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Site investigation SFR

Interpretation of geophysical borehole measurements from KFR102A, KFR102B, KFR103, KFR104 and KFR27 (0–500 m)

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Abstract

This report presents the compilation and interpretations of geophysical logging data from the cored boreholes KFR102A, KFR102B, KFR103, KFR104 and KFR27.

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 silicate density distribution in KFR102A shows that almost 50% of the borehole length is governed by rocks with densities in the range 2,680–2,730 kg/m^3, and nearly 40% of the borehole length is governed by rocks with densities < 2,680 kg/m^3. The physical properties indicate that the bedrock in the vicinity of the borehole mainly consists of meta granite – granodiorite and some pegmatitic granite. Four possible deformation zones are identified at 95–120 m, 185–210 m, 307–312 m and 425–475 m and they all coincide with fluid temperature anomalies indicating water bearing fractures.

The physical properties of the 180 m long KFR102B remind a great deal of those identified in the uppermost 200 m of KFR102A. The bedrock in the vicinity of the borehole is interpreted to mainly consist of meta granite – granodiorite rock, probably in combination with some pegmatitic granite. No major deformation zone is identified in KFR102B.

In KFR103 there is a fairly even distribution of silicate density < 2,680 kg/m^3, 2,680–2,730 kg/m^3 and 2,730–2,800 kg/m^3. The two lower density intervals most likely correspond to pegmatitic granite and meta granite – granodiorite rock respectively. The higher interval coincides with decreased natural gamma radiation and increased magnetic susceptibility, a combination that is typical for felsic to intermediate meta-volcanic rock. No major deformation zone is identified in KFR103.

62% of the borehole length of KFR104 is dominated by a silicate density < 2,680 kg/m^3, and 32% has silicate density in the range 2,680–2,730 kg/m^3. The magnetic susceptibility is < 0.001 SI for the vast majority of the borehole length and the natural gamma radiation is generally increased along the entire borehole, generally > 36 μR/h. This combination of physical properties suggests a dominant occurrence of pegmatitic granite rock. Possible deformation zones are identified at 20–25 m, 38–46 m, 144–152 m, 268–282 m, 397–407 m and 447–452 m.

In KFR27 there are two sets of logging data, one from 2008 (0–140 m) and one set measured in 2009 (0–500 m). Both sets of data were processed and interpreted in this activity. For 90% of the borehole length the silicate density is < 2,680 kg/m^3 or 2,680–2,730 kg/m^3. The interpretation suggests a large dominance of pegmatitic granite rocks. Two possible major deformation zones are identified at c. 310–380 m and 420–480 m. The natural gamma radiation level is significantly higher in the data from 2009 compared with those collected in 2008. The cause of the increased natural gamma radiation level is most likely geological, and the most probable reason is leakage of radon gas through fractures.

Sammanfattning

Föreliggande rapport presenterar resultat och tolkningar av geofysiska borrhåls-mätningar i kärnborrhålen KFR102A, KFR102B, KFR103, KFR104 och KFR27.

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 dels som stödjande data vid borrkärnekarteringen samt som underlag vid den geologiska enhålstolkningen.

Nästan 50% av borrhålslängden i KFR102A har silikatdensitet < 2 680 kg/m^3 och 40% ligger i intervallet 2 680–2 730 kg/m^3. Tillsammans med övriga mätta egenskaper tolkas berggrunden i närheten av borrhålet främst bestå av metagranit-granodiorit och till viss del pegmatitisk granit. Fyra möjliga deformationszoner kan identifieras vid 95–120 m, 185–210 m, 307–312 m och 425–475 m, och samtliga sammanfaller med anomalier i vätsketemperaturdata vilka indikerar vattenförande sprickzoner.

De fysikaliska egenskaperna uppmätta i det 180 m långa KFR102B påminner till stor del om de som identifieras i de översta 200 m av KFR102A. Berggrunden i närheten av KFR102B består troligen till stor del av metagranit-granodiorit och till viss del pegmatitisk granit. Inga större deformationszoner kan identifieras i KFR102B.

I KFR103 är silikatdensiteten relativt jämnt fördelad i intervallen < 2 680 kg/m^3, 2 680–2 730 kg/m^3 och 2 730–2 800 kg/m^3. De två förstnämnda indikerar troligen förekomst av pegmatitgranit respektive metagranit-granodiorit. För det sistnämnda intervallet sammanfaller densiteten med förhöjd magnetisk susceptibilitet i kombination med sänkt naturlig gammastrålning, vilket sannolikt indikerar förekomst av sur eller intermediär metavulkanit. Inga större deformationszoner kan identifieras i KFR103.

62% av borrhålslängden i KFR104 domineras av silikatdensitet < 2 680 kg/m^3 och 32% av silikatdensitet är i intervallet 2 680–2 730 kg/m^3. Den magnetiska susceptibiliteten är < 0,001 SI längs mycket stora delar av borrhålet och den naturliga gammastrålningen är generellt förhöjd, > 36 µR/h. Kombinationen av fysikaliska egenskaper är typisk för pegmatitisk granit. Möjliga deformationszoner kan identifieras längs 20–25 m, 38–46 m, 144–152 m, 268–282 m, 397–407 m och 447–452 m.

För KFR27 förekommer två olika uppsättningar loggdata. Under 2008 loggades sektionen 0–140 m, och efter vidare borrningar loggades i 2009 sektionen 0–500 m. Båda dataseten processerades och tolkades inom ramen för denna aktivitet. För 90% av borrhålslängden är silikatdensiteten < 2 680 kg/m^3 eller 2 680–2 730 kg/m^3. Vår tolkning indikerar en stor dominans av pegmatitisk granit i närheten av KFR27. Två möjliga större deformationszoner kan identifieras längs 310–380 m och 420–480 m. En jämförelse mellan mätdata från 2008 och 2009 visar att den naturliga gammastrålningen är betydligt högre i data från 2009 jämfört med 2008. Allt tyder på att skillnaden är geologiskt betingad (ej orsakad av mätfel) och en trolig förklaring är inläckage av radongas från sprickor i hålets djupare del.

Contents

1 Introduction

This document reports the interpretations of geophysical borehole measurements gained from the cored boreholes KFR102A, KFR102B, KFR103, KFR104 and KFR27 (0–500 m), 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 plans AP SFR-08-010 and AP SFR-08-019. In Table 1-1 controlling documents for performing this activity are listed. Activity plans 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 and 2009 by Rambøll /1 and 2/.

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 numbers.

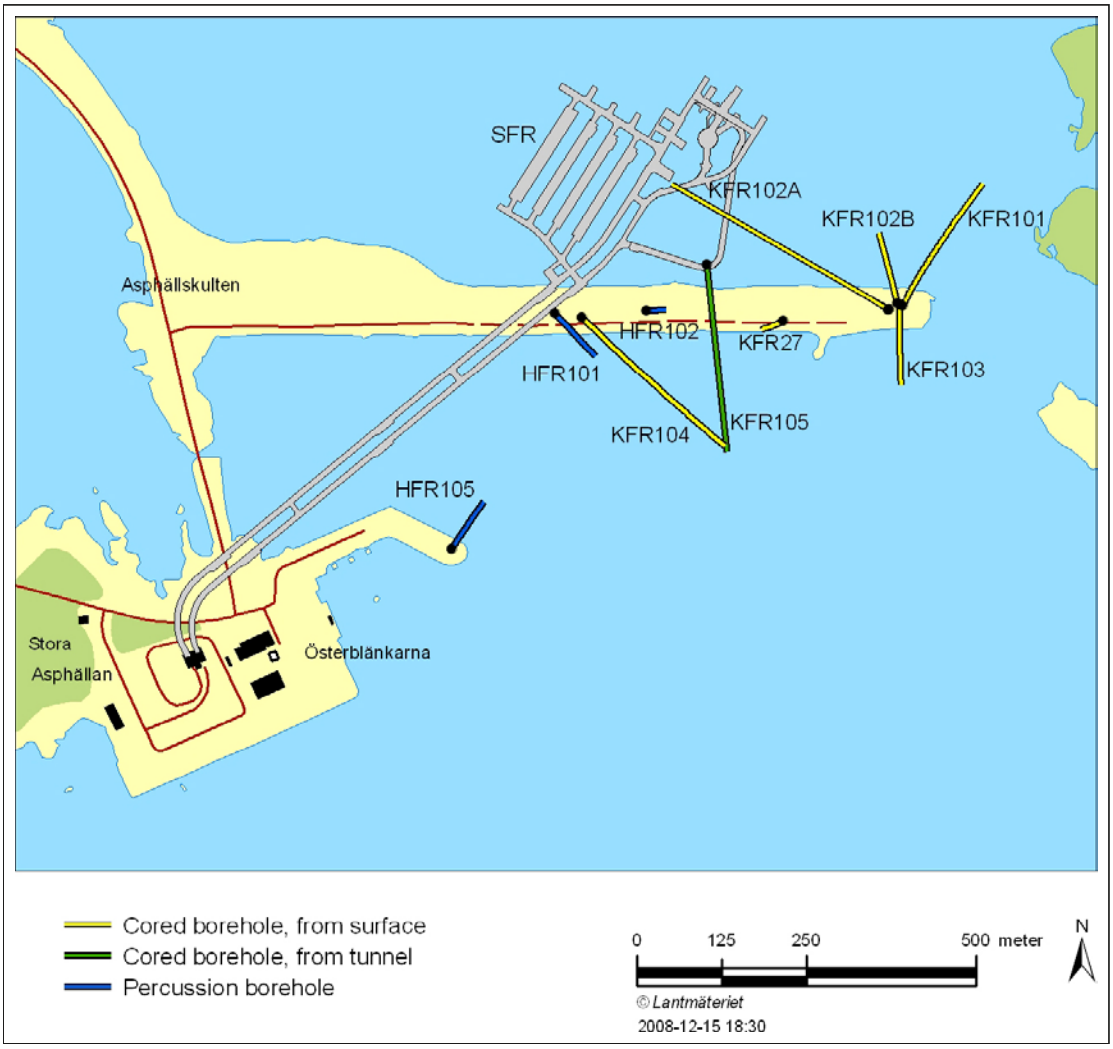

Figure 1-1. *General overview over SFR site investigation area showing the locations of the investigated boreholes KFR102A, KFR102B, KFR103, KFR104 and KFR27.*

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
Tolkning av geofysiska borrhålsdata från KFR102A, KFR102B, KFR103, KFR104 samt KFR27 (140–500m)	AP SFR-08-019	1.0
Method descriptions	**Number**	**Version**
Metodbeskrivning för tolkning av geofysiska borrhålsdata	SKB MD 221.003	3.0

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

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 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 /3/.

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

The silicate density is calculated with reference to /4/ and the data are then divided into 5 sections *indicating* a mineral composition corresponding to granite, granodiorite, tonalite, diorite and gabbro rocks, according to /5/. 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” (< 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. 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 /6/.

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	KFR102A	1.0	2.0	0.5
Weight	KFR102A	2.56	4.0	2.0
Threshold	KFR102B	1.0	0.7	0.5
Weight	KFR102B	2.56	4.0	2.0
Threshold	KFR103	1.0	1.0	0.35
Weight	KFR103	2.56	4.0	2.0
Threshold	KFR104	1.2	1.3	0.5
Weight	KFR104	2.56	4.0	2.0
Threshold	KFR27	2.0	2.0	0.4
Weight	KFR27	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.

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

4.4 Nonconformities

There are two sets of logging data from KFR27. KFR27, section 0 – 140 m, was originally drilled in 1981 and geophysical logging was performed in July 2008 in this section. After that, the borehole was prolonged to 500 m length. A new geophysical logging was then performed in January 2009, covering the entire length 0 – 500 m. Both sets of logging data were processed within the work presented in this report. Apart from this, no nonconformities are reported.

5 Results

5.1 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 of 0.3 μR/h. In KFR27 the noise level of the natural gamma radiation data is extremely high. Also the density data of all logs show increased noise levels, but only moderately 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.

5.2 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)

5.2.1 Interpretation of KFR102A

The results of the generalized logging data and fracture estimations of KFR102A are presented in Figure 5-1. The distribution of silicate density classes with borehole length is presented in Table 5-2.

The silicate density distribution in KFR102A shows that almost 50% of the borehole length is governed by rocks with densities in the range 2,680–2,730 kg/m^3, which corresponds to a mineral composition of granodiorite. Nearly 40% of the borehole length is governed by rocks with densities < 2,680 kg/m^3, which corresponds to a mineral composition of granite. The natural gamma radiation is mainly in the range 25–40 μR/h and the magnetic susceptibility is generally decreased along the major part of the borehole length. The combination of physical properties indicates that the bedrock in the vicinity of the borehole mainly consists of meta granite – granodiorite rock, probably in combination with some pegmatitic granite.

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

Logging method	KFR102A	KFR102B	KFR103	KFR104	KFR27	Recommended max noise level
Density (kg/m^3)	10	7	6	6	10	3 – 5
Magnetic susceptibility (SI)	2×10^{-4}	3×10^{-4}	1×10^{-4}	5×10^{-5}	1×10^{-4}	1×10^{-4}
Natural gamma radiation (μR/h)	1.2	0.9	0.9	1.1	2.3	0.3
Fluid resistivity (%)	0.02	0.01	0.02	0.01	0.02	2
Fluid temperature (°C)	3×10^{-4}	3×10^{-4}	5×10^{-4}	2×10^{-4}	4×10^{-4}	0.01
Caliper mean (meter)	2×10^{-5}	2×10^{-5}	2×10^{-5}	2×10^{-5}	2×10^{-5}	0.0005
Focused resistivity 300 (%)	23	19	18	15	18	No data
Focused resistivity 128 (%)	2	3	2	3	3	No data

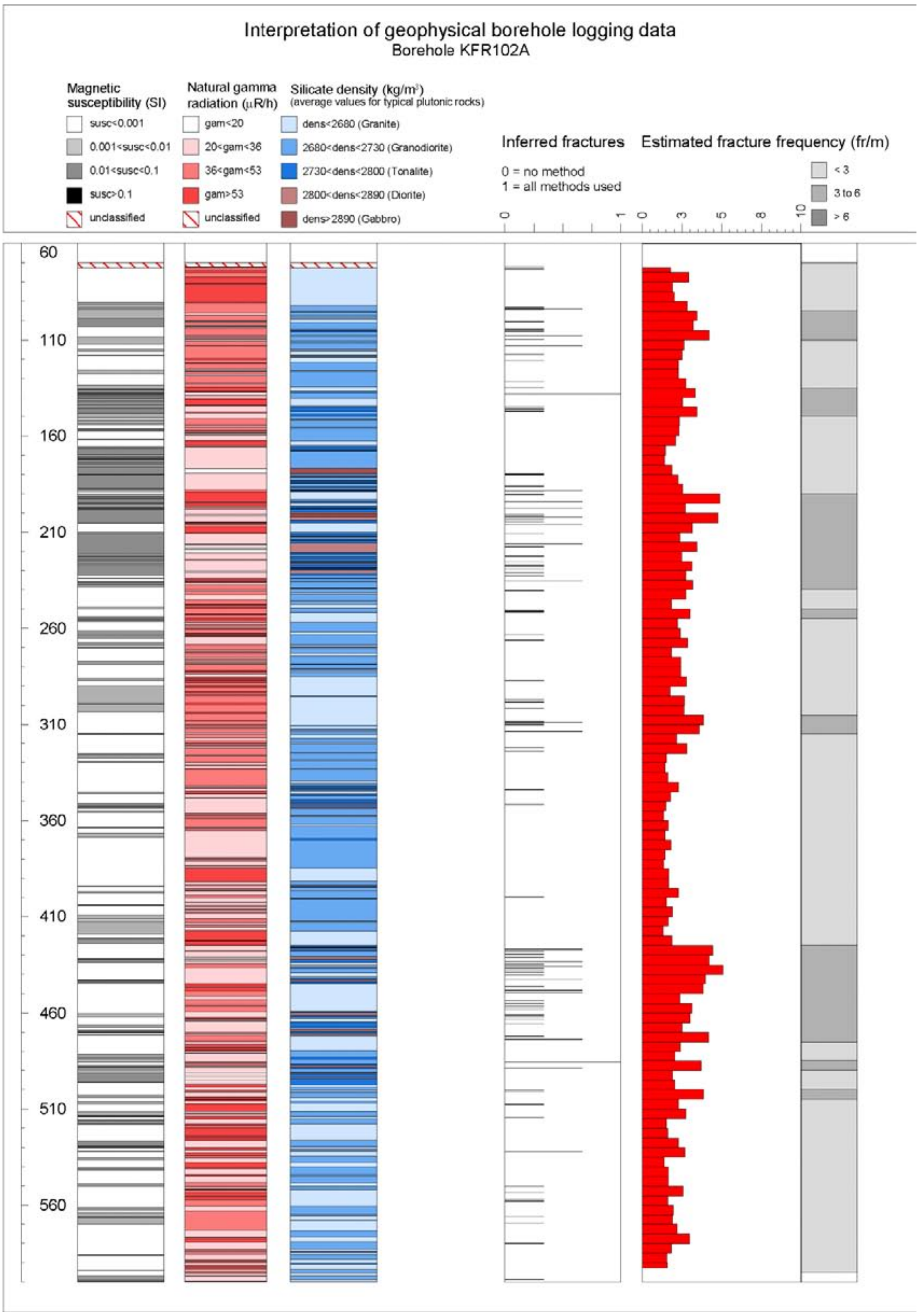

Figure 5-1. *Generalized geophysical logs of KFR102A.*

Table 5-2. Distribution of silicate density classes with borehole length in KFR102A.

Silicate density interval (kg/m^3)	Borehole length (m)	Relative borehole length (%)
dens < 2,680 (granite)	196	37
2,680 < dens < 2,730 (granodiorite)	260	49
2,730 < dens < 2,800 (tonalite)	46	9
2,800 < dens < 2,890 (diorite)	21	4
dens > 2,890 (gabbro)	5	1

Along the sections 70–90 m and 285–310 m the density is decreased in combination with increased natural gamma radiation, which indicates the occurrence of pegmatite granite or pegmatite. Strong positive density and magnetic susceptibility anomalies are concentrated in the sections 175–235 m and 430–500 m. The anomalies most likely correspond to occurrences of mafic dykes with high content of ferromagnetic minerals, such as magnetite or pyrrhotite. In the section 175–235 m there is also an increased occurrence of strong positive natural gamma radiation anomalies that most likely correspond to dykes of pegmatite and/or fine-grained granite. This spatial relation between mafic and felsic dykes is common in the Forsmark area, and tend to coincide with increased fracturing.

In the section 500–540 m there are several short anomalies with increased natural gamma radiation that most likely indicate the occurrences of dykes of pegmatite and/or fine-grained granite.

The estimated fracture frequency is generally low in KFR102A but there are several sections with indicated increased fracturing. The intervals with most significant geophysical anomalies occur at 95–120 m, 185–210 m, 307–312 m, 425–475 m.

All four possible deformation zones are characterized by low resistivity anomalies and caliper anomalies, and they coincide with fluid temperature anomalies, which suggest that they are related with water bearing fractures. The lowermost section (425–475 m) is characterized by a major decrease in bulk resistivity and several strong anomalies in the fluid temperature data.

5.2.2 Interpretation of KFR102B

The results of the generalized logging data and fracture estimations of KFR102B are presented in Figure 5-2 below. The distribution of silicate density classes with borehole length is presented in Table 5-3.

The physical properties of the 180 m long KFR102B remind a great deal of those identified in the uppermost 200 m of KFR102A. The silicate density distribution in KFR102B is dominated by densities of < 2,680 kg/m^3 and 2,680–2,730 kg/m^3 (totally 73% of the hole length). The silicate density corresponds to a mineral composition of granite-granodiorite rock. The natural gamma radiation is mainly in the range 20–45 μR/h and the magnetic susceptibility is generally 0.005–0.015 SI. The combination of physical properties indicates that the bedrock in the vicinity of the borehole mainly consists of meta granite – granodiorite. The sections with increased natural gamma radiation and decreased density most likely indicate pegmatitic granite or pegmatite rock.

Along the entire borehole there are several c 2–5 m long sections with significantly increased density in combination with increased magnetic susceptibility and decreased natural gamma radiation. The combination of properties is typical for mafic rocks (dolerite, gabbro or amphibolites) containing ferromagnetic minerals, such as magnetite or pyrrhotite. The mafic dykes are, just as for KFR102A, spatially related with felsic dykes, indicated by short intervals of significantly increased natural gamma radiation.

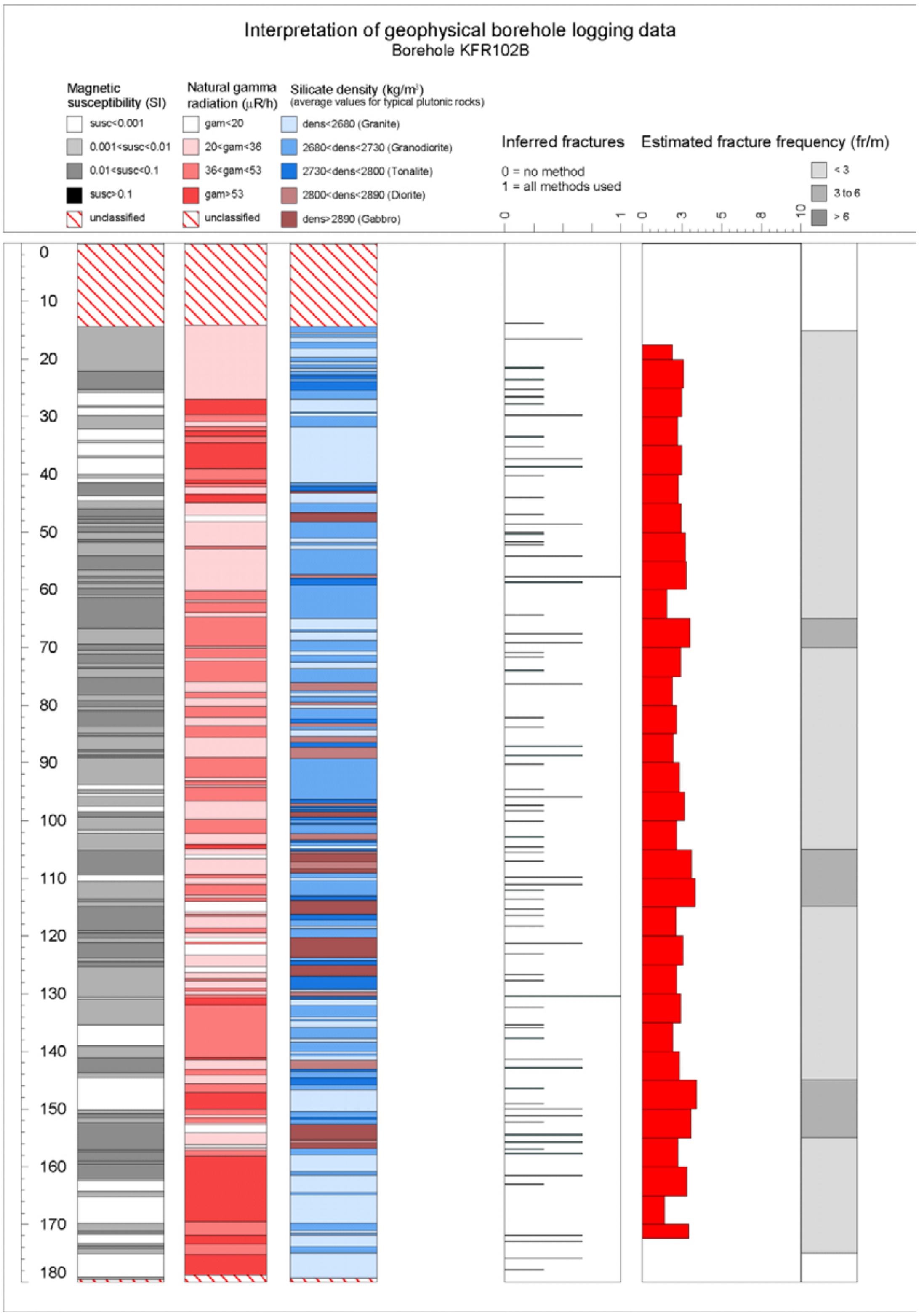

Figure 5-2. Generalized geophysical logs of KFR102B.

Table 5-3. Distribution of silicate density classes with borehole length in KFR102B.

Silicate density interval (kg/m^3)	Borehole length (m)	Relative borehole length (%)
dens < 2,680 (granite)	52	31
2,680 < dens < 2,730 (granodiorite)	69	42
2,730 < dens < 2,800 (tonalite)	16	10
2,800 < dens < 2,890 (diorite)	12	7
dens > 2,890 (gabbro)	16	10

The estimated fracture frequency is generally low apart from three intervals with indicated increased fracturing, occurring at c. 67–69 m, 109–112 m and 149–151 m. By the look of the anomalies in the rawdata these three possible deformation zones seem to be related to occurrences of single large fractures. However, the section 28–40 m is characterized by decreased magnetic susceptibility and bulk resistivity, which indicates generally increased fracturing.

5.2.3 Interpretation of KFR103

The results of the generalized logging data and fracture estimations of KFR103 are presented in Figure 5-3 below. The distribution of silicate density classes with borehole length is presented in Table 5-4.

The silicate density distribution shows a dominance of rocks with silicate density in the range 2,680–2,730 kg/m^3, which corresponds to granodiorite rock, probably meta granite-granodiorite. There are two fairly long sections at c 45–58 m and 133–153 m with silicate density < 2,680 kg/m^3 in combination with increased natural gamma radiation and decreased magnetic susceptibility, which most likely corresponds to occurrences of pegmatitic granite rocks or pegmatite dykes.

There are several 1–10 m long sections with silicate density in the range 2,730–2,800 kg/m^3 that coincide with increased magnetic susceptibility and decreased natural gamma radiation. This combination of physical properties is, in the Forsmark-SFR area, typical for felsic to intermediate meta-volcanic rock.

Some 8–10 short sections (c 1 m long) with significantly increased density occur along the entire borehole. In these sections the magnetic susceptibility varies greatly. The low-magnetic high-density sections most likely indicate the occurrences of amphibolites, whereas the high-magnetic section could indicate dolerite dykes.

The estimated fracture frequency is generally low along the entire borehole. In the sections c 85–87 m, 99–101 m and 180–182 m decreased resistivity and caliper anomalies indicate occurrences of minor deformation zones, most likely large single fractures.

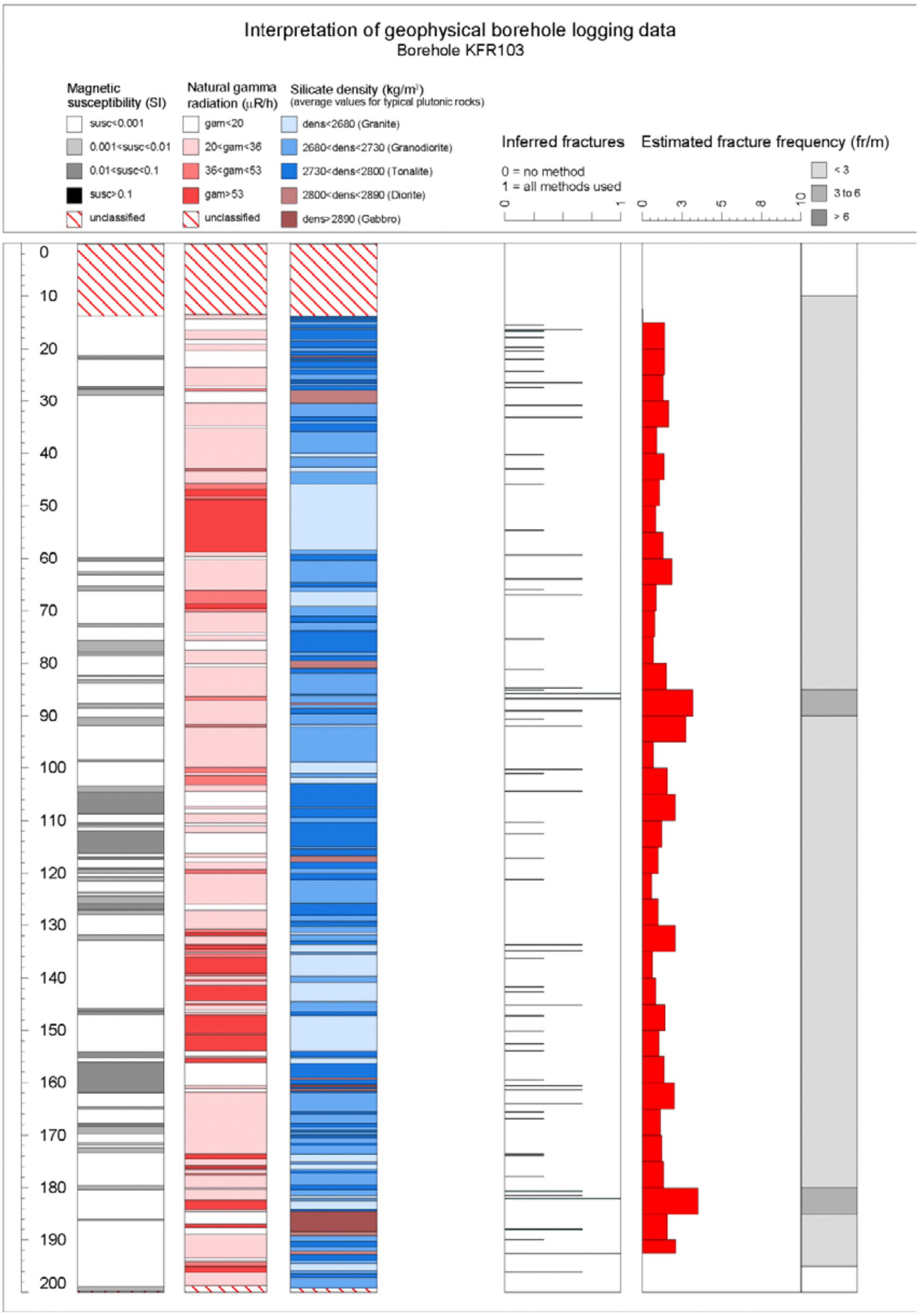

Figure 5-3. *Generalized geophysical logs of KFR103.*

Table 5-4. Distribution of silicate density classes with borehole length in KFR103.

Silicate density interval (kg/m^3)	Borehole length (m)	Relative borehole length (%)
dens < 2,680 (granite)	44	24
2,680 < dens < 2,730 (granodiorite)	75	41
2,730 < dens < 2,800 (tonalite)	53	29
2,800 < dens < 2,890 (diorite)	8	4
dens > 2,890 (gabbro)	4	2

5.2.4 Interpretation of KFR104

The results of the generalized logging data and fracture estimations of KFR104 are presented in Figure 5-4 below. The distribution of silicate density classes with borehole length is presented in Table 5-5.

62% of the borehole length of KFR104 is dominated by a silicate density < 2,680 kg/m^3, and 32% has silicate density in the range 2,680–2,730 kg/m^3. The magnetic susceptibility is < 0.001 SI for the vast majority of the borehole length and the natural gamma radiation is generally increased along the entire borehole, generally > 36 μR/h. This combination of physical properties suggests a dominant occurrence of pegmatitic granite rocks in the vicinity of KFR104. The sections with density in the range 2,680–2,730 kg/m^3 may however also correspond to meta granite-granodiorite rocks.

There are a few short sections with increased density that most likely correspond to mafic dykes, probably amphibolites.

The estimated fracture frequency is generally low in KFR104. Sections with increased fracturing, possible deformation zones, are identified at 20–25 m, 38–46 m, 144–152 m, 268–282 m, 397–407 m and 447–452 m. The sections are characterized by decreased resistivity and caliper anomalies.

Four distinct fluid temperature anomalies, that most likely indicate water bearing fractures, are identified at c. 64 m, 210 m, 276 m and 293 m.

Table 5-5. Distribution of silicate density classes with borehole length in KFR104.

Silicate density interval (kg/m^3)	Borehole length (m)	Relative borehole length (%)
dens < 2,680 (granite)	275	62
2,680 < dens < 2,730 (granodiorite)	140	32
2,730 < dens < 2,800 (tonalite)	24	5
2,800 < dens < 2,890 (diorite)	4	1
dens > 2,890 (gabbro)	1	0

Figure 5-4. Generalized geophysical logs of KFR104.

5.2.5 Interpretation of KFR27 (0–500 m)

The results of the generalized logging data and fracture estimations of KFR27 (0–500 m) are presented in Figure 5-5 below. In Figure 5-5 we have also added the natural gamma radiation data from the first logging measurement from July 2008 (0–140 m), see further discussions in the following paragraphs. The distribution of silicate density classes with borehole length is presented in Table 5-6.

The same methods of the two sets of logging data, measurement 1 (0–140 m) and measurement 2 (0–500 m), were compared to each other. The comparison shows only minor differences apart for the natural gamma radiation data. The natural gamma radiation level is significantly higher in the second measurement compared to the first. However, the anomaly pattern is very similar between the two sets of data. In Figure 5-6 the two data sets are plotted in the same graph. From the start of the borehole to 30 m section length there are no significant differences between the logs. At c. 30 m they start to deviate, for the newer measurement (No 2) the general level is increased compared to measurement 1. The level difference increases with increasing borehole length, but possibly seems to stabilize at a constant level of c. 70 µR/h at 170 m borehole length (Figure 5-7).

The calibration of the logging tools used for the radiation measurements was carefully checked, and there are no indications of any measurement errors. The cause of the increased increased natural gamma radiation level of the second measurement is most likely geological, and the most probable reason is leakage of radon gas through fractures located somewhere beneath 140 m section length. The source of the radon gas is not known, but could e.g. be uranium bearing dykes such as pegmatites.

The silicate density distribution in KFR27 is dominated (65%) by densities < 2,680 kg/m^3. The magnetic susceptibility is generally < 0.001 SI. There are several sections with silicate density in the range 2,680–2,730 kg/m^3, and these sections also show decreased magnetic susceptibility. This combination of physical properties suggests a dominant occurrence of pegmatitic granite rocks and probably also some meta granite-granodiorite rocks in the vicinity of KFR27.

In the section c. 290–345 m there are several anomalies of significantly increased density and magnetic susceptibility that most likely correspond to occurrences of mafic dykes, dolerite or amphibolite, carrying ferromagnetic minerals (magnetite and/or pyrrhotite).

In Figure 5-6 we can clearly see long sections (35–45 m, 190–207 m, 237–257 m and 268–290 m) with greatly increased natural gamma radiation. The data may indicate occurrences of pegmatite dykes, fine-grained granite dykes or pegmatitic granite.

The estimated fracture frequency is generally low in KFR27. A few possible minor deformation zones, or large single fractures, occur in the upper half of the borehole. Two sections with indicated strongly increased fracturing are identified at c. 310–380 m and 420–480 m. The anomaly pattern of the focused resistivity 300 log indicates that the section 310–380 m is characterized by an increased frequency of brittle fractures surrounded by fairly fresh rock. The section 420–480 m shows a major decrease in bulk resistivity, which often indicates heavily crushed rock and alteration.

There are three distinct anomalies in the fluid temperature data, occurring at c. 193 m, 355 m and 426 m. The uppermost anomaly coincides with a narrow distinct low resistivity anomaly most likely indicating a single fracture. The two other fluid temperature anomalies are located within the two suggested deformation zones at 310–380 m and 420–480 m.

Table 5-6. Distribution of silicate density classes with borehole length in KFR27 (0–500m).

Silicate density interval (kg/m^3)	Borehole length (m)	Relative borehole length (%)
dens < 2,680 (granite)	318	65
2,680 < dens < 2,730 (granodiorite)	123	25
2,730 < dens < 2,800 (tonalite)	29	6
2,800 < dens < 2,890 (diorite)	19	4
dens > 2,890 (gabbro)	0	0

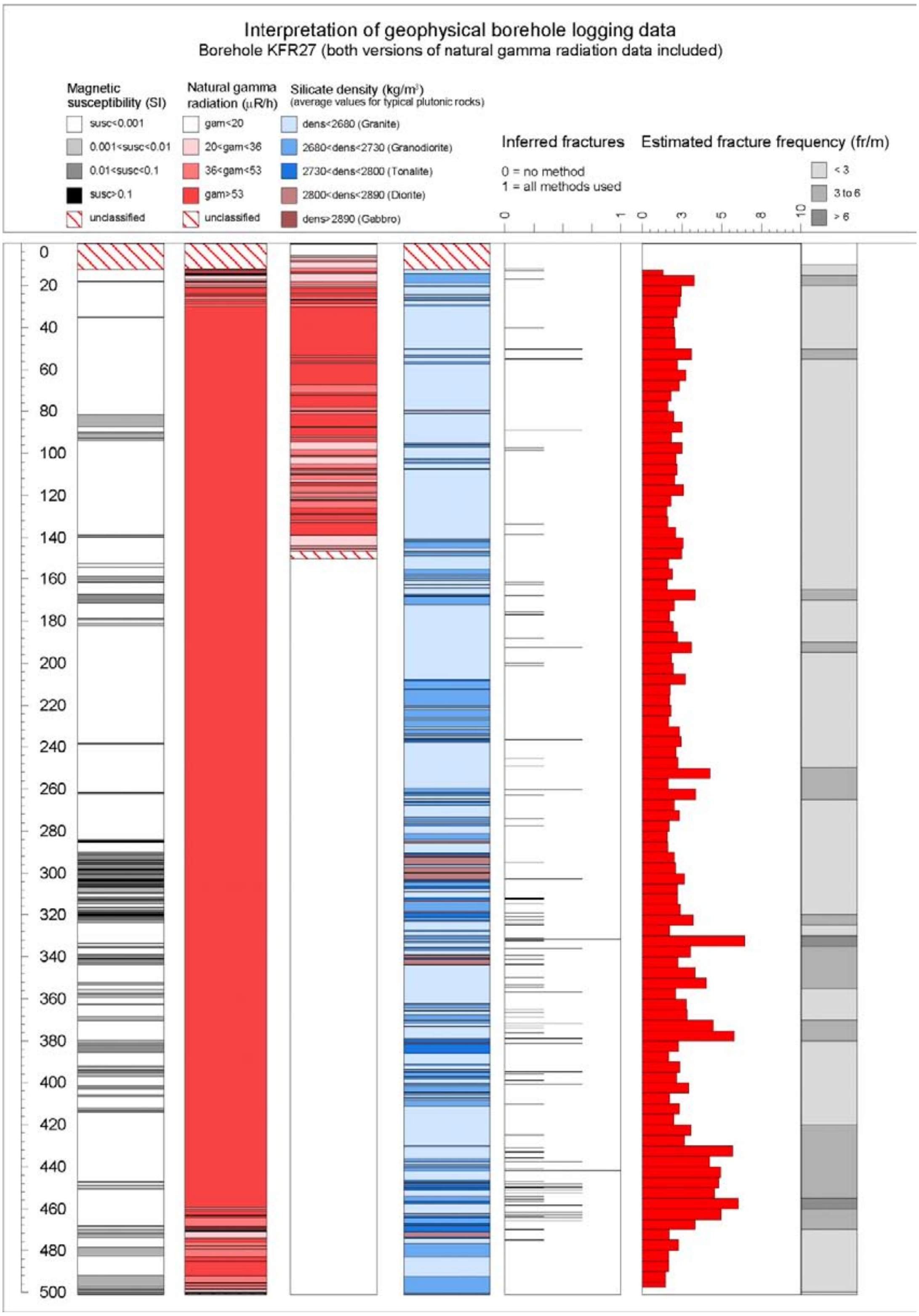

Figure 5-5. Generalized geophysical logs of KFR27 (0–500m). The two versions of natural gamma radiation data are both displayed in the figure.

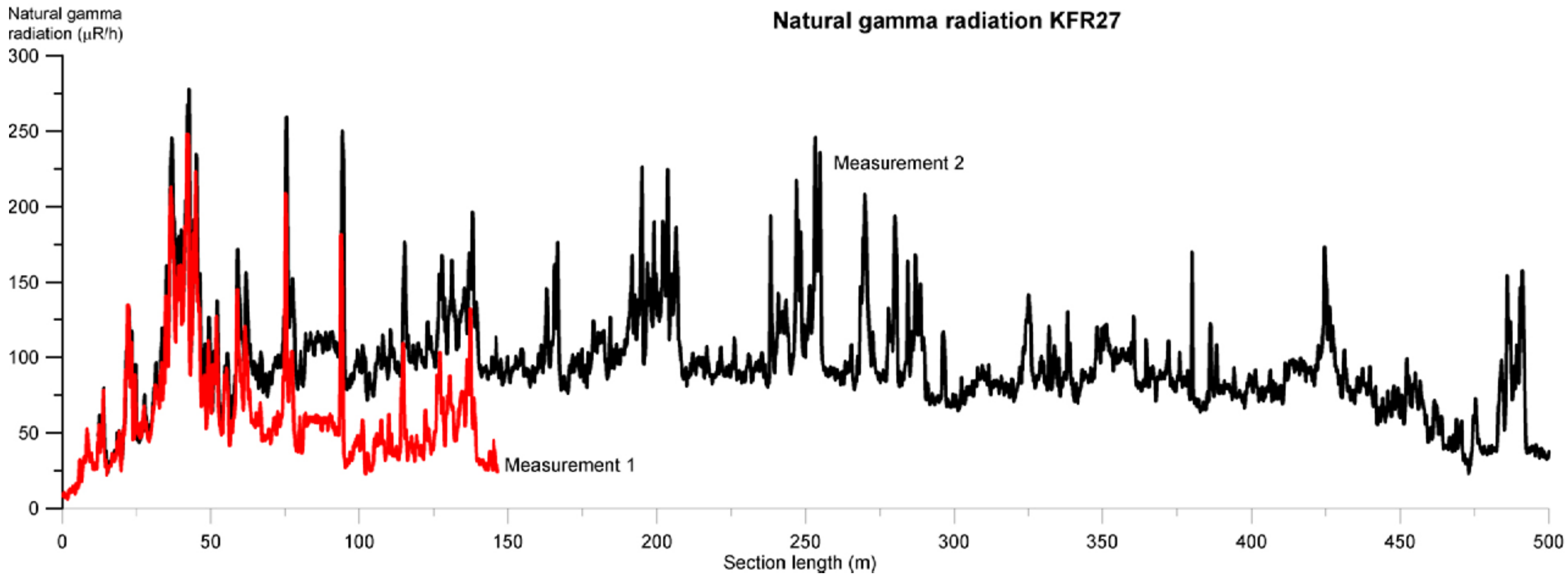

Figure 5-6. *Graph showing the two versions of natural gamma radiation data, the first measurement in red (0–140 m) and the second in black (0–500 m).*

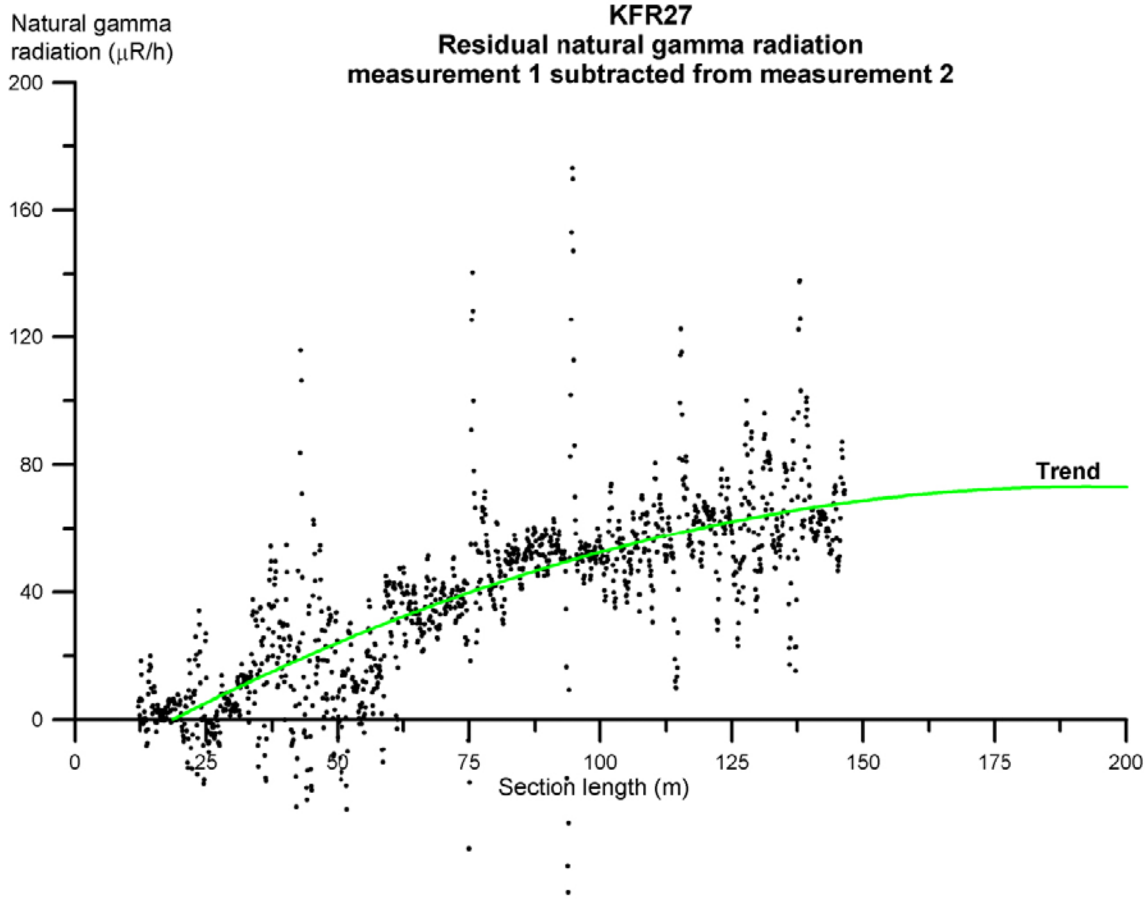

Figure 5-7. *Graph showing the residual between the two natural gamma radiation measurements (0–140 m). The green line displays the trend of the residual estimated by a 2:nd degree polynomial curve.*

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