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Forsmark site investigation

Geological single-hole interpretation of KFM12A, HFM36 and HFM37

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June 2007

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Abstract

This report presents geological single-hole interpretations of the cored borehole KFM12A and the percussion boreholes HFM36 and HFM37 at Forsmark. The interpretation combines the geological core mapping, generalized geophysical logs and borehole radar measurements to identify where rock units and possible deformation zones occur in the boreholes. A brief description of the character of each rock unit and possible deformation zone is provided.

The geological single-hole interpretation shows that twelve rock units (RU1–RU12) occur in KFM12A. However, the borehole can be divided into seventeen separate sections due to the repetition of RU3 (RU3a and RU3b), RU4 (RU4a and RU4b), RU8 (RU8a and RU8b) and RU9 (RU9a, RU9b and RU9c).

Metagranodiorite (101056), which shows variable texture and degree of foliation development and is partly affected by grain-size reduction related to high ductile strain, dominates borehole KFM12A in rock units RU1, RU3, RU8, RU10 and RU12. The interval from 145 m down to 170 m borehole length (RU2) is heterogeneous and composed of metagranodiorite (101056) in the lower part, and fine- to medium-grained granite (111058), fine- to medium-grained metagranitoid (101051), aplitic metagranite (101058), metagabbro/diorite (101033) and amphibolite (102017) in the upper part. Banded and variably foliated amphibolite (102017) dominates in RU4 and pegmatitic granite (101061) in RU5. Cataclastic rock (108003) occurs in RU6 and strongly cataclastic rock (108003) is present in RU7. The development of fault rock is so extensive (c. 50 m borehole interval) that it has not been possible to identify the protolith along these sections. Felsic to intermediate metavolcanic rock (103076) occurs in RU9 and banded metatonalite to granodiorite (101054) dominates in RU11. Three possible deformation zones have been identified in KFM12A (DZ1–DZ3). One of the possible deformation zones (DZ2), in the long borehole interval 170 to 402 m, exhibits both high ductile strain and cataclastic fault rock (RU6 and RU7).

The percussion borehole HFM36 contains three rock units (RU1–RU3). However, the borehole can be divided into five separate sections due to the repetition of RU1 (RU1a, RU1b and RU1c). The borehole contains foliated amphibolite (102017) and metatonalite-granodiorite (101054) in RU1a, a heterogeneous section with foliated amphibolite (102017), metatonalite-granodiorite (101054), pegmatitic granite (101061) and fine- to medium-grained metagranitoid (101051) in RU1b, banded amphibolite (102017) and foliated metadiorite-gabbro (101033) in RU1c, a section with pegmatitic granite (101061) in RU2, and a section with foliated metagranite-granodiorite (101057) in RU3. One possible deformation zone has been identified in HFM36 (DZ1).

The percussion borehole HFM37 is dominated by foliated metagranodiorite (101056) and foliated amphibolite (102017), which alternate and constitute four rock units (RU1–RU4). Subordinate rock types are fine- to medium-grained metagranitoid (101051), pegmatitic granite (101061), aplitic metagranite (101058) and metatonalite-granodiorite (101054). Three possible deformation zones have been identified in HFM37 (DZ1-DZ3).

Sammanfattning

Denna rapport behandlar geologisk enhålstolkning av kärnborrhål KFM12A och hammarborrhålen HFM36 och HFM37 i Forsmark. Den geologiska enhålstolkningen syftar till att utifrån den geologiska karteringen, tolkade geofysiska loggar och borrhålsradar indikera olika litologiska enheters fördelning i borrhålen samt möjliga deformationszoners läge och utbredning. En kort beskrivning av varje bergenhet och möjlig deformationszon presenteras.

Denna undersökning visar att det i KFM12A finns tolv litologiska enheter (RU1–RU12). Baserat på repetition av enheterna RU3 (RU3a och RU3b), RU4 (RU4a och RU4b), RU8 (RU8a och RU8b) och RU9 (RU9a, RU9b och RU9c) kan borrhålet delas in i sjutton sektioner.

I kärnborrhålet KFM12A är metagranodiorit (101056) dominerande bergart i de litologiska enheterna RU1, RU3, RU8, RU10 och RU12. Den är här delvis påverkad av kornstorleksreduktion relaterad till hög plastisk deformation, och har varierande textur och omväxlande grad av foliationsutveckling. Intervallet från 145 m och ner till 170 m borrhålslängd (RU2) består av en heterogen blandning av metagranodiorit i den nedre delen och fin- till medelkornig granit (111058), fin- till medelkornig metagranitoid (101051), aplitisk metagranit (101058), metagabbro/diorit (101033) och amfibolit (102017) i den övre delen av enheten. Bandad och varierat folierad amfibolit (102017) dominerar i RU4 och pegmatitisk granit (101061) i RU5. Kataklastisk bergart (108003) uppträder i RU6 och starkt kataklastisk bergart (108003) finns i RU7. Utvecklingen av förkastningsbergart är så pass genomgripande (ca. 50 m borrhålsintervall), så att det inte har varit möjligt att identifiera ursprungsbergarten längs denna borrhålssektion. Felsisk till intermediär metavulkanisk bergart (103076) förekommer i RU9, och bandad metatonalit till granodiorit (101054) dominerar enheten RU11. Pegmatitisk granit (101061) dominerar enheten RU5. Tre möjliga deformationszoner har identifierats i KFM12A (DZ1–DZ3). En av dessa möjliga deformationszoner (DZ2), vilken upptar det långa borrhålsintervallet 170 m till 402 m, uppvisar både en hög grad av plastisk deformation och förekomst av kataklastisk förkastningsbergart (RU6 och RU7).

Hammarborrhål HFM36 innehåller tre bergartsenheter (RU1–RU3). Baserat på repetition av enheten RU1 (RU1a, RU1b och RU1c) kan borrhålet delas in i fem sektioner. Folierad amfibolit (102017) och metatonalit-granodiorit (101054) förekommer i RU1a, en heterogen sektion med folierad amfibolit (102017), metatonalit-granodiorit (101054), pegmatitisk granit (101061) och fin- till medelkornig metagranitoid (101051) förekommer i RU1b, bandad amfibolit (102017) och folierad metadiorit-gabbro (101033) i RU1c, en sektion med pegmatitisk granit (101061) förekommer i RU2 samt en sektion med folierad metagranit-granodiorit (101057) förekommer i RU3. En möjlig deformationszon har identifierats i HFM36 (DZ1).

Hammarborrhål HFM37 domineras av folierad metagranodiorit (101056) och folierad amfibolit (102017), vilka förekommer växelvis och utgör fyra bergartsenheter (RU1–RU4). I mindre omfattning förekommer fin- till medelkornig metagranitoid (101051), pegmatitisk granit (101061), aplitisk metagranit (101058) och metatonalit-granodiorit (101054). Tre möjliga deformationszoner har identifierats i HFM37 (DZ1-DZ3).

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1 Introduction

Much of the primary geological and geophysical borehole data stored in the SKB database SICADA need to be integrated and synthesized before they can be used for modelling in the 3D-CAD Rock Visualization System (RVS). The end result of this procedure is a geological single-hole interpretation, which consists of an integrated series of different logs and accompanying descriptive documents.

This document reports the geological single-hole interpretations of boreholes KFM12A, HFM36 and HFM37 in the Forsmark area. The horizontal projections of the boreholes are shown in Figure 1-1. The work was carried out in accordance with Activity Plan AP PF 400-07-027 and the controlling documents for performing this activity are listed in Table 1-1. Both the Activity Plan and Method Description are SKB's internal controlling documents.

Original data from the reported activity are stored in the primary database Sicada, where they are traceable by the Activity Plan number (AP PF 400-07-027). Only data in SKB's databases are accepted for further interpretation and modelling. The data presented in this report are regarded as copies of the original data. Data in the databases may be revised, if needed. Such revisions will not necessarily result in a revision of the P-report, although the normal procedure is that major data revisions entail a revision of the P-report. Minor data revisions are normally presented as supplements, available at www.skb.se.

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

Activity Plan	Number	Version
Geologisk enhålstolkning av KFM12A samt HFM36–37	AP PF 400-07-027	1.0
Method Description	**Number**	**Version**
Metodbeskrivning för geologisk enhålstolkning	SKB MD 810.003	3.0

Figure 1-1. *Map showing position and horizontal projection of the cored borehole KFM12A and the percussion boreholes HFM36 and HFM37.*

2 Objective and scope

A geological single-hole interpretation is carried out in order to identify and to describe briefly the characteristics of major rock units and possible deformation zones within a borehole. The work involves an integrated interpretation of data from the geological mapping of the borehole (Boremap), different borehole geophysical logs and borehole radar data.

The geological mapping of the cored borehole involves a documentation of the character of the bedrock in the drill core. This work component is carried out in combination with an inspection of the oriented image of the borehole walls that is obtained with the help of the Borehole Image Processing System (BIPS). The geological mapping of the percussion borehole focuses more attention on an integrated interpretation of the information from the geophysical logs and the BIPS images. For this reason, the results from the percussion borehole mapping are more uncertain. The interpretations of the borehole geophysical and radar logs are available when the single-hole interpretation is completed. The result from the geological single-hole interpretation is presented in a WellCad plot. A more detailed description of the technique is provided in the Method Description for geological single-hole interpretation (SKB MD 810.003, internal document). The work reported here concerns stage 1 in the single-hole interpretation, as defined in the Method Description.

3 Data used for the geological single-hole interpretation

The following data and interpretations have been used for the single-hole interpretation of the boreholes KFM12A, HFM36 and HFM37:

- Boremap data (including BIPS and geological mapping data) /3, 4/.
- Generalized geophysical logs and their interpretation /5, 6/.
- Radar data and their interpretation /7, 8/.

The material used as a basis for the geological single-hole interpretation was a WellCad plot consisting of parameters from the geological mapping in the Boremap system, geophysical logs and borehole radar. An example of a WellCad plot used during geological single-hole interpretation is shown in Figure 3-1. The plot consists of ten main columns and several subordinate columns. These include:

1: Length along the borehole

2: Rock type
  2.1: Rock type
  2.2: Rock type structure
  2.3: Rock type texture
  2.4: Rock type grain size
  2.5: Structure orientation.
  2.6: Rock occurrence (< 1 m)
  2.7: Rock alteration
  2.8: Rock alteration intensity

3: Unbroken fractures
  3.1: Primary mineral
  3.2: Secondary mineral
  3.3: Third mineral
  3.4: Fourth mineral
  3.5: Alteration, dip direction

4: Broken fractures
  4.1: Primary mineral
  4.2: Secondary mineral
  4.3: Third mineral
  4.4: Fourth mineral
  4.5: Aperture (mm)
  4.6: Roughness
  4.7: Surface
  4.8: Alteration, dip direction

5: Crush zones
  5.1: Primary mineral
  5.2: Secondary mineral
  5.3: Third mineral
  5.4: Fourth mineral
  5.5: Roughness
  5.6: Surface
  5.7: Crush alteration, dip direction
  5.8: Piece (mm)
  5.9: Sealed network
  5.10: Core loss

6: Fracture frequency
    6.1: Open fractures
    6.2: Sealed fractures

7: Geophysics
    7.1: Magnetic susceptibility
    7.2: Natural gamma radiation
    7.3: Possible alteration
    7.4: Silicate density
    7.5: Estimated fracture frequency

8: Radar
    8.1: Length
    8.2: Angle

9: Reference mark (not used for percussion-drilled boreholes)

10: BIPS

The geophysical logs are described below:

Magnetic susceptibility: The rock has been classified into sections of low, medium, high, and very high magnetic susceptibility. The susceptibility measurement is strongly connected to the magnetite content in the different rock types.

Natural gamma radiation: The rock has been classified into sections of low, medium, and high natural gamma radiation. Low radiation may indicate mafic rock types and high radiation may indicate younger, fine-grained granite or pegmatite. The rocks with high natural gamma radiation have been included in the younger, Group D intrusive suite /1/.

Possible alteration: This parameter has not been used in the geological single-hole interpretation in the Forsmark area.

Silicate density: This parameter indicates the density of the rock after subtraction of the magnetic component in the rock. It provides general information on the mineral composition of the rock types, and serves as a support during classification of rock types.

Estimated fracture frequency: This parameter provides an estimate of the fracture frequency along 5 m sections, calculated from short and long normal resistivity, SPR, P-wave velocity as well as focused resistivity 140 and 300. The estimated fracture frequency is based on a statistical connection after a comparison has been made between the geophysical logs and the mapped fracture frequency. The log provides an indication of sections with low and high fracture frequencies.

Close inspection of the borehole radar data was carried out during the interpretation process, especially during the identification of possible deformation zones. The occurrence and orientation of radar anomalies within the possible deformation zones are commented upon in the text that describes these zones.

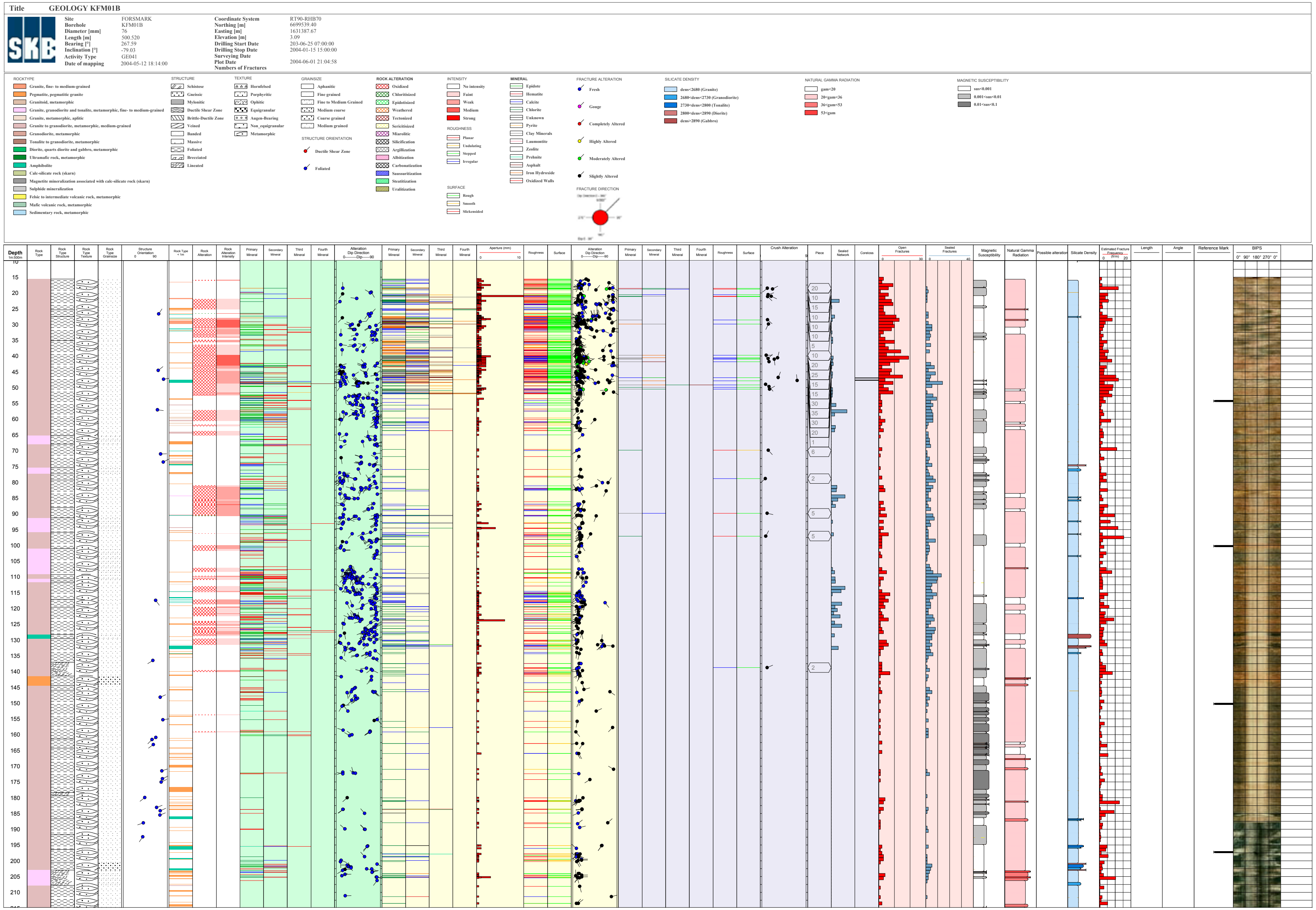

Figure 3-1. *Example of WellCad plot (from borehole KFM01B) used as a basis for the single-hole interpretation.*

4 Execution of the geological single-hole interpretation

4.1 General

The geological single-hole interpretation has been carried out by a group of geoscientists consisting of both geologists and geophysicists. Several of these geoscientists previously participated in the development of the source material for the single-hole interpretation. All data to be used (see Chapter 3) are visualized side by side in a borehole document extracted from the software WellCad. The working procedure is summarized in Figure 4-1 and in the text below.

The first step in the working procedure is to study all types of data (rock type, rock alteration, silicate density, natural gamma radiation, etc.) related to the character of the rock type and to merge sections of similar rock types, or sections where one rock type is very dominant, into rock units (minimum length of c. 5 m). Each rock unit is defined in terms of the borehole length interval and provided with a brief description for inclusion in the WellCad plot. The confidence in the interpretation of a rock unit is made on the following basis: 3 = high, 2 = medium and 1 = low.

The second step in the working procedure is to identify possible deformation zones by visual inspection of the results of the geological mapping (fracture frequency, fracture mineral, aperture, alteration, etc) in combination with the geophysical logging and radar data. The section of each identified possible deformation zone is defined in terms of the borehole length interval and provided with a brief description for inclusion in the WellCad plot. This includes a brief description of the rock types affected by the possible deformation zone. The confidence in the interpretation of a possible deformation zone is made on the following basis: 3 = high, 2 = medium and 1 = low.

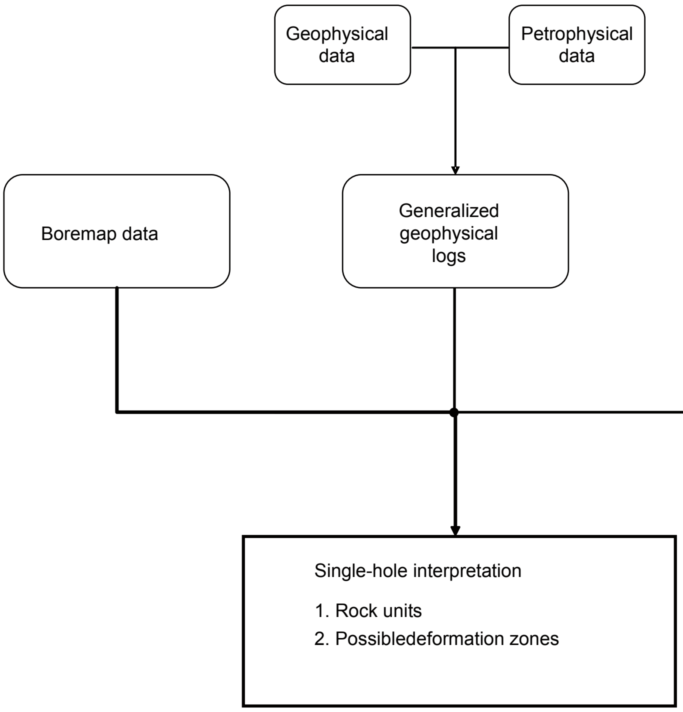

Figure 4-1. *Schematic chart that shows the procedure for the development of a geological single-hole interpretation.*

Inspection of BIPS images is carried out wherever it is judged necessary during the working procedure. Furthermore, following definition of rock units and possible deformation zones, with their respective confidence estimates, the drill cores are inspected in order to check the selection of the boundaries between these geological entities. If judged necessary, the location of these boundaries is adjusted.

Possible deformation zones that are brittle in character have been identified primarily on the basis of the frequency of fractures, according to the concept presented in /2/. Brittle deformation zones defined by an increased fracture frequency of extensional fractures (joints) or shear fractures (faults) are not distinguished. Both the transitional part, with a fracture frequency in the range 4–9 fractures/m, and the core part, with a fracture frequency > 9 fractures/m, have been included in each zone (Figure 4-2). The frequencies of open and sealed fractures have been assessed in the identification procedure, and the character of the zone has been described accordingly. Partly open fractures are included together with open fractures in the brief description of each zone. The presence of bedrock alteration, the occurrence and, locally, inferred orientation of radar reflectors, the resistivity, SPR, P-wave velocity, caliper and magnetic susceptibility logs have all assisted in the identification of the zones. The anomalies in these parameters that assist with the identification are presented in the short description.

Since the frequency of fractures is of key importance for the definition of the possible deformation zones, moving average plots for this parameter are shown for the cored borehole KFM12A and the percussion boreholes HFM36 and HFM37 (Figures 4-3 to 4-5). A 5 m window and 1 m steps have been used in the calculation procedure. The moving average for open fractures alone, the total number of open fractures (open, partly open and crush), the sealed fractures alone, and the total number of sealed fractures (sealed and sealed fracture network) are shown in each diagram.

The occurrence and orientation of radar anomalies within the possible deformation zones are used during the identification of these zones. Overviews of the borehole radar measurements in KFM12A and the percussion boreholes HFM36 and HFM37 are shown in Figures 4-6 to 4-8. A conductive environment causes attenuation of the radar wave, which in turn decreases the penetration. The effect of attenuation can be observed in the borehole and is conspicuous in the central part (220–400 m) of KFM12A (Figure 4-6) and generally in HFM36 (Figure 4-7). The effect of attenuation varies between the different antenna frequencies (20 MHz, 100 MHz, 250 MHz and 60 MHz directional antenna). In some cases, alternative orientations for oriented radar reflectors are presented. One of the alternatives is considered to be correct, but due to uncertainty in the interpretation of radar data, a decision concerning which of the alternatives that represent the true orientation cannot be made. Orientations from directional radar are presented as strike/dip using the right-hand-rule method.

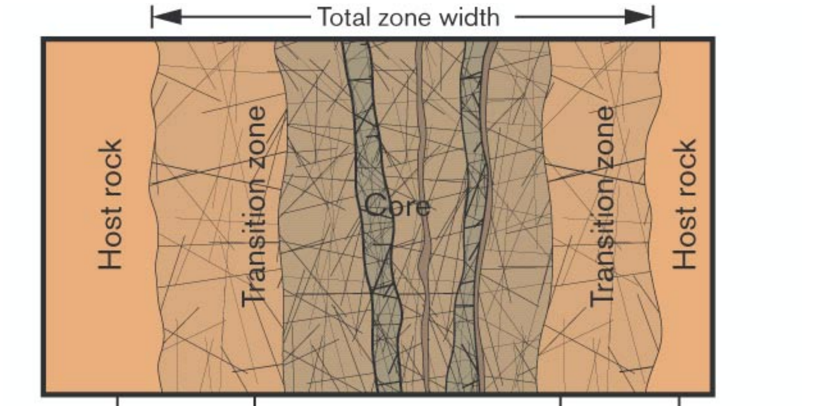

***Figure 4-2.** Terminology for brittle deformation zones (after /2/).*

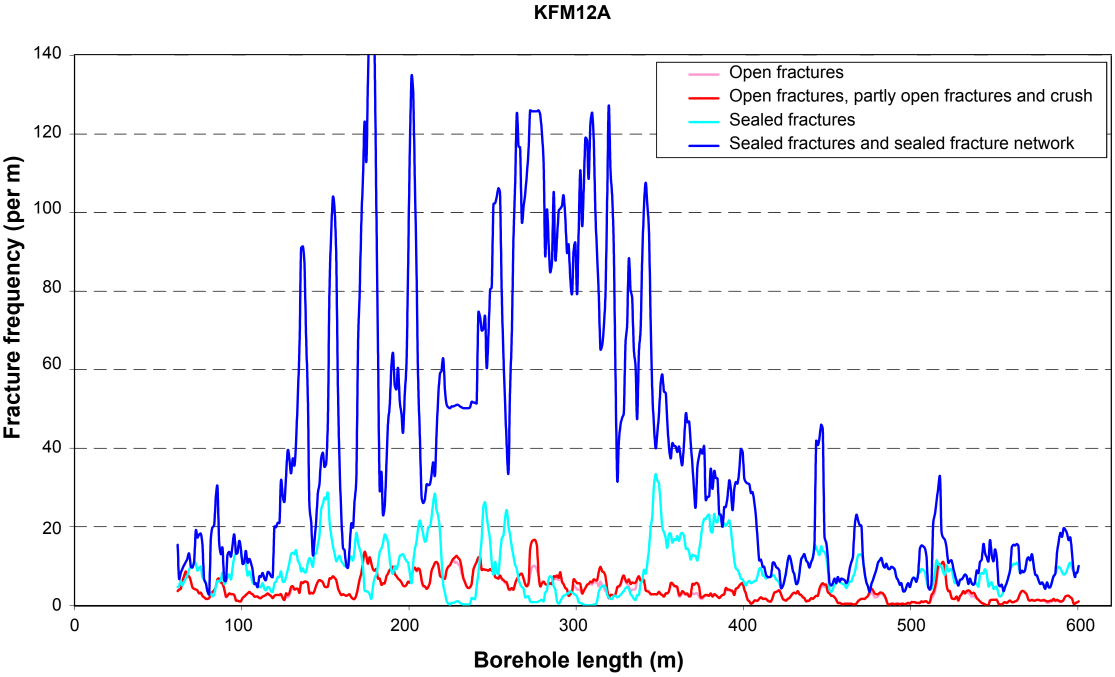

Figure 4-3. *Fracture frequency plot for KFM12A. Moving average with a 5 m window and 1 m steps.*

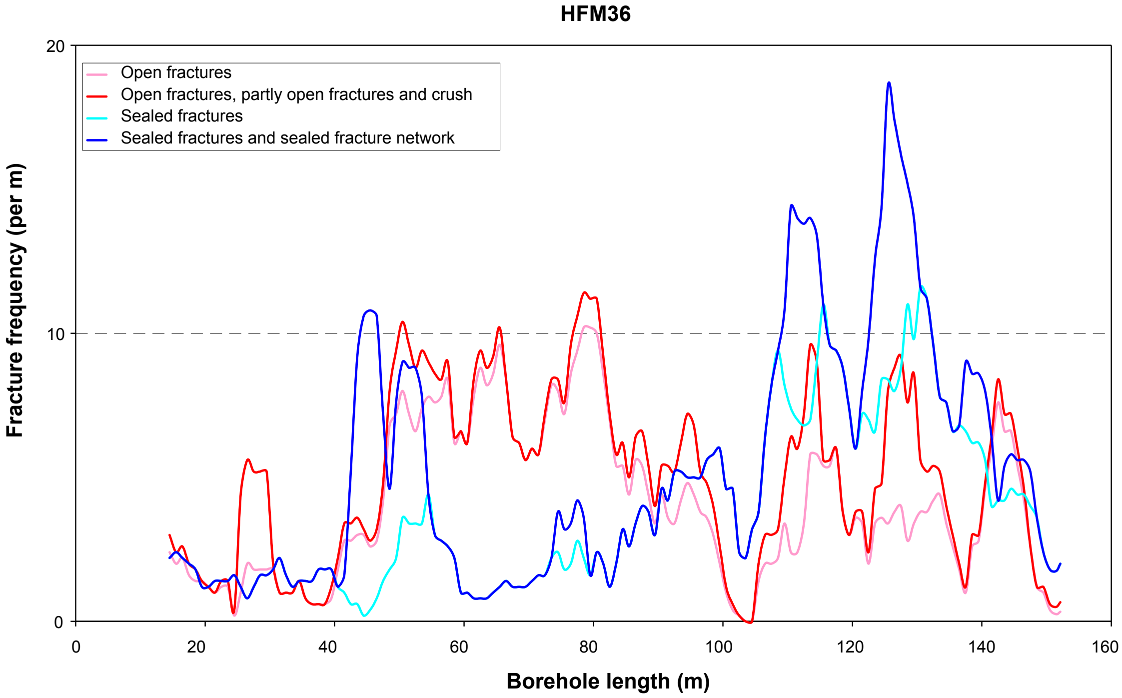

Figure 4-4. *Fracture frequency plot for HFM36. Moving average with a 5 m window and 1 m steps.*

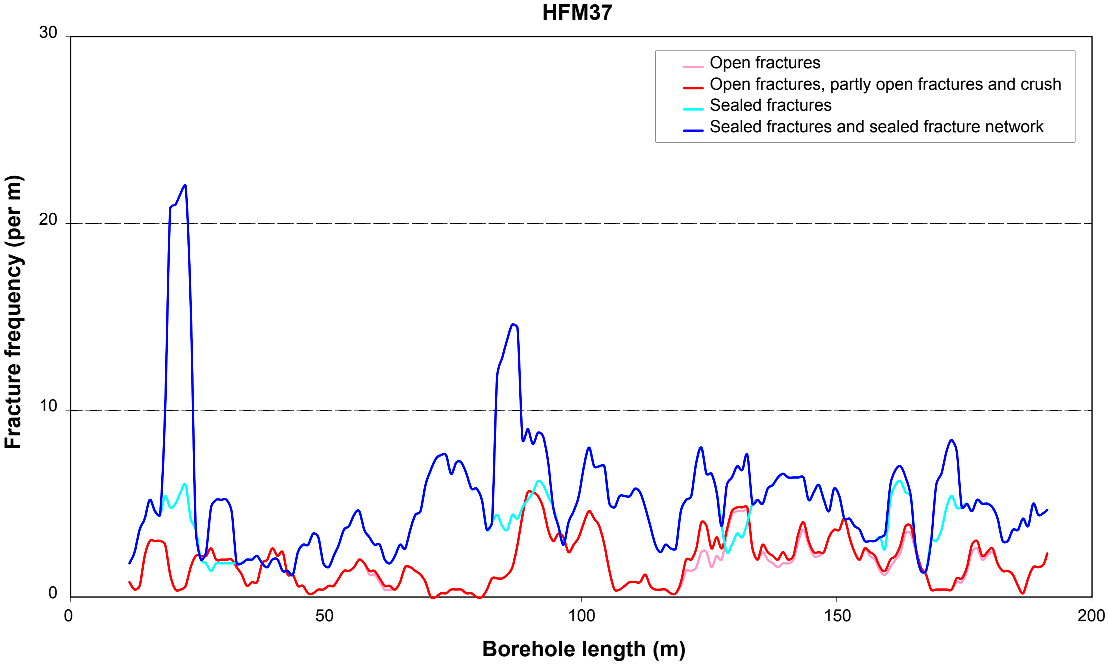

***Figure 4-5.** Fracture frequency plot for HFM37. Moving average with a 5 m window and 1 m steps.*

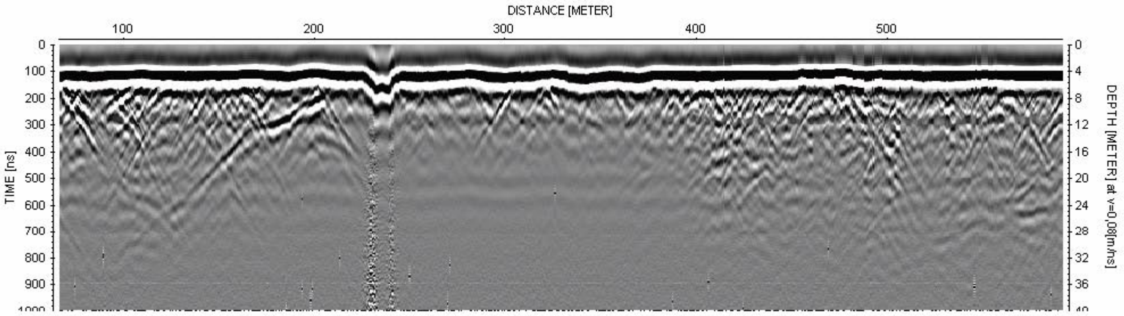

***Figure 4-6.** Overview (20 MHz data) of the borehole radar measurements in KFM12A.*

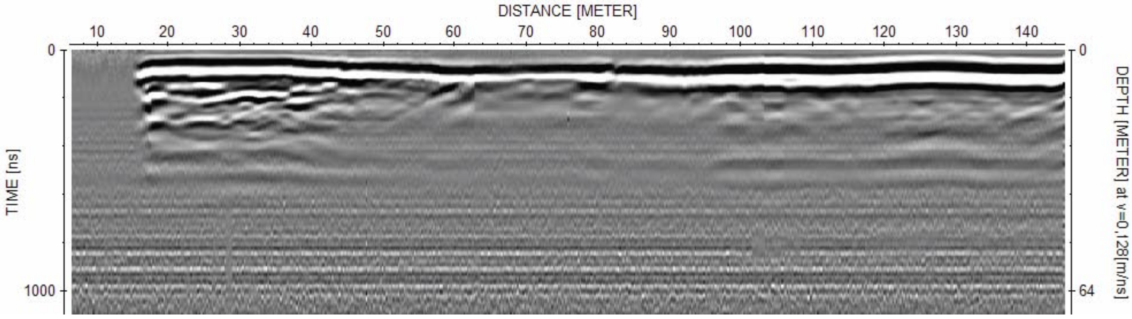

***Figure 4-7.** Overview (20 MHz data) of the borehole radar measurements in HFM36.*

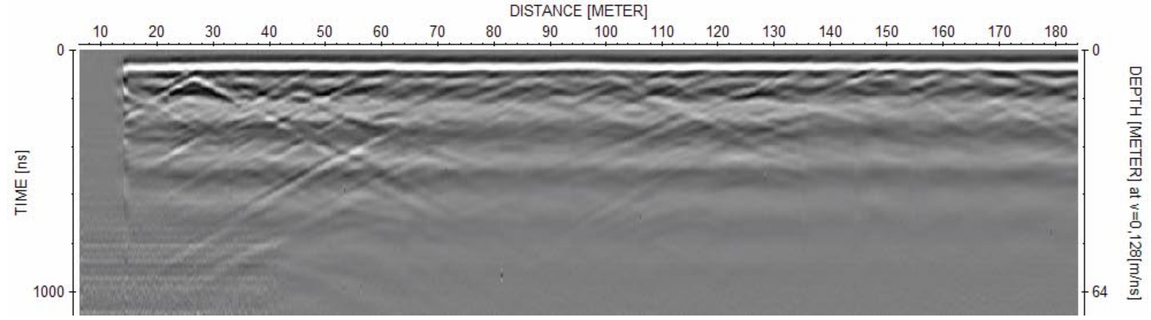

Figure 4-8. *Overview (20 MHz data) of the borehole radar measurements in HFM37.*

4.2 Nonconformities

The sections 60.23–61.39 m and 598.52–600.903 m in KFM12A were mapped without access to BIPS-images.

5 Results

The results of the geological single-hole interpretations are presented as print-outs from the software WellCad (Appendix 1 for KFM12A, Appendix 2 for HFM36 and Appendix 3 for HFM37).

5.1 KFM12A

The borehole direction at the start is 036°/–61°.

Rock units

The borehole can be divided into twelve different rock units, RU1–RU12. Rock unit 3 occurs in two separate length intervals, rock unit 4 in two separate length intervals, rock unit 8 in two separate intervals and rock unit 9 in three separate length intervals. These rock units have been recognized with a high degree of confidence.

60.21–145.0 m

RU1: Porphyritic metagranodiorite (101056), locally tonalitic (101054). Subordinate metagabbro/diorite (101033), fine- to medium-grained granite (111058), amphibolite (102017), pegmatitic granite (101061), fine- to medium-grained metagranitoid (101051), felsic to intermediate metavolcanic rock (103076) and one occurrence of aplitic metagranite (101058). Two intervals of increased fracture frequency associated with low resistivity, low P-wave velocity and decreased radar amplitude at 65 and 85–90 m. Low magnetic susceptibility throughout the section and locally faint to medium oxidation. Confidence level = 3.

145.0–169.84 m

RU2: Heterogeneous rock unit. Upper part composed of fine- to medium-grained granite (111058), fine- to medium-grained metagranitoid (101051), aplitic metagranite (101058), metagabbro/diorite (101033) and amphibolite (102017). Lower part composed of metagranodiorite (101056) with subordinate fine- to medium-grained metagranitoid (101051), aplitic metagranite (101058) and amphibolite (102017). Low magnetic susceptibility throughout the section and locally faint to medium oxidation. Confidence level = 3.

169.84–180.0 m

RU3a: Strongly foliated metagranodiorite (101056) with subordinate occurrences of pegmatitic granite (101061) and amphibolite (102017). Confidence level = 3.

180.0–191.26 m

RU4a: Banded and foliated amphibolite (102017). Subordinate metagranodiorite (101056) and pegmatitic granite (101061). Confidence level = 3.

191.26–266.97 m

RU3b: Strongly foliated metagranodiorite (101056) with subordinate fine- to medium-grained metagranitoid (101051), pegmatitic granite (101061), amphibolite (102017) and in the lowermost part felsic to intermediate metavolcanic rock (103076). Confidence level = 3.

266.97–285.04 m

RU5: Pegmatitic granite (101061) with subordinate amphibolite (102017) and metagranodiorite (101056) in the lowermost part. Confidence level = 3.

285.04–313.55 m

RU6: Cataclastic rock (108003) with intervals of calc-silicate rock (108019). Increased gamma radiation associated with high density between 291 and 306 m. Faint to medium epidotization, faint to weak saussuritization, faint to medium oxidation and locally weak to medium chloritization. Confidence level = 3.

313.55–337.86 m

RU7: Strongly cataclastic rock (108003). Decreased gamma radiation associated with low to moderate density above 332 m. Silicification and epidotization of varying intensity throughout the borehole interval. Weak to medium oxidation in the lowermost part. Confidence level = 3.

337.86–348.62 m

RU4b: Strongly foliated amphibolite (102017) above pegmatitic granite (101061) and foliated metagabbro/diorite (101033). Subordinate metagranodiorite (101056) and felsic to intermediate metavolcanic rock (103076). Several brittle-ductile and ductile shear zones. Confidence level = 3.

348.62–401.77 m

RU8a: Metagranodiorite (101056) affected by grain-size reduction related to high ductile strain. Subordinate metagabbro/diorite (101033), amphibolite (102017), fine- to medium-grained metagranitoid (101051), pegmatitic granite (101061) and felsic to intermediate metavolcanic rock (103076). Several brittle-ductile and ductile shear zones. Confidence level = 3.

401.77–416.46 m

RU9a: Partly banded felsic to intermediate metavolcanic rock (103076) and subordinate amphibolite (102017), metagranodiorite (101056) and pegmatitic granite (102017). Density of metavolcanic rock = 2,740–2,810 kg/m^3. Confidence level = 3.

416.46–484.03 m

RU8b: Metagranodiorite (101056) affected by grain-size reduction related to high ductile strain. Subordinate felsic to intermediate metavolcanic rock (103076), fine- to medium-grained metagranitoid (101051), amphibolite (102017) and pegmatitic granite (101061). Several brittle-ductile and ductile shear zones. Generally faint to medium oxidation in the upper part and faint to medium muscovitization in the lower part. Low magnetic susceptibility and slightly reduced resistivity associated with the muscovitization. Confidence level = 3.

484.03–492.57 m

RU9b: Banded felsic to intermediate metavolcanic rock (103076) and subordinate amphibolite (102017). Density of metavolcanic rock is 2,830–2,875 kg/m^3. Confidence level = 3.

492.57–522.53 m

RU10: Metagranodiorite (101056) affected by grain-size reduction related to high ductile strain and lineated, fine- to medium-grained granite (111058). Subordinate amphibolite (102017). Locally faint to weak oxidation even outside the possible deformation zone DZ3 (513–523 m). Confidence level = 3.

522.53–570.25 m

RU11: Banded metatonalite to granodiorite (101054). Subordinate felsic to intermediate metavolcanic rock (103076) in the upper part, pegmatitic granite (101061) and amphibolite (102017) throughout the unit and fine- to medium-grained, lineated granite (111058) in the lower part. Confidence level = 3.

570.25– 591.42 m

RU9c: Felsic to intermediate metavolcanic rock (103076) and subordinate amphibolite (102017), pegmatitic granite (101061), fine- to medium-grained metagranitoid (101051). Density of metavolcanic rock is 2,710–2,740 kg/m^3. Confidence level = 3.

591.42–600.95 m

RU12: Metagranodiorite (101056) affected by grain-size reduction related to high ductile strain and lineated fine- to medium-grained metagranitoid (101051). Subordinate amphibolite (102017) and pegmatitic granite (101061). Confidence level = 3.

Possible deformation zones

Three possible deformation zones have been recognised with a high degree of confidence in KFM12A.

125–158 m

DZ1: Increased frequency of sealed fractures, sealed fracture networks and, to some extent, open fractures. Fractures predominantly dip gently to the SE or steeply to the SW. One crush zone at 128.08–128.10 m. Apertures generally 1 mm or less, with a few ranging up to 7 mm. Locally faint to medium oxidation. Sixteen identified radar reflectors with intersection angles 22 to 83° to the borehole axis. Low resistivity, P-wave velocity and magnetic susceptibility. The possible zone is situated on both sides of the contact between porphyritic (RU1) and more equigranular (RU2) metagranodiorite. Subordinate fine- to medium-grained granite (111058), metagabbro/diorite (101033), amphibolite (102017), fine- to medium-grained metagranitoid (101051) and aplitic metagranite (101058). Confidence level = 3.

170–402 m

DZ2: High ductile strain. Increased frequency of sealed fractures, sealed fracture networks and open fractures, especially above 338 m. Fractures predominantly dip steeply to the SW. Fractures with variable moderate to gentle dips, particularly to the S and SE, are also conspicuous. Ten crush zones of which the majority occur between 270 and 338 m. Apertures generally 1 mm or less, with a few ranging up to 6 mm. Generally faint to medium oxidation. Seventy identified radar reflectors of which six are oriented (192/43, 173/35, 034/32, 345/52, 105/68 and 161/33). Low magnetic susceptibility and bulk resistivity with an overprint of frequent low resistivity anomalies. Vuggy rock, in the upper part affected by cataclasis, between 230 and 240 m. A strong and continuous radar reflector oriented 345/52 is seen from 110 to 220 m, probably associated with the vuggy rock. The vuggy rock is associated with very low resistivity, P-wave velocity, low density and increased gamma radiation. Cataclastic rock and different types of alteration between 285 and 338 m (see RU6 and RU7). The possible deformation zone is situated in metagranodiorite (101056), pegmatitic granite (101061), metagabbro/diorite (101033), amphibolite (102017) and fine- to medium-grained metagranitoid (101051). It occurs directly above a rock unit dominated by felsic to intermediate metavolcanic rock (103076) (RU9a). Confidence level = 3.

513–523 m

DZ3: Increased frequency of sealed and open fractures. Open fractures show a concentration with moderate dip to the S. Sealed fractures show a highly variable orientation. One crush zone in the upper part at 514.35–514.38 m. Apertures 2 mm or less. Generally faint oxidation. Four identified radar reflectors with intersection angles 51 to 73° to the borehole axis. Low magnetic susceptibility, resistivity and P-wave velocity. The possible deformation zone is situated in fine- to medium-grained granite (111058) and metagranodiorite (101056). Confidence level = 3.

5.2 HFM36

The borehole direction at the start is 252°/–58˚.

Rock units

The borehole consists of three rock units, RU1–RU3 which have been recognized with a medium degree of confidence. Rock unit 1 occurs in three separate length intervals (RU1a, RU1b and RU1c). The radar map shows very high attenuation from borehole length 40 m to the bottom of the borehole. A probable sub-parallel structure can be observed in the radar map between 20 m and 40 m.

12.06–17.45 m

RU1a: Foliated amphibolite (102017) and metatonalite-granodiorite (101054). Subordinate pegmatitic granite (101061). Density varies in the range 2,660–3,130 kg/m^3. Confidence level = 2.

17.45–42.28 m

RU2: Pegmatitic granite (101061) with subordinate amphibolite (102017). Density mainly in the range 2,530–2,580 kg/m^3. Magnetic susceptibility generally < 0.001 SI and natural gamma radiation varies in the range 30–80 μR/h. Confidence level = 2.

42.28–123.33 m

RU1b: Heterogeneous rock unit with foliated amphibolite (102017) and metatonalite-granodiorite (101054), pegmatitic granite (101061) and fine- to medium-grained metagranitoid (101051). Density varies in the range 2,600–3,160 kg/m^3. Confidence level = 2.

123.33–133.78 m

RU3: Foliated metagranite-granodiorite (101057) with subordinate pegmatitic granite (101061) and amphibolite (102017). Density varies in the range 2,550–2,650 kg/m^3. Confidence level = 2.

133.78–152.25 m

RU1c: Banded amphibolite (102017), foliated metadiorite-gabbro (101033) and subordinate pegmatitic granite (101061), metatonalite-granodiorite (101054) and metagranite-granodiorite (101057). Density varies in the range 2,640–3,050 kg/m^3. Confidence level = 2.

Possible deformation zones

One possible deformation zone of brittle character, which has been recognised with a medium degree of confidence, is present in HFM36.

42–147 m

DZ1: Generally increased frequency of open and sealed fractures. Open fractures dominate between 55 and 90 m, while sealed fractures including networks dominate between 42 to 55 m and beneath 90 m. Subhorizontal fractures and fractures that dip gently to the SE dominate. Steeply dipping fractures that strike NW-SE and NNE-SSW are also present. Three crush zones at c. 51 m, 112 m and 127 m. Aperture generally less than 1 mm with a range up to 5 mm. Weak to medium oxidation and chloritization is concentrated in the intervals 42–52 m and 83–117 m. Four non-oriented radar reflectors occur with intersection angles from 50° to 73° to the borehole axis. Geophysical logs indicate a significant decrease in bulk resistivity and magneticsusceptibility along the entire interval. Cataclastic rock and breccia present along several short intervals. Zone situated directly beneath pegmatitic granite in heterogeneous rock units with foliated amphibolite (102017), metatonalite-granodiorite (101054), pegmatitic granite (101061), metagranite-granodiorite (101057) and fine- to medium-grained metagranitoid (101051). Confidence level = 2.

5.3 HFM37

The borehole direction at the start is 041/–59˚.

Rock units

The borehole consists of four rock units, RU1–RU4. The rock units have been recognized with a medium degree of confidence. The radar map shows generally high attenuation, especially in the interval 15–19 m.

9.07–71.15 m

RU1: Foliated metagranodiorite (101056) and metatonalite-granodiorite (101054) which is generally porphyritic. Subordinate amphibolite (102017), fine- to medium-grained metagranitoid (101051) and pegmatitic granite (101061). Density generally in the range 2,650–2,780 kg/m^3. Confidence level = 2.

71.15–105.29 m

RU2: Foliated metagranodiorite (101056) with subordinate amphibolite (102017), pegmatitic granite (101061) and aplitic metagranite (101058). Density generally in the range 2,590–2,650 kg/m^3 which is anomalously low for a granodiorite. Confidence level = 2.

105.29–133.34 m

RU3: Heterogeneous, generally foliated rock unit with amphibolite (102017) and subordinate fine- to medium-grained metagranitoid (101051), aplitic metagranite (101058), pegmatitic granite (101061) and metatonalite-granodiorite (101054). Density generally in the range 2,700–2,880 kg/m^3. Confidence level = 2.

133.34–191.46 m

RU4: Foliated metagranodiorite (101056) with subordinate amphibolite (102017), pegmatitic granite (101061), fine- to medium-grained granite (111058) and metatonalite-granodiorite (101054). Density generally in the range 2,600–2,720 kg/m^3. Confidence level = 2.

Possible deformation zones

Three possible deformation zones of brittle character, all of which have been recognised with a medium degree of confidence, are present in HFM37.

15–23 m

DZ1: Increased frequency of mostly sealed fractures. Fractures with variable, moderate to gentle dips dominate. Some steeply dipping fractures that strike WNW-ESE are also present. Apertures generally less than 1 mm and up to 2 mm. Locally weak oxidation. One non-oriented radar reflector occurs at 15.6 m with an angle of 56° to the borehole axis. Geophysical logs indicate a significant decrease in bulk resistivity, magnetic susceptibility and several caliper anomalies. Zone situated in foliated metagranodiorite (101056), metatonalite-granodiorite (101054) and subordinate amphibolite (102017). Confidence level = 2.

72–104 m

DZ2: Increased frequency of sealed fractures and in the lower half even open fractures. Sealed fractures that are subhorizontal or dip steeply to the SSW and to the W dominate. Open fractures are predominantly subhorizontal. Apertures less than 1 mm and up to 1.5 mm. Three non-oriented radar reflectors occur at 76.3 m (67°), 88.6 m (58°) and at 104.9 m (54°). Faint to strong oxidation. Geophysical logs indicate a significant decrease in bulk resistivity, magnetic susceptibility and partly decreased P-wave velocity. Zone situated directly beneath amphibolite (102017) in foliated metagranodiorite (101056) with subordinate amphibolite (102017), pegmatitic granite (101061) and aplitic metagranite (101058). Confidence level = 2.

130–191.455 m

DZ3: Increased frequency of sealed and open fractures. Sealed fractures that dip steeply to the SW or WNW dominate. Gently dipping to subhorizontal sealed and open fractures are also conspicuous. Apertures less than 1 mm and up to 2 mm. Generally weak to medium oxidation. Seven non-oriented radar reflectors with intersection angles in the interval 33–81° to the borehole axis. Geophysical logs indicate partly decreased resistivity, magnetic susceptibility and P-wave velocity. Zone situated in foliated metagranodiorite (101056), amphibolite (102017), pegmatitic granite (101061), fine- to medium-grained granite (111058) and metatonalite-granodiorite (101054). Confidence level = 2.

6 Comments

The results of the geological single-hole interpretation of KFM12A, HFM36 and HFM37 are presented in WellCad plots (Appendix 1-3). Each WellCad plot consists of the following columns:

1: Depth (length along the borehole).
2: Rock type.
3: Rock alteration.
4: Sealed fractures.
5: Open and partly open fractures.
6: Crush zones.
7: Silicate density.
8: Magnetic susceptibility.
9: Natural gamma radiation.
10: Estimated fracture frequency.
11: Description: Rock unit.
12: Stereogram for sealed fractures in rock unit (blue symbols).
13: Stereogram for open and partly open fractures in rock unit (red symbols).
14: Description: Possible deformation zone.
15: Stereogram for sealed fractures in possible deformation zone (blue symbols).
16: Stereogram for open and partly open fractures in possible deformation zone (red symbols).

References

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/3/ **Petersson J, Samuelsson E, Andersson U B, Dahlin P, Danielsson P, Ehrenborg J, Lindström L, Lundberg E, Rauséus G, Wängnerud A, 2007**. Forsmark site investigation. Boremap mapping of KFM12A. SKB P-07-xx (in prep.), Svensk Kärnbränslehantering AB.

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/7/ **Gustafsson J, Gustafsson C, 2007.** Forsmark site investigation. RAMAC and BIPS logging in borehole KFM12A. SKB P-07-112, Svensk Kärnbränslehantering AB.

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Geological single-hole interpretation of KFM12A

Title SINGLE HOLE INTERPRETATION KFM12A

Site	FORSMARK	**Inclination [°]**	-60.55	**Elevation [m.a.s.l.]**	10.74	**Signed data**
Borehole	KFM12A	**Date of mapping**	2007-03-29 08:32:00	**Drilling Start Date**	2006-09-04 07:00:00	
Diameter [mm]	77	**Coordinate System**	RT90-RHB70	**Drilling Stop Date**	2007-03-12 00:00:00	
Length [m]	601.040	**Northing [m]**	6696576.85	**Surveying Date**		
Bearing [°]	36.20	**Easting [m]**	1630051.64	**Plot Date**	2007-09-24 22:04:52	

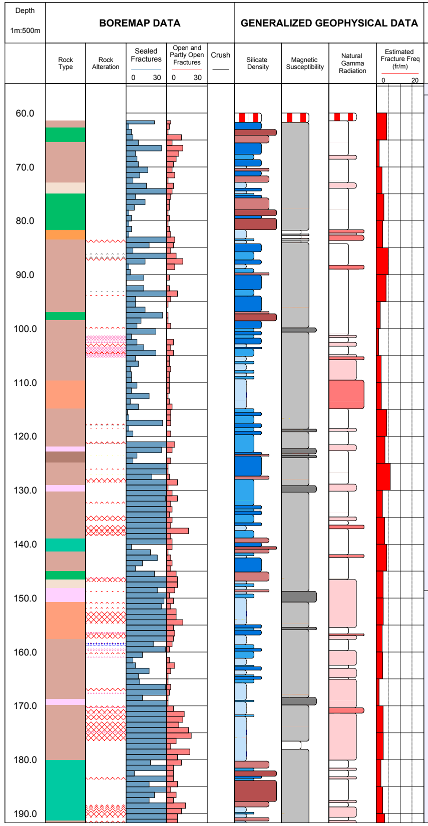
ROCKTYPE FORSMARK
- 🟧 Granite, fine- to medium-grained
- 🟧 Pegmatite, pegmatitic granite
- 🟪 Granite, granodiorite and tonalite, metamorphic, fine- to medium-grained
- 🟫 Granite, metamorphic, aplitic
- 🟫 Granodiorite, metamorphic
- 🟫 Tonalite to granodiorite, metamorphic
- 🟩 Diorite, quarts diorite and gabbro, metamorphic
- 🟩 Amphibolite
- 🟩 Calc-silicate rock (skarn)
- 🟨 Felsic to intermediate volcanic rock, metamorphic

ROCK ALTERATION
- ▨ Oxidized
- ▨ Chloritisized
- ▨ Epidotisized
- ▨ Sericitisized
- ▨ Quartz dissolution
- ▨ Silicification
- ▨ Argillization
- ▨ Albitization
- ▨ Carbonatization
- ▨ Saussuritization
- ▨ Laumontitization

SILICATE DENSITY
- 🟥 unclassified
- 🟦 dens<2680 (Granite)
- 🟦 2680<dens<2730 (Granodiorite)
- 🟦 2730<dens<2800 (Tonalite)
- 🟥 2800<dens<2890 (Diorite)
- 🟥 dens>2890 (Gabbro)

SUSCEPTIBILITET
- 🟥 unclassified
- □ sus<0.001
- ■ 0.001<sus<0.01
- ■ 0.01<sus<0.1

NATURAL GAMMA
- 🟥 unclassified
- □ gam<20
- 🟥 20<gam<36
- 🟥 36<gam<53



ROCK UNIT

Description Rock Unit

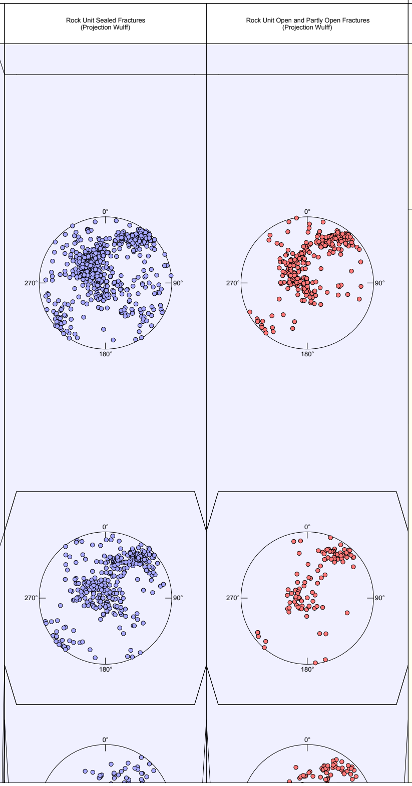
60.21

RU1
Porphyritic metagranodiorite (101056), locally tonalitic (101054). Subordinate metagabbro/diorite (101033), fine- to medium-grained granite (111058), amphibolite (102017), pegmatitic granite (101061), fine- to medium-grained metagranitoid (101051), felsic to intermediate metavolcanic rock (103076) and one occurrence of aplitic metagranite (101058). Two intervals of increased fracture frequency associated with low resistivity, low P-wave velocity and decreased radar amplitude at 65 and 85-90 m. Low magnetic susceptibility throughout the section and locally faint to medium oxidation. Confidence level = 3.

144.99

144.99

RU2
Heterogeneous rock unit. Upper part composed of fine- to medium-grained granite (111058), fine- to medium-grained metagranitoid (101051), aplitic metagranite (101058), metagabbro/diorite (101033) and amphibolite (102017). Lower part composed of

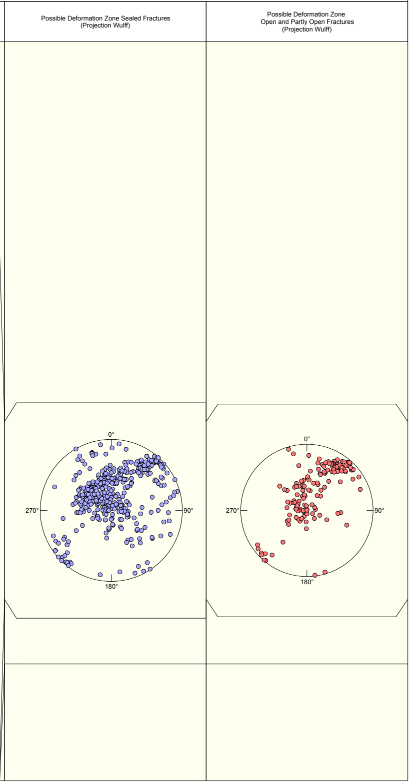


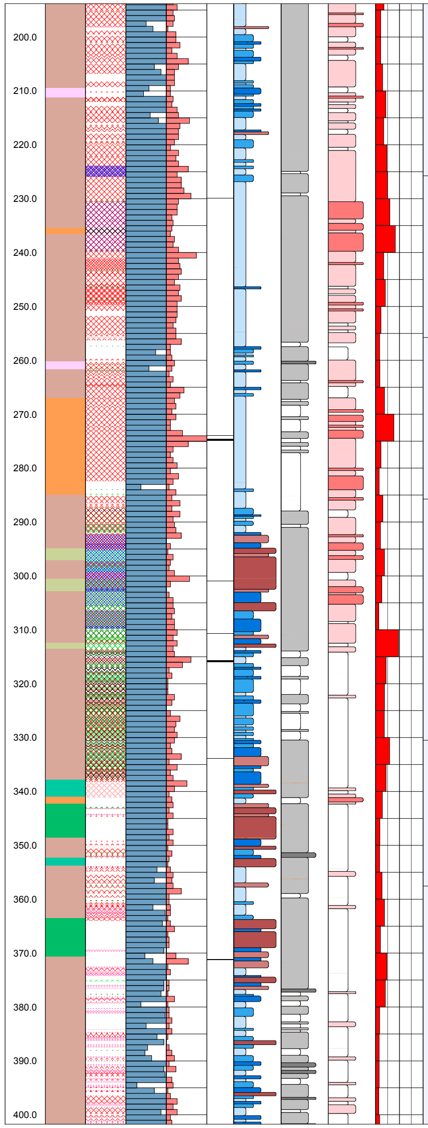
POSSIBLE DEFORMATION ZONES

Description Possible Deformation Zone

125.00

DZ1
Increased frequency of sealed fractures, sealed fracture networks and, to some extent, open fractures. Fractures predominantly dip gently to the SE or steeply to the SW. One crush zone at 128.08-128.10 m. Apertures generally 1 mm or less, with a few ranging up to 7 mm. Locally faint to medium oxidation. Sixteen identified radar reflectors with intersection angles 22 to 83° to the borehole axis. Low resistivity, P-wave velocity and magnetic susceptibility. The possible zone is situated on both sides of the contact between porphyritic (RU1) and more equigranular (RU2) metagranodiorite. Subordinate fine- to medium-grained granite (111058), metagabbro/diorite (101033), amphibolite (102017), fine- to medium-grained metagranitoid (101051) and aplitic metagranite (101058). Confidence level





with subordinate fine- to medium-grained metagranitoid (101051), aplitic metagranite (101058) and amphibolite (102017). Low magnetic susceptibility throughout the section and locally faint to medium oxidation. Confidence level = 3.

169.84

169.84

RU3a

Strongly foliated metagranodiorite (101056) with subordinate occurrences of pegmatitic granite (101061) and amphibolite (102017). Confidence level = 3.

179.99

179.99

RU4a

Banded and foliated amphibolite (102017). Subordinate metagranodiorite (101056) and pegmatitic granite (101061). Confidence level = 3.

191.26

191.26

RU3b

Strongly foliated metagranodiorite (101056) with subordinate fine- to medium-grained metagranitoid (101051), pegmatitic granite (101061), amphibolite (102017) and in the lowermost part felsic to intermediate metavolcanic rock (103076). Confidence level = 3.

266.97

266.97

RU5

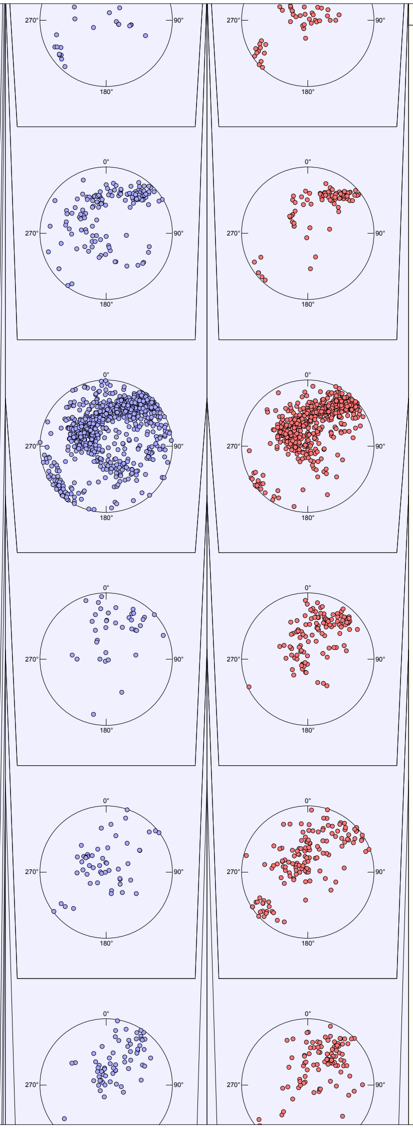
Pegmatitic granite (101061) with subordinate amphibolite (102017) and metagranodiorite (101056) in the lowermost part. Confidence level = 3.

285.04

285.04

RU6

Cataclastic rock (108003) with intervals of calc-silicate rock (108019). Increased gamma radiation associated with high density between 291 and 306 m. Faint to medium epidotization, faint to weak saussuritization, faint to medium oxidation and locally weak to medium chloritization. Confidence level = 3.

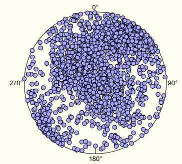


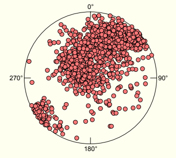
158.00

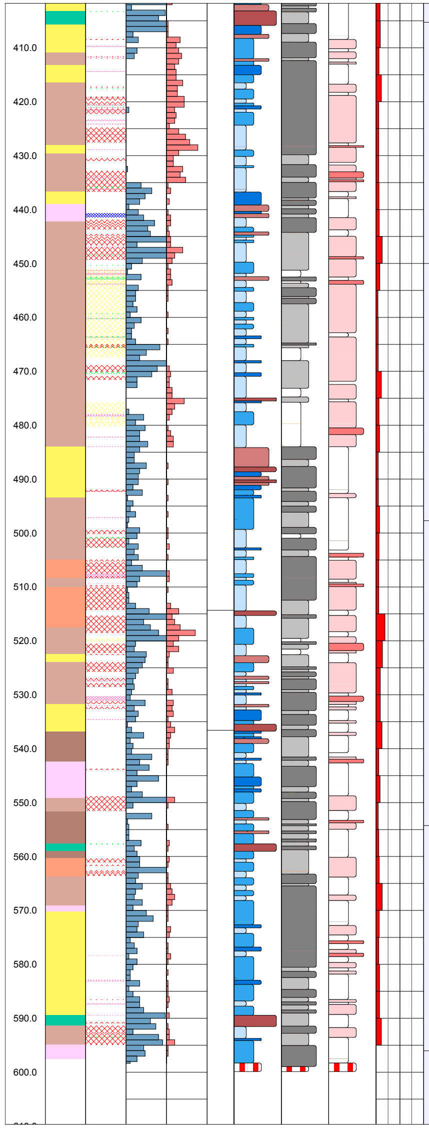
170.00

DZ2 High ductile strain. Increased frequency of sealed fractures, sealed fracture networks and open fractures, especially above 338 m. Fractures predominantly dip steeply to the SW. Fractures with variable moderate to gentle dips, particularly to the S and SE, are also conspicuous. Ten crush zones of which the majority occur between 270 and 338 m. Apertures generally 1 mm or less, with a few ranging up to 6 mm. Generally faint to medium oxidation. Seventy identified radar reflectors of which six are oriented (192/43, 173/35, 034/32, 345/52, 105/68 and 161/33). Low magnetic susceptibility and bulk resistivity with an overprint of frequent low resistivity anomalies. Vuggy rock, in the upper part affected by cataclasis, between 230 and 240 m. A strong and continuous radar reflector oriented 345/52 is seen from 110 to 220 m, probably associated with the vuggy rock. The vuggy rock is associated with very low resistivity, P-wave velocity, low density and increased gamma radiation. Cataclastic rock and different types of alteration between 285 and 338 m (see RU6 and RU7). The possible deformation zone is situated in metagranodiorite (101056), pegmatitic granite (101061), metagabbro/diorite (101033), amphibolite (102017) and fine- to medium-grained metagranitoid (101051). It occurs directly above a rock unit dominated by felsic to intermediate metavolcanic rock (103076) (RU9a). Confidence level = 3.

402.00







313.55

313.55

RU7
Strongly cataclastic rock (108003). Decreased gamma radiation associated with low to moderate density above 332 m. Silicification and epidotization of varying intensity throughout the borehole interval. Weak to medium oxidation in the lowermost part. Confidence level = 3.

337.86

337.86

RU4b
Strongly foliated amphibolite (102017) above pegmatitic granite (101061) and foliated metagabbro/diorite (101033). Subordinate metagranodiorite (101056) and felsic to intermediate metavolcanic rock (103076). Several brittle-ductile and ductile shear zones. Confidence level = 3.

348.62

348.62

RU8a
Metagranodiorite (101056) affected by grain-size reduction related to high ductile strain. Subordinate metagabbro/diorite (101033), amphibolite (102017), fine- to medium-grained metagranitoid (101051), pegmatitic granite (101061) and felsic to intermediate metavolcanic rock (103076). Several brittle-ductile and ductile shear zones. Confidence level = 3.

401.77

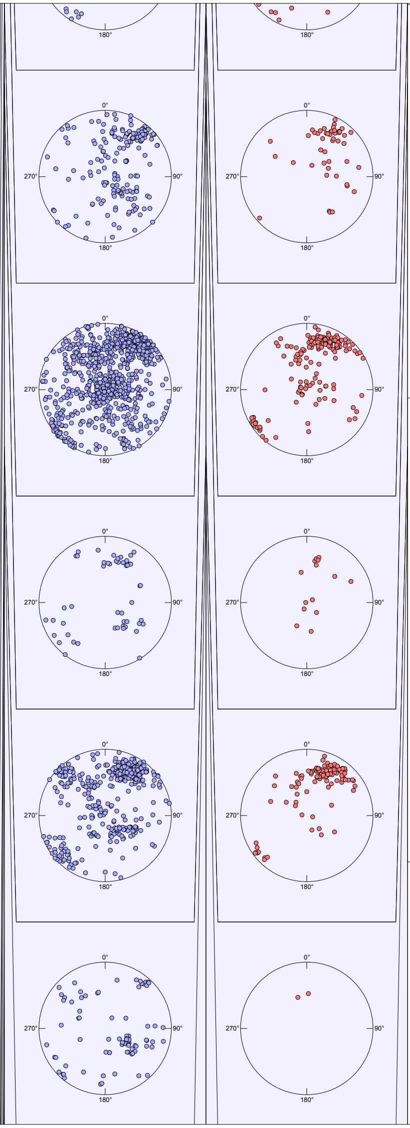
401.77

RU9a
Partly banded felsic to intermediate metavolcanic rock (103076) and subordinate amphibolite (102017), metagranodiorite (101056) and pegmatitic granite (102017). Density of metavolcanic rock = 2740-2810 kg/m³. Confidence level = 3.

416.46

416.46

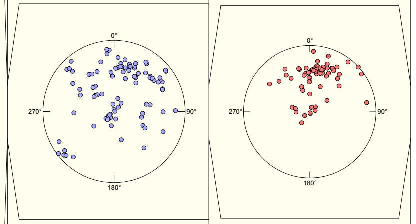
RU8b
Metagranodiorite (101056) affected by grain-size reduction related to high



513.00

DZ3
Increased frequency of sealed and open fractures. Open fractures show a concentration with moderate dip to the S. Sealed fractures show a highly variable orientation. One crush zone in the upper part at 514.35-514.38 m. Apertures 2 mm or less. Generally faint oxidation. Four identified radar reflectors with intersection angles 51 to 73° to the borehole axis. Low magnetic susceptibility, resistivity and P-wave velocity. The possible deformation zone is situated in fine- to medium-grained granite (111058) and metagranodiorite (101056). Confidence level = 3.

523.00



610.0
620.0
630.0
640.0
650.0
660.0
670.0
680.0
690.0
700.0
710.0
720.0
730.0
740.0
750.0
760.0
770.0
780.0
790.0
800.0
810.0

reduction related to high ductile strain. Subordinate felsic to intermediate metavolcanic rock (103076), fine- to medium-grained metagranitoid (101051), amphibolite (102017) and pegmatitic granite (101061). Several brittle-ductile and ductile shear zones. Generally faint to medium oxidation in the upper part and faint to medium muscovitization in the lower part. Low magnetic susceptibility and slightly reduced resistivity associated with the muscovitization. Confidence level = 3.

484.03

484.03

RU9b

Banded felsic to intermediate metavolcanic rock (103076) and subordinate amphibolite (102017). Density of metavolcanic rock is 2830-2875 kg/m³. Confidence level = 3.

492.57

492.57

RU10

Metagranodiorite (101056) affected by grain-size reduction related to high ductile strain and lineated, fine- to medium-grained granite (111058). Subordinate amphibolite (102017). Locally faint to weak oxidation even outside the possible deformation zone DZ3 (513-523 m). Confidence level = 3.

522.53

522.53

RU11

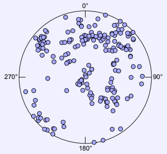
Banded metatonalite to granodiorite (101054). Subordinate felsic to intermediate metavolcanic rock (103076) in the upper part, pegmatitic granite (101061) and amphibolite (102017) throughout the unit and fine- to medium-grained, lineated granite (111058) in the lower part. Confidence level = 3.

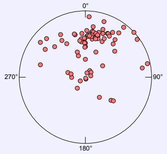
570.25

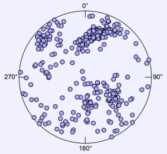
570.25

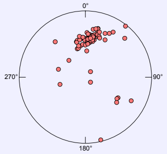
RU9c

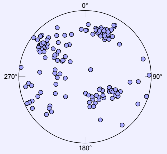
Felsic to intermediate metavolcanic rock (103076) and subordinate amphibolite (102017)

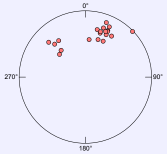


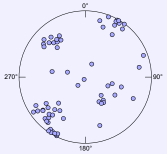


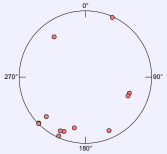












820.0	amphibolite (102017), pegmatitic granite (101061), fine- to medium-grained metagranitoid (101051). Density of metavolcanic rock is 2710-2740 kg/m³. Confidence level = 3. 591.42
830.0	
840.0	
850.0	591.42 RU12 Metagranodiorite (101056) affected by grain-size reduction related to high ductile strain and lineated fine- to medium-grained metagranitoid (101051). Subordinate amphibolite (102017) and pegmatitic granite (101061). Confidence level = 3. 600.95
860.0	
870.0	
880.0	

Appendix 2

Geological single-hole interpretation of HFM36

Title **SINGLE HOLE INTERPRETATION HFM36**

Site	FORSMARK	**Inclination [°]**	-59.00	**Elevation [m.a.s.l.]**	8.42	**Signed data**
Borehole	HFM36	**Date of mapping**	2007-03-09 10:58:00	**Drilling Start Date**	2006-08-28 14:00:00	
Diameter [mm]	137	**Coordinate System**	RT90-RHB70	**Drilling Stop Date**	2006-09-04 11:00:00	
Length [m]	152.550	**Northing [m]**	6696504.03	**Surveying Date**		
Bearing [°]	256.61	**Easting [m]**	1630081.68	**Plot Date**	2007-09-24 22:04:52	

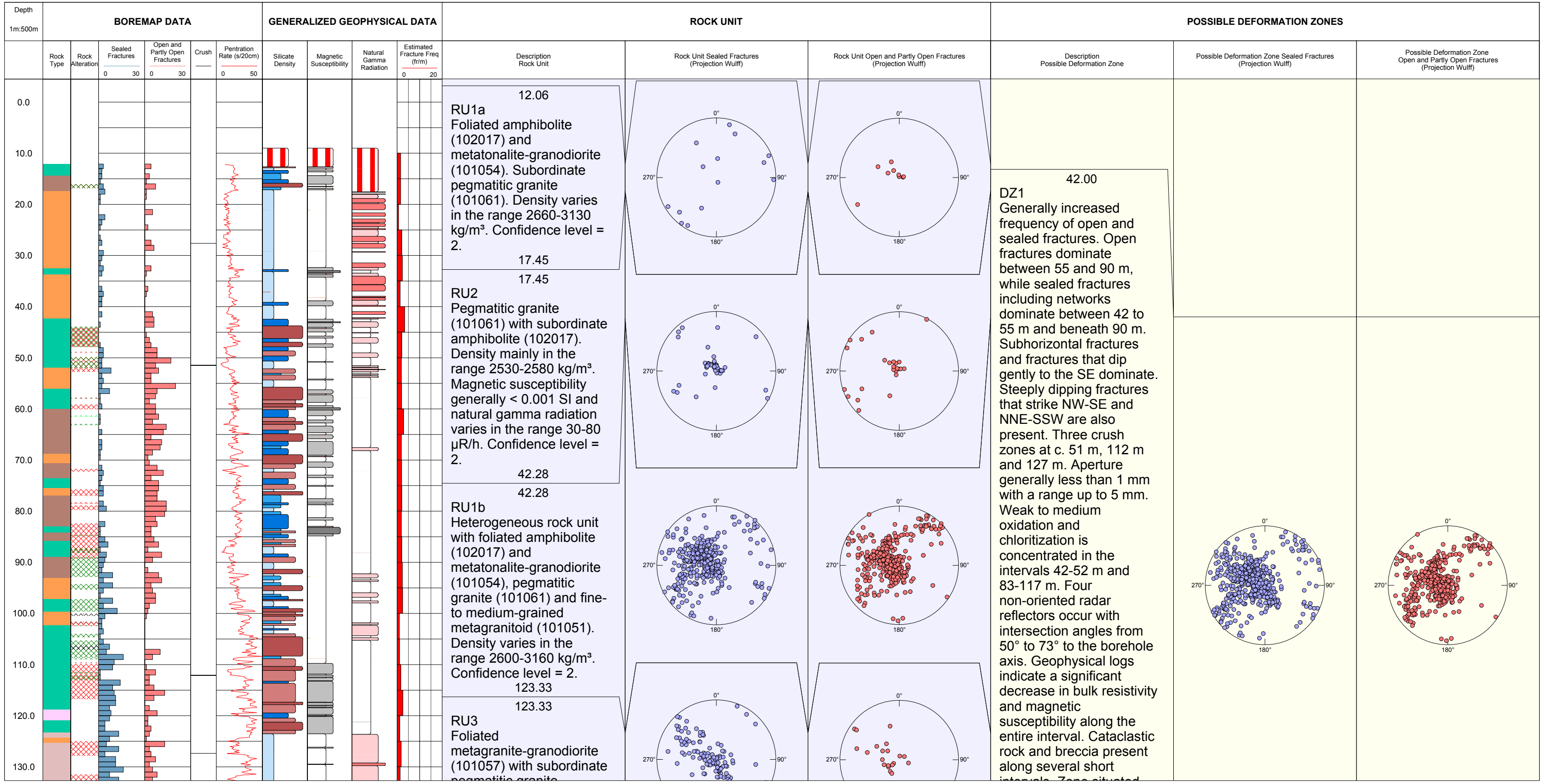
ROCKTYPE FORSMARK
- 🟧 Pegmatite, pegmatitic granite
- 🟪 Granite, granodiorite and tonalite, metamorphic, fine- to medium-grained
- ▨ Granite to granodiorite, metamorphic, medium-grained
- 🟫 Tonalite to granodiorite, metamorphic
- 🟩 Diorite, quarts diorite and gabbro, metamorphic
- 🟩 Amphibolite

ROCK ALTERATION
- ▨ Oxidized
- ▨ Chloritisized
- ▨ Epidotisized
- ▨ Carbonatization

SILICATE DENSITY
- 🟥 unclassified
- 🟦 dens<2680 (Granite)
- 🟦 2680<dens<2730 (Granodiorite)
- 🟦 2730<dens<2800 (Tonalite)
- 🟥 2800<dens<2890 (Diorite)
- 🟥 dens>2890 (Gabbro)

SUSCEPTIBILITET
- 🟥 unclassified
- ☐ sus<0.001
- ▨ 0.001<sus<0.01
- ▨ 0.01<sus<0.1

NATURAL GAMMA
- 🟥 unclassified
- ☐ gam<20
- 🟥 20<gam<36
- 🟥 36<gam<53



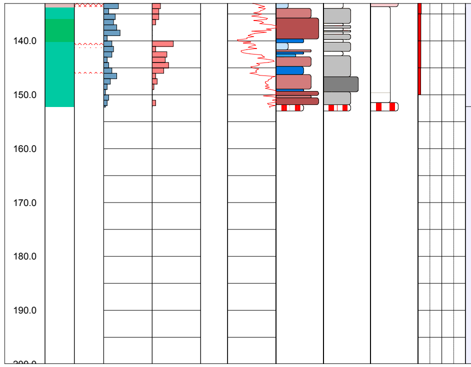
12.06
RU1a
Foliated amphibolite (102017) and metatonalite-granodiorite (101054). Subordinate pegmatitic granite (101061). Density varies in the range 2660-3130 kg/m³. Confidence level = 2.
17.45

17.45
RU2
Pegmatitic granite (101061) with subordinate amphibolite (102017). Density mainly in the range 2530-2580 kg/m³. Magnetic susceptibility generally < 0.001 SI and natural gamma radiation varies in the range 30-80 μR/h. Confidence level = 2.
42.28

42.28
RU1b
Heterogeneous rock unit with foliated amphibolite (102017) and metatonalite-granodiorite (101054), pegmatitic granite (101061) and fine- to medium-grained metagranitoid (101051). Density varies in the range 2600-3160 kg/m³. Confidence level = 2.
123.33

123.33
RU3
Foliated metagranite-granodiorite (101057) with subordinate

42.00
DZ1
Generally increased frequency of open and sealed fractures. Open fractures dominate between 55 and 90 m, while sealed fractures including networks dominate between 42 to 55 m and beneath 90 m. Subhorizontal fractures and fractures that dip gently to the SE dominate. Steeply dipping fractures that strike NW-SE and NNE-SSW are also present. Three crush zones at c. 51 m, 112 m and 127 m. Aperture generally less than 1 mm with a range up to 5 mm. Weak to medium oxidation and chloritization is concentrated in the intervals 42-52 m and 83-117 m. Four non-oriented radar reflectors occur with intersection angles from 50° to 73° to the borehole axis. Geophysical logs indicate a significant decrease in bulk resistivity and magnetic susceptibility along the entire interval. Cataclastic rock and breccia present along several short



pegmatitic granite (101061) and amphibolite (102017). Density varies in the range 2550-2650 kg/m³. Confidence level = 2.

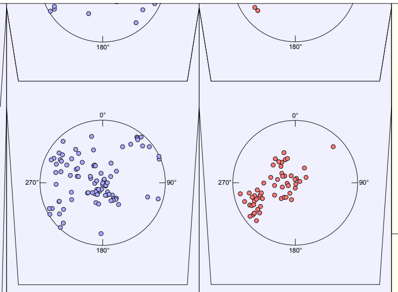
133.78

133.78

RU1c

Banded amphibolite (102017), foliated metadiorite-gabbro (101033) and subordinate pegmatitic granite (101061), metatonalite-granodiorite (101054) and metagranite-granodiorite (101057). Density varies in the range 2640-3050 kg/m³. Confidence level = 2.

152.25



intervals. Zone situated directly beneath pegmatitic granite in heterogeneous rock units with foliated amphibolite (102017), metatonalite-granodiorite (101054), pegmatitic granite (101061), metagranite-granodiorite (101057) and fine- to medium-grained metagranitoid (101051). Confidence level = 2.

147.00

Appendix 3

Geological single-hole interpretation of HFM37

Title SINGLE HOLE INTERPRETATION HFM37

Site	FORSMARK	**Inclination [°]**	-59.16	**Elevation [m.a.s.l.]**	11.39	**Signed data**
Borehole	HFM37	**Date of mapping**	2007-03-14 14:35:00	**Drilling Start Date**	2006-08-07 16:00:00	
Diameter [mm]	139	**Coordinate System**	RT90-RHB70	**Drilling Stop Date**	2006-08-16 15:00:00	
Length [m]	191.750	**Northing [m]**	6696592.43	**Surveying Date**		
Bearing [°]	41.35	**Easting [m]**	1630137.37	**Plot Date**	2007-09-24 22:04:52	

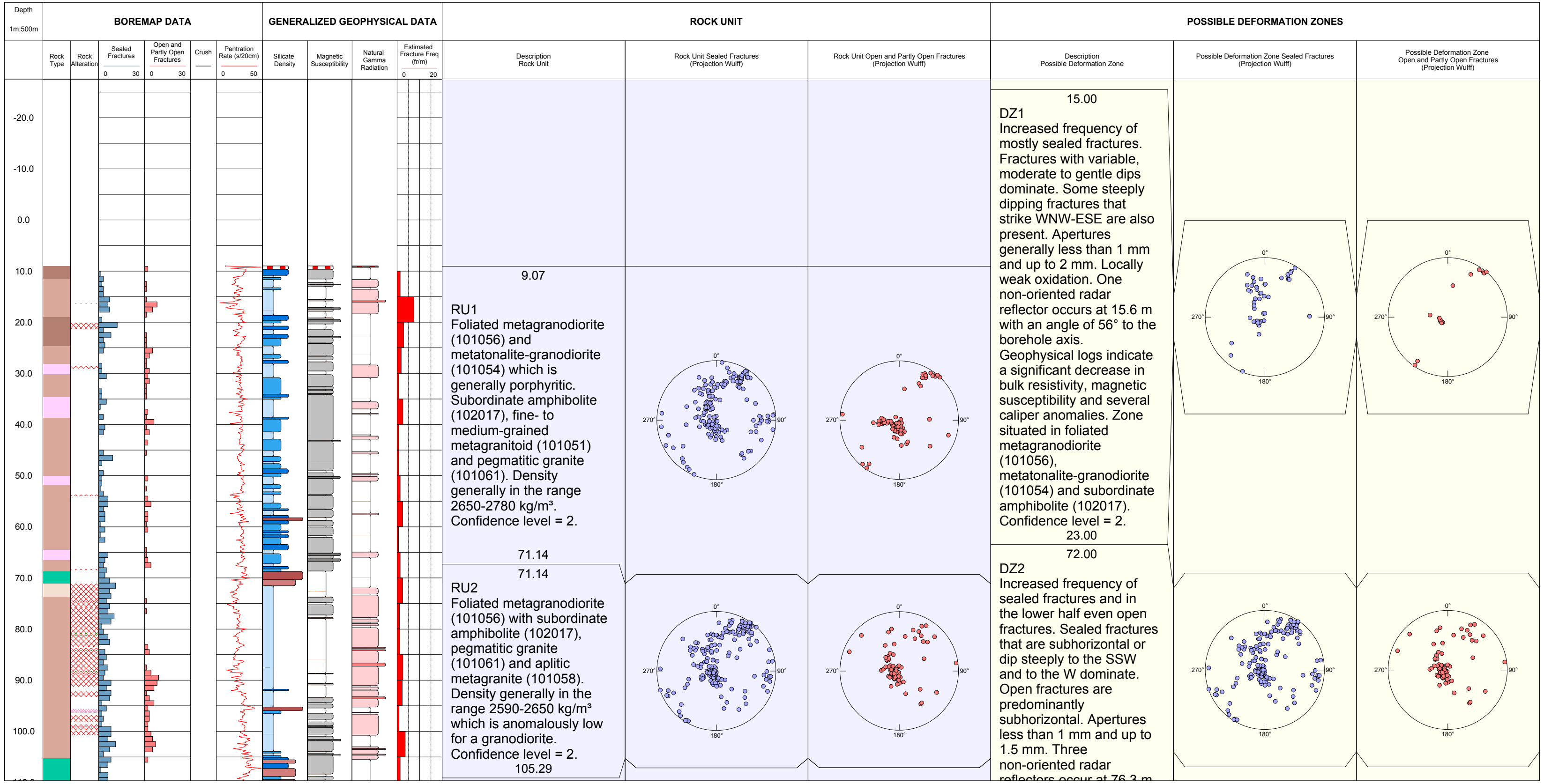
ROCKTYPE FORSMARK
- 🟧 Pegmatite, pegmatitic granite
- ▭ Granite, granodiorite and tonalite, metamorphic, fine- to medium-grained
- ▭ Granite, metamorphic, aplitic
- ▭ Granodiorite, metamorphic
- ▭ Tonalite to granodiorite, metamorphic
- 🟩 Amphibolite

ROCK ALTERATION
- ▨ Oxidized
- ▨ Chloritisized
- ▨ Albitization

SILICATE DENSITY
- 🟥 unclassified
- ▭ dens<2680 (Granite)
- 🟦 2680<dens<2730 (Granodiorite)
- 🟦 2730<dens<2800 (Tonalite)
- 🟥 2800<dens<2890 (Diorite)
- 🟥 dens>2890 (Gabbro)

SUSCEPTIBILITET
- 🟥 unclassified
- ▭ sus<0.001
- ▭ 0.001<sus<0.01
- ▭ 0.01<sus<0.1

NATURAL GAMMA
- 🟥 unclassified
- ▭ gam<20
- ▭ 20<gam<36
- 🟥 36<gam<53



9.07

RU1
Foliated metagranodiorite (101056) and metatonalite-granodiorite (101054) which is generally porphyritic. Subordinate amphibolite (102017), fine- to medium-grained metagranitoid (101051) and pegmatitic granite (101061). Density generally in the range 2650-2780 kg/m³. Confidence level = 2.

71.14

71.14

RU2
Foliated metagranodiorite (101056) with subordinate amphibolite (102017), pegmatitic granite (101061) and aplitic metagranite (101058). Density generally in the range 2590-2650 kg/m³ which is anomalously low for a granodiorite. Confidence level = 2.

105.29

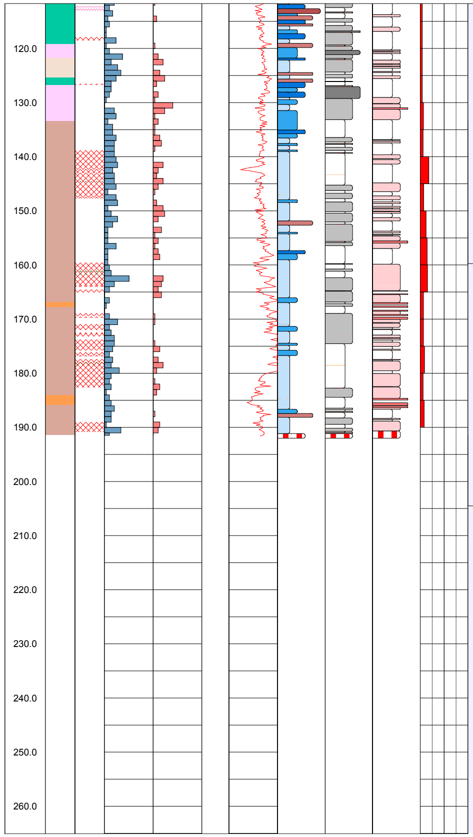
15.00

DZ1
Increased frequency of mostly sealed fractures. Fractures with variable, moderate to gentle dips dominate. Some steeply dipping fractures that strike WNW-ESE are also present. Apertures generally less than 1 mm and up to 2 mm. Locally weak oxidation. One non-oriented radar reflector occurs at 15.6 m with an angle of 56° to the borehole axis. Geophysical logs indicate a significant decrease in bulk resistivity, magnetic susceptibility and several caliper anomalies. Zone situated in foliated metagranodiorite (101056), metatonalite-granodiorite (101054) and subordinate amphibolite (102017). Confidence level = 2.

23.00

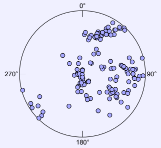
72.00

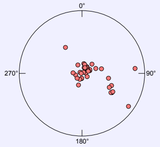
DZ2
Increased frequency of sealed fractures and in the lower half even open fractures. Sealed fractures that are subhorizontal or dip steeply to the SSW and to the W dominate. Open fractures are predominantly subhorizontal. Apertures less than 1 mm and up to 1.5 mm. Three non-oriented radar reflectors occur at 76.3 m

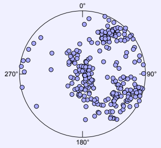


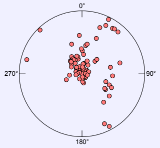
RU3
Heterogeneous, generally foliated rock unit with amphibolite (102017) and subordinate fine- to medium-grained metagranitoid (101051), aplitic metagranite (101058), pegmatitic granite (101061) and metatonalite-granodiorite (101054). Density generally in the range 2700-2880 kg/m³. Confidence level = 2.
133.34

133.34
RU4
Foliated metagranodiorite (101056) with subordinate amphibolite (102017), pegmatitic granite (101061), fine- to medium-grained granite (111058) and metatonalite-granodiorite (101054). Density generally in the range 2600-2720 kg/m³. Confidence level = 2.
191.46









(67°), 88.6 m (58°) and at 104.9 m (54°). Faint to strong oxidation. Geophysical logs indicate a significant decrease in bulk resistivity, magnetic susceptibility and partly decreased P-wave velocity. Zone situated directly beneath amphibolite (102017) in foliated metagranodiorite (101056) with subordinate amphibolite (102017), pegmatitic granite (101061) and aplitic metagranite (101058). Confidence level = 2.
104.00

130.00
DZ3
Increased frequency of sealed and open fractures. Sealed fractures that dip steeply to the SW or WNW dominate. Gently dipping to subhorizontal sealed and open fractures are also conspicuous. Apertures less than 1 mm and up to 2 mm. Generally weak to medium oxidation. Seven non-oriented radar reflectors with intersection angles in the interval 33-81° to the borehole axis. Geophysical logs indicate partly decreased resistivity, magnetic susceptibility and P-wave velocity. Zone situated in foliated metagranodiorite (101056), amphibolite (102017), pegmatitic granite (101061), fine- to medium-grained granite (111058) and metatonalite-granodiorite (101054). Confidence level = 2.
191.46