P-06-133

Forsmark site investigation

Boremap mapping of core drilled borehole KFM01C

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July 2006

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ISSN 1651-4416
SKB P-06-133

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Keywords: Geology, Fractures, BIPS, Boremap, Drill core, AP PF 400-05-129.

Abstract

This report presents the result from the Boremap mapping of core drilled borehole KFM01C at drill site 1 in the Forsmark candidate area. Drill site 1 is situated in the north-western part of the tectonic lens that has been selected as a candidate area for deposition of nuclear waste. The borehole was drilled with the bearing 165.4° and the inclination –49.6°, with the aim to verify the existence of a brittle deformation zone (ZFMNE060A).

The dominant rock type in KFM01C is a generally foliated metagranite-granodiorite (~ 70%), followed by pegmatite or pegmatitic granite (~ 13%), and amphibolite (~ 7%). Subordinate rock types are fine- to medium-grained metatonalite, granodiorite to granite (~ 4%), fine- to medium grained granite of different ages (~ 3%) and felsic- to intermediate metavolcanic rock (~ 1%). The upper 100 m is generally weakly to moderately oxidized. Other alteration types occur but they are mostly sporadic.

The borehole is relatively rich in fractures, having fracture frequencies of 3.4 open fractures/m (crush excluded), and 8.5 sealed fractures/m (sealed fracture networks excluded). Open and partly open fractures, as well as the few mapped crushed sections are concentrated to the upper 100 m of the borehole, while laumontite sealed fractures are concentrated to the lower half of the borehole, suggesting intersection of the brittle deformation zone.

Sammanfattning

Denna rapport redovisar resultatet från Boremapkartering av kärnborrhål KFM01C vid borrplats 1 i Forsmark kandidatområde. Borrplats 1 är belägen i den nordvästra delen av den tektoniska lins, som har valts som kandidatområde för deponi av högaktivt kärnavfall. Borrhålet är borrat med riktning 165,4° och lutning –49,6°, med målet att verifiera existensen av en spröd deformationszon (ZFMNE060A).

Den dominerande bergarten i KFM01C är generellt folierad metagranit-granodiorit (~ 70 %), följt av pegmatit till pegmatitisk granit (~ 13 %) och amfibolit (~ 7 %). Underordnade bergarter är fin- till medelkornig metatonalit till granodiorit-granit (~ 4 %), fin- till medelkornig granit av olika generationer (~ 3 %) och felsisk- till intermediär metavulkanit (~ 1 %). Bergarterna i de översta 100 metrarna är generellt svagt till måttligt oxiderade. Andra omvandlingar förekommer, men de är för det mesta sporadiska.

Borrhålet är relativt rikt på sprickor, och uppvisar sprickfrekvenser på 3,4 öppna sprickor/m (krossar exkluderade) och 8,5 läkta sprickor/m (läkta spricknätverk exkluderade). Öppna och delvis öppna sprickor är koncentrerade till de översta 100 metrarna av borrhålet, liksom även de få dokumenterade sektionerna med kross, medan företrädesvis laumontitläkta sprickor är koncentrerade till borrhålets nedre partier, och kan tolkas utgöra en spröd deformationszon.

Contents

1 Introduction

This document reports the data gained by the Boremap mapping of the cored borehole KFM01C, which is one of the activities performed within the site investigation at Forsmark. The work was carried out in accordance with activity plan SKB PF 400-05-129. In Table 1-1 controlling documents for performing this activity are listed. Both activity plan and method descriptions are SKB's internal controlling documents.

The borehole KFM01C was drilled from drill site 1 (DS 1) in the north-western part of the tectonic lens, which is of interest for future nuclear waste disposal (Figure 2-1) /1/. The borehole was drilled in order to verify the existence of a brittle deformation zone (ZFMNE060A). The drilling of KFM01C was finished in the end of November 2005. The Boremap mapping of the borehole started in January 2006 and was finished in May 2006.

The geological documentation of core drilled boreholes according to the Boremap method is based on the use of BIPS-images of the borehole wall and the simultaneous study of the drill core. Position, aperture and orientation data of features are based on the adjusted BIPS-image, while other data such as rock type, alteration, fracture mineralogy and surface are observed in the drill core. The results from the Boremap mapping will be used for further analyses and 3D-modelling of the Forsmark area.

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

Activity plan	Number	Version
Boremapkartering av kärnborrhål KFM07B	AP PF 400-05-129	1.0
Method descriptions	**Number**	**Version**
Metodbeskrivning för Boremapkartering	SKB MD 143.006	2.0
Mätsystembeskrivning för Boremap	SKB MD 146.001	1.0
Nomenklatur vid Boremapkartering	SKB MD 143.008	1.0
Instruktion: Regler för bergarters benämningar vid platsundersökningen i Forsmark	SKB MD 132.005	1.0

2 Objective and scope

The aim of this activity was to verify the existence of a brittle deformation zone (ZFMNE060A) and to document lithologies, alterations, ductile structures and the occurrence and character of fractures in the bedrock penetrated by the cored borehole KFM01C.

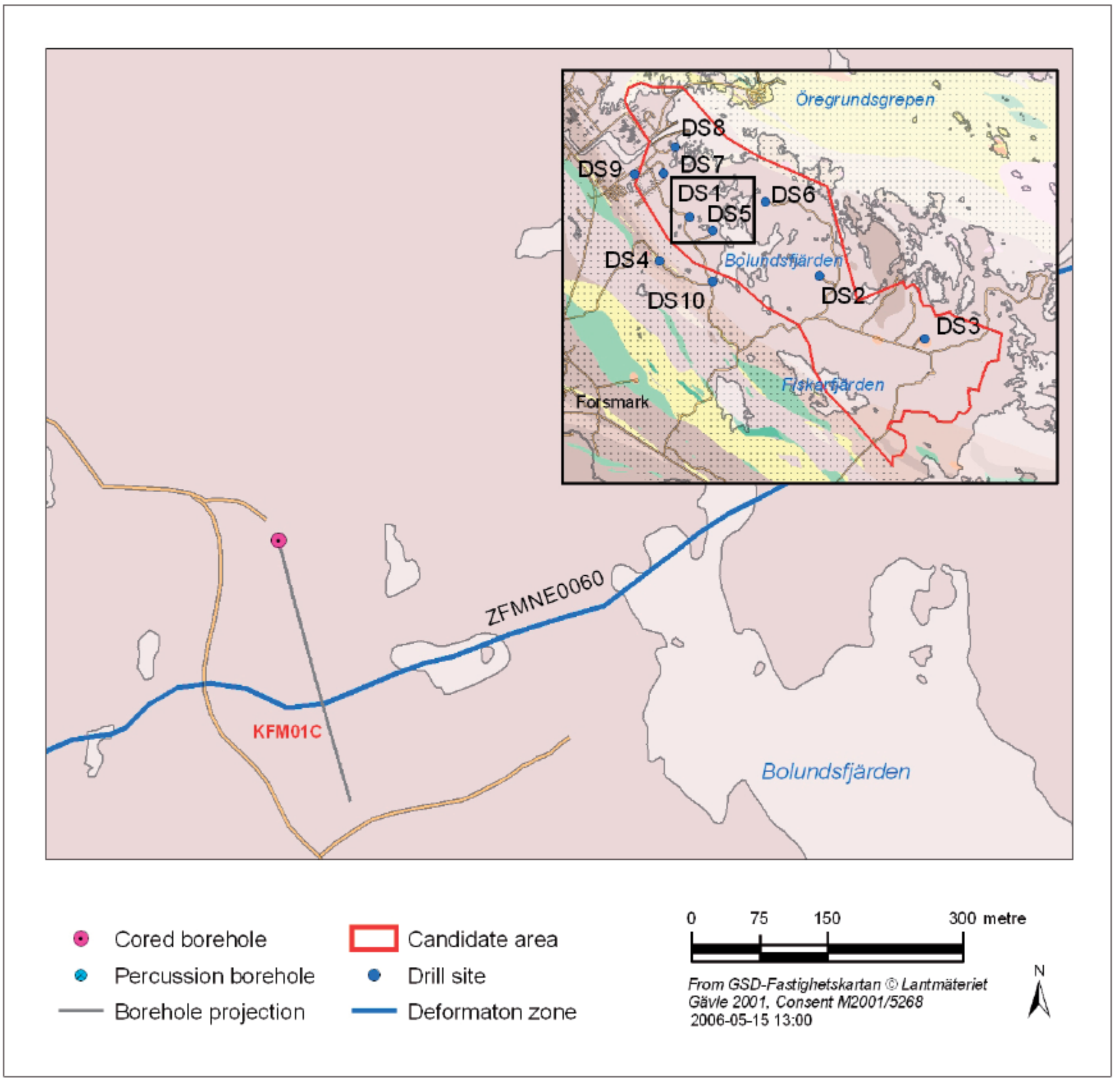

Figure 2-1. *Location of borehole KFM01C, at drill site 1 (DS1).*

3 Equipment

3.1 Description of equipment and interpretation tools

Mapping of BIPS-images and drill core was performed with the software Boremap v. 3.7.5.3. The Boremap software is loaded with the bedrock and mineral standard used for surface mapping at the Forsmark investigation site to enable correlation with the surface geology. The Boremap software calculates actual directions (strike and dip) of planar structures penetrated by the borehole (foliations, fractures, fracture zones, rock contacts etc). Data on inclination, bearing and diameter of the borehole are used as in-data for the calculations (Table 4-2, Appendix 2). The BIPS-image lengths were calibrated (Table 4-1).

Additional software used during mapping is BIPS Image Viewer and MicroSoft Access 2002. The schematic data presentation was made in WellCad v. 4.0.

The following equipment was used to facilitate the core documentation: folding rule, 10% hydrochloric acid, mineral hardness test tool, hand lens, paint brush and a tap water.

3.1.1 BIPS-image quality

The following factors may disturb the mapping:

1) blackish coatings probably related to the drilling equipment,
2) vertical bleached bands from the drill cuttings in suspension,
3) light and dark bands at high angle to the borehole related to the automatic aperture of the video camera,
4) vertical enlargements of pixels due to stick-slip movement of the camera probe.

The BIPS-image quality is listed in Table 3-1.

Table 3-1. BIPS Image Quality.

BIPS-image	From	To	% visible	Comment
1	11.96	81.26	80–90%	Good. Image from lower side of borehole is overexposed.
1	81.26	83.41	70%	Relatively good. As earlier, but also whitish pixels (spotted apperance, possibly due to rough borehole wall surface).
1	83.41	84.31	80–90%	Good. Image from lower side of borehole is overexposed.
1	84.31	86.27	0–5%	Borehole shielded.
1	86.27	94.6	80%	Good. Image from lower side of borehole is overexposed.
1	94.6	208.86	40–80%	Varying quality. Image from lower side of borehole is overexposed. Sporadically brownish coating on borehole wall.
2	208.86	276.30	90–100%	Good. Image from lower side of borehole is overexposed.
3	276.30	299.15	50–70%	Acceptable. Image from lower side of borehole is overexposed.
3	299.15	300.85	0–50%	Poor to very poor. Partly overexposed, clayey material, mosaic image due to stick-slip of the camera.
3	300.85	305.84	80%	Good. Image from lower side of borehole is overexposed.
3	305.84	305.97	0%	No image.
3	305.97	427.16	80–100	Good. Image from lower side of borehole is overexposed. Sporadically mosaic image due to stick-slip of the camera.
3	427.16	435.5	40%	Poor to acceptable. Clayey coating covers 60%.
3	435.50	441.73	0–50%	Very poor. Clayey coating and borehole fluid rich in suspensions.

4 Execution

4.1 General

Boremap mapping of the drill core KFM01C was performed and documented in accordance with the activity plan AP PF 400-05-129 (SKB, internal document) and the method description for Boremap mapping (SKB, MD 143.006, Version 2.0, Metodbeskrivning för Boremap-kartering, SKB, internal controlling document). The mapping was preceded by an overview documentation of the geology in the borehole by Kenneth Åkerström. All observations are made on ocular inspection, since no other data were available.

The mapping was performed between January 17th and May 4th in 2006 by Christin Döse, Eva Samuelsson and Peter Dahlin from Geosigma AB. The last section of the borehole was mapped without BIPS-image (Table 4-2).

4.2 Preparations

Since the borehole length, registered during the BIPS-logging, deviates from the true length of the borehole with increases depth, length adjustments were made. The length of the BIPS-image was adjusted with reference to slots cut into the borehole wall approximately every 50th meter, and with reference to the end of casing (see Table 4-1).

Geometrical data for the borehole is given in Table 4-2. Background data (Appendix 2) collected from SICADA prior to the Boremap mapping included:

- Borehole diameter.
- Reference slots for length adjustments.
- Borehole deviation.

Table 4-1. Length adjustments.

Rec. length (m)	Adj. length (m)	Difference (m)
11.816	11.96	0.144
50.708	51	0.292
99.598	100	0.402
149.516	150	0.484
199.415	200	0.585
251.239	252	0.761
298.095	299	0.905
348.894	350	1.106
398.731	400	1.269

Table 4-2. Borehole data for KFM01C.

Mapping Nr	Interval	Northing	Easting	Bearing (degrees)	Inclination (degrees)	Diameter (mm)	Borehole length (m)	BIPS-image interval (m)	End of casing
1	0–441.73 m	6699526.14	1631403.75	165.4	–49.6	76		11.00–441.73 m	11.96
2	441.73–449.92 m			163.6	–46.0	76	450.02 m	No image	

4.3 Execution of measurements

Concepts used during the core mapping, are defined in this chapter.

4.3.1 Fracture definitions

Definitions of different fracture types and apertures, crush zones and sealed fracture network are found in SKB MD 143.008 (Nomenklatur vid Boremapkartering, internal controlling document).

Two types of fractures are mapped in Boremap; broken and unbroken. Broken fractures are splitting the core, while unbroken fractures do not split the core. All fractures are described including fracture minerals and width, aperture, roughness, etc. Apertures visible in the BIPS-image are measured down to 1 mm. Apertures less than 1 mm, are denoted a value of 0.5 mm. If the aperture is visible in BIPS it is considered certain, otherwise it is considered probable or possible. If the core pieces do not fit well, the aperture is considered "probable". If the core pieces do fit well, but the fracture surfaces are dull or altered, the aperture is considered "possible".

Laumontite in fractures tend to dehydrate when exposed to air. Therefore laumontite-sealed fractures usually break apart in the core box. These fractures are mapped as broken fractures with aperture = 0 when it is certain that the fracture was originally sealed.

4.3.2 Fracture alteration and joint alteration number

Joint alteration number is principally related to the thickness of, and the clay content in a fracture /2/. Fractures > 1 mm thick and rich in clay minerals, are usually given joint alteration numbers between 2 and 4. The majority of the broken fractures are very thin to extremely thin and do seldom contain clay minerals. These fractures receive joint alteration numbers between 1 and 2.

A subdivision of fractures with joint alteration numbers between 1 and 2 was introduced to facilitate both the evaluation process for fracture alterations and the possibility to compare the alterations between different fractures in boreholes. The subdivision is in accordance with the subdivision introduced by Ehrenborg and Steiskal /3/.

4.3.3 Mapping fractures not visible in the BIPS-image

Not all fractures are visible in the BIPS-image. These fractures are oriented using the *guide-line method* /3/, with one modification. The orientation performed in this work is based on the following data:

- Amplitude (measured along the drill core), which is the interval between fracture extremes along the drill core.
- The relation between the rotation of the fracture trace and a well defined structure visible in both drill core and BIPS-image. This rotation is measured with measuring tape on the drill core.
- Absolute depth relative to a well defined structure visible in both drill core and BIPS-image.

Orientation of fractures with the *guide-line method* is performed in the following way: The first step is to delineate the fracture trace in the BIPS-image the right angle to the drill core. The second step is the correction of strike and dip. This is done by rotating the fracture trace in the BIPS-image relative to a feature with known orientation. The fracture trace is then positioned at the correct depth in the BIPS-image in accordance with the depth measured on the drill core.

The *guide-line method* can be used to orient any feature that is not visible in the BIPS-image. It is also a valuable tool to control that the personnel working with the drill core is observing the same feature as the personnel delineating the trace in the BIPS-image, especially in intervals rich in fractures.

The error of orienting fractures using the *guide-line method* is not known but experience and an estimation using stereographic plots indicated that the error is most likely insignificant. Accordingly, the *guide-line method* is so far considered better than mapping lots of non-oriented fractures. The fractures in question are mapped as “non-visible in BIPS” and can therefore be separated from fractures visible in BIPS which probably have a more accurate orientation.

4.3.4 Definition of veins and dikes

A rock sequence that covers less than 1 m of the drill core is mapped as a “rock occurrence” in Boremap. Rock occurrences that cover more than 1 m of the drill core are mapped as *rock type.*

Mainly two different types of rock occurrences are mapped; veins and dikes. These two are separated by their respectively length in the drill core; veins are set to 0–20 cm and dikes are set to 20–100 cm, if evidence for intrusion is visible in the drill core. If a rock occurrence cannot be classified as a vein or a dyke, the occurrence type is mapped as “unspecified”. In Forsmark there are boudinaged veins, xenoliths, blobs etc and the occurrence type is usually difficult to determine from the drill core.

4.3.5 Mineral codes

In cases where properties or minerals are not represented in the mineral list, the following mineral codes have been used in the mapping of KFM01C:

- X1 = bleached fracture walls.
- X2 = interpreted grouting, which is only observed in the borehole wall and hence in the BIPS-image.
- X3 = the drill core is broken at a right angle and the broken surfaces have a polished appearance. This is caused by rotation of two core pieces along an intermediate fracture wearing away possible mineral filling. It is impossible to say whether this fracture was open or sealed in situ.

- X4 = dull fracture surface, no visible fracture mineral.
- X5 = Fresh fracture surface, no detectable fracture mineral.
- X6 = Striated surfaces, probably slickensided.

4.4 Data handling

In order to obtain the best possible data security, the mapping was performed on the SKB network, with regular back-ups on the local drive in accordance with the consultants' quality plan. Each day, a summary report was printed in order to find possible misprints. If misprints were observed, they were corrected before the mapping proceeded. A WellCad-diagram was also plotted every day for the mapped section. When the mapping was completed, data was checked once more for possible misprints. Before exporting data to SICADA, borehole lengths, mapping lengths, deviation data and length adjustments were checked again where after the mapping was checked by a routine in Boremap which detects logical defects. The data are stored in SICADA.

4.5 Nonconformities

According to the quality plan, daily quality controls should be performed in order to observe possible misprints (for a brief description, see Section 4.4 in this report). Signed paper copies of Summary reports and WellCad-diagrams should be stored in a folder and, when finished mapping, be handed over to SKB. Summary reports were not printed on paper in the beginning of the mapping, because of lacking network printer in the mapping hall. Instead quality control was performed by checking the summary report on the computer screen. WellCad-diagrams were not plotted in the beginning of the mapping for the same reason. This quality control was performed in accordance with the quality plan after a network printer was installed to the mapping hall.

5 Results

The Boremap mapping of KFM01C is stored in SICADA and it is only these data that shall be used for further interpretation and modelling. The interpreter should be aware of the assumptions mentioned in Chapter 4.

Results from the Boremap mapping are briefly described in this chapter and the graphical presentation of the data is given in Appendix 1.

5.1 Rock type

The dominant rock type of KFM01C is a foliated metagranite-granodiorite (~ 70%) followed by massive or lineated pegmatite or pegmatitic granite (~ 13%) and foliated amphibolite (~ 7%). Subordinate rock types are fine- to medium-grained metatonalite, granodiorite to granite (~ 4%), fine- to medium grained granites of different ages (~ 3%), felsic- to intermediate metavolcanic rock (~ 1%), quartz-dominated hydrothermal veins (< 1%), calc-silicate rock (< 1%, Figure 5-4) and metagranitoid (< 1%).

5.2 Fractures and crushed sections

3585 unbroken and 1927 broken fractures were documented in KFM01C (11.96–449.92 m). 273 of the unbroken fractures show an aperture, while 436 of the broken fractures are considered artificial and have an aperture = 0. Most of the broken fractures that are considered artificial are filled with laumontite. This result in the following interpreted fracture frequencies, 8.5 sealed fractures/m (sealed network excluded) and 3.4 open fractures/m (crushed sections excluded).

5.2.1 Sealed fractures and fracture networks

Borehole sections with high frequency of sealed fractures are common in KFM01C (Appendix 1). The following borehole sections are worth to mention: 29–48 m, 64–88 m, 96–99 m, 118–126 m, 233–392 m (233–343 m with increased fracture intensity) and 402–411 m. The interval 233–392 m with increased frequency of sealed fractures is characterized by laumontite-calcite fracture mineral filling usually associated with oxidized walls and occasionally also by laumontization. The laumontite is probably flushed away in some fractures during drilling, which is seen on the BIPS-image of the borehole wall, while the fractures in the drill core are intact, containing laumontite filling (Figure 5-1).

5.2.2 Open fractures and crush

Sections with high frequencies of open fractures occur at 33–44 m, 78–90 m, 119–122 m and 156–158 m. The intervals with increased frequency of open fractures are also associated with wide to moderately wide apertures (0.5–10 mm). In the borehole interval 33–44 m, many sealed fractures have voids. Some of these voids may be artificial and may be a result of flushing away their clay filling during drilling. The open fractures in the upper 100 m of

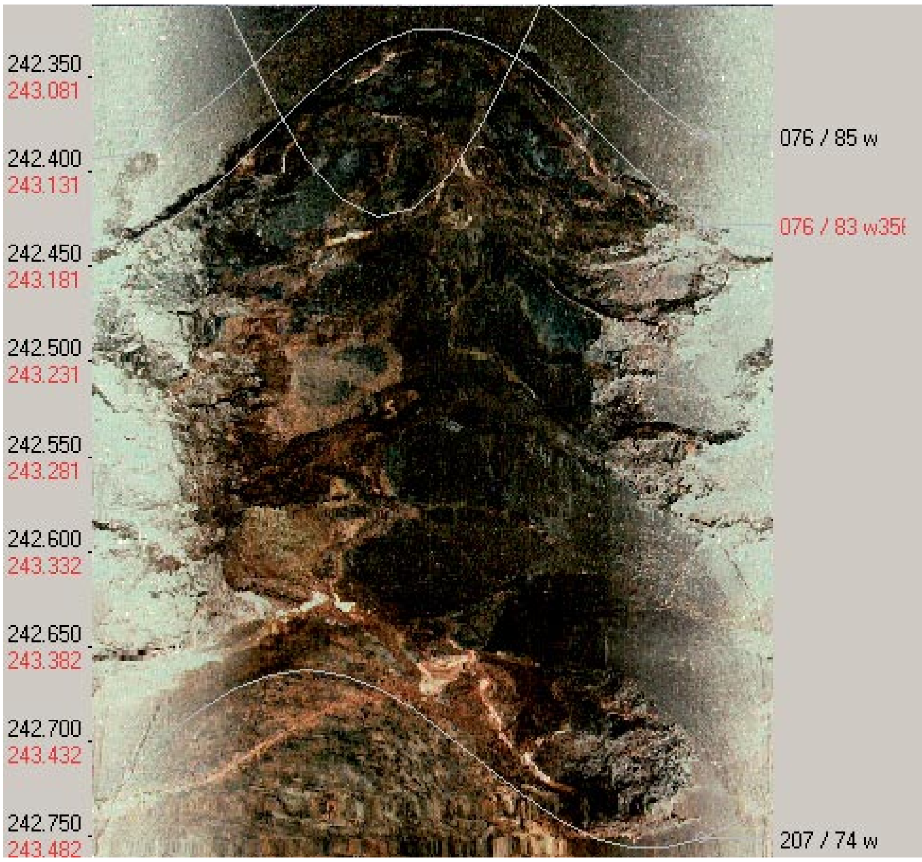

Figure 5-1. *Laumontite that has flushed away in the borehole wall during drilling, resulting in a crushed appearance in the BIPS-image despite a whole drill core.*

the borehole are more commonly horizontal to gently dipping, relative to the fractures in the lower part of the borehole. They are also characterized by fillings of clay minerals, hematite and asphaltite.

Four sub-horizontal crushed sections are associated with borehole sections with high frequency of open fractures. They occur at 40.47–40.58 m, 40.99–41.02 m, 43.05–43.60 m and 84.38–86.10 m. The exact width and orientation of the last borehole section is uncertain, since the borehole has been covered by a Plex-sheet and therefore very little from this borehole section can be observed in the BIPS-image. Signs of an earlier brittle-ductile deformation can also be observed in the last crushed borehole section. The fracture surfaces in the crushed sections are rough and slightly altered with the exception of the borehole interval 40.99–41.02 m, which show smooth fracture surfaces. The fracture minerals in the crushed sections are mostly clay minerals, but also hematite, asphaltite and chlorite are observed. The mineralogy in the crushed sections is equivalent to the mineralogy in other broken fractures in the upper 100 m of the borehole.

Possible outflow from open fractures are observed at 79.04 m, 110.75 m and 172.65 m. The fractures are sub-horizontal, except for the last one which is almost vertical striking 253°.

5.3 Brittle to ductile deformation

The rock types in borehole KFM01C show commonly weak to moderate foliation. The foliation is undulating in the borehole striking mostly SSE with a moderate to steep dip (see Appendix 1).

Very thin deformation bands occur in the borehole. They are principally brittle, i.e. breccias, cataclasites or brittle-ductile shear zones concentrated to the most intensely fractured part of the borehole, between 230 and 420 m (Figure 5-2 and 5-3). Common orientation is usually ~ 235°/80°, as the interval 29–48 m, which is also rich in sealed fractures, where thin cataclasites strike ~ 240° /70°.

Figure 5-2. *Laumontite-sealed breccia, KFM01C, probably the one at 33.60 m borehole length.*

Figure 5-3. *Cataclasite with cutting calcite-laumontite sealed fracture in KFM01C, 36.83 m borehole length.*

5.4 Alteration

The rock intersected by KFM01C is weakly to moderately oxidized down to approximately 100 m borehole legth, and weakly to faintly oxidized in the interval 120–209 m (Appendix 1). In the lower part of the borehole oxidation is usually only occurring as thin rims around fractures and sealed fracture networks.

Albitization occur in shorter sections throughout the borehole, usually in the contacts to amphibolitic dykes /5/.

The occurrences of mostly weak epidotisation are observed in the following borehole section: 30–40 m, 96–123 m, 239–242 m and 408–422 m, of which the first section also is related to an interval with increased frequency of sealed fractures, and the second section to silicification. Sporadic short intervals with chloritization co-inside with sections with increased fracture frequency in the upper 100 m of the borehole. Argillization is related to intervals rich in clay-filled fractures.

Laumontization is related to the highly fractured borehole interval between ca. 230–420 m, and is most frequent in the interval 237–247 m. Interpreted saussuritization occurs sporadically in the borehole interval 279–362 m.

__Figure 5-4.__ Reactivated skarn alteration in KFM01C, 113.98–114.02 m.

5.5 Disclaims

5.5.1 Core loss and Plex-sheet

The borehole section 84.31–86.27 m, was stabilised with Plex-sheet. The extent and orientation of the crushed section is therefore uncertain, as well as the core loss at 84.50–85.88 m and at 86.17–86.18 m.

Core loss is also observed in the intervals 241.31–241.35 m, 263.76–263.80 m and 292.35–292.45 m.

5.5.2 Overrepresented fracture mineral

The frequency of calcite in fractures is *overrepresented* relative to other minerals, since it is detected by reaction with diluted hydrochloric acid even though it is macroscopically invisible.

5.5.3 Fracture roughness and surface

The estimation of roughness of fractures in this work diverges rather much from the mappings by SwedPower. For example: Geosigma considers over half of the fractures as undulating, while the rest are stepped, planar and irregular. The proportion of planar, undulating, stepped and irregular fractures in the mappings of SwedPower is different. This is due to the personal interpretation of the definitions of fractures /4/, since the definitions are made for another scale, i.e. tunnels and excavations, and not for boreholes. Work has been started to synchronize the mapping teams.

Only very few slickensided fracture surfaces have been mapped. Instead striated surfaces (X6) has been documented in the mineral column. The term striated surfaces was used because it was uncertain whether the rock mechanics use the term slickensided in the same sense as geologists.

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WellCad diagram of KFM01C

Title LEGEND FOR FORSMARK KFM01C

SKB

Site FORSMARK
Borehole KFM01C
Plot Date 2006-06-14 21:12:07
Signed data

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

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

MINERAL
- Biotite
- Epidote
- White Feldspar
- Hematite
- Calcite
- Chlorite
- Quartz
- Unknown
- Pyrite
- Clay Minerals
- Laumontite
- Zeolite
- Prehnite
- Asphalt
- Iron Hydroxide
- Oxidized Walls

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

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

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

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

ROCK ALTERATION INTENSITY
- No intensity
- Faint
- Weak
- Medium
- Strong

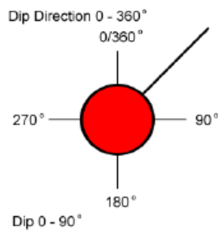
ROUGHNESS
- Planar
- Undulating
- Stepped
- Irregular

SURFACE
- Rough
- Smooth
- Slickensided

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

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

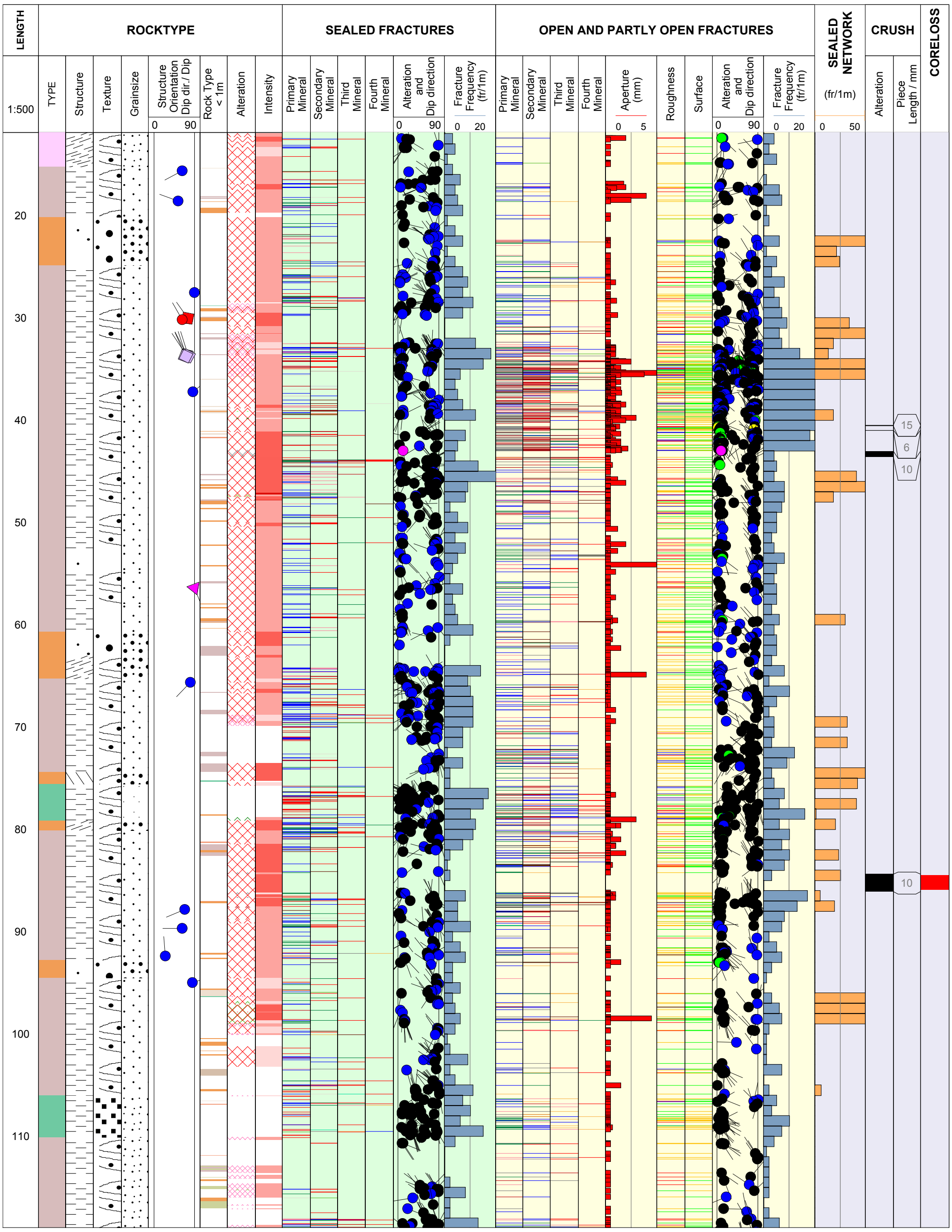
FRACTURE DIRECTION
STRUKTURE ORIENTATION



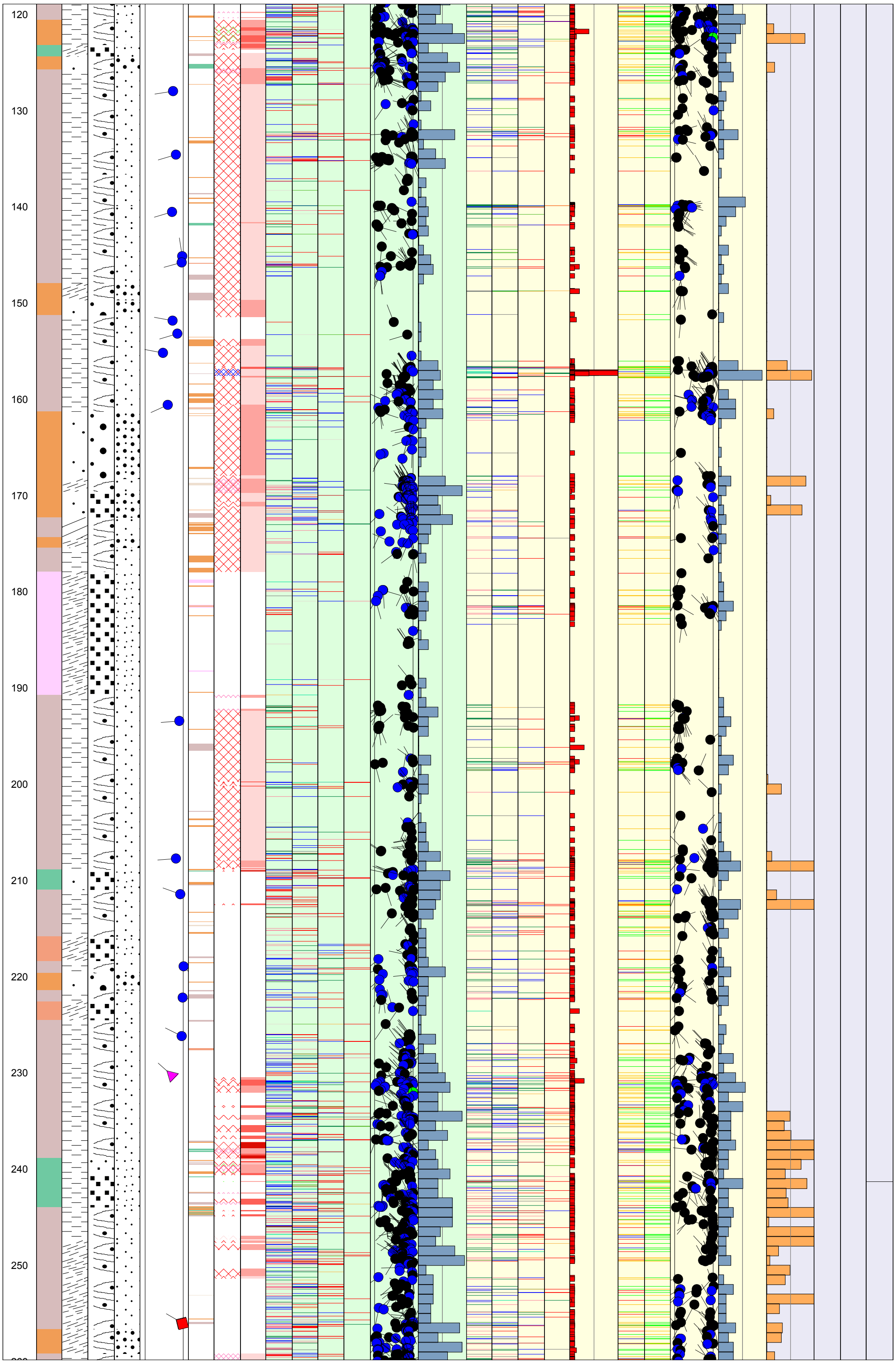
Page 1

Title GEOLOGY IN KFM01C **Appendix:**

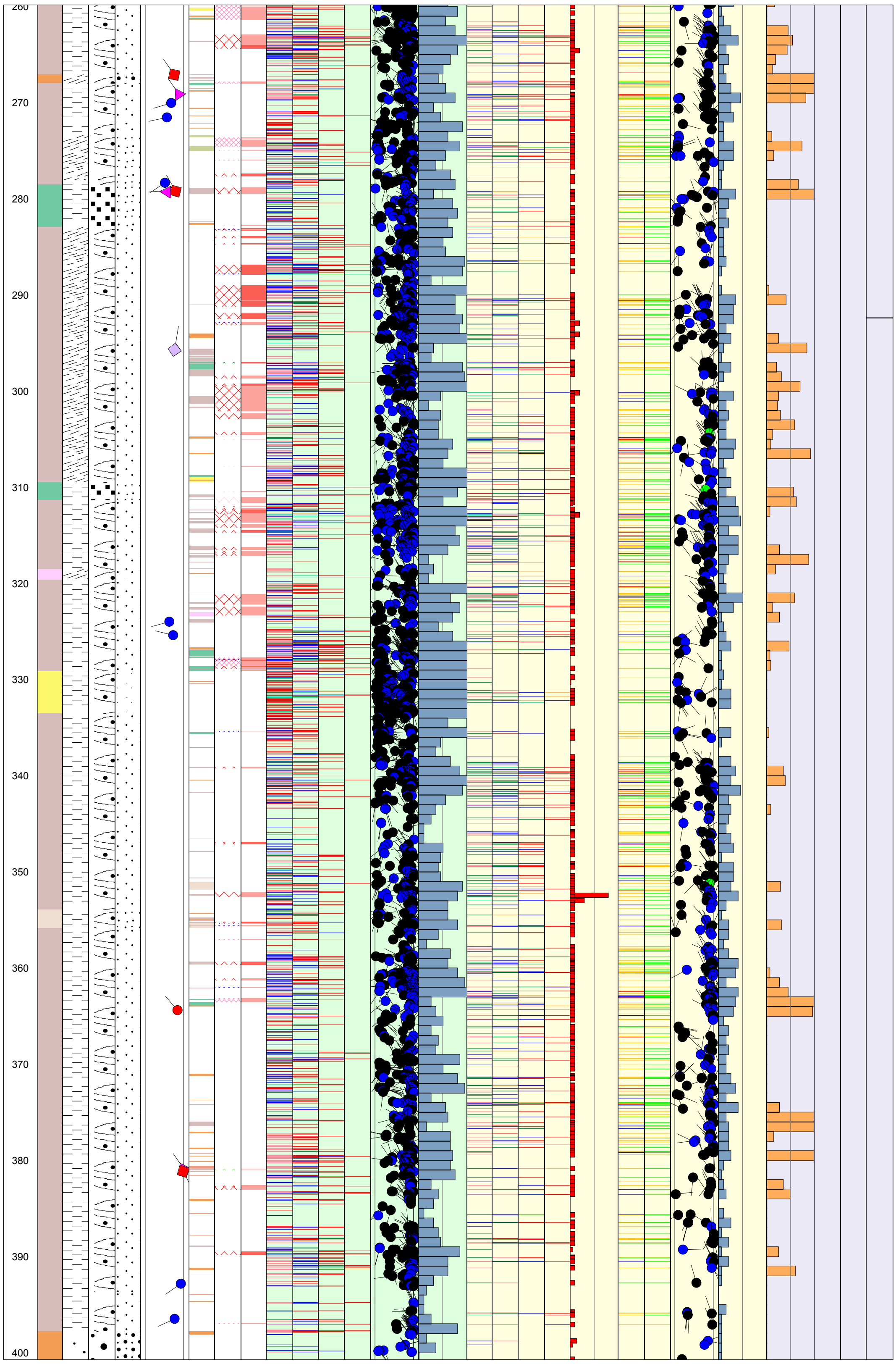
Site	FORSMARK	**Coordinate System**	RT90-RHB70
Borehole	KFM01C	**Northing [m]**	6699526.14
Diameter [mm]	76	**Easting [m]**	1631403.75
Length [m]	450.020	**Elevation [m.a.s.l.]**	2.91
Bearing [°]	165.35	**Drilling Start Date**	2005-11-05 13:56:00
Inclination [°]	-49.60	**Drilling Stop Date**	2005-11-29 13:52:00
Date of coremapping	2006-01-17 10:57:00	**Plot Date**	2006-06-14 21:12:07
Rocktype data from	p_rock	**Signed data**	



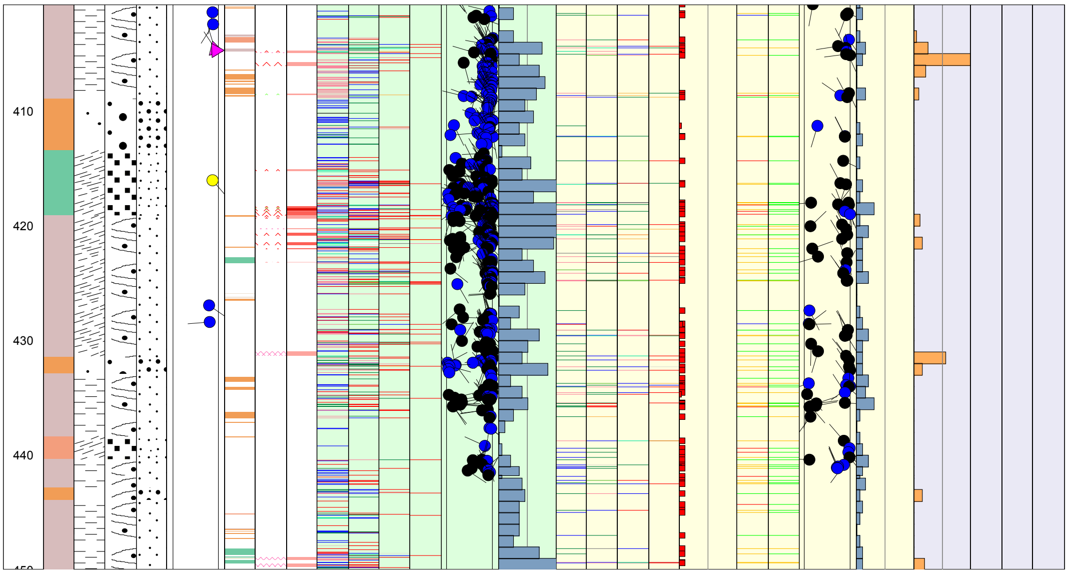
Page 1



Page 2



Page 3



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Appendix 2

Indata: Length reference marks, borehole diameter and borehole length

Reference Mark T – Reference mark in drillhole

KFM01C, 2005-11-24 10:00:00–2005-11-24 18:30:00 (51.000–400.000 m)

Bhlen (m)	Rotation Speed (rpm)	Start Flow (l/min)	Stop Flow (l/min)	Stop Pressure (bar)	Cutter Time (s)	Trace Detectable	Cutter Diameter (mm)	Comment
51.00	400.00	300	450	28.0	45	JA		51,30/51,40
100.00	400.00	300	440	25.0	20	JA		100,55/100,65
150.00	400.00	300	440	25.0	40	JA		150,81/150,91
200.00	400.00	300	440	25.0	35	JA		201,02/201,12
252.00	400.00	300	440	25.0	40	JA		252,91/253,01
299.00	400.00	300	440	25.0	40	JA		300,14/300,24
350.00	400.00	300	440	25.0	40	JA		341,40/241,50
400.00	400.00	300	440	25.0	35	JA		401,63/401,73

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Hole Diam T – Drilling: Borehole diameter

KFM01C, 2005-11-05 13:56:00–2005-11-29 13:52:00 (0.000–450.020 m)

Sub Secup (m)	Sub Seclow (m)	Hole Diam (m)	Comment
6.150	11.960	0.0920	
11.960	450.020	0.0758	

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Maxibor T – Borehole deviation: Maxibor

KFM01C, 2006-04-26 00:00:00 (0.000–447.000 m)

Length (m)	Northing (m)	Easting (m)	Elevation (m)	Coord System	Inclination (degrees)	Bearing (degrees)	Local A (m)	Local B (m)	Local C (m)	Extrapol Flag
0.00	6699526.14	1631403.75	–2.91	RT90-RHB70	–49.61	165.35				
3.00	6699524.26	1631404.24	–0.62	RT90-RHB70	–49.61	165.35				
6.00	6699522.38	1631404.73	1.66	RT90-RHB70	–49.62	165.35				
9.00	6699520.50	1631405.22	3.95	RT90-RHB70	–49.59	165.39				
12.00	6699518.62	1631405.71	6.23	RT90-RHB70	–49.58	165.36				
15.00	6699516.74	1631406.20	8.52	RT90-RHB70	–49.59	165.34				
18.00	6699514.85	1631406.70	10.80	RT90-RHB70	–49.56	165.37				
21.00	6699512.97	1631407.19	13.08	RT90-RHB70	–49.51	165.39				
24.00	6699511.09	1631407.68	15.37	RT90-RHB70	–49.48	165.38				
27.00	6699509.20	1631408.17	17.65	RT90-RHB70	–49.46	165.35				

Length (m)	Northing (m)	Easting (m)	Elevation (m)	Coord System	Inclination (degrees)	Bearing (degrees)	Local A (m)	Local B (m)	Local C (m)	Extrapol Flag
30.00	6699507.31	1631408.66	19.93	RT90-RHB70	–49.46	165.33				
33.00	6699505.43	1631409.16	22.21	RT90-RHB70	–49.45	165.34				
36.00	6699503.54	1631409.65	24.49	RT90-RHB70	–49.38	165.38				
39.00	6699501.65	1631410.14	26.76	RT90-RHB70	–49.27	165.45				
42.00	6699499.76	1631410.64	29.04	RT90-RHB70	–49.21	165.50				
45.00	6699497.86	1631411.13	31.31	RT90-RHB70	–49.19	165.48				
48.00	6699495.96	1631411.62	33.58	RT90-RHB70	–49.19	165.49				
51.00	6699494.06	1631412.11	35.85	RT90-RHB70	–49.19	165.55				
54.00	6699492.16	1631412.60	38.12	RT90-RHB70	–49.17	165.59				
57.00	6699490.26	1631413.09	40.39	RT90-RHB70	–49.15	165.59				
60.00	6699488.36	1631413.58	42.66	RT90-RHB70	–49.13	165.57				
63.00	6699486.46	1631414.06	44.93	RT90-RHB70	–49.13	165.58				
66.00	6699484.56	1631414.55	47.20	RT90-RHB70	–49.12	165.72				
69.00	6699482.66	1631415.04	49.47	RT90-RHB70	–49.10	165.87				
72.00	6699480.75	1631415.52	51.73	RT90-RHB70	–49.15	165.87				
75.00	6699478.85	1631416.00	54.00	RT90-RHB70	–49.12	165.82				
78.00	6699476.95	1631416.48	56.27	RT90-RHB70	–49.09	165.76				
81.00	6699475.04	1631416.96	58.54	RT90-RHB70	–49.13	165.68				
84.00	6699473.14	1631417.45	60.81	RT90-RHB70	–49.16	165.64				
87.00	6699471.24	1631417.93	63.08	RT90-RHB70	–49.13	165.62				
90.00	6699469.34	1631418.42	65.34	RT90-RHB70	–49.08	165.54				
93.00	6699467.44	1631418.91	67.61	RT90-RHB70	–49.09	165.30				
96.00	6699465.54	1631419.41	69.88	RT90-RHB70	–49.09	165.18				
99.00	6699463.64	1631419.91	72.14	RT90-RHB70	–49.05	165.08				
102.00	6699461.74	1631420.42	74.41	RT90-RHB70	–49.03	164.96				
105.00	6699459.84	1631420.93	76.68	RT90-RHB70	–49.05	164.76				
108.00	6699457.94	1631421.45	78.94	RT90-RHB70	–49.03	164.58				
111.00	6699456.04	1631421.97	81.21	RT90-RHB70	–48.97	164.54				
114.00	6699454.15	1631422.49	83.47	RT90-RHB70	–48.92	164.58				
117.00	6699452.25	1631423.02	85.73	RT90-RHB70	–48.88	164.64				
120.00	6699450.34	1631423.54	87.99	RT90-RHB70	–48.93	164.66				
123.00	6699448.44	1631424.06	90.25	RT90-RHB70	–49.01	164.71				
126.00	6699446.54	1631424.58	92.52	RT90-RHB70	–48.98	164.75				
129.00	6699444.64	1631425.10	94.78	RT90-RHB70	–48.96	164.78				
132.00	6699442.74	1631425.62	97.04	RT90-RHB70	–48.95	164.80				
135.00	6699440.84	1631426.13	99.31	RT90-RHB70	–48.95	164.81				
138.00	6699438.94	1631426.65	101.57	RT90-RHB70	–48.97	164.79				
141.00	6699437.04	1631427.17	103.83	RT90-RHB70	–49.00	164.82				
144.00	6699435.14	1631427.68	106.10	RT90-RHB70	–49.02	164.85				
147.00	6699433.24	1631428.19	108.36	RT90-RHB70	–49.03	164.83				
150.00	6699431.34	1631428.71	110.63	RT90-RHB70	–49.03	164.80				
153.00	6699429.45	1631429.23	112.89	RT90-RHB70	–49.05	164.79				
156.00	6699427.55	1631429.74	115.16	RT90-RHB70	–49.07	164.82				
159.00	6699425.65	1631430.25	117.42	RT90-RHB70	–49.07	164.82				
162.00	6699423.75	1631430.77	119.69	RT90-RHB70	–49.07	164.80				
165.00	6699421.86	1631431.28	121.96	RT90-RHB70	–49.07	164.82				
168.00	6699419.96	1631431.80	124.22	RT90-RHB70	–49.05	164.81				
171.00	6699418.06	1631432.31	126.49	RT90-RHB70	–49.02	164.75				
174.00	6699416.17	1631432.83	128.75	RT90-RHB70	–48.98	164.72				
177.00	6699414.27	1631433.35	131.02	RT90-RHB70	–48.92	164.72				

Length (m)	Northing (m)	Easting (m)	Elevation (m)	Coord System	Inclination (degrees)	Bearing (degrees)	Local A (m)	Local B (m)	Local C (m)	Extrapol Flag
180.00	6699412.37	1631433.87	133.28	RT90-RHB70	–48.88	164.68				
183.00	6699410.46	1631434.39	135.54	RT90-RHB70	–48.85	164.63				
186.00	6699408.56	1631434.92	137.80	RT90-RHB70	–48.82	164.59				
189.00	6699406.66	1631435.44	140.06	RT90-RHB70	–48.77	164.56				
192.00	6699404.75	1631435.97	142.31	RT90-RHB70	–48.73	164.54				
195.00	6699402.84	1631436.50	144.57	RT90-RHB70	–48.70	164.54				
198.00	6699400.93	1631437.02	146.82	RT90-RHB70	–48.67	164.53				
201.00	6699399.02	1631437.55	149.07	RT90-RHB70	–48.66	164.50				
204.00	6699397.11	1631438.08	151.33	RT90-RHB70	–48.65	164.48				
207.00	6699395.21	1631438.61	153.58	RT90-RHB70	–48.63	164.46				
210.00	6699393.29	1631439.14	155.83	RT90-RHB70	–48.61	164.43				
213.00	6699391.38	1631439.67	158.08	RT90-RHB70	–48.59	164.41				
216.00	6699389.47	1631440.21	160.33	RT90-RHB70	–48.54	164.40				
219.00	6699387.56	1631440.74	162.58	RT90-RHB70	–48.48	164.40				
222.00	6699385.64	1631441.28	164.82	RT90-RHB70	–48.43	164.37				
225.00	6699383.73	1631441.81	167.07	RT90-RHB70	–48.39	164.36				
228.00	6699381.81	1631442.35	169.31	RT90-RHB70	–48.35	164.38				
231.00	6699379.89	1631442.89	171.55	RT90-RHB70	–48.33	164.40				
234.00	6699377.97	1631443.42	173.79	RT90-RHB70	–48.30	164.39				
237.00	6699376.04	1631443.96	176.04	RT90-RHB70	–48.30	164.37				
240.00	6699374.12	1631444.50	178.27	RT90-RHB70	–48.31	164.38				
243.00	6699372.20	1631445.03	180.51	RT90-RHB70	–48.31	164.40				
246.00	6699370.28	1631445.57	182.76	RT90-RHB70	–48.29	164.40				
249.00	6699368.36	1631446.11	184.99	RT90-RHB70	–48.27	164.39				
252.00	6699366.43	1631446.65	187.23	RT90-RHB70	–48.22	164.42				
255.00	6699364.51	1631447.18	189.47	RT90-RHB70	–48.15	164.45				
258.00	6699362.58	1631447.72	191.71	RT90-RHB70	–48.10	164.44				
261.00	6699360.65	1631448.26	193.94	RT90-RHB70	–48.06	164.43				
264.00	6699358.72	1631448.79	196.17	RT90-RHB70	–48.05	164.46				
267.00	6699356.79	1631449.33	198.40	RT90-RHB70	–48.04	164.51				
270.00	6699354.85	1631449.87	200.63	RT90-RHB70	–48.02	164.57				
273.00	6699352.92	1631450.40	202.86	RT90-RHB70	–48.02	164.59				
276.00	6699350.99	1631450.93	205.09	RT90-RHB70	–48.05	164.57				
279.00	6699349.05	1631451.47	207.32	RT90-RHB70	–48.05	164.53				
282.00	6699347.12	1631452.00	209.55	RT90-RHB70	–48.03	164.52				
285.00	6699345.18	1631452.54	211.78	RT90-RHB70	–48.00	164.53				
288.00	6699343.25	1631453.07	214.01	RT90-RHB70	–47.97	164.50				
291.00	6699341.32	1631453.61	216.24	RT90-RHB70	–47.96	164.46				
294.00	6699339.38	1631454.15	218.47	RT90-RHB70	–47.98	164.42				
297.00	6699337.45	1631454.69	220.70	RT90-RHB70	–47.95	164.42				
300.00	6699335.51	1631455.23	222.93	RT90-RHB70	–47.92	164.42				
303.00	6699333.57	1631455.77	225.15	RT90-RHB70	–47.88	164.41				
306.00	6699331.63	1631456.31	227.38	RT90-RHB70	–47.81	164.40				
309.00	6699329.70	1631456.85	229.60	RT90-RHB70	–47.79	164.36				
312.00	6699327.75	1631457.39	231.82	RT90-RHB70	–47.76	164.34				
315.00	6699325.81	1631457.94	234.04	RT90-RHB70	–47.72	164.33				
318.00	6699323.87	1631458.48	236.26	RT90-RHB70	–47.67	164.32				
321.00	6699321.92	1631459.03	238.48	RT90-RHB70	–47.63	164.28				
324.00	6699319.98	1631459.58	240.70	RT90-RHB70	–47.61	164.26				
327.00	6699318.03	1631460.13	242.91	RT90-RHB70	–47.59	164.29				

Length (m)	Northing (m)	Easting (m)	Elevation (m)	Coord System	Inclination (degrees)	Bearing (degrees)	Local A (m)	Local B (m)	Local C (m)	Extrapol Flag
330.00	6699316.08	1631460.67	245.13	RT90-RHB70	–47.55	164.26				
333.00	6699314.13	1631461.22	247.34	RT90-RHB70	–47.51	164.26				
336.00	6699312.18	1631461.77	249.56	RT90-RHB70	–47.48	164.27				
339.00	6699310.23	1631462.32	251.77	RT90-RHB70	–47.43	164.28				
342.00	6699308.28	1631462.87	253.98	RT90-RHB70	–47.39	164.28				
345.00	6699306.32	1631463.42	256.18	RT90-RHB70	–47.36	164.26				
348.00	6699304.37	1631463.97	258.39	RT90-RHB70	–47.34	164.24				
351.00	6699302.41	1631464.52	260.60	RT90-RHB70	–47.31	164.22				
354.00	6699300.45	1631465.08	262.80	RT90-RHB70	–47.27	164.19				
357.00	6699298.50	1631465.63	265.01	RT90-RHB70	–47.22	164.18				
360.00	6699296.54	1631466.19	267.21	RT90-RHB70	–47.16	164.18				
363.00	6699294.57	1631466.74	269.41	RT90-RHB70	–47.09	164.16				
366.00	6699292.61	1631467.30	271.60	RT90-RHB70	–47.00	164.14				
369.00	6699290.64	1631467.86	273.80	RT90-RHB70	–46.91	164.10				
372.00	6699288.67	1631468.42	275.99	RT90-RHB70	–46.81	164.09				
375.00	6699286.69	1631468.99	278.18	RT90-RHB70	–46.73	164.08				
378.00	6699284.72	1631469.55	280.36	RT90-RHB70	–46.66	164.08				
381.00	6699282.74	1631470.11	282.54	RT90-RHB70	–46.60	164.09				
384.00	6699280.75	1631470.68	284.72	RT90-RHB70	–46.56	164.07				
387.00	6699278.77	1631471.25	286.90	RT90-RHB70	–46.52	164.04				
390.00	6699276.79	1631471.81	289.08	RT90-RHB70	–46.46	163.99				
393.00	6699274.80	1631472.38	291.25	RT90-RHB70	–46.38	163.96				
396.00	6699272.81	1631472.96	293.42	RT90-RHB70	–46.27	163.92				
399.00	6699270.82	1631473.53	295.59	RT90-RHB70	–46.16	163.89				
402.00	6699268.82	1631474.11	297.76	RT90-RHB70	–46.08	163.85				
405.00	6699266.82	1631474.69	299.92	RT90-RHB70	–46.02	163.83				
408.00	6699264.82	1631475.26	302.07	RT90-RHB70	–46.01	163.82				
411.00	6699262.82	1631475.85	304.23	RT90-RHB70	–46.01	163.80				
414.00	6699260.82	1631476.43	306.39	RT90-RHB70	–46.02	163.79				
417.00	6699258.82	1631477.01	308.55	RT90-RHB70	–46.01	163.78				
420.00	6699256.82	1631477.59	310.71	RT90-RHB70	–45.99	163.75				
423.00	6699254.82	1631478.17	312.87	RT90-RHB70	–45.97	163.71				
426.00	6699252.82	1631478.76	315.02	RT90-RHB70	–45.95	163.69				
429.00	6699250.81	1631479.35	317.18	RT90-RHB70	–45.94	163.66				
432.00	6699248.81	1631479.93	319.34	RT90-RHB70	–45.93	163.64				
435.00	6699246.81	1631480.52	321.49	RT90-RHB70	–45.94	163.62				
438.00	6699244.81	1631481.11	323.65	RT90-RHB70	–45.94	163.60				
441.00	6699242.81	1631481.70	325.80	RT90-RHB70	–45.95	163.61				
447.00	6699238.80	1631482.87	330.12	RT90-RHB70	–45.96	163.61				

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