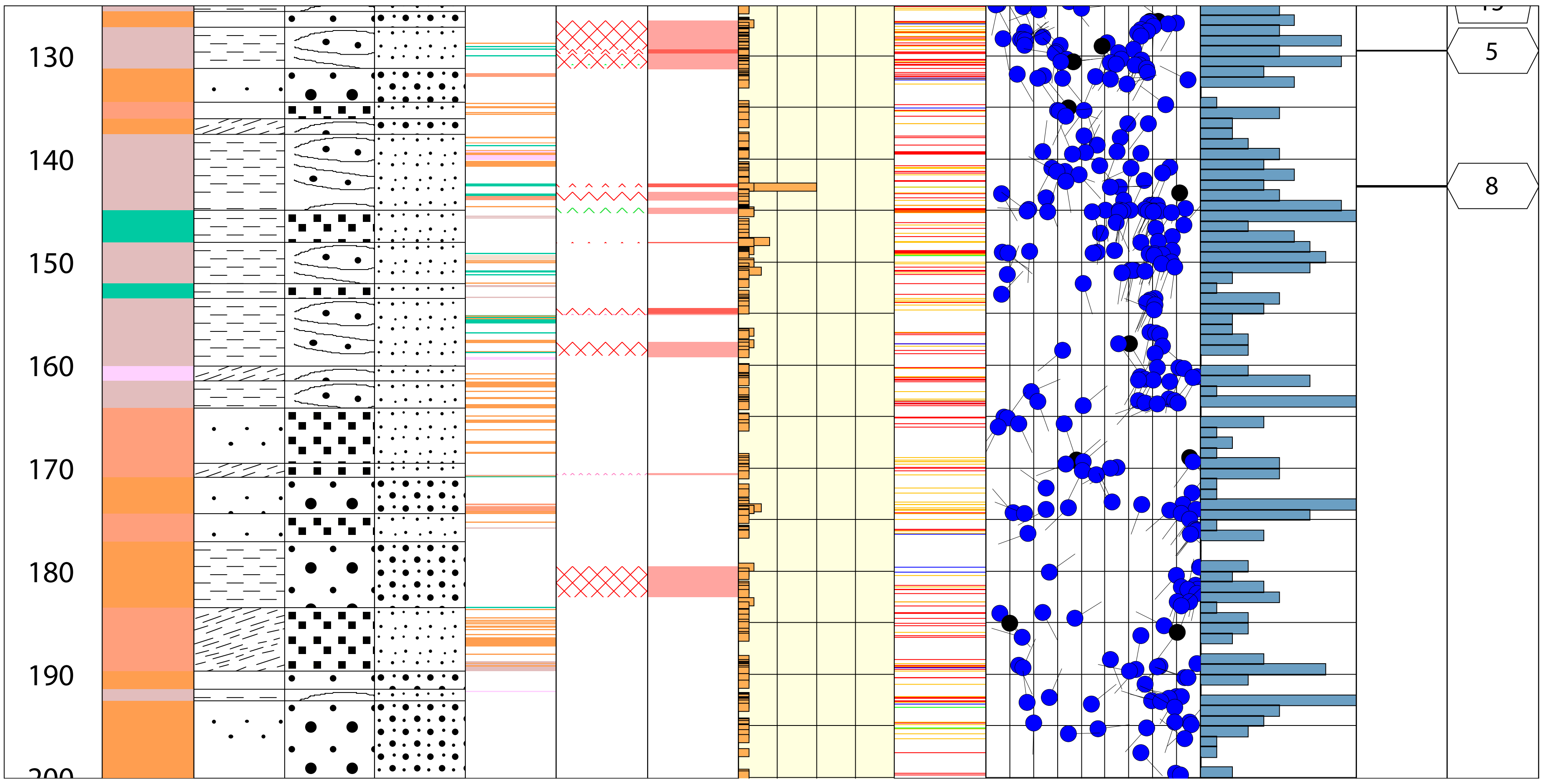


Title	LEGEND FOR FORSMARK - SFR	KFR27	Appendix 1

Site	FORSMARK - SFR
Borehole	KFR27
Plot Date	2009-04-21 23:10:54
Signed data	

ROCKTYPE FORSMARK - SFR

- Granite, fine- to medium-grained
- Pegmatite, pegmatitic granite
- Granitoid, metamorphic
- Granite, granodiorite and tonalite, metamorphic, fine- to medium-grained
- Granite, metamorphic, aplitic
- Granite to granodiorite, metamorphic, medium-grained
- Granodiorite, metamorphic
- Tonalite to granodiorite, metamorphic
- Diorite, quarts diorite and gabbro, metamorphic
- Ultramafic rock, metamorphic
- Amphibolite
- Calc-silicate rock (skarn)
- Magnetite mineralization associated with calc-silicate rock (skarn)
- Sulphide mineralization
- Felsic to intermediate volcanic rock, metamorphic
- Mafic volcanic rock, metamorphic
- Sedimentary rock, metamorphic
- Cataclastic rock

ROCK ALTERATION TYPE

- Oxidized
- Chloritisized
- Epidotisized
- Weathered
- Tectonized
- Sericitisized
- Quartz dissolution
- Silicification
- Argillization
- Albitization
- Carbonatization
- Saussuritization
- Steatitization
- Uralitization
- Laumontitization
- Fract zone alteration

MINERAL

- Flourite
- White Feldspar
- Graphite
- Hematite
- Calcite
- Chlorite
- Chalcopyrite
- Quartz
- Muscovite
- Unknown
- Pyrite
- Clay Minerals
- Laumontite
- Prehnite
- Iron Hydroxide
- Oxidized Walls

STRUCTURE

- Cataclastic
- Schistose
- Gneissic
- Mylonitic
- Ductile Shear Zone
- Brittle-Ductile Zone
- Veined
- Banded
- Massive
- Foliated
- Brecciated
- Lineated

TEXTURE

- Hornfelsed
- Porphyritic
- Ophitic
- Equigranular
- Augen-Bearing
- Unequigranular
- Metamorphic

GRAINSIZE

- Aphanitic
- Fine-grained
- Fine to medium grained
- Medium to coarse grained
- Coarse-grained
- Medium-grained

STRUCTURE ORIENTATION

- Cataclastic
- Brecciated
- Bedded
- Schistose
- Mylonitic
- Foliated
- Lineated
- Veined
- Ductile Shear Zone
- Banded
- Brittle-Ductile Shear Zone
- Gneissic

ROCK ALTERATION INTENSITY

- No intensity
- Faint
- Weak
- Medium
- Strong

ROUGHNESS

- Planar
- Undulating
- Stepped
- Irregular

SURFACE

- Rough
- Smooth
- Slickensided

CRUSH ALTERATION

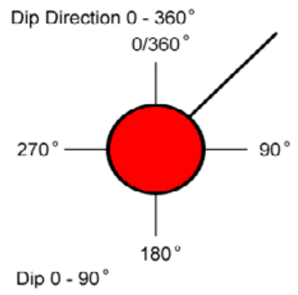
- Slightly Altered
- Moderately Altered
- Highly Altered
- Completley Altered
- Gouge
- Fresh

FRACTURE ALTERATION

- Highly Altered
- Completely Altered
- Gouge
- Fresh
- Slightly Altered
- Moderately Altered

FRACTURE DIRECTION

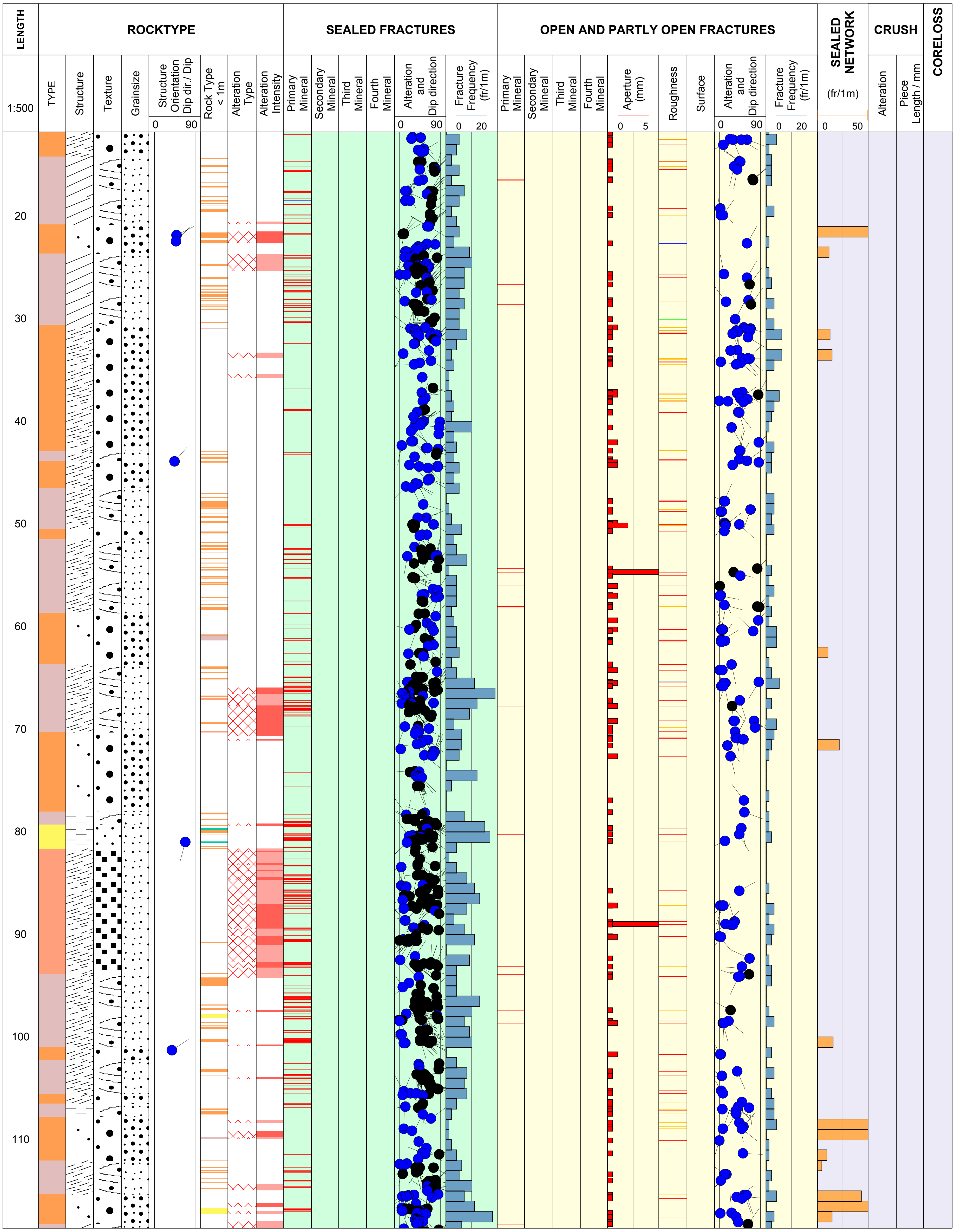
STRUKTURE ORIENTATION



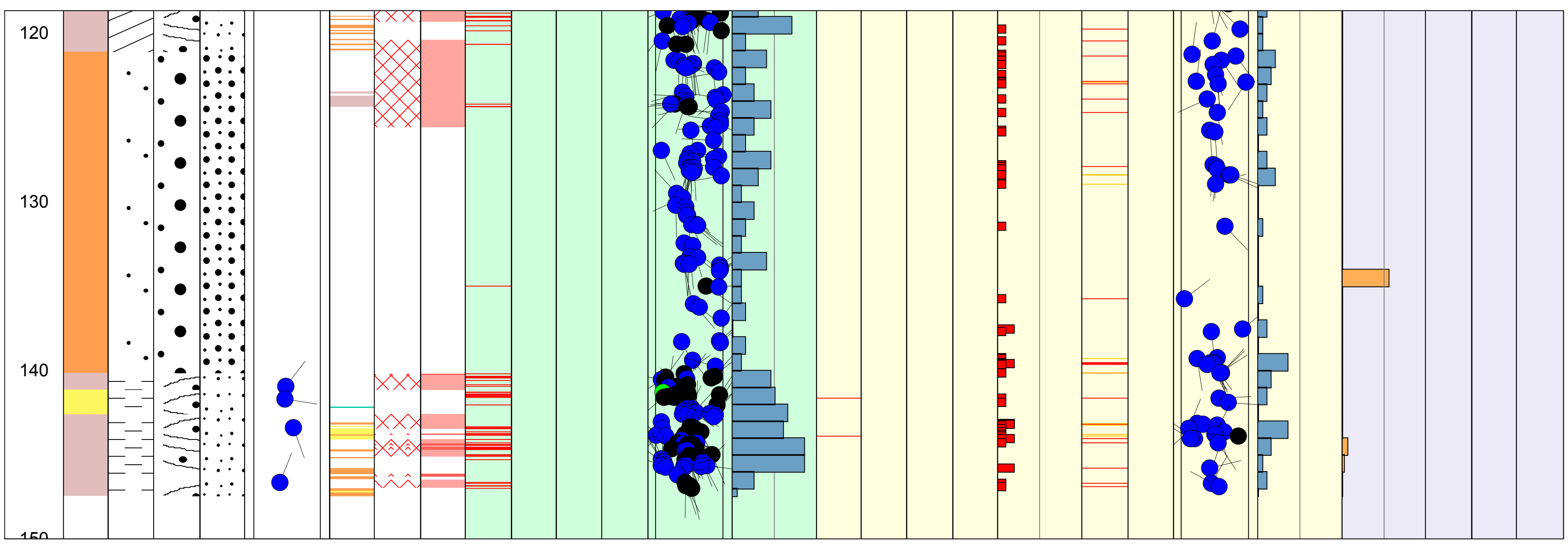
Title GEOLOGY IN KFR27

Appendix: 1

Site	FORSMARK - SFR	**Coordinate System**	RT90-RHB70
Borehole	KFR27	**Northing [m]**	6701714.42
Diameter [mm]	76	**Easting [m]**	1633175.52
Length [m]	501.640	**Elevation [m.a.s.l.]**	2.87
Bearing [°]	248.20	**Drilling Start Date**	1981-08-06 00:00:00
Inclination [°]	-87.60	**Drilling Stop Date**	1981-09-10 00:00:00
Date of coremapping	2008-09-05 13:21:00	**Plot Date**	2009-04-21 23:10:54
Rocktype data from	p_rock	**Signed data**	



P-09-37



In-data

Borehole T – Drilling: Borehole information

HFR101, 2008-05-14 13:00:00–2008-05-14 15:00:00 (0.000–209.300 m).

Bhlen (m)	Case Ground (m)	Case Rock (m)	Soil Len (m)	Reference Level	Comment	QC
209.30				Concrete surface	Spolvatten fylld vid brandpost i bostadsmområdet	*

Printout from SICADA 2008-05-20 16:08:24.

Hole Diam T – Drilling: Borehole diameter

HFR101, 2008-04-23 10:10:00–2008-04-28 17:30:00 (0.000–149.250 m).

Sub Secup (m)	Sub Seclow (m)	Hole Diam (m)	Comment	QC
0.350	8.040	0.1750	Krona vid start 139,5 mm	*
8.040	50.050	0.1393	Omslipning vid 50,05 m till 139,2 mm	*
50.050	149.250	0.1385	Krona vid borrslut 138,5 mm	*

Printout from SICADA 2008-05-20 16:04:28.

Borehole T – Drilling: Borehole information

HFR102, 2008-04-29 13:00:00–2008-05-05 15:00:00 (0.000–55.040 m).

Bhlen (m)	Case Ground (m)	Case Rock (m)	Soil Len (m)	Reference Level	Comment	QC
55.04	0.350	7.60	7.05	Top of casing (center)	case ground mäts från marknivån längs foder-rörets centrumlinje till överkant.	*

Printout from SICADA 2008-05-20 16:14:24.

Hole Diam T – Drilling: Borehole diameter

HFR102, 2008-04-29 13:00:00–2008-05-05 15:00:00 (0.000–55.040 m).

Sub Secup (m)	Sub Seclow (m)	Hole Diam (m)	Comment	QC
0.350	9.040	0.1750	Krona vid start 138,3 mm	*
9.040	55.040	0.1380	Krona vid borrslut 138,0 mm	*

Printout from SICADA 2008-06-26 19:33:39.

Borehole T – Drilling: Borehole information

HFR105, 2008-04-16 08:45:00–2008-04-22 10:45:00 (0.000–200.500 m).

Bhlen (m)	Case Ground (m)	Case Rock (m)	Soil Len (m)	Reference Level	Comment	QC
200.50	0.380	19.80	19.42	Top of casing (center)	Spolvatten från brandpost intill BP7 i bostadsområdet överfört till tank.	*

Printout from SICADA 2008-05-20 16:16:58.

Hole Diam T – Drilling: Borehole diameter

HFR105, 2008-04-16 08:45:00–2008-04-22 10:45:00 (0.000–200.500 m).

Sub Secup (m)	Sub Seclow (m)	Hole Diam (m)	Comment	QC
0.380	21.120	0.1750	Krona vid start vid 21,20 m är 141,3 mm	*
21.120	140.050	0.1405	Omslipning vid 140,05 m till 140,3 mm	*
140.050	200.500	0.1398	Krona vid borrslut 139,8 mm	*

Printout from SICADA 2008-05-20 16:15:30.

Borehole T – Drilling: Borehole information

KFR27, 2008-06-02 09:00:00–2008-06-10 11:00:00 (0.000–148.510 m).

Bhlen (m)	Case Ground (m)	Case Rock (m)	Soil Len (m)	Reference Level	Comment	QC
148.51	0.250			Top of casing (center)	Spolvatten intill borrplats 7 i bostadsområdet överfört till tank.	*

Printout from SICADA 2008-09-05 10:17:32.

Hole Diam T – Drilling: Borehole diameter

KFR27, 2008-06-02 09:00:00–2008-06-10 11:00:00 (0.000–148.510 m).

Sub Secup (m)	Sub Seclow (m)	Hole Diam (m)	Comment	QC
11.910	147.000	0.0765	Kalibrering vid start upprymning 11,91 m är 76,8 mm. Vid slut 147,00 m är 76,45 mm.	*
147.000	148.510	0.0758	Corac	*

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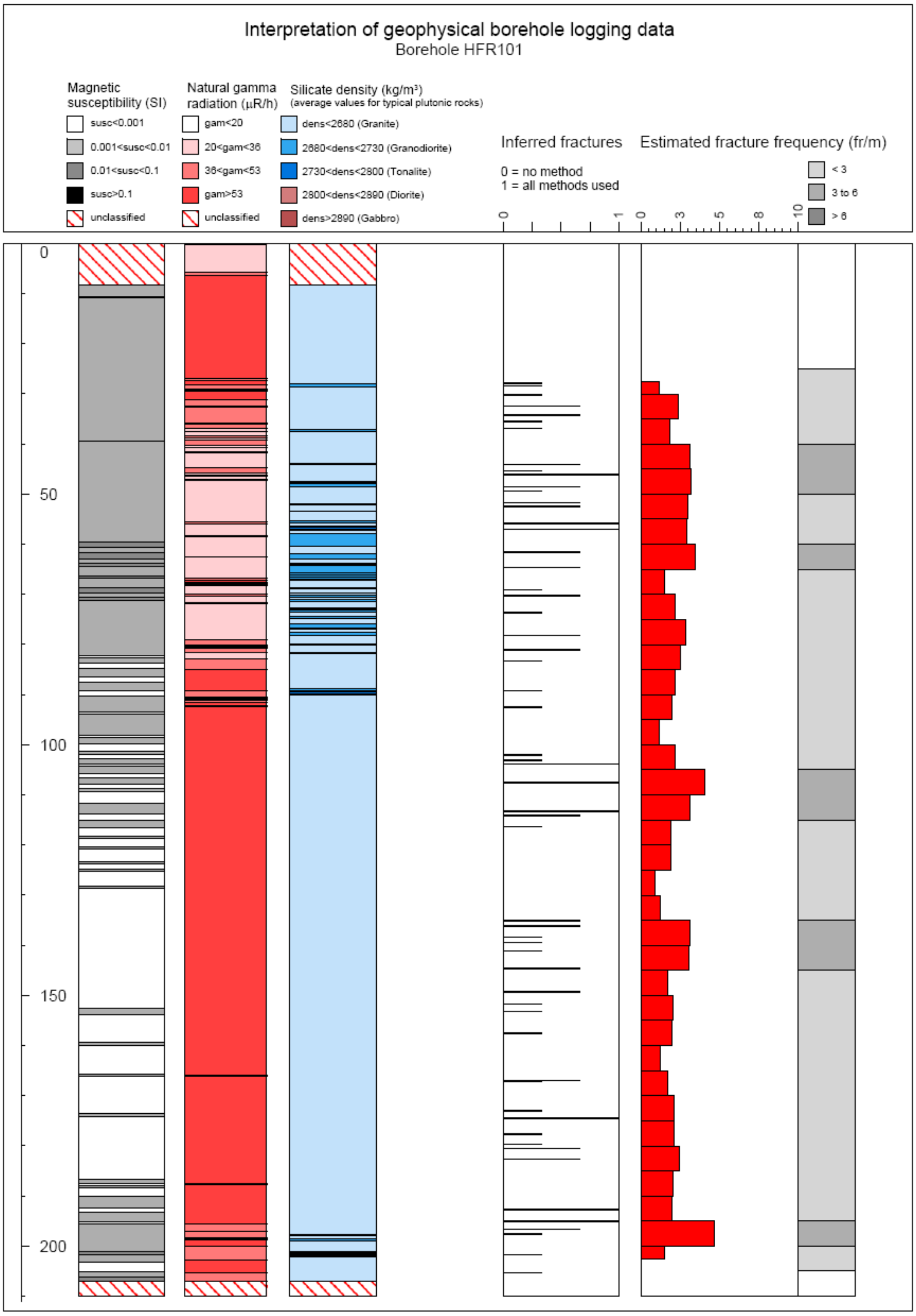
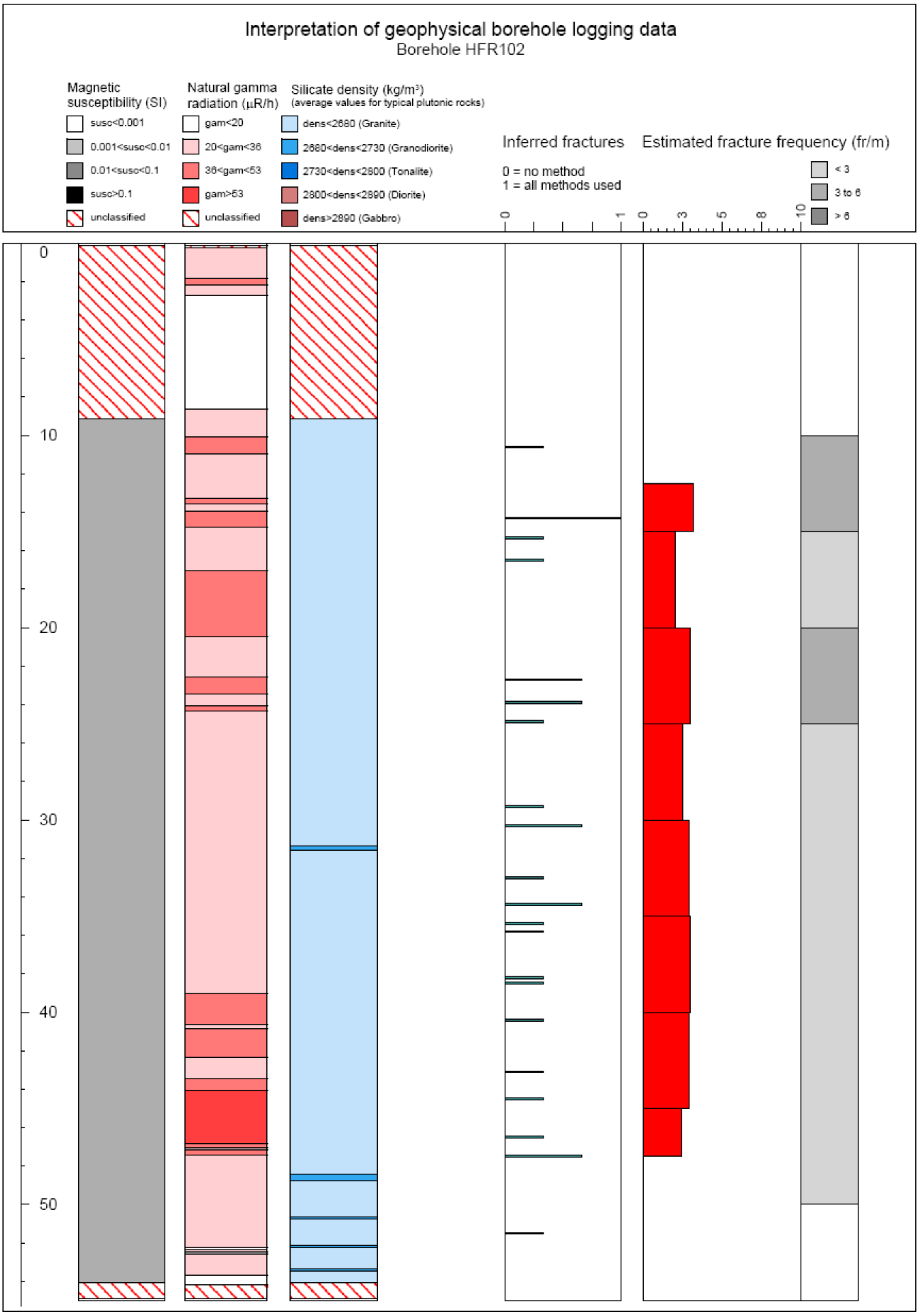
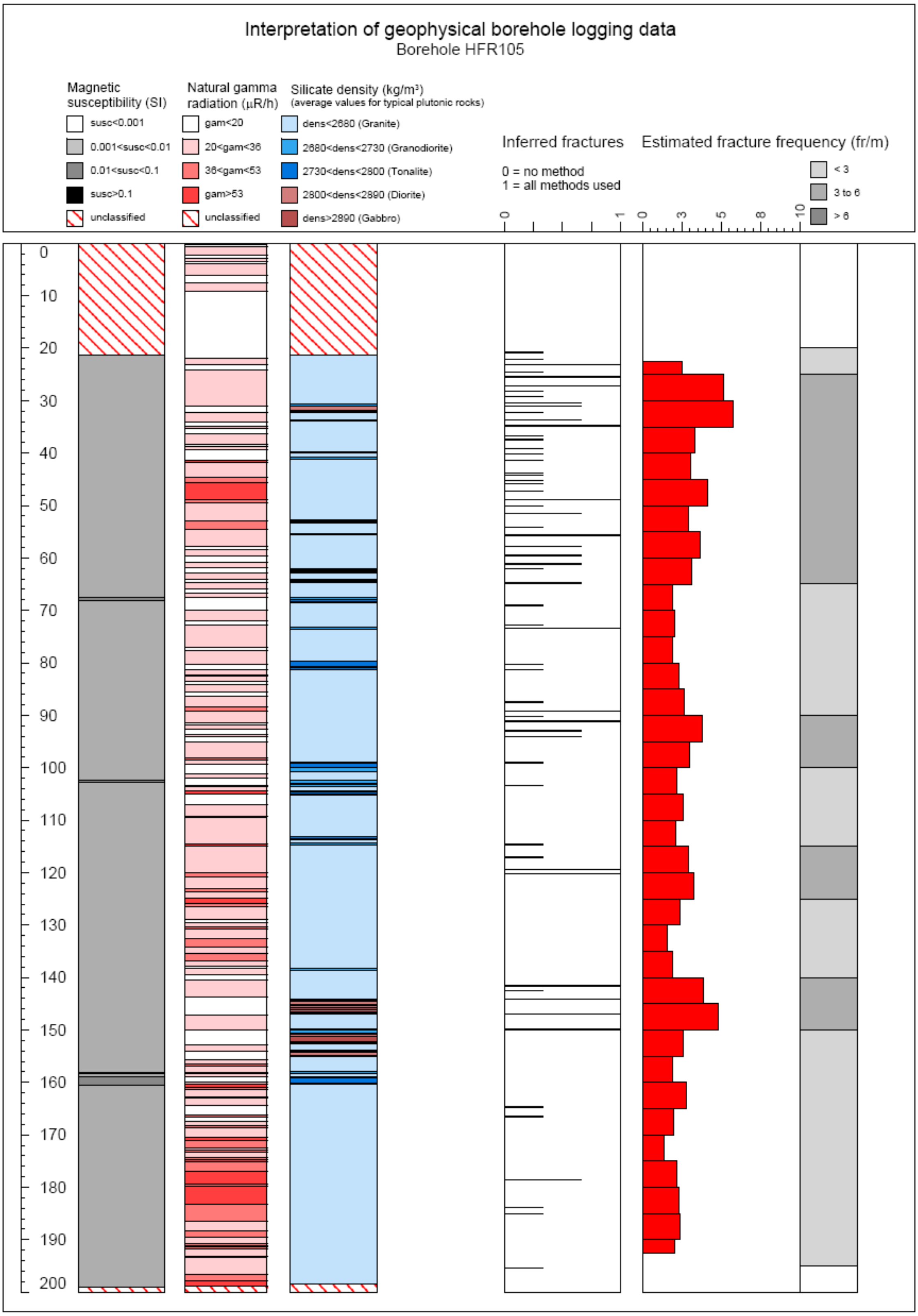
Generalized geophysical logs

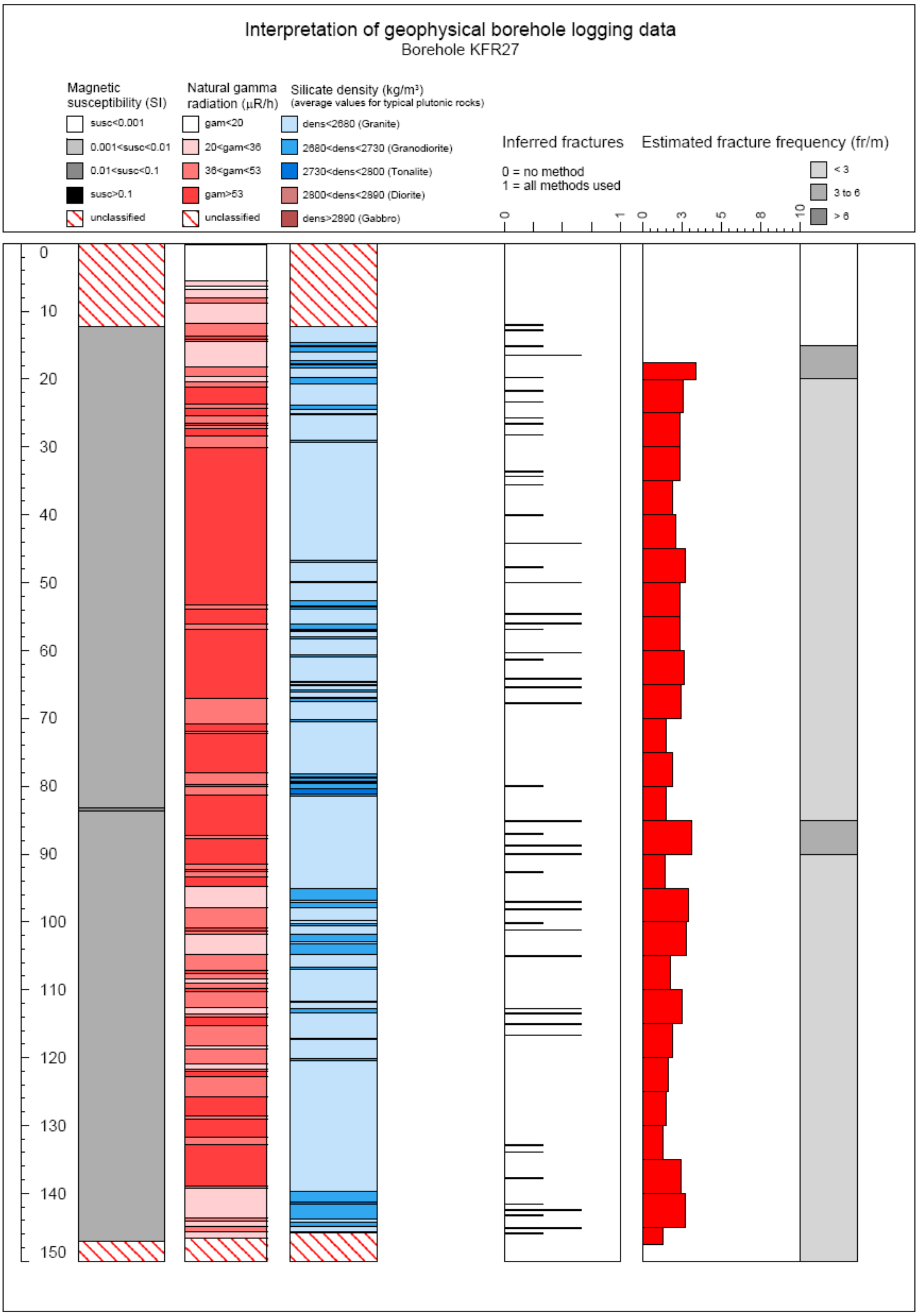




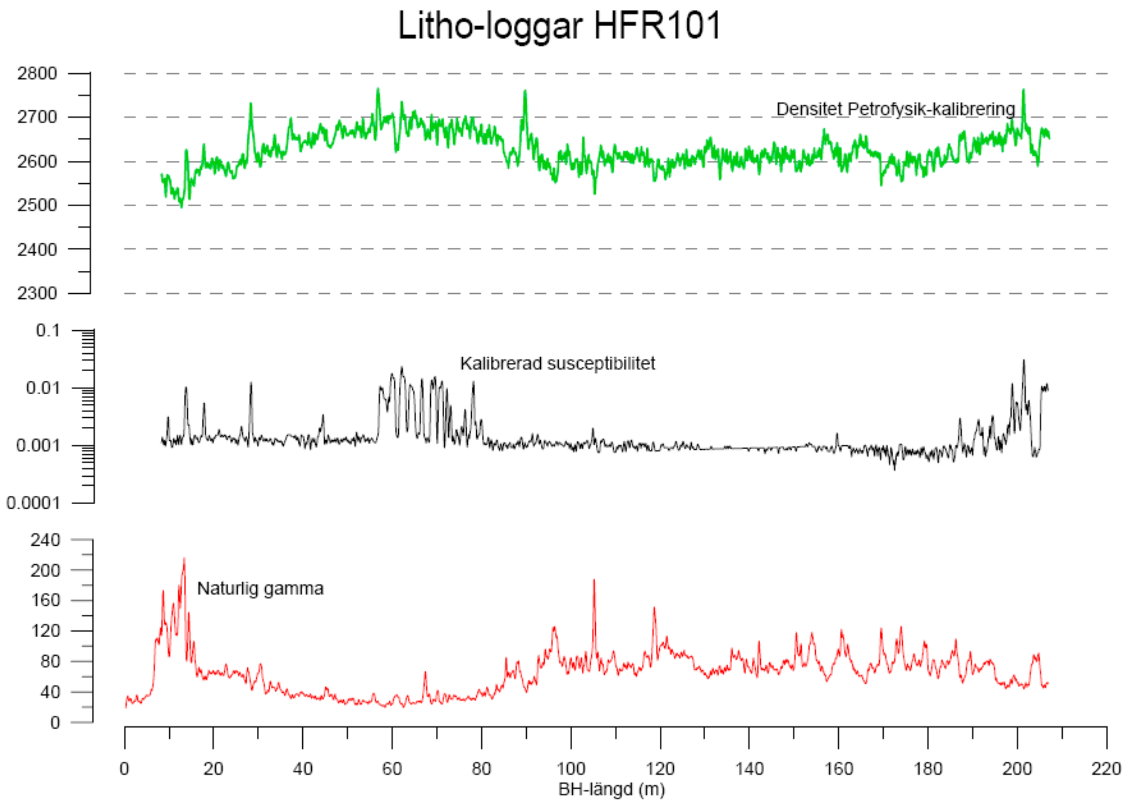
Interpretation of geophysical borehole logging data
Borehole HFR102
Magnetic susceptibility (SI)
susc<0.001
0.001<susc<0.01
0.01<susc<0.1
susc>0.1
unclassified
Natural gamma radiation (µR/h)
gam<20
20<gam<36
36<gam<53
gam>53
unclassified
Silicate density (kg/m³)
(average values for typical plutonic rocks)
dens<2680 (Granite)
2680<dens<2730 (Granodiorite)
2730<dens<2800 (Tonalite)
2800<dens<2890 (Diorite)
dens>2890 (Gabbro)
Inferred fractures
0 = no method
1 = all methods used
Estimated fracture frequency (fr/m)
< 3
3 to 6
> 6



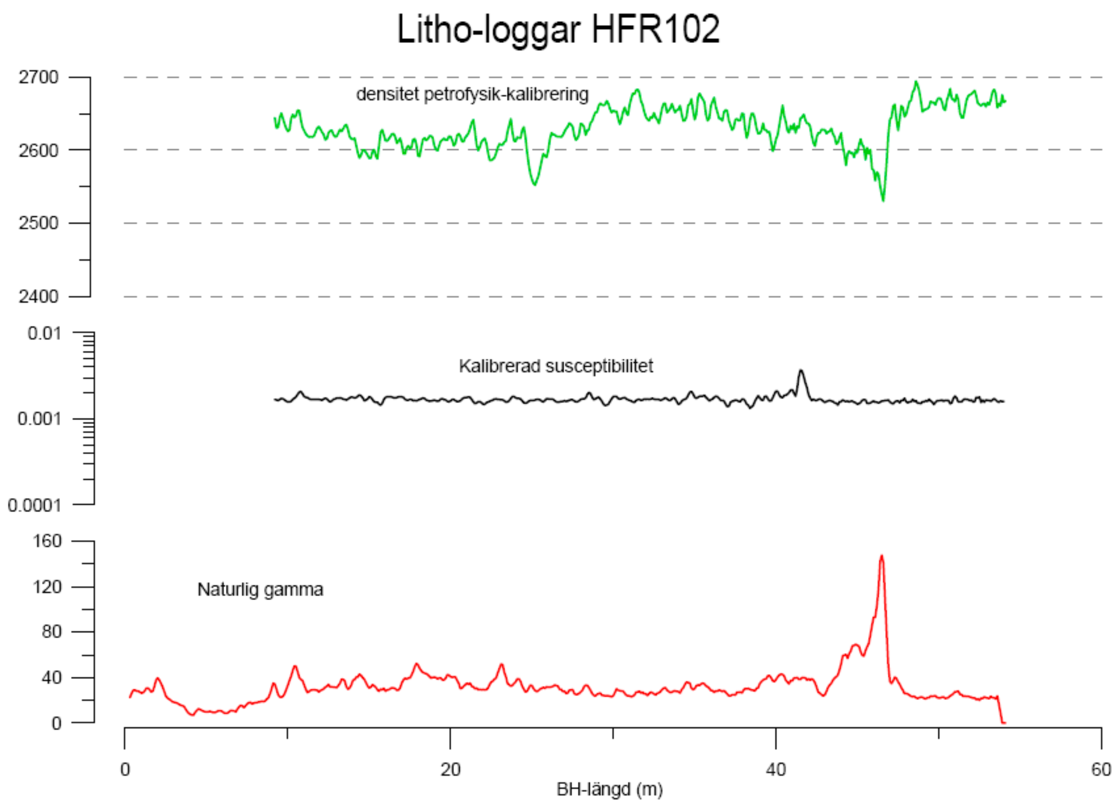
Interpretation of geophysical borehole logging data
Borehole HFR105
Magnetic susceptibility (SI)
susc<0.001
0.001<susc<0.01
0.01<susc<0.1
susc>0.1
unclassified
Natural gamma radiation (µR/h)
gam<20
20<gam<36
36<gam<53
gam>53
unclassified
Silicate density (kg/m³)
(average values for typical plutonic rocks)
dens<2680 (Granite)
2680<dens<2730 (Granodiorite)
2730<dens<2800 (Tonalite)
2800<dens<2890 (Diorite)
dens>2890 (Gabbro)
Inferred fractures
0 = no method
1 = all methods used
Estimated fracture frequency (fr/m)
< 3
3 to 6
> 6
0 1
0 3 5 8 10
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200



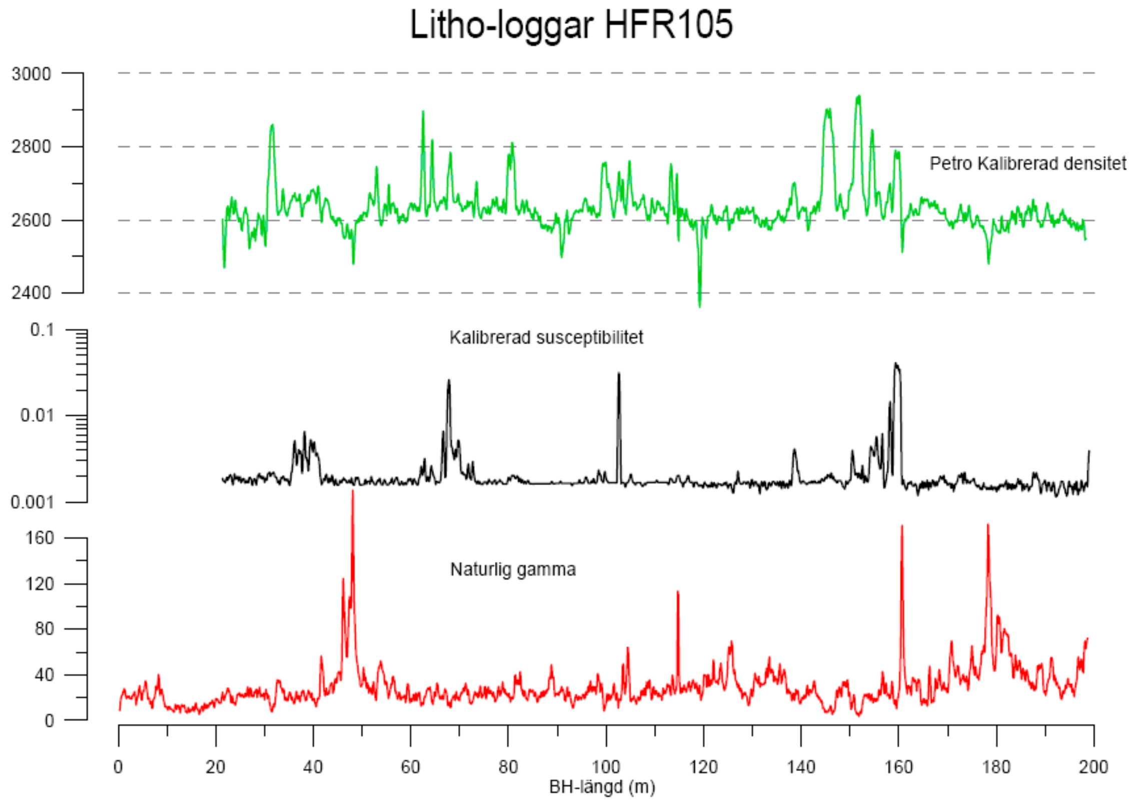
Interpretation of geophysical borehole logging data
Borehole KFR27
Magnetic susceptibility (SI)
susc<0.001
0.001<susc<0.01
0.01<susc<0.1
susc>0.1
unclassified
Natural gamma radiation (μR/h)
gam<20
20<gam<36
36<gam<53
gam>53
unclassified
Silicate density (kg/m³)
(average values for typical plutonic rocks)
dens<2680 (Granite)
2680<dens<2730 (Granodiorite)
2730<dens<2800 (Tonalite)
2800<dens<2890 (Diorite)
dens>2890 (Gabbro)
Inferred fractures
0 = no method
1 = all methods used
Estimated fracture frequency (fr/m)
< 3
3 to 6
> 6



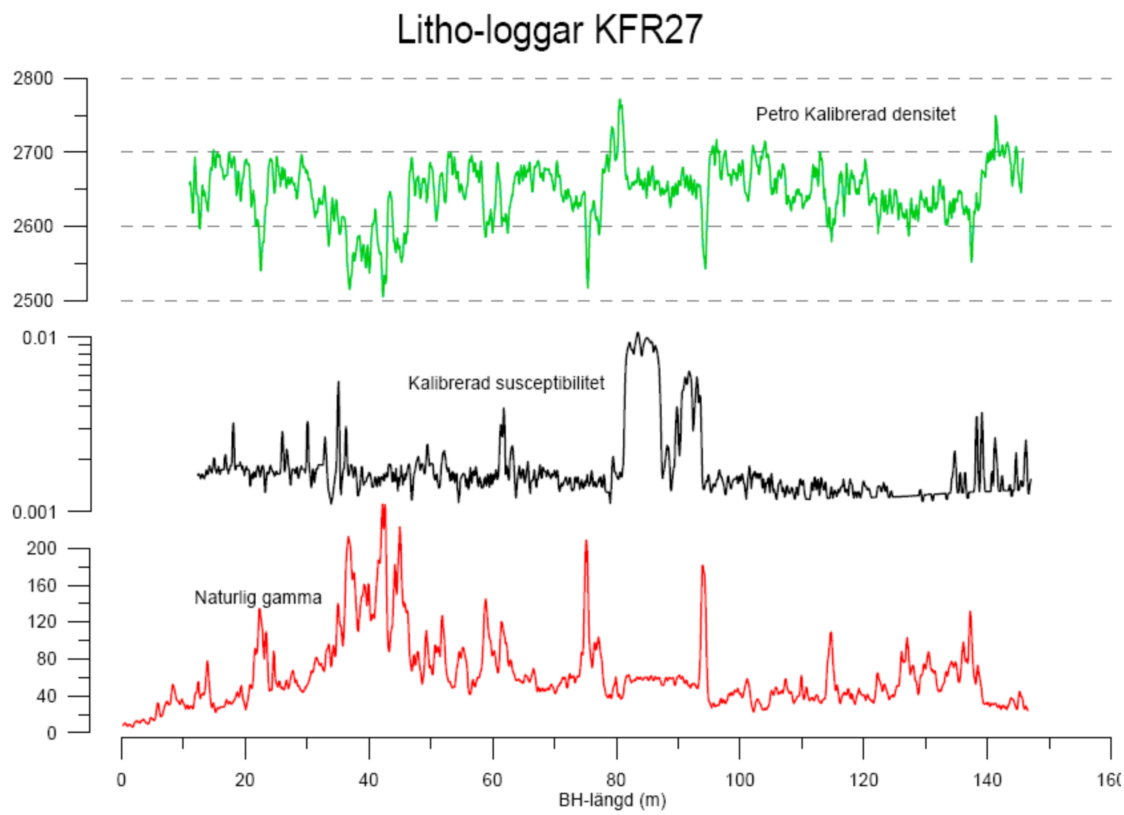
Litho-loggar HFR101
2800
2700
2600
2500
2400
2300
Densitet Petrofysik-kalibrering
0.1
0.01
0.001
0.0001
Kalibrerad susceptibilitet
240
200
160
120
80
40
0
Naturlig gamma
0
20
40
60
80
100
120
140
160
180
200
220
BH-längd (m)



Litho-loggar HFR102
2700
2600
2500
2400
densitet petrofysik-kalibrering
0.01
0.001
0.0001
Kalibrerad susceptibilitet
160
120
80
40
0
Naturlig gamma
0
20
40
60
BH-längd (m)



Litho-loggar HFR105
Petro Kalibrerad densitet
Kalibrerad susceptibilitet
Naturlig gamma
BH-längd (m)



Litho-loggar KFR27
Petro Kalibrerad densitet
Kalibrerad susceptibilitet
Naturlig gamma
BH-längd (m)

Appendix 4

Investigation of drill cuttings

Borehole	m	Rock type	Colour	Grain size	Comment
HFR101	69	101057	Greyish red	Fine- to medium-grained	Foliated/lineated. Some quartz-grains.
HFR101	70	103076	Dark reddish grey	Fine- to medium-grained	Probably foliated. Also some 101057 (~ 30%).
HFR101	166	111058	Greyish pink	Fine- to medium-grained	Also some 101061.
HFR101	167	111058	Greyish pink	Fine- to medium-grained	
HFR101	168	111058	Greyish pink	Fine- to medium-grained	
HFR101	169	111058	Greyish pink	Fine- to medium-grained	Also some 101061.
HFR102	30	101057	Greyish red	Fine- to medium-grained	
HFR102	31	101057	Greyish red	Fine- to medium-grained	Foliated.
HFR102	36	102017	Dark reddish grey	Fine- to medium-grained	Foliated. Also 101057 (~ 40%).
HFR102	41	111058	Light greyish red	Fine- to medium-grained	
HFR102	42	111058	Light greyish red	Fine- to medium-grained	
HFR102	49	101057	Dark pinkish grey	Fine- to medium-grained	101061 fragments.
HFR102	50	101057	Light reddish grey	Fine- to medium-grained	Some fragments are strongly foliated.
HFR105	26	101057	Dark greyish red	Fine- to medium-grained	With chlorite planes.
HFR105	27	101057	Dark greyish red	Fine- to medium-grained	With fragments of 102017 (~ 10%).
HFR105	30	101057	Dark greyish red	Fine- to medium-grained	And 102017.
HFR105	31	101057	Dark greyish red	Fine- to medium-grained	With hematite and chlorite on probable fracture planes. Strongly foliated.
HFR105	51	111058	Pink	Fine- to medium-grained	And 101061.
HFR105	52	101057	Greyish red	Fine- to medium-grained	With chlorite on probable fracture planes.
HFR105	53	101057	Greyish red	Fine- to medium-grained	Traces of 101061.
HFR105	54	101061	Light greyish red	Medium-grained	And 101057 (~ 10%).
HFR105	81	102017	Dark reddish green	Fine- to medium-grained	Strongly foliated. And 101057 and 101061.
HFR105	83	111058	Light greyish red	Fine- to medium-grained	Possibly also 101057 and 101061. Traces of epidote.
HFR105	85	101061	Greyish pink	Medium-grained	And 101057 (50%?).
HFR105	90	101061	Greenish pink	Medium-grained	And 101057 and 102017? Epidote-sealed sealed fractures. Calcite. Some fragments look deformed.
HFR105	91	101057	Dark greenish red	Fine-grained	Stronlgy oxidized. Small drill cuttings (2 mm). Epidote and chlorite.
HFR105	92	101057	Dark red	Fine- to medium-grained	Some grains seem to be aphanitic. Biotite seems chlorite altered.
HFR105	105	101057	Dark greenish red	Fine- to medium-grained	Strongly foliated. Relatively rich in dark minerals.
HFR105	106	101057	Greenish red	Fine- to medium-grained	Strongly foliated. Adularia-laumontite on probable fracture plane. Epidote-sericite on possible fracture plane.
HFR105	107	101057	Greyish red	Fine- to medium-grained	Adularia-laumontite and chlorite and epidote on probable fracture planes.

Borehole	m	Rock type	Colour	Grain size	Comment
HFR105	117	111058	Light red	Fine- to medium-grained	Some fragments of strongly foliated 101057. Traces of epidote.
HFR105	118	111058	Light red	Fine- to medium-grained	Laumontite-calcite on probable fracture plane. Fragments of stronlgy foliated 101057 with chlorite altered biotite.
HFR105	145	101057	Greyish red	Fine- to medium-grained	Strongly foliated. Adularia on probable fracture plane.
HFR105	146	101057	Dark greyish red	Fine- to medium-grained	Laumontite and adularia and calcite on probable fracture planes. Also 101061 (~ 30%).
HFR105	165	111058	Greyish pink	Fine- to medium-grained	And 101057 (< 10%).
HFR105	166	111058	Greyish pink	Fine- to medium-grained	Probably also 101061.
HFR105	170	111058	Greyish pink	Fine- to medium-grained	
HFR105	171	111058	Greyish pink	Fine- to medium-grained	And foliated granite. Altered fragment (from crush?). Quartz-fragment with muscovite and possible garnet (< 1 mm size). Laumontite on probable fracture plane.
HFR105	175	111058	Greyish pink	Fine- to medium-grained	One small chlorite-clay-rich fragment (~ 2 mm).
HFR105	176	111058	Greyish pink	Fine- to medium-grained	Also 101061.