P-09-72

Site investigation SFR

Interpretation of geophysical borehole measurements from KFR01, KFR02, KFR03, KFR04, KFR05, KFR19 and KFR20 and petrophysical measurements from KFR04, KFR05 and KFR20

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Abstract

This report presents the compilation and interpretations of geophysical logging data from the cored boreholes KFR01, KFR02, KFR03, KFR04, KFR05, KFR19 and KFR20, and petrophysical measurements on rock samples from the boreholes KFR04, KFR05 and KFR20.

The boreholes are all older holes that were drilled and investigated in the 1980's during the construction of the present SFR. The logging data are therefore sparser for these holes compared with the data collected during the site investigation at Forsmark. For example, density data only exist for KFR04, KFR05, KFR19 and KFR20.

The main objective of the investigation was to use the results as supportive information during the geological core mapping and as supportive information during the geological single-hole interpretation.

The silicate density distributions in KFR04, KFR05, KFR19 and KFR20 show a clear dominance, c 70%, of rocks with mineral composition that corresponds to granite rock. The majority of these borehole sections also show decreased magnetic susceptibility and increased natural gamma radiation. This combination of physical properties is typical for pegmatitic granite and fine-grained granite.

In most of the boreholes there are fairly long sections (1–10 m) with decreased natural gamma radiation, increased susceptibility and silicate density of 2,730–2,800 kg/m^3, and this combination of properties is typical for felsic to intermediate volcanic rock. There are also short sections (< 2 m) witch indicate the occurrence of amphibolite dykes in all the investigated boreholes.

The identification of possible deformation zones was mainly performed only by use of Single Point Resistance (SPR) data, plus normal resistivity data in KFR01 and KFR02. In KFR01 the SPR data show a significantly lower level of 200 ohm compared with all the other boreholes, in which the SPR level is c 1,000 ohm. The interpretation is that the entire rock volume around KFR01 has increased fracturing. In KFR19 and KFR20 no possible deformation zones were identified. In the remaining boreholes the interpreted fracture frequency is generally low, but there are 1–4 possible deformation zones (DZ) in each borehole, one possible DZ in KFR03 seems to be wider than 10 m.

Sammanfattning

Föreliggande rapport presenterar resultat och tolkningar av geofysiska borrhålsmätningar i kärnborrhålen KFR01, KFR02, KFR03, KFR04, KFR05, KFR19 och KFR20 och petrofysiska mätningar på borrkärnebitar från borrhålen KFR04, KFR05 och KFR20.

Borrhålen och mätningarna i dem härstammar från de undersökningar som gjordes på 1980-talet inför byggandet av nuvarande SFR. Loggdata är därför mer sparsamma än de data som samlades in under platsundersökningarna i Forsmark. Densitetsdata finns t.ex. endast för fyra av hålen, KFR04, KFR05, KFR19 och KFR20.

Syftet med undersökningen är framförallt att ta fram ett material som på ett förenklat sätt åskådliggör resultaten av de geofysiska loggningarna, s.k. generaliserade geofysiska loggar. Materialet används främst som underlag vid den geologiska enhålstolkningen.

Fördelningen av silikatdensiteten i KFR04, KFR05, KFR19 och KFR20 uppvisar en tydlig dominans, ca 70 %, med silikatdensitet som motsvarar mineralsammansättningen för granit. Huvuddelen av dessa sektioner uppvisar samtidigt låg magnetisk susceptibilitet och förhöjd naturlig gammastrålning. Kombinationen av fysikaliska egenskaper är typisk för pegmatitgranit och finkorning granit.

I de flesta borrhålen förekommer 1–10 m långa sektioner med avvikande låg naturlig gammastrålning, förhöjd magnetisk susceptibilitet samt silikatdensitet i intervallet 2,730–2,800 kg/m^3 och dessa egenskaper är typiska för sur till intermediär vulkanit. Det förekommer i de flesta borrhålen även kortare sektioner (< 2 m) med indikerad förekomst av amfibolitgångar.

Identifieringen av möjliga deformationszoner har i de flesta fall gjorts endast utifrån data från SPR-loggen (Single Point Resistance), förutom i KFR01 och KFR02 där vi också hade tillgång till normal resistivitetsdata. I KFR01 ligger nivån på SPR data på ca 200 ohm, vilket är betydligt lägre än de ca 1,000 ohm som nivån är i de övriga borrhålen. Tolkningen av detta är att berggrunden längs hela borrhålet är generellt mer uppsprucken än vad som är normalfallet. I KFR19 och KFR20 kan inga möjliga deformationszoner identifieras. I de övriga borrhålen förekommer 1–4 st möjliga deformationszoner i vart och ett av hålen, varav en i KFR03 ser ut att vara bredare än 10 m.

Contents

1 Introduction

This document reports the interpretations of geophysical borehole measurements and petrophysical data gained from the cored boreholes KFR01, KFR02, KFR03, KFR04, KFR05, KFR19 and KFR20, which is one of the activities performed within the site investigation at SFR (Figure 1-1). The work was carried out in accordance with activity plan AP SFR-09-009. In Table 1-1 controlling documents for performing this activity are listed. Activity plan and method description are SKB's internal controlling documents.

Generalized geophysical loggings related to lithological variations are presented together with indicated fracture loggings, including estimated fracture frequency. The logging measurements were conducted by Sveriges Geologiska AB in 1984–1985.

The investigations performed prior to the building of the present SFR did not follow the same standards used within the present site investigation in SFR. Therefore the old geophysical logging data used in this investigation differ from the data collected in 2008–2009 and the number of logging methods was fewer compared with today's logging program, see Table 1-2. Only 7 boreholes of the more than 30 drilled boreholes were logged with geophysical methods,

The interpretation presented in this report is performed by GeoVista AB in accordance with the instructions and guidelines from SKB and under supervision of Johan Nissen, SKB.

The data and interpretation products are stored in the database Sicada and are traceable by the activity plan number.

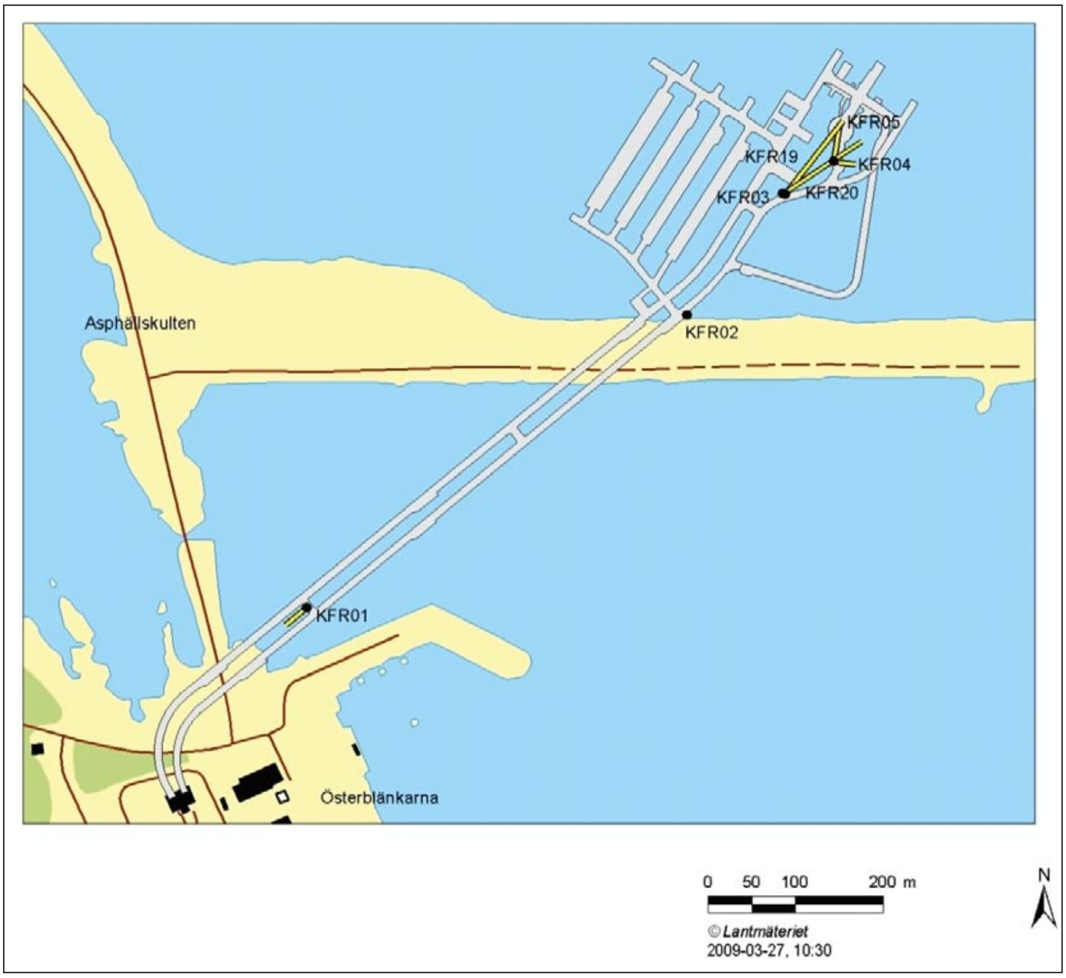


Figure 1-1. General overview over SFR site investigation area showing the locations of the investigated boreholes KFR01, KFR02, KFR03, KFR04, KFR05, KFR19 and KFR20.

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

Activity plan	Number	Version
Tolkning av tidigare loggade geofysiska data från borrhålen KFR01, KFR02, KFR03, KFR04, KFR05, KFR19 och KFR20	AP SFR-09-009	1.0
Method descriptions	**Number**	**Version**
Metodbeskrivning för tolkning av geofysiska borrhålsdata	SKB MD 221.003	3.0

Table 1-2. Existing logging data.

Loggningsparameter	KFR01	KFR02	KFR03	KFR04	KFR05	KFR19	KFR20
Fluid temperature / borehole fluid resistivity	X	X	X	X	X		
Natural gamma	X	X	X	X	X	X	X
Single Point Resistance (SPR)	X	X	X	X	X	X	X
Normal resistivity 1.6 m	X	X					
Magnetic susceptibility			X	X	X	X	X
Neutron-Neutron			X		X	X	
Density				X	X	X	X

2 Objective and scope

The purpose of geophysical measurements in boreholes is to gain knowledge of the physical properties of the bedrock in the vicinity of the borehole. A combined interpretation of the “lithological” logging data silicate density, magnetic susceptibility and natural gamma radiation, together with petrophysical data makes it possible to estimate the physical signature of different rock types. The three loggings are generalized and are then presented in a simplified way. The location of major fractures and an estimation of the fracture frequency along the borehole are calculated by interpreting data from the resistivity loggings.

The main objective of these investigations is to use the results as supportive information during the geological core mappings and as supportive information during the so called “single-hole interpretation”, which is a combined borehole interpretation of core logging (Boremap) data, geophysical data and radar data.

3 Equipment

3.1 Description of interpretation tools for analyses of logging data

The software used for the interpretation are WellCad v4.0 (ALT) and Strater 1.00.24 (Golden Software), that are mainly used for plotting, Grapher v5 (Golden Software), mainly used for plotting and some statistical analyses, and a number of in-house software developed by GeoVista AB on behalf of SKB.

4 Execution

4.1 Interpretation of logging data in general

The execution of the interpretation can be summarized in the following five steps:

1. Preparations of the logging data (calculations of noise levels, median filtering, error estimations, re-sampling, drift correction, length adjustment). The length adjustment procedure was specifically important since no such processing have previously been performed on the data. The length adjustment was performed in WellCAD with reference to the geological Boremap data.

The loggings are median or mean filtered (generally 5 point filters for the resistivity loggings and 3 point filters for other loggings) and re-sampled to common depth co-ordinates (0.1 m point distance).

The density and magnetic susceptibility logging data are calibrated with respect to petrophysical data from KFR04, KFR05 and KFR20.

2. Interpretation rock types (generalization of the silicate density, magnetic susceptibility and natural gamma radiation loggings).

The silicate density is calculated with reference to /1/ and the data are then divided into 5 sections *indicating* a mineral composition corresponding to granite, granodiorite, tonalite, diorite and gabbro rocks, according to /2/. The sections are bounded by the threshold values for silicate density:

	granite	< 2,680 kg/m^3
2,680 kg/m^3 <	granodiorite	< 2,730 kg/m^3
2,730 kg/m^3 <	tonalite	< 2,800 kg/m^3
2,800 kg/m^3 <	diorite	< 2,890 kg/m^3
2,890 kg/m^3 <	gabbro	

The magnetic susceptibility logging is subdivided into steps of decades and the natural gamma radiation is divided into steps of ”low” (< 20 µR/h), ”medium” (20 µR/h < gamma < 36 µR/h), ”high” (36 µR/h < gamma < 53 µR/h) and “very high” (> 53 µR/h).

3. Interpretation of the position of large fractures and estimated fracture frequency (classification to fracture logging and calculation of the estimated fracture frequency logging are based on analyses of the “fracture loggings” SPR, normal resistivity and fluid temperature data. The position of large fractures is estimated by applying a second derivative filter to the logging data and then locating maxima (or minima depending on the logging method) in the filtered logging. Maxima (or minima) above (below) a certain threshold value (Table 4-1) are selected as probable fractures. The result is presented as a column diagram where column height 0 = no fracture, column height 1 = fracture indicated by all logging methods.

4. The estimated fracture frequency is calculated by applying a power function to the weighted sum of the maxima (minima) derivative loggings. Parameters for the power functions used in the previous site investigation at Forsmark were estimated by correlating the weighted sum to the mapped fracture frequency in the cored boreholes KFM01A and KFM02A. The parameters were based on logging data from sonic, caliper, normal resistivity, SPR and focused resistivity measurements. However, in these old SFR data the main fracture indicative loggings used are SPR and normal resistivity. The parameters of the power functions have therefore been adjusted to fit a “back ground” fracture frequency of ca 2–3 fractures/m. The linear coefficients (weights) used are presented in Table 4-1.

5. Report evaluating the results.

Table 4-1. Threshold values and weights used for estimating position of fractures and calculate estimated fracture frequency, respectively.

	Borehole	SPR	Normal res.
Threshold	KFR01	0.9	4.0
Weight	KFR01	2.56	4.0
Threshold	KFR02	1.0	4.0
Weight	KFR02	2.56	4.0
Threshold	KFR03	0.5	–
Weight	KFR03	2.56	–
Threshold	KFR04	0.5	–
Weight	KFR04	2.56	–
Threshold	KFR05	2.0	–
Weight	KFR05	2.56	–
Threshold	KFR19	0.6	–
Weight	KFR19	2.56	–
Threshold	KFR20	0.6	–
Weight	KFR20	2.56	–

4.2 Preparations and data handling

The logging data were delivered as Microsoft Excel files via email from SKB. The data of each logging method were saved separately in ASCII-files. The data processing was performed on the ASCII-files. The data used for interpretation were:

- Density (gamma-gamma).
- Magnetic susceptibility.
- Natural gamma radiation.
- Normal resistivity (160 cm).
- Single point resistance (SPR).
- Fluid resistivity.
- Fluid temperature.

The density and susceptibility logging data were calibrated with reference to petrophysical measurements made on core samples from KFR04, KFR05 and KFR20. The logging data at the same section coordinate as the sample core location were extracted from the data files and a cross-plot was created with logging data on one axis and the petrophysical data on the other. Linear regression technique was applied to establish a calibration equation, which then was applied to the logging data.

4.3 Analyses and interpretations

The analyses of the logging data are made with respect to identifying major variations in physical properties with depth as indicated by the silicate density, the natural gamma radiation and the magnetic susceptibility. Since these properties are related to the mineral composition of the rocks in the vicinity of the borehole they correspond to variations in lithology and in thermal properties.

The SPR and fluid temperature loggings are mainly used for identifying sections with increased fracturing.

4.4 Nonconformities

No nonconformities are reported.

5 Results

5.1 Results of the petrophysical measurements and calibrations of logging data

Density is considered one of the most important physical parameters since it is directly related to the rock mineral content. Density logging data exist for the boreholes KFR04, KFR05, KFR19 and KFR20. An overview of the density data collected in the boreholes shows that the density data in KFR19 and KFR20 have similar background level and amplitude, but the data from KFR04 and KFR05 differ significantly from the former two boreholes, and also from each other, regarding both level and amplitude. In order to achieve high quality density data for the interpretations it was necessary to calibrate KFR19 and KFR20 with one set of petrophysical sample density data, and KFR04 and KFR05 with separate sets of petrophysical data, one obtained from sample data in KFR20 and the other from KFR04 and KFR05.

All susceptibility logging data appeared to have similar background level and amplitude interval, and were therefore calibrated with reference to petrophysical measurements on samples from KFR04.

Density and magnetic susceptibility measurements were carried out on 11 samples collected from the core of KFR04. The result is presented in Figure 5-1 and the data show that 5 samples classify as rock with granitic mineral composition, 2 samples have granite-granodiorite mineral composition and 3 samples classify in the interval diorite-gabbro. One sample is not visible in the diagram of Figure 5-1 since its magnetic susceptibility is 0 SI. This sample has a density of 2,649 kg/m^3 and it is classified as metagranite-granodiorite (101057). In Figure 5-1 we can see that the geological

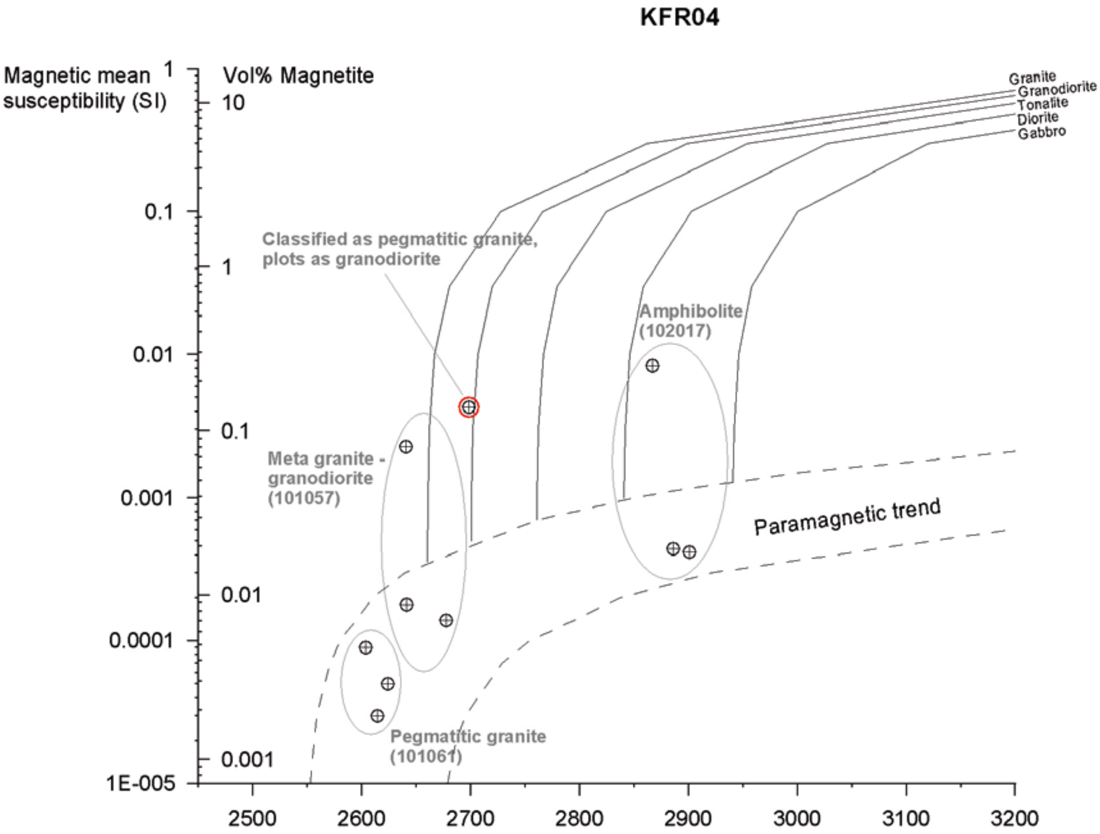


Figure 5-1. Density – susceptibility classification diagram of 10 rock samples from KFR04.

rock classification fits well with the distribution of the density-susceptibility data apart from one sample (marked by a red ring), which is classified as pegmatitic granite but clearly plots close to the granodiorite composition curve. The petrophysical result indicates a miss-classification.

Cross-plots between the sample data and logging data of from KFR04 are presented in Figure 5-2, where Figure 5-2a shows the data prior to length adjustment and Figure 5-2b is after length adjustment. The length adjustment improves the correlation and thus strengthens the statistical validity of the calibration equation indicated by the straight line in the diagrams.

Density measurements were also performed on samples from KFR05 and KFR20. In Figure 5-3 there are two cross-plots, both after length adjustment, for these boreholes. The data are a bit scattered, but there is a clear linear trend in both data sets.

5.2 Quality control of the logging data

Noise levels of the raw data for each logging method are presented in Table 5-1. For all boreholes the natural gamma radiation data have noise levels significantly above the recommended value 0.3 μR/h. These high noise levels do affect the interpretation of the data, especially the response from small rock bodies such as dykes. The susceptibility data generally have noise levels close to, or slightly above, the recommended level, and most other parameters have noise levels below the recommended levels. To reduce the influence of the noise, all logs were average filtered prior to the interpretation.

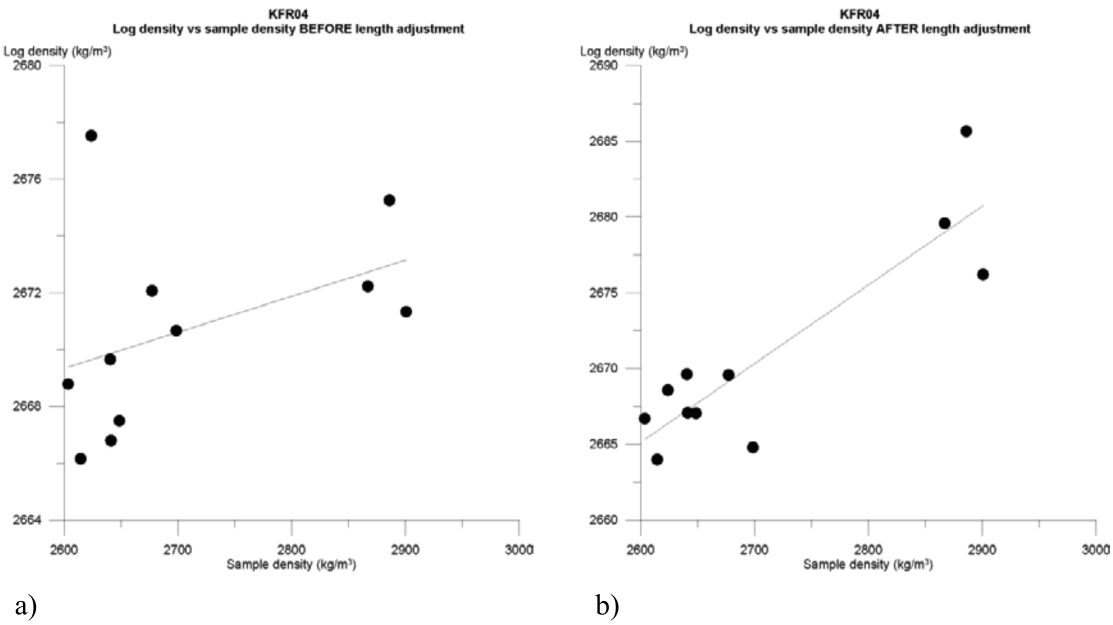
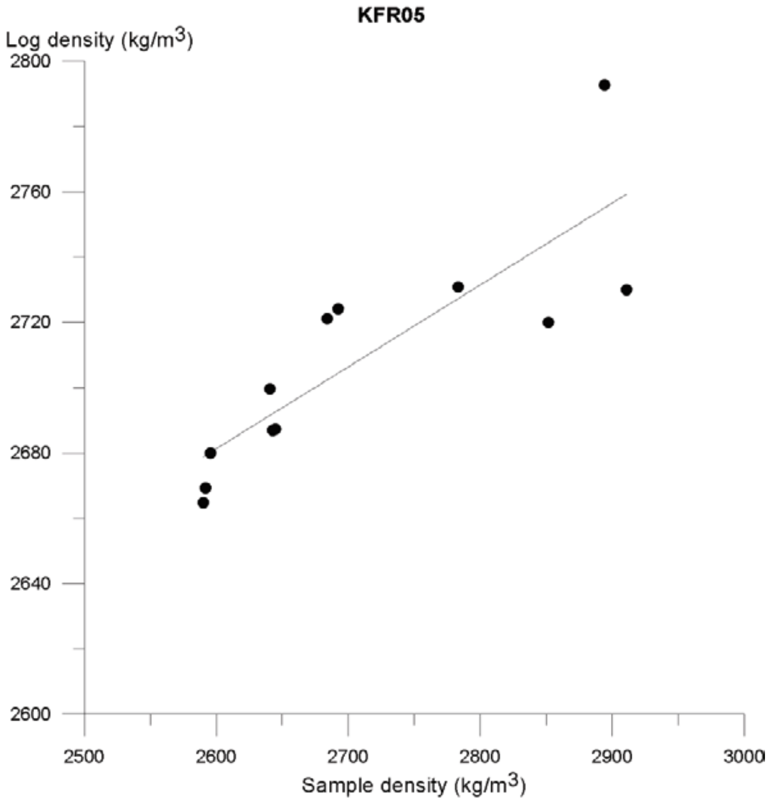


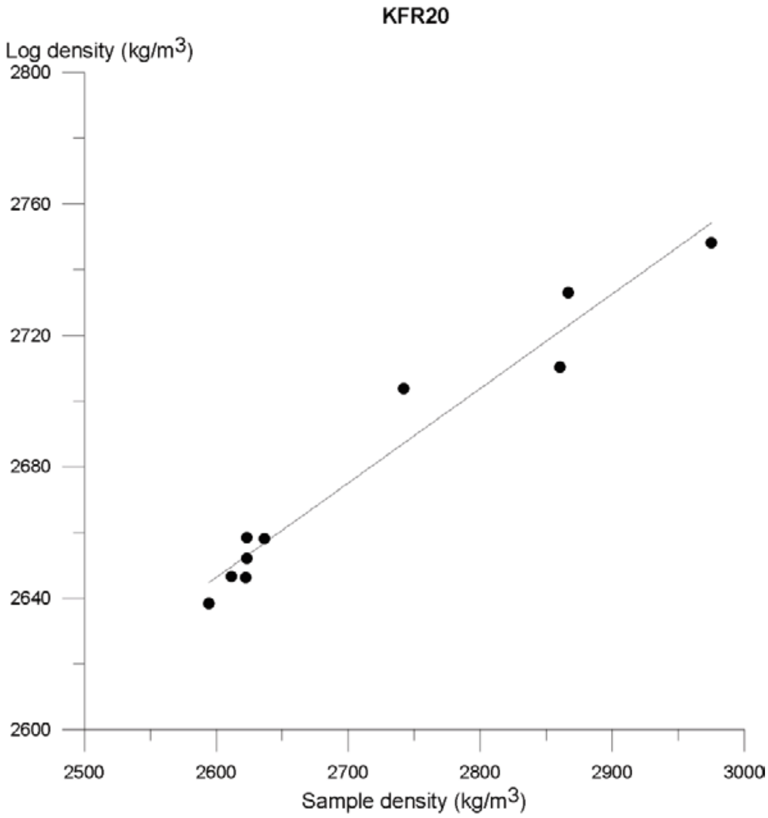
Figure 5-2. *Density cross-plots of logging versus sample data for KFR04. The diagram in a) is prior to length adjustment and b) is after length adjustment.*

Table 5-1. Noise levels in the investigated geophysical logging data.

Logging method	KFR01	KFR02	KFR03	KFR04	KFR05	KFR19	KFR20	Recommended max noise level
Density (kg/m³)	–	–	–	0.4	1.3	1.1	1.1	3–5
Magnetic susceptibility (SI)	–	–	$4 \cdot 10^{-5}$	$3 \cdot 10^{-4}$	$1 \cdot 10^{-4}$	$3 \cdot 10^{-4}$	$2 \cdot 10^{-4}$	$1 \cdot 10^{-4}$
Natural gamma radiation (μR/h)	2.1	4.2	4.4	1.7	3.1	3.1	3.8	0.3
Fluid resistivity (%)	0.4	2.1	0.5	3.6	0.6	–	–	2
Fluid temperature (ºC)	$1 \cdot 10^{-4}$	$3 \cdot 10^{-4}$	$3 \cdot 10^{-3}$	$4 \cdot 10^{-3}$	$2 \cdot 10^{-3}$	–	–	0.01
SPR (%)	3.4	0.4	2.5	1.5	0.5	6.2	3.6	No data
Normal resistivity (%)	1.2	0.5	–	–	–	–	–	No data



a)



b)

Figure 5-3. *Density cross-plots of logging versus sample data for a) KFR05 and b) KFR20 (both plots after length adjustment).*

A qualitative inspection was performed on the loggings. The data were checked for spikes and/or other obvious incorrect data points. Erroneous data were replaced by null values (–999), and all null values were disregarded in the interpretation.

5.3 Interpretation of the logging data

The presentation of interpretation products presented below includes:

- Classification of silicate density.
- Classification of natural gamma radiation.
- Classification of magnetic susceptibility.
- Position of inferred fractures (0 = no method, 1 = all methods).
- Estimated fracture frequency in 5 metre sections.
- Classification of estimated fracture frequency (0 to 3, 3 to 6 and > 6 fractures/m).

5.3.1 Interpretation of KFR01

The results of the generalized logging data and fracture estimations of KFR01 are presented in Figure 5-4. There were no density data or magnetic susceptibility data collected in this borehole.

The borehole can, with reference to the natural gamma radiation data, be divided into three sub sections of c 0–15 m, 15–40 m and 40–60 m. The upper and lowermost sections have natural gamma radiation mainly in the range 30–50 μR/h, whereas the intermediate section is dominated by radiation levels in the range 20–30 μR/h. With reference to other investigated boreholes close to SFR, and in the site investigation area of Forsmark, we know that the range 30–50 μR/h often indicates occurrence of pegmatitic granite or fine-grained granite. The range 20–30 μR/h generally indicates metagranite-granodiorite rock. However, in the SFR area the background level of the natural gamma radiation is often increased, so radiation levels of 20–30 μR/h may also occur in sections with felsic to intermediate volcanic rocks. The short sections with natural gamma radiation < 20 μR/h most likely correspond to mafic rock, amphibolite dykes.

There are few distinct anomalies in the SPR-data. However, the SPR logging data shows a generally decreased level along the entire borehole, c 200 ohm relative to the “normal” background of 1,000 ohm in the other boreholes. This suggests an increased frequency of open fractures along the entire borehole.

5.3.2 Interpretation of KFR02

The results of the generalized logging data and fracture estimations of KFR02 are presented in Figure 5-5. There were no density data or magnetic susceptibility data collected in this borehole.

The natural gamma radiation is generally increased along the entire borehole length, which most likely indicates a dominance of felsic rocks in the borehole. In the section 0–50 m the natural gamma radiation is in the range 45–100 μR/h, which is significantly increased and indicates a large dominance of pegmatite and/or pegmatitic granite, or a possible leakage of radon gas from e.g. uranium bearing pegmatites into the borehole. In the lower half of the borehole, section c 50–116 m, the radiation level is mainly in the range 30–45 μR/h, but there are several strong positive anomalies with amplitudes up to 275 μR/h. The background level may correspond to metagranite-granodiorite, but there must be significant sections with pegmatite, pegmatitic granite and/or fine-grained granite.

The estimated fracture frequency is generally low. In the sections 32–37 m and 98–103 m there are distinctly decreased levels in the resistivity and SPR data which indicates increased fracturing, and in the fluid temperature data there are significant anomalies that indicate in or out flow of water.

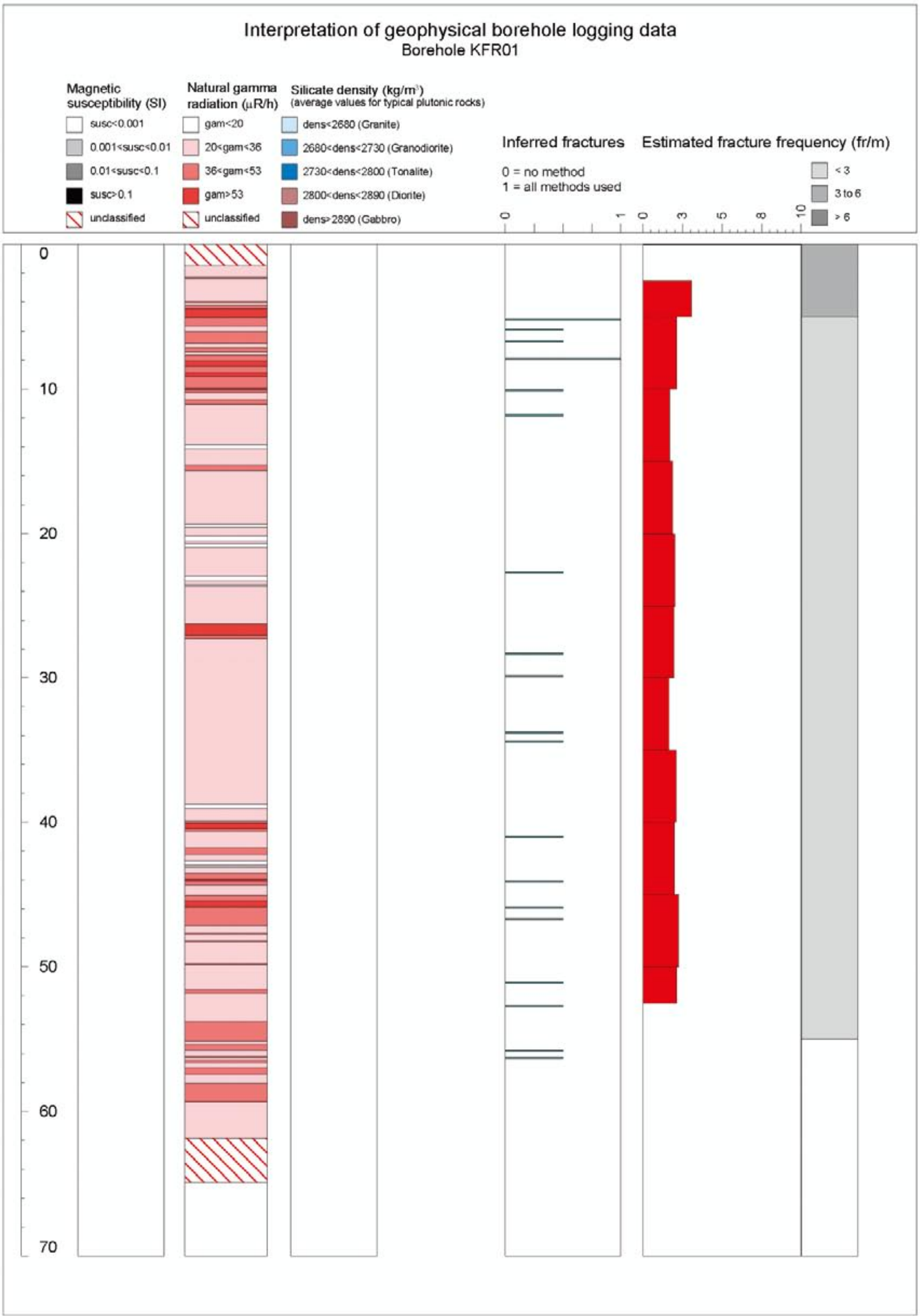


Figure 5-4. *Generalized geophysical logs of KFR01.*

Figure 5-5. Generalized geophysical logs of KFR02.

5.3.3 Interpretation of KFR03

The results of the generalized logging data and fracture estimations of KFR03 are presented in Figure 5-6. There was no density data collected in the borehole.

The natural gamma radiation is significantly increased with a background level of c 50 µR/h, which indicates a large dominance of pegmatite and/or pegmatitic granite, or a possible leakage of radon gas from e.g. uranium bearing pegmatites into the borehole. The geological core mapping shows a wide variety of rocks in the borehole, and most of these rock types should have radiation levels far below the background level of 50 µR/h, which supports the hypothesis of radon gas. The original "raw" data

__Figure 5-6.__ Generalized geophysical logs of KFR03.

indicates large variations in the natural gamma radiation that most likely correspond to different rock types. However, due to the high background level it is not possible to connect the radiation variations with known rock types.

The magnetic susceptibility is generally decreased along the entire borehole section length. This is common for pegmatitic granite and fine-grained granite. Increased susceptibility occurs in the sections c 4–20 m, 32–37 m and 45–68 m, and these sections most likely indicate occurrences of rock types such as metagranite, granodiorite, felsic to intermediate volcanic rock or mafic rocks.

The estimated fracture frequency is generally low along the entire borehole. Increased fracture frequency, indicating possible deformation zones, is indicated by distinct decrease in the SPR logging data along the intervals c 6–12 m, 48–54 m, 70–73 m and 82–95.

5.3.4 Interpretation of KFR04

The results of the generalized logging data and fracture estimations of KFR04 are presented in Figure 5-7. The distribution of silicate density classes with borehole length is presented in Table 5-2.

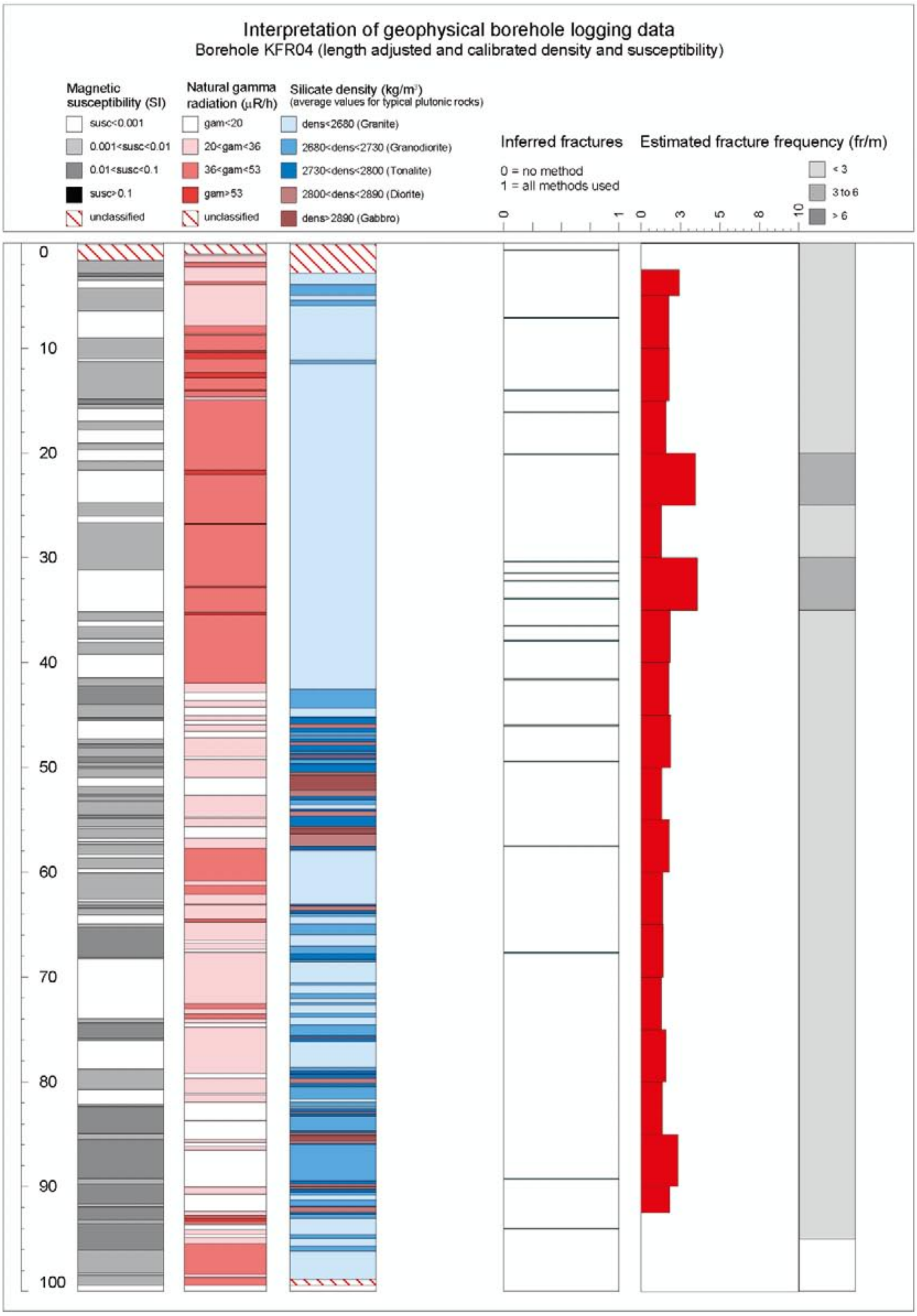


Figure 5-7. Generalized geophysical logs of KFR04.

Table 5-2. Distribution of silicate density classes with borehole length in KFR04.

Silicate density interval (kg/m^3)	Borehole length (m)	Relative borehole length (%)
dens < 2,680 (granite)	59	61
2,680 < dens < 2,730 (granodiorite)	19	20
2,730 < dens < 2,800 (tonalite)	9	9
2,800 < dens < 2,890 (diorite)	6	6
dens > 2,890 (gabbro)	3	4

In about 81% of the borehole length of KFR04 the silicate density data indicate rocks with a mineral composition that corresponds to granite or granodiorite rock (Table 5-2). As seen in Figure 5-7, the upper half of the borehole, section c 5–45 m, is characterized by silicate density < 2,680 kg/m^3, natural gamma radiation in the interval 36–53 μR/h and magnetic susceptibility < 0.01 SI. This distribution of physical properties is typical for pegmatitic granite or fine-grained granite rock.

In the lower half of the borehole, section c 45–100 m there are several sections with increased density and decreased natural gamma radiation, which clearly indicates rock types with different mineral composition compared to the upper half of the borehole. Several intervals with silicate density > 2,800 kg/m^3 most likely correspond to amphibolite dykes. In the section c 45–55 m there are intervals with silicate density of 2,730–2,800 kg/m^3, which may correspond to tonalite or felsic to intermediate volcanic rock. The decrease in natural gamma radiation in the interval 82–92 m suggests the occurrence of felsic to intermediate volcanic rock. There are a few sections also in the lower half of the borehole with indicated pegmatitic granite or fine-grained granite rock, e.g. at 58–62 m and 96–100 m.

The estimated fracture frequency in KFR04 is generally low. There are two sections at c 19–20 m and 31–34 m where there are significant decreases in the SPR logging data which indicates increased fracturing related to possible deformation zones. At c 89 m there is a distinct SPR anomaly indicating the occurrence of a large single fracture. At the same location there is a significant anomaly in the fluid temperature data that most likely indicates the presence of a water bearing fracture.

5.3.5 Interpretation of KFR05

The results of the generalized logging data and fracture estimations of KFR05 are presented in Figure 5-8 below. The distribution of silicate density classes with borehole length is presented in Table 5-3.

The silicate density distribution in KFR05 indicates that c 60% of the rocks have a mineral composition that corresponds to granite rocks (Table 5-3). The sections c 0–7 m, 45–75 m and 120–124 m are dominated by silicate density in the range 2,730–2,750 kg/m^3, increased magnetic susceptibility and natural gamma radiation < 20 μR/h. This combination of physical properties is typical for felsic to intermediate volcanic rock. The sections c 7–45 m, 75–103 m and 110–120 m are characterized by silicate density < 2,670 kg/m^3, decreased magnetization and natural gamma radiation > 40 μR/h, which most likely indicates the occurrence of pegmatitic granite and/or fine-grained granite. A few short sections with silicate density > 2,800 kg/m^3 indicate minor occurrences of amphibolites.

The estimated fracture frequency in KFR05 is generally low. In the section c 84–88 m there is a distinct decrease in the SPR logging data that most likely indicate highly increased fracturing. There is also an anomaly in the fluid temperature data, with its minima at c 86.6 m, which may indicate in or out flow of water.

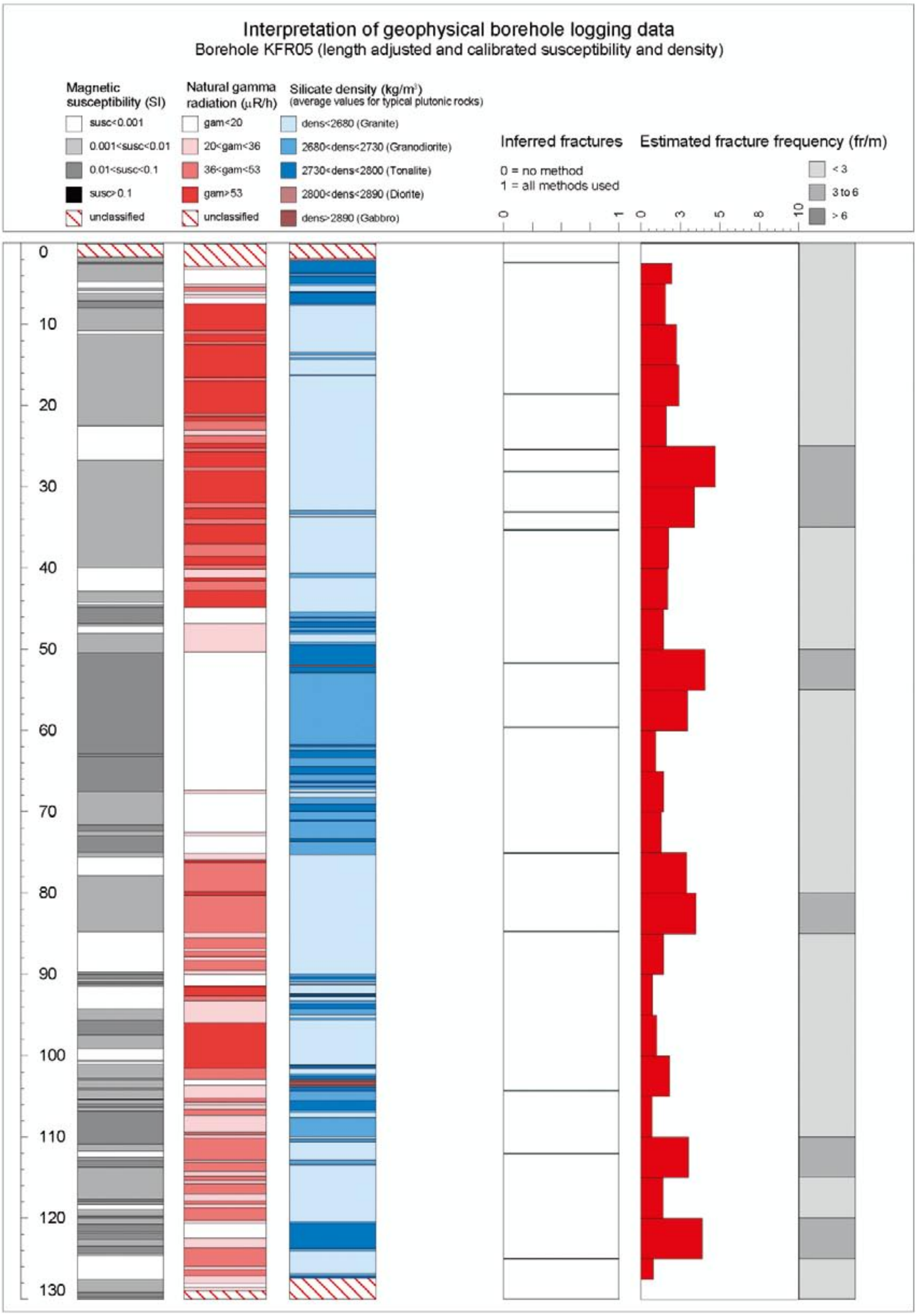


Figure 5-8. Generalized geophysical logs of KFR05.

Table 5-3. Distribution of silicate density classes with borehole length in KFR05.

Silicate density interval (kg/m^3)	Borehole length (m)	Relative borehole length (%)
dens < 2,680 (granite)	74	59
2,680 < dens < 2,730 (granodiorite)	31	25
2,730 < dens < 2,800 (tonalite)	19	15
2,800 < dens < 2,890 (diorite)	1	1
dens > 2,890 (gabbro)	0.5	0

5.3.6 Interpretation of KFR19

The results of the generalized logging data and fracture estimations of KFR19 are presented in Figure 5-9. The distribution of silicate density classes with borehole length is presented in Table 5-4.

The silicate density distribution in KFR19 indicates that there is a large dominance, c 80%, of rocks that have a mineral composition that corresponds to granite rocks (Table 5-4). Along the sections where the silicate density < 2,680 kg/m^3 the natural gamma radiation is generally > 45 μR/h and the magnetic susceptibility is significantly decreased. This combination of physical properties is typical for pegmatitic granite and fine-grained granite.

In the upper half of the borehole there are several short sections (1–5 m long) with increased density, increased magnetic susceptibility and decreased natural gamma radiation. Silicate density > 2,800 kg/m^3 (brown colors in Figure 5-9 most likely indicate occurrences of amphibolite dykes, whereas the intermediate density values most likely correspond to felsic to intermediate volcanic rock or possibly metagranite rocks.

The estimated fracture frequency in KFR19 is generally low and there are no significant anomalies in the SPR data that may indicate possible deformation zones.

5.3.7 Interpretation of KFR20

The results of the generalized logging data and fracture estimations of KFR20 are presented in Figure 5-10. The distribution of silicate density classes with borehole length is presented in Table 5-5.

The natural gamma radiation data show an increased background level (c 50 μR/h) that, with reference to the density distribution, cannot reflect the rock type distribution in the borehole. It is possible that the high radiation level indicates leakage of radon gas into the borehole, a similar situation as in KFR03.

The silicate density distribution indicate that c 64% of the rock along the borehole have silicate density < 2,680 kg/m^3, which indicates a mineral composition corresponding to granite rock. Along these low density sections the magnetic susceptibility is significantly decreased and this combination of properties is typical for pegmatitic granite and fine-grained granite. C 2–5 m long sections with partly increased density occur along the entire borehole. Silicate densities in the range 2,680–2,730 kg/m^3 (20% of the borehole length) may indicate occurrences of metagranite-granodiorite rocks. Densities in the range 2,730–2,800 kg/m^3, in combination with decreased natural gamma radiation and increased susceptibility, would typically correspond to that of felsic to intermediate volcanic rock. A total of 7 meters (7% of the borehole length) of the borehole has silicate densities > 2,800 kg/m^3, and these sections most likely correspond to amphibolite dykes.

The estimated fracture frequency in KFR20 is generally low and there are no significant anomalies in the SPR data that may indicate possible deformation zones.

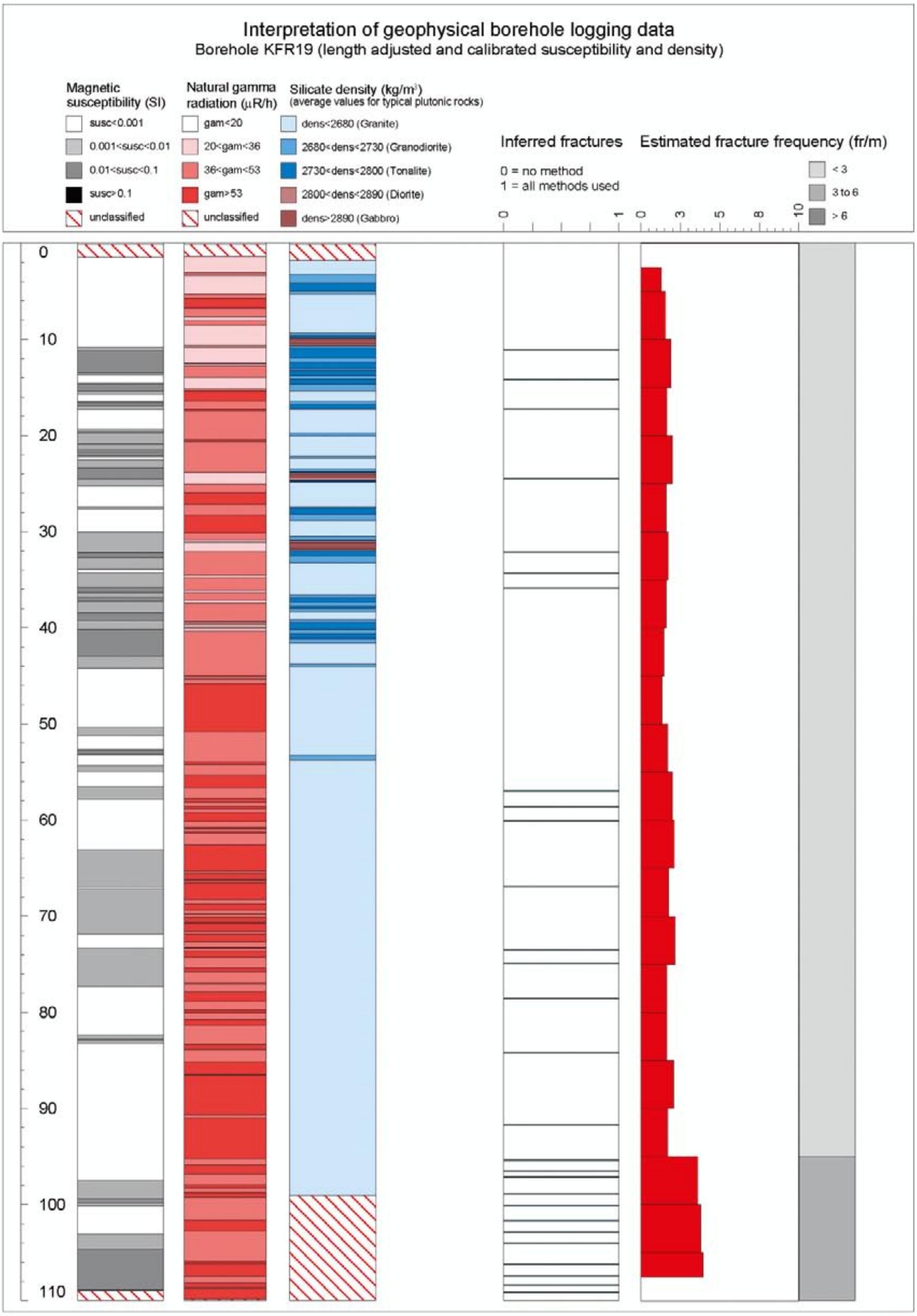


Figure 5-9. Generalized geophysical logs of KFR19.

Table 5-4. Distribution of silicate density classes with borehole length in KFR19.

Silicate density interval (kg/m^3)	Borehole length (m)	Relative borehole length (%)
dens < 2,680 (granite)	77	80
2,680 < dens < 2,730 (granodiorite)	10	10
2,730 < dens < 2,800 (tonalite)	8	8
2,800 < dens < 2,890 (diorite)	1	1
dens > 2,890 (gabbro)	1	1

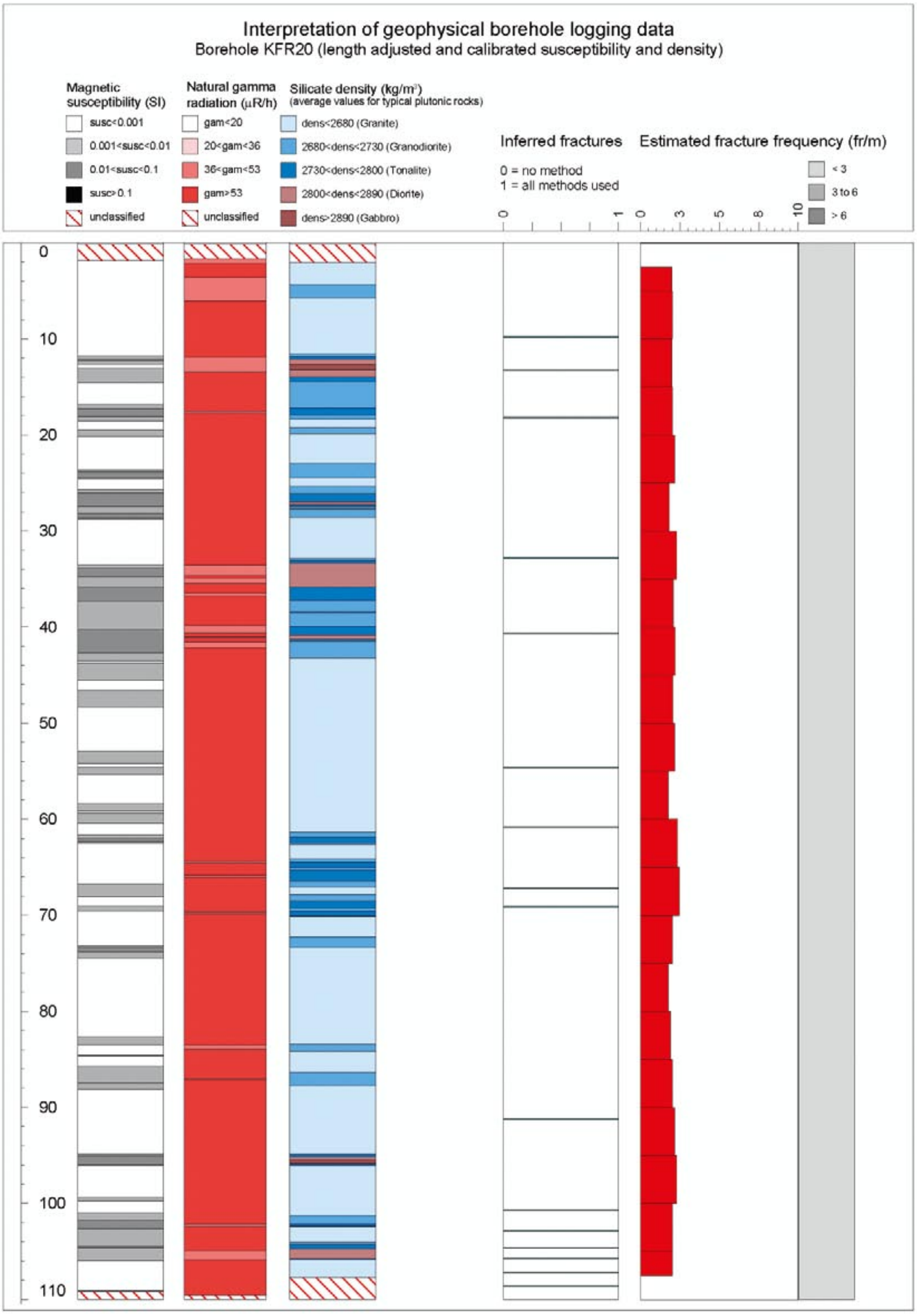


Figure 5-10. Generalized geophysical logs of KFR20.

Table 5-5. Distribution of silicate density classes with borehole length in KFR20.

Silicate density interval (kg/m^3)	Borehole length (m)	Relative borehole length (%)
dens < 2,680 (granite)	68	64
2,680 < dens < 2,730 (granodiorite)	21	20
2,730 < dens < 2,800 (tonalite)	10	9
2,800 < dens < 2,890 (diorite)	6	6
dens > 2,890 (gabbro)	1	1

References

/1/ **Henkel H, 1991.** Petrophysical properties (density and magnetization) of rock from the northern part of the Baltic Shield. Tectonophysics 192, 1–19.

/2/ **Puranen R, 1989.** Susceptibilities, iron and magnetite content of precambrian rocks in Finland. Geological survey of Finland, Report of investigations 90, 45 pp.