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Abstract

This report presents the compilation and interpretations of geophysical logging data from the cored borehole KFR101 and the percussion drilled boreholes HFR101, HFR102 and HFR105. Density and magnetic susceptibility measurements were performed on 14 core samples from KFR101 and results and interpretations of these petrophysical data are also presented in the report.

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

The petrophysical data show an overall resemblance with reference data from the site investigation performed at Forsmark. However, two of the amphibolite samples have increased magnetic susceptibility and one of these also shows a density close to that of diorite. Within the site investigation area increased susceptibility only occurs in diorite-gabbro rocks and never in amphibolites

The silicate density distribution in KFR101 is dominated (88.4%) by silicate density < 2,730 kg/m^3, the natural gamma radiation is mainly 20–36 μR/h and the magnetic susceptibility is generally < 0.001 SI. This combination of physical properties is typical for metagranite rock with low content of magnetite. Probable occurrences of pegmatitic granite rocks are also identified. Short sections (1–10 m long) with significantly increased density occur mainly in the interval c. 10–85 m, and these most likely correspond to amphibolite. The estimated fracture frequency is generally low in KFR101. Possible deformation zones are indicated along the sections c. 100–113 m, 180–183 m, 260–270 m and 293–320 m. All four possible deformation zones coincide with significant fluid temperature anomalies, which suggest that they are related with water bearing fractures.

The silicate density distribution in HFR101 is completely dominated by values < 2,680 kg/m^3, greatly increased natural gamma radiation and significantly decreased magnetic susceptibility, and this combination of physical properties suggests that the bedrock in the vicinity of HFR101 is dominated by pegmatitic granite. The estimated fracture frequency is generally low in HFR101. Four possible deformation zones are indicated of which only one, at c. 30–50 m, is interpreted as severe.

The silicate density distribution in HFR102 is completely dominated by values < 2,680 kg/m^3, natural gamma radiation of 20–36 μR/h and significantly decreased magnetic susceptibility, and this combination of physical properties suggests that the bedrock in the vicinity of HFR102 is dominated by meta granite to granodiorite rock. No possible deformation zones are indicated. However, the bulk resistivity is anomalously low in the entire borehole.

The silicate density distribution in HFR105 is completely dominated by values < 2,680 kg/m^3, which together with natural gamma radiation of 20–36 μR/h and decreased magnetic susceptibility suggests that the bedrock in the vicinity of the borehole is dominated by meta granite to granodiorite rock. Four possible deformation zones are clearly indicated at c. 20–30 m, 89–95 m, 117–120 m and 141–148 m.

Sammanfattning

Föreliggande rapport presenterar resultat och tolkningar av geofysiska borrhålsmätningar i kärnborrhålet KFR101 och i hammarborrhålen HFR101, HFR102 samt HFR105. Dessutom presenteras resultat från densitets- och susceptibilitetsmätningar på 14 st. borrkärneprover från KFR101.

Syftet med denna undersökning 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 dels som stödjande data vid borrkärnekarteringen samt som underlag vid den geologiska enhålstolkningen.

De petrofysiska resultaten stämmer i stort väl överens med de referensdata som finns från platsundersökningen vid Forsmark. En tydlig avvikelse är dock att 2 av amfiboliterna är starkt magnetiserade, och en av dessa har dessutom avvikande låg densitet. Förhöjd magnetisering förekommer inte bland någon amfibolit inom platsundersökningen, däremot hos diorit-gabbro.

Silikatdensiteten i KFR101 domineras helt av värden < 2 730 kg/m^3, den naturliga gammastrålningen är generellt 20–36 μR/h och den magnetiska susceptibiliteten < 0,001 SI. Kombinationen av fysikaliska egenskaper indikerar förekomst av metagranit-granodiorit med låg halt magnetit. Trolig förekomst av pegmatitisk granit och tydliga indikationer på 1–10 m långa sektioner med amfibolit kan identifieras. Den beräknade sprickfrekvensen är generellt låg, men fyra möjliga deformationszoner förekommer vid sektionskoordinaterna ca 100–113 m, 180–183 m, 260–270 m och 293–320 m. Samtliga sektioner uppvisar tydliga anomalier i vätsketemperaturen vilket indikerar vattenförande sprickor.

Silikatdensiteten i HFR101 domineras av värden < 2 680 kg/m^3, den naturliga gammastrålningen är kraftigt förhöjd och den magnetiska susceptibiliteten < 0,001 SI. Kombinationen av fysikaliska egenskaper indikerar förekomst av pegmatitisk granit. Den beräknade sprickfrekvensen är generellt låg i HFR101; 4 möjliga deformationszoner kan identifieras, varav endast en vid 30–50 m tros vara allvarlig.

I HFR102 domineras silikatdensiteten av värden < 2 680 kg/m^3, den naturliga gammastrålningen är 20–36 μR/h och den magnetiska susceptibiliteten < 0,001 SI. Kombinationen av fysikaliska egenskaper indikerar förekomst av metagranit-granodiorit. Inga möjliga deformationszoner kan identifieras men resistiviteten är kraftigt sänkt längs hela borrhålet.

I HFR105 domineras silikatdensiteten av värden < 2 680 kg/m^3, den naturliga gammastrålningen är 20–36 μR/h och den magnetiska susceptibiliteten < 0,001 SI. Kombinationen av fysikaliska egenskaper indikerar förekomst av metagranit-granodiorit. Fyra möjliga deformationszoner kan identifieras tydligt vid ca 20–30 m, 89–95 m, 117–120 m och 141–148 m.

Contents

1 Introduction

This document reports the interpretations of geophysical borehole measurements and petrophysical data (only KFR101) gained from the cored borehole KFR101 and the percussion drilled boreholes HFR101, HFR102 and HFR105, 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-08-010. In Table 1-1 controlling documents for performing this activity are listed. Both activity plan and method descriptions 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 in 2008 by Rambøll /1/.

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.

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

Activity plan	**Number**	**Version**
Tolkning av geofysiska borrhålsdata från HFR101, HFR102, HFR103, HFR104, HFR105 samt KFR27 och KFR101	AP SFR-08-010	1.0
Method descriptions	**Number**	**Version**
Metodbeskrivning för tolkning av geofysiska borrhålsdata	SKB MD 221.003	3.0
Metodbeskrivning för bestämning av densiteten och porositeten hos det intakta berget.	SKB MD 160.002	2.0
Metodbeskrivning för mätning av bergarters petrofysiska egenskaper	SKB MD 230.001	2.0

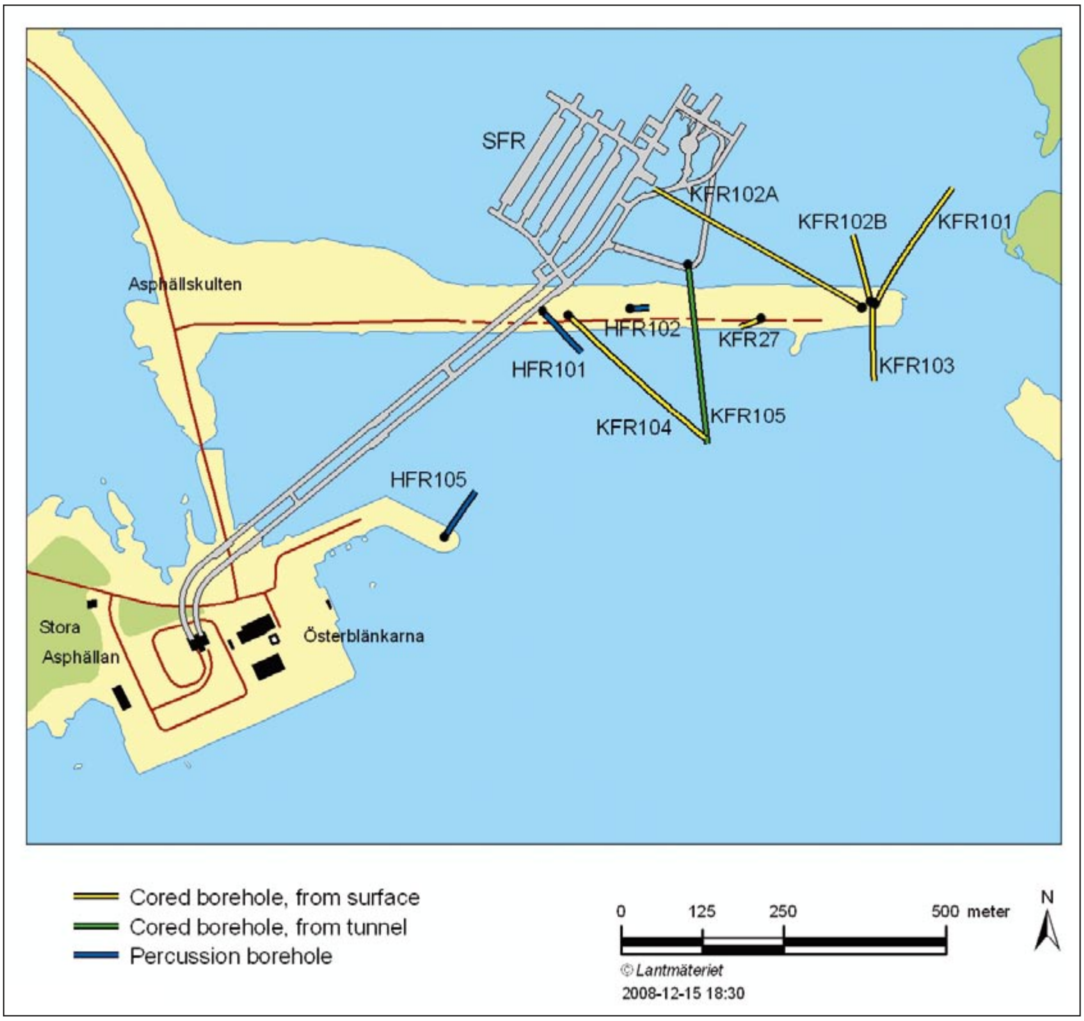


***Figure 1-1.** General overview over SFR site investigation area with the locations of the investigated boreholes KFR101, HFR101, HFR102 and HFR105.*

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 and caliper 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.

3.2 Description of equipment for analyses of petrophysical data

The measurements of magnetic susceptibility were performed with a KLY-3 Kappabridge from Geofyzika Brno. Masses for the density determinations were measured with a digital Mettler Toledo PG 5002. The measurements were performed by the petrophysical laboratory at Luleå University of Technology.

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 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 KFR101.

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

   The silicate density is calculated with reference to /2/ and the data are then divided into 5 sections indicating a mineral composition corresponding to granite, granodiorite, tonalite, diorite and gabbro rocks, according to /3/. The sections are bounded by the threshold values

		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” (< 20µR/h), ”medium” (20 µR/h < gamma < 36 µR/h), ”high” (36 µR/h < gamma < 53 µR/h) and “very high” (> 53 µR/h).

3. The caliper mean data are calibrated with reference to borehole technical specifications (caliber ring diameter data) supplied by the SKB (extracted from Sicada). The calibration procedure is described in detail in /4/.

4. 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 caliper mean, focused resistivity 128 and focused resistivity 300 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.

   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 were previously 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 the SFR investigation the only fracture indicative loggings used are the focused resistivity and caliper mean. The parameters of the power functions have therefore been adjusted to fit a “back ground” fracture frequency in KFR101 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	Focused res. 128	Focused res. 300	Caliper
Threshold	KFR101	1.5	1.5	0.5
Weight	KFR101	2.56	4.0	2.0
Threshold	HFR101	1.3	1.3	0.5
Weight	HFR101	2.56	4.0	2.0
Threshold	HFR102	1.5	0.8	0.5
Weight	HFR102	2.56	4.0	2.0
Threshold	HFR105	1.0	1.2	0.4
Weight	HFR105	2.56	4.0	2.0

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.
- Focused resistivity (300 cm).
- Focused resistivity (128 cm).
- Caliper mean.
- Fluid resistivity.
- Fluid temperature.

The density and susceptibility logging data were calibrated with reference to petrophysical measurements made on core samples from KFR101. 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. The results of the calibrations are presented in the Result-chapter.

4.3 Analyses and interpretations

4.3.1 Logging data

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 resistivity and caliper loggings are mainly used for identifying sections with increased fracturing and alteration.

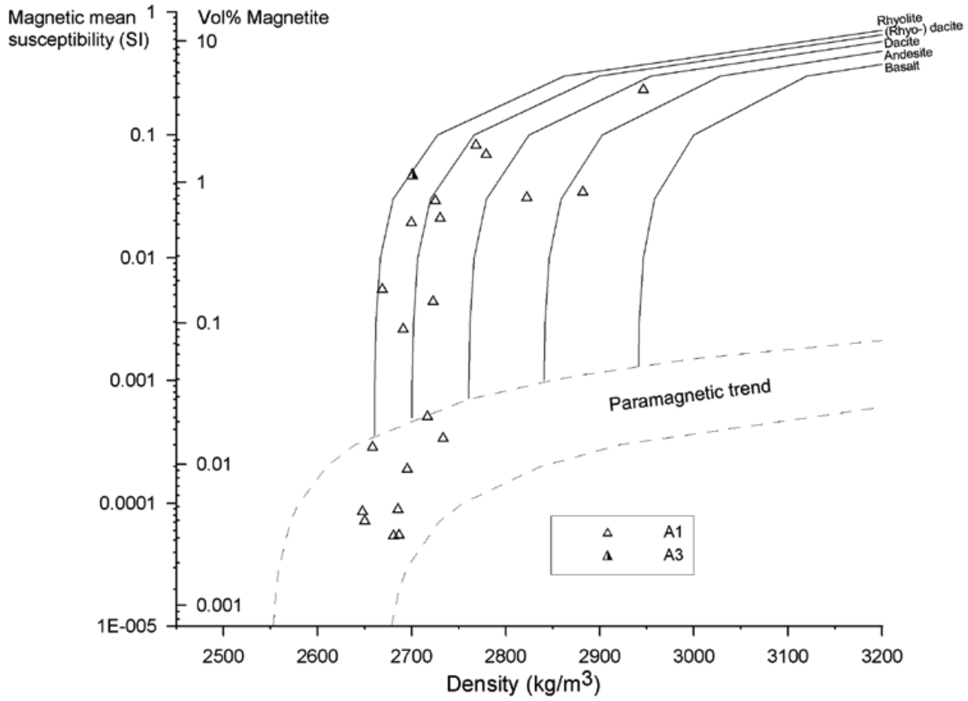
4.3.2 Petrophysical data

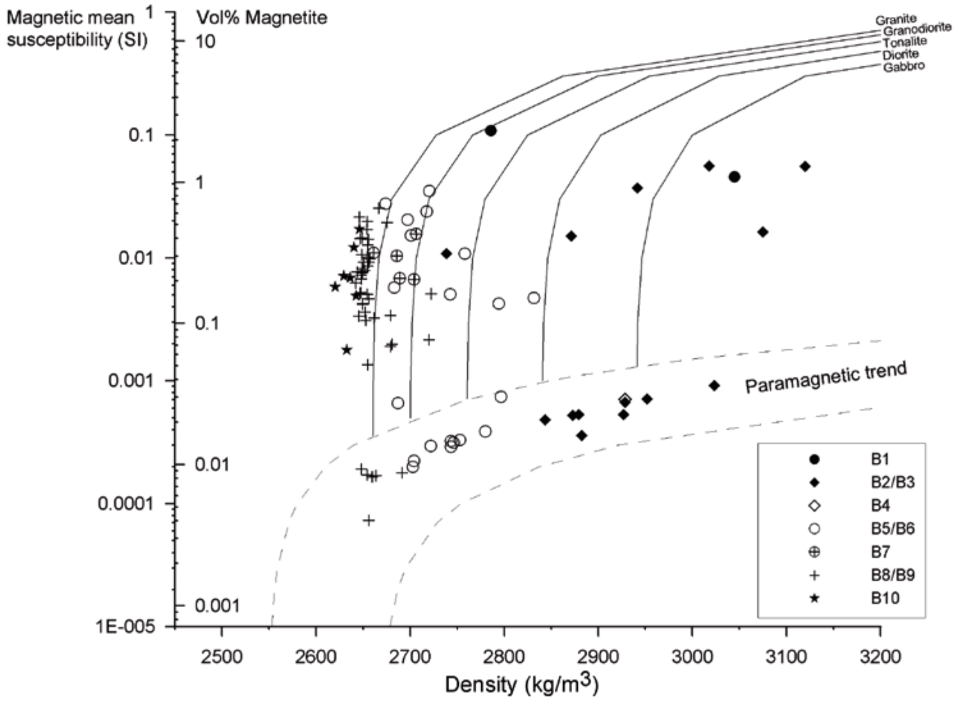
The analyses of the petrophysical data are, besides calibrating logging data, performed in order to support the rock type classification. The density and susceptibility data are therefore plotted in a so called density-susceptibility classification diagram with indicative boundaries for different rock types. The distribution of the data in the diagram is related to variations in mineral composition and the diagram is constructed with reference to /2/ and /3/.

In the Figure 4-1 all surface petrophysical data (groups A, B, C and D rocks, see Table 4-1) from the Forsmark site investigation are plotted in density-susceptibility classifycation diagram /5/. These diagrams are used as references for the petrophysical data from KFR101.

Table 4-2. Code table for the different rock groups in the Forsmark area.

Rock Group (SGU)	Code (SKB)	Composition Name (IUGS/SGU)
A1	103,076	Dacite and andesite, metamorphic
A1	106,000	Sedimentary rock, metamorphic
A2	109,014	Magnetite mineralization associated with calc-silicate rocks
A3		Veined gneiss
A4	108,019	Calc-silicate rock (skarn)
A5	109,010	Pyrite-pyrrhotite-chalcopyrite-sphalerite mineralisation
A2	109,014	Magnetite mineralisation associated with calc-silicate rock
B1	101,004	Ultramafic rock (olivine-hornblende pyroxenite)
B2/B3	101,033	Diorite, quartz diorite and gabbro, metamorphic
B4	102,017	Amphibolite
B5/B6	101,054	Tonalite and granodiorite, metamorphic
B7	101,056	Granodiorite, metamorphic
B8/B9	101,057	Granite and granodiorite, metamorphic, medium-grained (the most common rock type in the candidate area)
B10	101,058	Granite, metamorphic, aplitic
	111,051	Granitoid, metamorphic
C	101,051	Granodiorite, tonalite and granite, metamorphic, fine- to medium-grained
D1	111,058	Granite, fine- to medium-grained
D2/D3	101,061	Pegmatitic granite, pegmatite


Magnetic mean susceptibility (SI)
Vol% Magnetite
1
10
0.1
1
0.01
0.1
0.001
0.01
0.0001
0.001
1E-005
Rhyolite
(Rhyo-) dacite
Dacite
Andesite
Basalt
Paramagnetic trend
A1
A3
2500
2600
2700
2800
2900
3000
3100
3200
Density (kg/m3)


Magnetic mean susceptibility (SI)
Vol% Magnetite
1
10
0.1
1
0.01
0.1
0.001
0.01
0.0001
0.001
1E-005
Granite
Granodiorite
Tonalite
Diorite
Gabbro
Paramagnetic trend
B1
B2/B3
B4
B5/B6
B7
B8/B9
B10
2500
2600
2700
2800
2900
3000
3100
3200
Density (kg/m3)

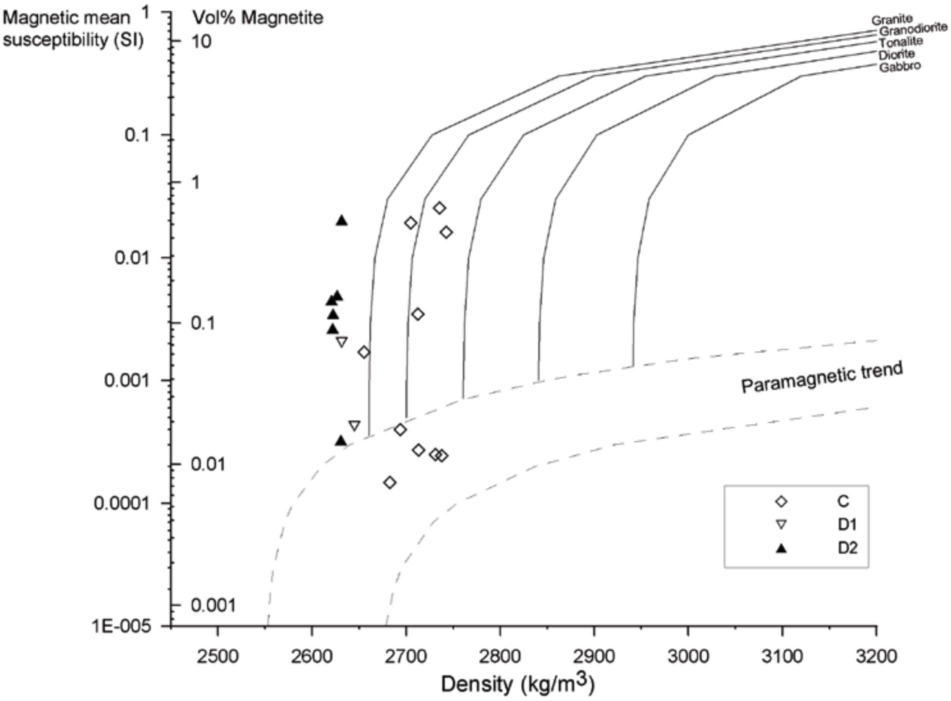


Figure 4-1. *Density-susceptibility rock classification diagrams for rock type group A (upper plot), group B (middle plot) and group C and D (lower plot) of the Forsmark site investigation area, surface data only /5/. See the text for explanation.*

4.4 Nonconformities

No interpretation products are presented for the borehole KFR27, which is part of the activity. The reason for this is that it was decided to continue the drilling of the borehole, and also to continue the geophysical logging measurements in the prolonged borehole section. A complete interpretation of this borehole will be presented in a future report when a full data set from the entire borehole is available.

5 Results

5.1 Results of the petrophysical measurements

The petrophysical measurements were conducted on 14 core samples from KFR101 collected and classified by Jesper Petersson, geologist at Vattenfall Power Consultant (Table 5-1). The aim of the sampling was focused on covering different rock types with significant variations in density and susceptibility values in order to achieve good conditions for the calibration and rock type classification. A secondary aim was to collect samples well distributed along the entire borehole.

The density susceptibility classification diagram of the 14 core samples from KFR101 is shown in Figure 5-1, with the same symbols as used in reference diagrams of the Figure 4-1. When comparing the KFR101 data with the site investigation data there is an overall resemblance. However, there are a few distinct differences. In KFR101 two of the amphibolite samples have increased magnetic susceptibility and one of these also shows a density close to that of diorite. Within the site investigation area increased susceptibility only occurs in diorite-gabbro rocks and never in amphibolites (several measurements were made on core samples not shown in Figure 4-1). Another anomaly is the high density of the single aplitic granite samples (star symbol). Normally this rock type shows density < 2,650 kg/m^3. The two fine- to medium grained granite samples also have increased densities compared with the surface petrophysical data.

Table 5-1. Section length co-ordinates and rock type information for the 14 core samples collected for density and magnetic susceptibility measurements.

secup (m)	seclow (m)	Rock type code	Rock type name
18.88	18.93	103,076	Felsic to intemediate metavolcanic rock
65.02	65.07	103,076	Felsic to intemediate metavolcanic rock
77.53	77.58	102,017	Amphibolite
79.54	79.59	102,017	Amphibolite
82.35	82.40	102,017	Amphibolite
83.69	83.75	102,017	Amphibolite
123.33	123.39	101,057	Fine- to medium grained meta granite to granodiorite
128.88	128.93	101,057	Fine- to medium grained meta granite to granodiorite
135.77	135.83	101,061	Pegmatitic granite
171.27	171.32	101,061	Pegmatitic granite
226.00	226.05	101,057	Fine- to medium grained meta granite to granodiorite
258.64	258.69	111,058	Fine- to medium grained granite
264.77	264.82	111,058	Fine- to medium grained granite
315.51	315.56	101,058	Aplitic granite

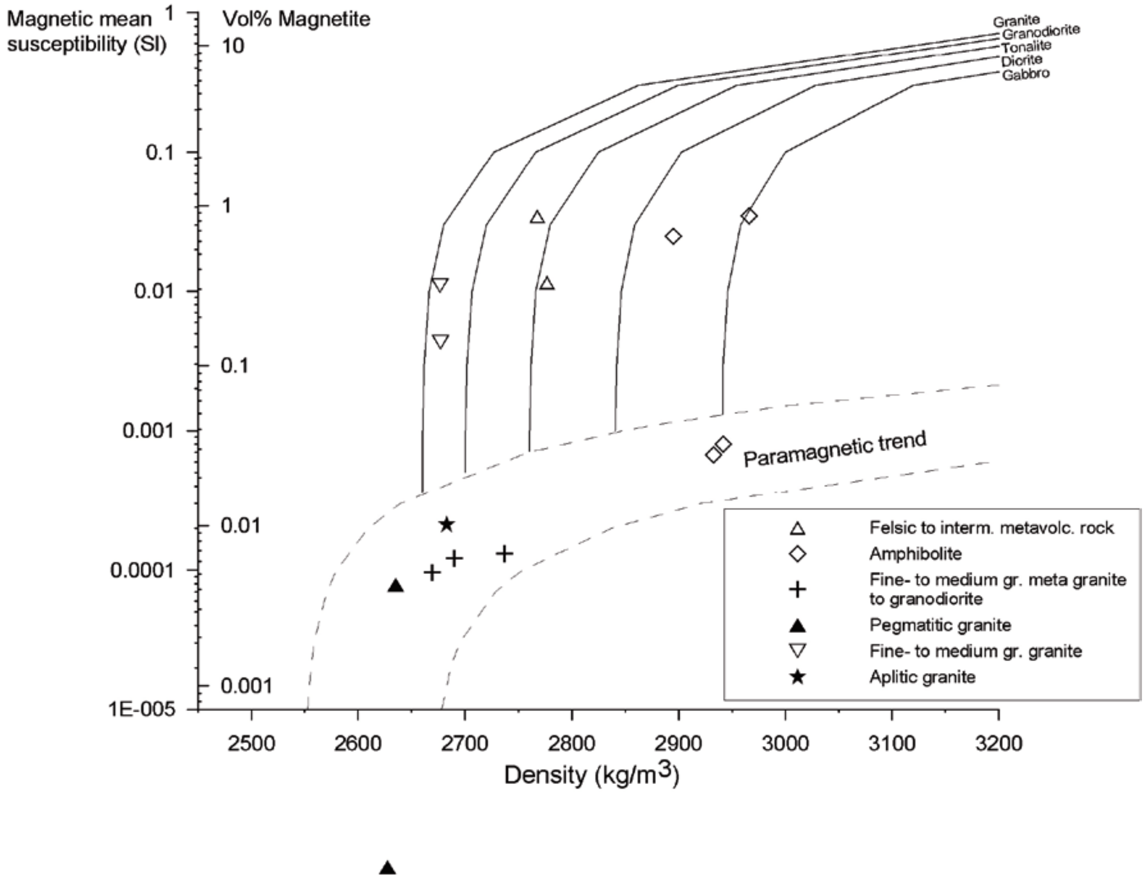


Figure 5-1. Density-susceptibility classification diagram for the 14 core samples of KFR101.

5.2 Calibration of density and susceptibility logging data

By extracting data from the density and magnetic susceptibility logs at the same borehole section co-ordinates as the core samples were collected it is possible to construct cross-plots with logging data versus sample data, see Figures 5-2 and 5-3. The logging data were average filtered prior to the extraction in order to remove random noise. Linear regression analysis was used to estimate calibration equations for the two methods.

The density data (Figure 5-2) show a fairly nice linear distribution and the linear fit is well established with a R^2 coefficient = 0.92. The residual mean of 43 kg/m^3 is a bit high. However, this value decreases down to c. 20 kg/m^3 if removing the two most divergent data points. Removing the two data points does not affect the calibration equation significantly.

The susceptibility data (Figure 5-3) also show a fairly nice linear distribution and the linear fit is well established with a R^2 coefficient = 0.97. The residual mean is 0.0013 SI.

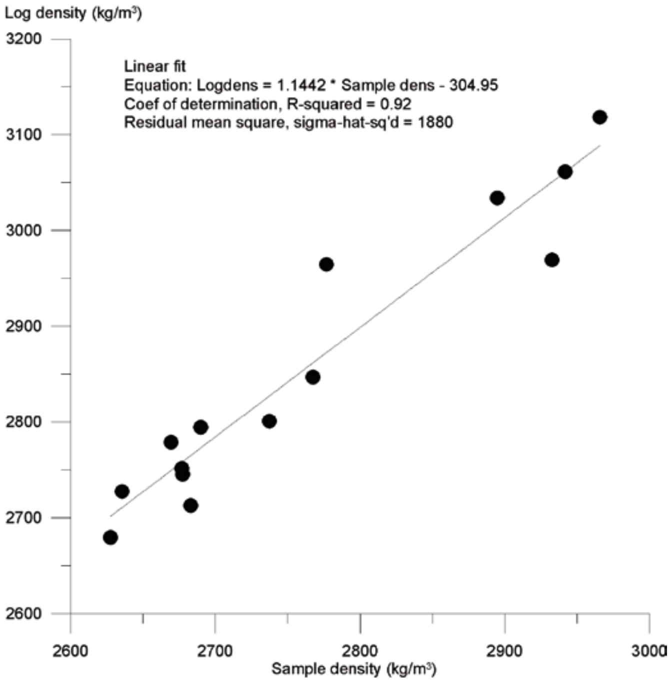


Figure 5-2. *Cross-plot showing logged density versus density measured on core samples for KFR101. The calibration equation is estimated by linear regression analysis.*

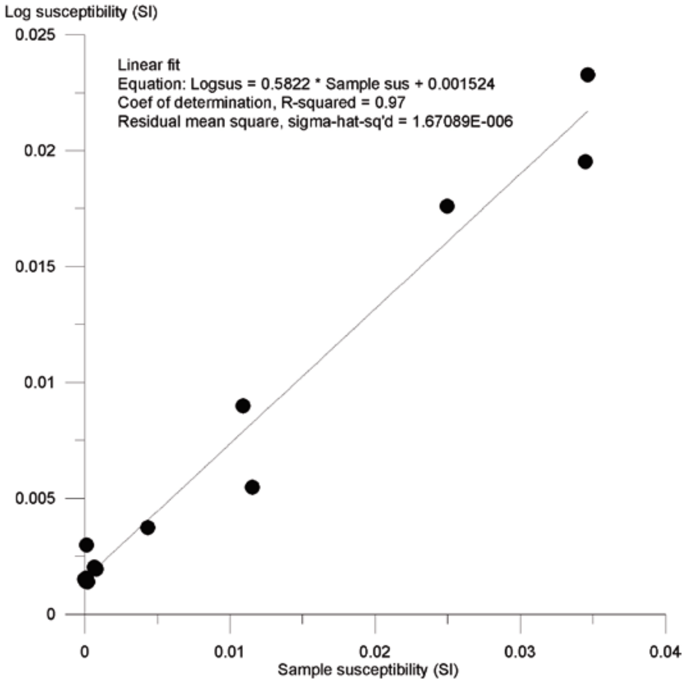


Figure 5-3. *Cross-plot showing logged magnetic susceptibility versus magnetic susceptibility measured on core samples for KFR101. The calibration equation is estimated by linear regression analysis.*

5.3 Quality control of the logging data

Noise levels of the raw data for each logging method are presented in Table 5-2. For all boreholes the natural gamma radiation data have noise levels significantly above the recommended value of 0.3 μR/h. Also the density data show noise levels above the recommended levels. To reduce the influence of the noise, all logs were average filtered prior to the interpretation.

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) by the contractor Rambøll prior to the delivery of the data, and all null values were disregarded in the interpretation.

Table 5-2. Noise levels in the investigated geophysical logging data.

Logging method	KFR101	HFR101	HFR102	HFR105	Recommended max noise level
Density (kg/m^3)	11	13	11	11	3–5
Magnetic susceptibility (SI)	$1*10^{-4}$	$0.8*10^{-4}$	$0.4*10^{-4}$	$0.9*10^{-4}$	$1*10^{-4}$
Natural gamma radiation (μR/h)	1.9	2.6	1.6	4.1	0.3
Fluid resistivity (%)	0.05	0.04	0.05	0.3	2
Fluid temperature (ºC)	$7*10^{-4}$	$4*10^{-4}$	$6*10^{-4}$	$1*10^{-3}$	0.01
Caliper mean (meter)	$3*10^{-5}$	$2*10^{-4}$	$3*10^{-4}$	$3*10^{-4}$	0.0005
Focused resistivity 300 (%)	23	8	18	13	No data
Focused resistivity 128 (%)	4	2	5	4	No data

5.4 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 meter sections.
- Classification of estimated fracture frequency (0 to 3, 3 to 6 and > 6 fractures/m).

5.4.1 Interpretation of KFR101

The results of the generalized logging data and fracture estimations of KFR101 are presented in Figure 5-4 below. The distribution of silicate density classes with borehole length is presented in Table 5-3.

The silicate density distribution in KFR101 is dominated (88.4%) by silicate density < 2,730 kg/m^3, which corresponds to granite – granodiorite. Along the majority of the borehole length the natural gamma radiation is 20–36 μR/h and the magnetic susceptibility is generally < 0.001 SI. This combination of physical properties is typical for metagranite rock with low content of magnetite. Along the sections c. 10–85 m and 220–270 m the magnetic susceptibility is mainly 0.001–0.01 SI, which corresponds to an increased content of magnetite.

Those section intervals with silicate density < 2,680 kg/m^3, decreased magnetic susceptibility and increased natural gamma radiation (> 36 μR/h), such as e.g. 165–185 m, are most likely dominated by pegmatitic granite rocks.

Short sections (1–10 m long) with significantly increased density occur mainly in the interval c. 10–85 m, but also a few scattered high density sections occur at higher section co-ordinates. The entire interval 10–85 m is characterized by increased magnetic susceptibility, but the high density sections coincide with both increased and decreased susceptibility. Referring to the petrophysical samples, the high density sections most likely correspond to amphibolite and/or diorite-gabbro rocks.

Short sections, 1–2 m long, with greatly increased natural gamma radiation (> 53 μR/h) are concentrated in the intervals 130–185 m and 250–300 m. When significantly increased gamma radiation coincides with decreased density and magnetic susceptibility it often indicates the occurrence of pegmatite dyke or fine-grained (aplitic) granite dyke.

The estimated fracture frequency is generally low in KFR101. Possible deformation zones are indicated along the sections c 100–113 m, 180–183 m, 260–270 m and 293–320 m. All these sections are characterized by decreased resistivity and some show single caliper anomalies. The most significant possible deformation zone occurs along the section 293–320 m with a bulk resistivity of 400–1,500 Ωm. The resistivity of "normal" crystalline rock with few fractures is c. 10,000–30,000 Ωm. All four possible deformation zones coincide with significant fluid temperature anomalies, which suggest that they are related with water bearing fractures.

Table 5-3. Distribution of silicate density classes with borehole length in KFR101.

Silicate density interval (kg/m^3)	Approximate length along borehole (m)	Approximate relative length along borehole (%)
dens < 2,680 (granite)	121.3	37.7
2,680 < dens < 2,730 (granodiorite)	162.9	50.7
2,730 < dens 2,800 (tonalite)	17.8	5.5
2,800 < dens < 2,890 (diorite)	12.5	3.9
dens > 2,890 (gabbro)	7.1	2.2

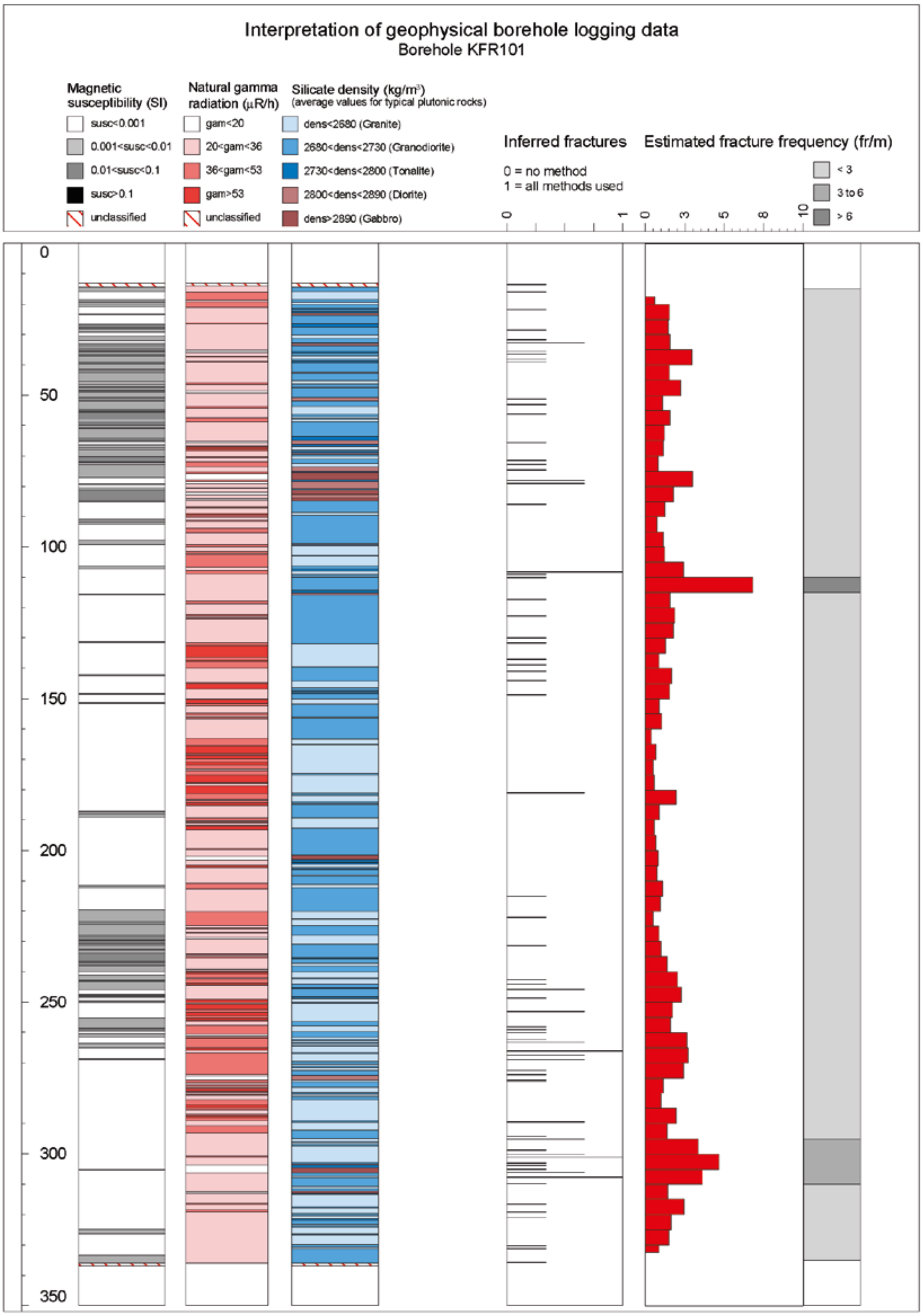


Figure 5-4. *Generalized geophysical logs of KFR101.*

5.4.2 Interpretation of HFR101

The results of the generalized logging data and fracture estimations of HFR101 are presented in Figure 5-5 below.

The silicate density distribution in HFR101 is completely dominated by values < 2,680 kg/m^3, which corresponds to that of granite rock. These low density sections coincide with greatly increased natural gamma radiation and significantly decreased magnetic susceptibility, and this combination of physical properties suggests that the bedrock in the vicinity of HFR101 is dominated by pegmatitic granite.

In the sections c. 40–85 m and 190–207 m the silicate density is mainly in the interval 2,680–2,730 kg/m^3, the natural gamma radiation is 20–36 μR/h and the magnetic susceptibility is 0.0010–0.050 SI, which most likely corresponds to occurrences of meta granite to granodiorite rocks.

The estimated fracture frequency is generally low in HFR101. Possible deformation zones are indicated at c. 30–50 m, 100–110 m, 173–183 m and 190–200 m. The three lowermost sections are mainly characterized by partly decreased resistivity (short low resistivity anomalies) and caliper anomalies suggesting high frequency of brittle fractures. The uppermost possible deformation zone is characterized by significantly decreased bulk resistivity and several caliper anomalies possibly corresponding to higher degree of deformation and/or alteration.

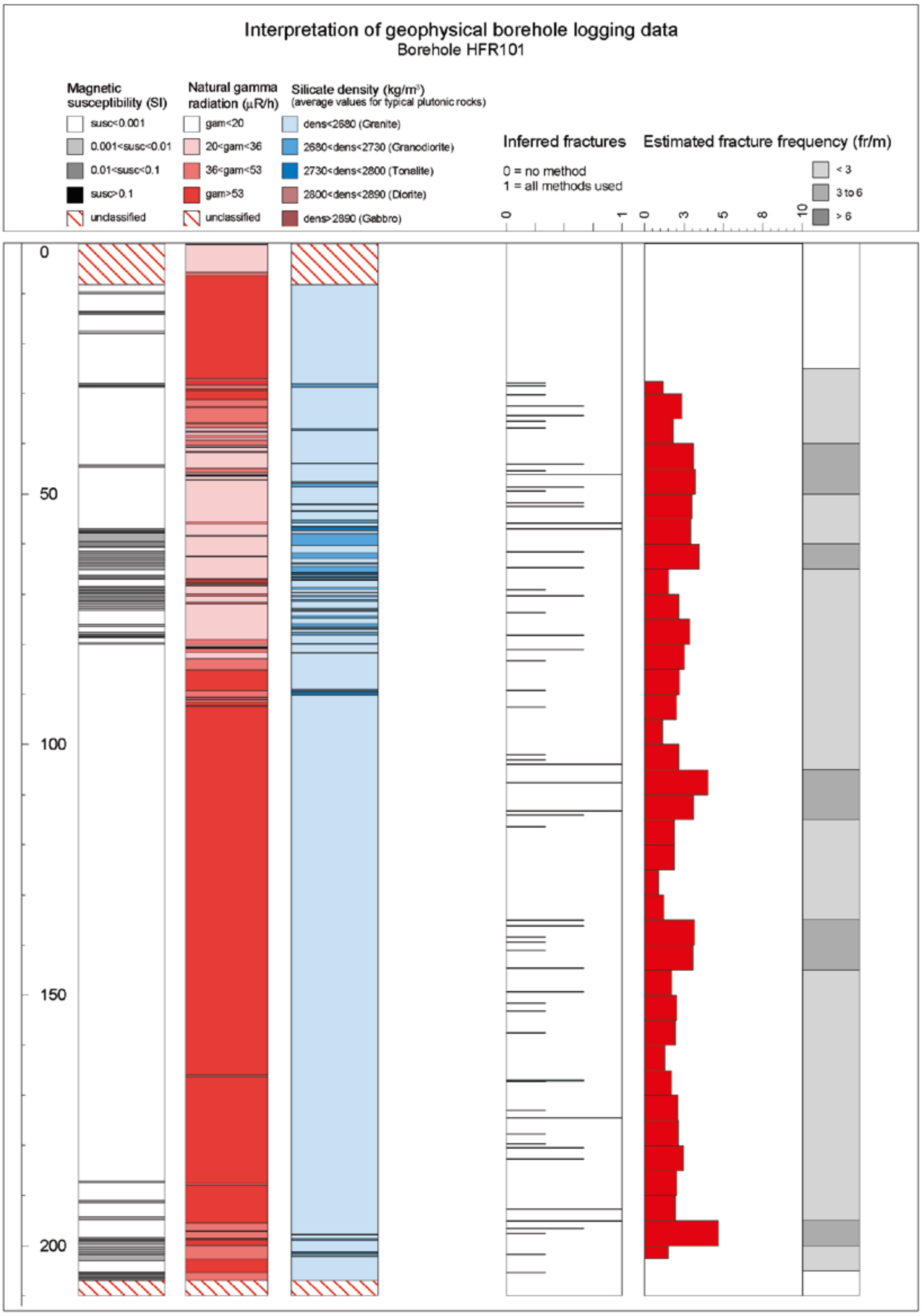


Figure 5-5. *Generalized geophysical logs of HFR101.*

5.4.3 Interpretation of HFR102

The results of the generalized logging data and fracture estimations of HFR102 are presented in Figure 5-6 below.

The silicate density distribution in HFR101 is completely dominated by values < 2,680 kg/m^3, which corresponds to that of granite rock. These low density sections coincide with natural gamma radiation of 20–36 μR/h (partly 36–53 μR/h) and significantly decreased magnetic susceptibility, and this combination of physical properties suggests that the bedrock in the vicinity of HFR102 is dominated by meta granite to granodiorite rock.

At 44–48 m there is a major increase in the natural gamma radiation that coincides with a significant decrease in density. This combination is typical for pegmatite.

The short sections with natural gamma radiation in the range 20–26 μR/h may correspond to pegmatitic granite.

The estimated fracture frequency is generally low in HFR102 and no possible deformation zones are indicated. However, it must be noted that the resistivity is generally very low in the entire borehole, c. 100–2,000 Ωm. This reminds of the uppermost c. 50 m of HFR101, and could thus be related to alteration and/or a generally increased fracture frequency.

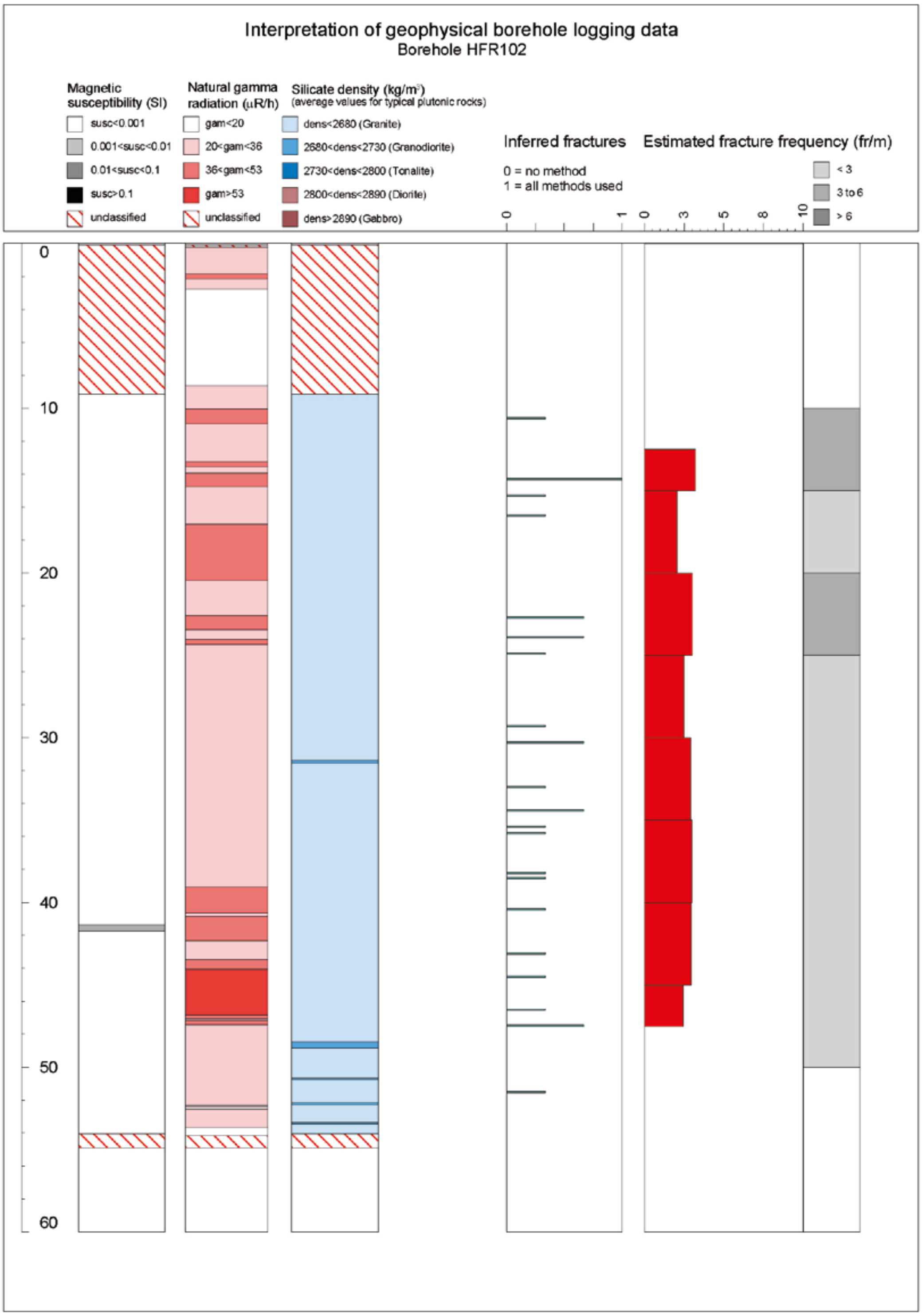


Figure 5-6. *Generalized geophysical logs of HFR102.*

5.4.4 Interpretation of HFR105

The results of the generalized logging data and fracture estimations of HFR105 are presented in Figure 5-7 below.

The silicate density distribution in HFR105 is completely dominated by values < 2,680 kg/m^3, which corresponds to that of granite rock. These low density sections mainly coincide with natural gamma radiation of 20–36 μR/h (partly 36–53 μR/h) and significantly decreased magnetic susceptibility, and this combination of physical properties suggests that the bedrock in the vicinity of HFR105 is dominated by meta granite to granodiorite rock.

Short sections (1–2 m long) with significantly increased density occur all along the borehole, partly concentrated in the interval c. 145–160 m. These sections coincide with decreased susceptibility and natural gamma radiation and most likely correspond to amphibolite dykes.

Short sections with intermediate silicate densities, 2,730–2,800 kg/m^3, decreased natural gamma radiation and partly increased magnetic susceptibility occur in the central part of the borehole. This combination of physical properties suggests the occurrences of meta volcanic rocks.

Few occurrences of minor pegmatite dykes at c. 48 m, 115 m, 161 m, and 178.5 m are indicated by extreme positive natural gamma radiation anomalies.

The estimated fracture frequency is generally low in HFR105. Four possible deformation zones are indicated at c. 20–30 m, 89–95 m, 117–120 m and 141–148 m. The four possible zones are clearly indicated by significantly decreased resistivity in combination with distinct caliper anomalies.

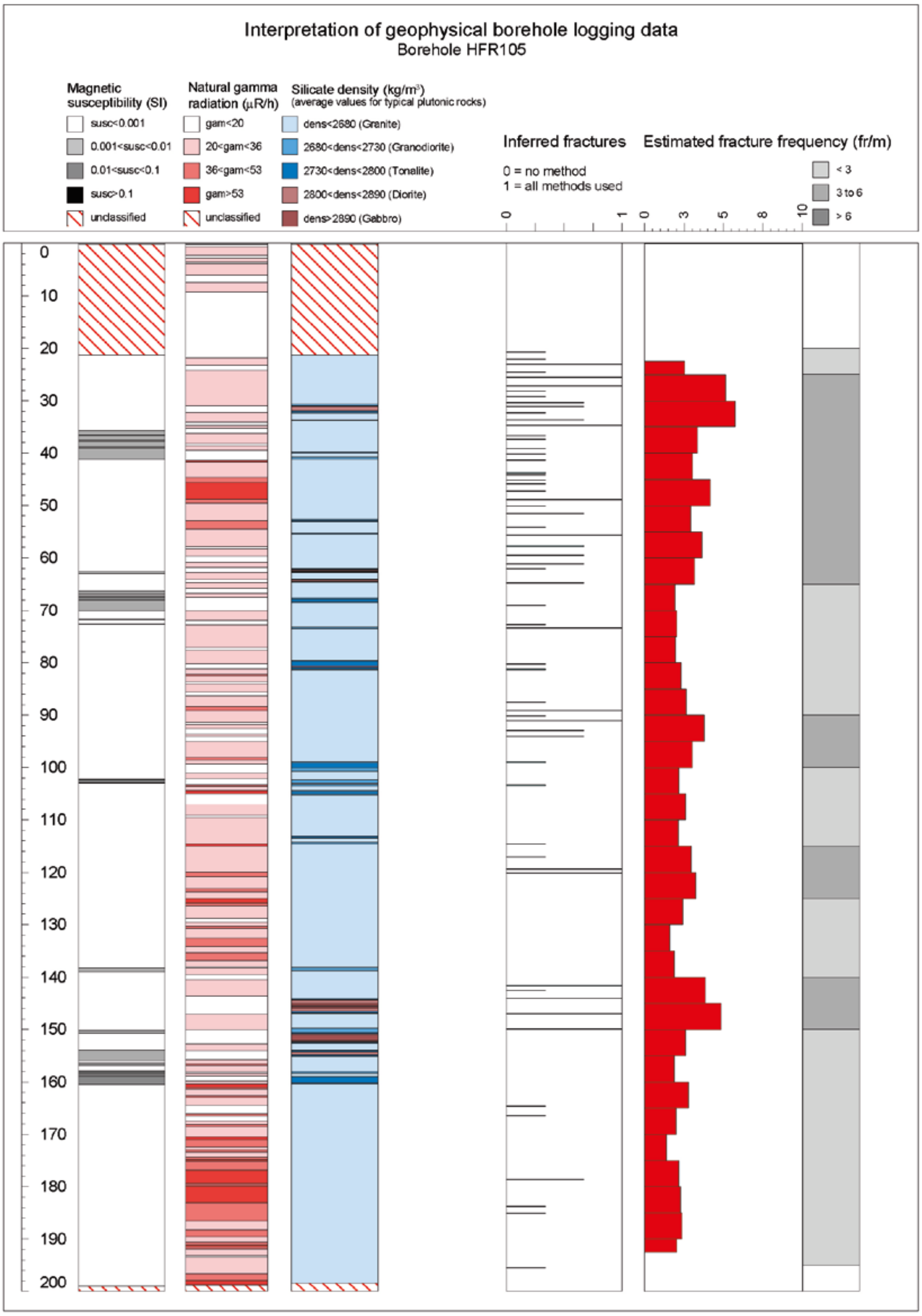


Figure 5-7. *Generalized geophysical logs of HFR105.*

6 References

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