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August 2006

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Abstract

This report presents the results from the Boremap logging of telescopic drilled borehole KFM01D. The borehole was drilled at drill site 1, in the western part of the candidate area at Forsmark, with 55° inclination towards NE. The main purpose for the location of this borehole was to provide geological data for the rock mass in central part of a potential repository, as well as to investigate the suggested existence of two brittle deformation zones. The full length of KFM01D is 800.24 metres. The BIPS-image usable for mapping covers the interval 91.61–798.64 metres after length adjustment. The lowermost 1.5 metres of the drill core were mapped in Boremap without any complementary BIPS-image. All intersected structures and lithologies have been documented in detail by integrating information from the drill core and the BIPS-image.

KFM01D is dominated by a metagranite, which locally is slightly granodioritic. In addition to the typical, medium-grained variety, found elsewhere in the area, there is a more or less continuous interval of a fine- to finely medium-grained variety between 191.2 and 499.8 metres (adjusted length) in KFM01D. The metagranite have been affected by intense static recrystallization in the interval from about 424.2 to 511.5 metres (adjusted length). The recrystallization has locally rendered recognition of the metagranite varieties difficult. Another important component is pegmatitic granite, which constitutes about one fifth of the mapped borehole interval. Other rock units in KFM01D, none of which forming occurrences that exceed a few metres in borehole length, include fine- to medium-grained metagranitoids of granitic to granodioritic composition, amphibolites and a fine-grained, intermediate rock of inferred volcanic origin. Virtually all rocks in the borehole have experienced Svecofennian metamorphism under amphibolite facies conditions.

Most rocks in KFM01D are characterized by composite L-S fabrics. The predominant component varies throughout the borehole. Totally 18 narrow zones of more intense ductile and brittle-ductile deformation have been registered in the borehole. The majority of the shear zones in KFM01D are moderately dipping and strikes roughly between ESE and SSE (i.e. more or less parallel with the local tectonic foliation).

The total number of fractures registered *outside crush zones and sealed networks* during the Boremap-logging of KFM01D amounts to 1,635. Of these are 431 open, 37 partly open and 1,167 sealed. In addition, there are 18 sealed networks and five breccias (or brecciated intervals, rather) registered in the mapped interval. The total length of all sealed networks in KFM01D amount to 2.3 metres. Chlorite and calcite are the most frequent fracture filling minerals within KFM01D. A typical mineral assemblage, commonly found in fractures inferred to be sealed, consists of adularia together with calcite, chlorite, and locally hematite and quartz. Another, less common, but yet characteristic assemblage, mainly found in the sealed fractures, is laumontite + calcite + chlorite ± quartz. Clay minerals are more or less restricted to open fractures. Pyrite and hematite occur both in sealed and open fractures.

Sammanfattning

Föreliggande rapport redovisar resultaten från Boremapkarteringen av kärnborrhål KFM01D. Borrhålet är beläget vid borrplats 1, i västra delen av kandidatområde Forsmark och stupar 55° mot NO. De huvudsakliga syftena med borrhålets placering var att ge geologiska data för bergvolymen i de centrala delarna av ett potentiellt djupförvar, samt att undersöka den eventuella existensen av två spröda deformationszoner. Den totala längden av KFM01D är 800,24 meter och den BIPS-bild som är användbar för kartering täcker intervallet 91,61–798,64 meter, efter längdjustering. De understa metrarna av borrhålet är karterade med Boremap utan kompletterande BIPS-bild. Alla strukturer och litologier i det Boremapkarterade intervallet har dokumenterats i detalj genom att integrera information från borrkärnorna och BIPS-bilderna.

KFM01D domineras av en metagranit som ställvis är svagt granodioritisk. Utöver den normalt förekommande medelkorniga varianten, finns ett mer eller mindre kontinuerligt intervall av en fin- till fint medelkornig variant mellan 191,2 och 499,8 meters längd (justerad) i KFM01D. Metagraniten har genomgått en intensiv statisk rekristallisation från ungefär 424,2 till 511,5 meters längd (justerad). Lokalt gör rekristallisationen det svårt att urskilja ursprungsvarianten av metagranit. En annan betydelsefull komponent är pegmatitisk granit, vilken utgör ungefär en femtedel av det karterade borrhålsintervallet. Andra bergartsenheter i KFM01D, av vilka inga överskrider ett fåtal meter i borrhålslängd, omfattar fin- till medelkorniga metagranitoider av granitisk till granodioritisk sammansättning, amfiboliter och en finkornig, intermediär bergart av förmodat vulkaniskt ursprung. Största delen av berggrunden i området har genomgått Svekofennisk amfibolitfacies-metamorfos.

Flertalet bergarter i KFM01D karaktäriseras av en sammansatt L-S struktur. Den förhärskande komponenten varierar längs borrhålet. Totalt 18 mindre zoner med plastisk och spröd-plastisk deformation har registrerats i borrhålet. Flertalet skjuvzoner i KFM01D stupar måttligt och stryker ungefär mellan OSO och SSO (dvs mer eller mindre parallellt med den lokala tektoniska foliationen).

Det totala antalet sprickor som registrerats och *inte ingår i krosszoner eller läkta spricknätverk* vid Boremapkarteringen av KFM01D uppgår till 1 635. Av dessa är 431 öppna, 37 partiellt öppna och 1 167 läkta. Dessutom har 18 läkta spricknätverk och fem breccior (eller breccierade intervall) registrerats i det karterade intervallet. Den totala längden av de läkta spricknätverken uppgår till 2,3 meter. Klorit och kalcit är de överlägset vanligaste sprickmineralen i KFM01D. En typisk mineralassociation, som vanligtvis uppträder i sprickor som bedömts vara läkta, utgörs av adularia tillsammans med kalcit och klorit, samt lokalt hematit och kvarts. En mindre vanlig, men likväl karaktäristisk mineralassociation, som huvudsakligen uppträder i läkta sprickor, är laumontit + kalcit + klorit ± kvarts. Lermineral är till största delen är begränsade till öppna sprickor. Pyrit och hematit är vanligt förekommande både i läkta och öppna sprickor.

Contents

1 Introduction

Since 2002, SKB investigates two potential sites at Forsmark and Oskarshamn, for a deep repository for spent nuclear fuel in the Swedish Precambrian basement. In order to characterise the bedrock down to a depth of about 1 km in the central part of the candidate area at Forsmark, three deep, sub-vertical boreholes were drilled. After completion of these initial drillings, SKB launched a more extensive, complementary drilling programme, aiming to solve more specific geological issues. An important aspect is to provide geological data for the rock mass in central part of a potential repository. Another aspect is to investigate the existence of brittle deformation zones that have been modelled on the basis of seismic reflectors and borehole data. To validate two such zones, ZFMNE00A2 and ZFMNE0061 cf. /SKB 2005/, borehole KFM01D was drilled at drill site 1, in the western part of the candidate area at Forsmark, with 55° inclination towards NE (035°) (Figure 1-1). The borehole has a total length of about 800 metres.

The drilling activities in KFM01D were finished 18 February 2006, and the geological logging of the borehole started 28 March and ended 18 May 2006.

A detailed geological logging of the drill cores obtained through the drilling programs is essential for subsequent sampling and borehole investigations, and consequently, for the three-dimensional modelling of the site geology. For this purpose, the so-called Boremap system has been developed. The system integrates results from geological drill core logging, or alternatively, the drill cuttings, when a core is not available, with information from BIPS-logging (Borehole Image Processing System) and calculates the absolute position and orientation of fractures and various planar lithological features (SKB MD 143.006 and 146.005).

This document reports the results gained by the geological logging of KFM01D, which is one of the activities performed within the site investigation at Forsmark. The work was carried out in accordance with activity plan AP PF 400-06-045. In Table 1-1 controlling documents for performing this activity are listed. Both activity plan and method descriptions are SKB's internal controlling documents.

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

Activity plan	Number	Version
Boremapkartering av teleskopborrhål KFM01D	AP PF 400-06-045	1.0
Method documents	**Number**	**Version**
Instruktion: Regler för bergarters benämningar vid plats-undersökningen i Forsmark	SKB MD 132.005	1.0
Metodbeskrivning för Boremap-kartering	SKB MD 143.006	2.0
Nomenklatur vid Boremap-kartering	SKB MD 143.008	1.0
Mätsystembeskrivning för Boremapkartering, Boremap v. 3.0	SKB MD 146.005	1.0

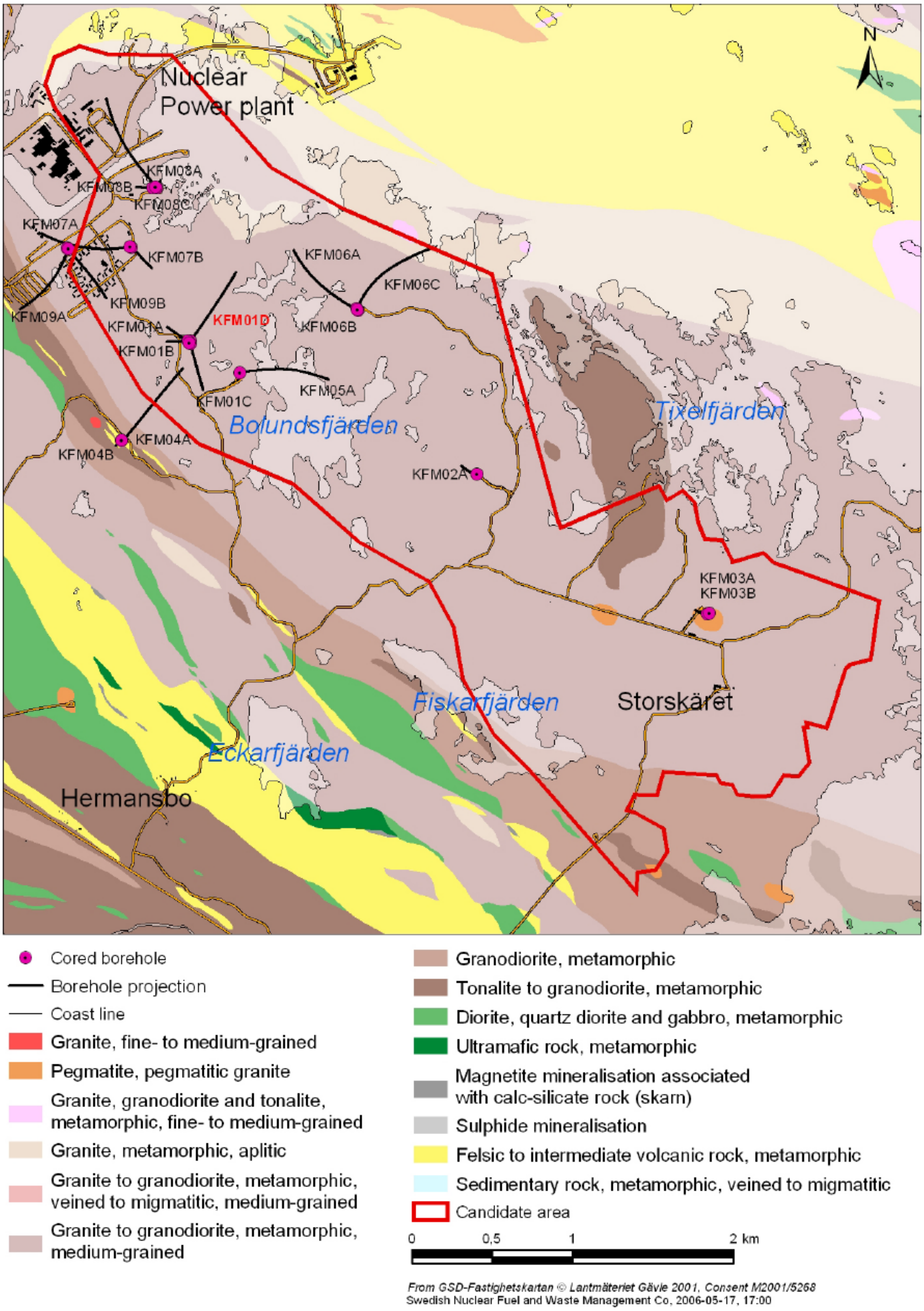

Figure 1-1. *Generalized geological map over Forsmark investigation area and the projection of KFM01D in relation to other cored boreholes from the drilling programme.*

2 Objective and scope

Borehole KFM01D starts with percussion drilling at Ø = 245.0 mm to a length of 89.75 metres, followed by core drilling at Ø = 86.0 mm to a length of 91.48 metres, and at Ø = 75.8 mm down to full its length at 800.24 metres. The soil cover is 7.55 metres. The diameters of the two drill cores are 70 and 51 mm, respectively, under ideal conditions. Material from the percussion drilled part is not included in the mapping engagement. The BIPS-image usable for geological logging covers the length interval 91.61–795.88 metres (after adjustment 91.61–798.64 metres). Thus, remaining part of the drill core, from 795.88 to 797.32 metres (after adjustment 798.64–800.18 metres), was mapped by Boremap without any complementary BIPS-image.

The aim of the geological borehole logging is to obtain a detailed documentation of *all* structures and lithologies in the interval that was core drilled at Ø = 75.8 mm. These data will serve as a platform for forthcoming analyses of the drill cores, aimed at investigating geological, petrophysical and mechanical aspects of the rock volume, as well as site descriptive three-dimensional modelling.

3 Equipment

3.1 Description of equipment/interpretation tools

All BIPS-based mapping was performed in Boremap v. 3.75. This software contains the bedrock and mineral standard used by the Geological Survey of Sweden (SGU) for geological mapping of the surface at the Forsmark site investigation area, to enable correlation with the surface geology. Additional software used during the course of the geological logging was BIPS Viewer v. 1.10 and Microsoft Access. The final data presentation was made in Geoplot and WellCAD v. 3.2.

The following equipment was used to facilitate the core logging: folding rule, concentrated hydrochloric acid diluted with three parts of water, unglazed porcelain plate, knife, hand lens, paintbrush and tap water.

4 Execution

4.1 General

During the core logging, the ~710 metres drill core obtained from the interval 89.75–800.24 metres of KFM01D was available in its full length on roller tables in the core-mapping accommodation at Forsmark (the Llentab hall, near the SKB/SFR-office). The BIPS-based mapping of KFM01D was preceded by an overview mapping made by Kenneth Åkerström. No thin-sections were available from the drill cores, and all lithological descriptions are based on ocular inspection. Most of the mapping was done by two geologists at a time, forming a core logging team. One of the geologists did the core logging while the other registered the information in Boremap.

The core logging of KFM01D was performed in Boremap v. 3.75 according to activity plan AP PF 400-06-045 (SKB internal document) following the SKB method description/instruction for Boremap mapping, SKB MD 143.006 (v. 2.0) and 143.008 (v. 1.0). However, the generalised geophysical logs arrived after the geological mapping of the borehole was finished. The use of these logs was, therefore, limited to a few lithological ambiguities that remained after the mapping.

A WellCAD summary of the mapping is presented in Appendix 1.

4.2 Preparations

The length registered in the BIPS-image deviates from the true borehole length with increasing depth, and the difference at the bottom of KFM01D is about 2.75 metres. It was thus necessary to adjust the length in KFM01D, with reference to groove millings cut into the borehole wall at every 50 metres, with the deepest slot at a length of 750 metres. The precise level of each reference mark can be found in SKB's database SICADA (Appendix 4). However, the adjusted length is still not completely identical with the one given in the drill core boxes, as the core recovery may yield erroneous lengths. The difference does never exceed 9 centimetres. All borehole lengths given in this report are adjusted with reference to the groove millings.

Data necessary for calculations of absolute orientation of structures in the borehole includes borehole diameter, azimuth and inclination, and these data were imported directly from SKB's database SICADA (Appendices 2 and 3).

4.3 Data handling

To obtain the best possible data security, the used mapping database was located on a SKB server, with regular back-ups on the local drives.

In order to avoid that some broken fractures not had been registered, the number of broken fractures in the drill core was regularly checked against the number of registered fractures. The quality routines include also daily controls of the mapping by detailed examination of Boremap generated variable/summary reports and WellCad log to match. The final quality check of the mapping was done by a routine in the Boremap software. The primary data were subsequently exported to the SKB database SICADA, where they are traceable by the activity plan number.

4.4 Analyses and interpretations

A problem with the Boremap system is that certain geological features (mainly fractures) only can be observed in the drill core. This problem usually arises from poor resolution in the BIPS-image, which in the present case often is caused by the occurrence of suspension from drilling and/or brownish black coating from the drilling rods on the borehole walls (see Section 4.5). However, even in the most perfect BIPS-image, it is sometimes difficult to distinguish a thin fracture, sealed by a low contrast mineral. All fractures observed in the drill core, but not recognized in the BIPS-image, have been registered as 'not visible in BIPS' in Boremap, to prevent them from being used in forthcoming fracture orientation analysis. If possible, they are still oriented relative to other structures with known orientations. Fractures supposed to be induced by the drilling activities fall within this category. Obviously drilling-induced fractures are not included in the mapping.

The resolution of the BIPS-image does generally make it possible to estimate the width of fractures with an error of ± 0.5 mm. Thus, reliable measurements of fracture widths/apertures less than 1 mm are possible to obtain in the drill core. The minimum width/aperture given is therefore 0.5 mm, in accordance with the nomenclature for Boremap mapping (SKB MD 143.008; v. 1.0).

The fracture mapping focuses on the division into broken and unbroken fractures, depending on whether they are parting the core or not. Broken fractures include both open fractures and originally sealed fractures, which were broken during the drilling or the following treatment of the core. To decide if a fracture was open, partly open or sealed in the rock volume (i.e. in situ), SKB has developed a confidence classification expressed at three levels, 'possible', 'probable' and 'certain', on the basis of the weathering of the fracture surface and fit of the fracture planes. The criteria for this classification are given in SKB method description for Boremap mapping, SKB MD 143.006 (v. 2.0).

Up to four infilling minerals can be registered in the database for each fracture. As far as possible, they are given in order of decreasing abundance in the fracture. Additional minerals (i.e. five or more), which occur in a few fractures, are noted in the attached comment. However, it must be emphasized that this provides no information of the volumetric amount of individual minerals. In a fracture with two minerals, the mineral registered as 'second mineral' may range from sub-microscopic staining up to amounts equal to that of the mineral registered as 'first mineral'. Hematite, for example, occurs consistently as extremely thin coatings or impurities in other fracture minerals, such as adularia and laumontite.

Three drill induced crushes have been registered in KFM01D: 159.43–159.53, 181.86–181.93 and 457.60–457.63 metres adjusted length. Core losses have been registered at the following intervals: 181.93–182.09, 668.65–668.74 and 668.98–669.07 metres adjusted length.

4.5 Nonconformities

Several fractures within KFM01D are sealed by laumontite (Ca-zeolite). These fractures occur as both broken and unbroken, but dehydration of laumontite tends to produce volumetric changes, and the sealing will eventually crackle and break the drill core. Thus, laumontite-bearing fractures suspected to have been sealed originally are registered as unbroken.

Some fracture filling minerals are more conspicuous than other. For example, the distinct red tinting shown by sub-microscopic hematite reveals extremely low concentrations of the mineral. Also the use of diluted hydrochloric acid for identification of calcite makes it possible to detect amounts that are macroscopically invisible. The amount of fractures filled with other less conspicuous minerals may, on the other hand, be underestimated. Pyrite, which typically forms up to millimetre-sized, isolated crystals, might for example be underrepresented in unbroken fractures.

As in previous cored boreholes, the mapping of KFM01D was locally hampered by deposited drill cuttings as well as brownish black coatings on the borehole. Deposited drill cuttings obscure the lower 150–160° of the borehole wall along the entire borehole. However, it is still possible to see most features in the borehole wall through the cuttings. Thus, the cuttings have no crucial effect on the quality of the mapping. The dark coating occurs generally below ~ 210 metres of KFM01D, where it typically forms a single, continuous band along the borehole axis. The amount of coating tends to increase towards depth in the borehole, though the problem is generally less serious in KFM01D than in most of the previous boreholes. This coating phenomenon is obviously drill induced, and the explanation proposed is that the coatings originate from metal fragments abraded from the drill rods.

Both during the mapping and the subsequent work with mapping data from other boreholes in the drilling programme, we have noted a few inexplicable errors in the databases. No such errors have been observed for KFM01D, though there might still be unnoticed errors. We disclaim the responsibility for all errors caused by the shortcomings in the software.

5 Results

5.1 Lithology

5.1.1 General

Similar to the previously drilled deep boreholes located in the Forsmark site investigation area, KFM01D is dominated by a metagranite (rock code 101057), which locally is slightly granodioritic. However, in addition to the typical, medium-grained variety, found elsewhere in the area, there is a major interval of a fine- to finely medium-grained variety in KFM01D. This fine- to finely medium-grained type appears to be identical to the variety found in the uppermost 286 metres of borehole KFM05A cf. /Petersson et al. 2004/. In KFM01D it occupies the length interval between 191.2 and 499.8 metres adjusted length. However, none of the contacts are especially well-defined. A more or less continuous interval from about 424.2 to 511.5 metres adjusted length have been affected by intense static recrystallization, after the development of the deformational fabric. The result is that the fabric has become more diffuse in this interval, whilst the plagioclase generally is more conspicuous with a whitish, chalk-like character. Another characteristic feature in the interval is the increased content of feldspar megacrysts and minor pegmatitic accumulations. The recrystallization has locally rendered the recognition of separate metagranite varities difficult, and some sections are reminiscent of the fine- to medium-grained metagranitoid (rock code 101051), as described below. Intervals of metagranite affected by intense static recrystallization are distinguished in the database by the use of the textural term ‘recrystallised’ instead of the normally used ‘metamorphic’.

Additional rock types within the borehole, none of which forming occurrences that exceed ten metres in borehole length, include pegmatitic granite (rock code 101061), fine- to medium-grained metagranitoids (rock code 101051) of mainly granodioritic composition, amphibolites (rock code 102017), fine- to medium-grained granite (rock code 111058) and a fine-grained, intermediate rock of inferred volcanic origin (rock code 103076). Except for a few minor late veins or dykes, all rocks have experienced Svecofennian metamorphism under amphibolite facies conditions.

5.1.2 Rock types

The predominant medium-grained metagranite (rock code 101057) is rather equigranular with elongated quartz domains, alternating with feldspar-dominated domains and thin streaks of biotite. The fine- to finely medium-grained variety appears to be texturally and compositionally identical to the medium-grained metagranite. The colour of the rock ranges from greyish red to grey. In some intervals, especially in contact with amphibolites and skarn-like material, the rock is variably bleached and characterized by flecks of stretched biotite aggregates. This bleached variety occurs sporadically throughout the borehole and individual occurrences ranges up to about two metres in borehole length. The overall appearance of the variety is highly reminiscent of the albitized rock in the lower part of KFM06A and outcrops along the northeastern margin of the investigation site cf. /Petersson et al. 2005ab/. Bleached intervals were, therefore, mapped as ‘albitized’. However, defining the relative intensity of the albitization is more difficult, but the majority has been mapped as ‘faint’ to ‘medium’. In addition to the major interval of intense static recrystallization at 424.1–511.5 metres adjusted length, there are numerous minor intervals variably affected by static recrystallization. This is noted in the comment attached to each occurrence, but none of them are registered as ‘recrystallised’.

Dykes, veins and segregations of pegmatite and pegmatitic granite are frequent throughout KFM01D, of which many of the segregated pegmatitic granites are related to the recrystallised rock mention in previous section. Most occurrences are some decimetre or less, but several pegmatites/pegmatitic granites reach up to a few metres in borehole length. The most extensive pegmatitic granite forms a continuous occurrence at 274.6–284.4 metres adjusted length. The pegmatitic granites are generally texturally heterogeneous, often with a highly variable grain-size, and some occurrences include intervals of finely medium-grained, equigranular granite. Rather coarse magnetite, up to about one centimetre in diameter, has been identified in some pegmatites. Despite the textural variability and temporal span within this unit, most of these rocks were grouped as 'pegmatite, pegmatitic granite' (rock code 101061).

Fine- to medium-grained metagranitoids (rock code 101051) of mostly granodioritic composition occupy about 4% of the mapped interval. The most extensive occurrence, which exceeds 6 metres in length, occurs at 701.1–707.2 metres adjusted length in KFM01D. Other occurrences range up to 2.6 metres in borehole length. The rocks are equigranular and ranges from grey to reddish grey in colour. The mineral fabric is commonly linear and external contacts are typically discordant to the tectonic foliation in the wall rock. Several occurrences of a fine- to medium-grained granite (rock code 111058), which locally is highly reminiscent of the fine-to medium-grained metagranitoid, are found in the borehole. A distinctive criterion apart from their late-tectonic character is, however, their anomalously high natural gamma radiation cf. /Mattsson and Keisu 2006/. Individual occurrences range up to 3.3 metres in borehole length.

Amphibolites (rock code 102017) occur sporadically throughout KFM01D. They comprise less than 3% of the mapped interval and individual occurrences range up to 3.5 metres in borehole length. Generally, the amphibolites are fine-grained, equigranular with a large proportion of biotite. Extensions and contacts of the amphibolites are more or less parallel with the tectonic fabric. Some occurrences are surrounded by up to one decimetre wide rims of bleached wall rock, inferred to be the result of albitization. Disseminations of pyrite and/or other unidentifiable sulphides are macroscopically visible in some of the occurrences.

One major occurrence of fine-grained, intermediate rock of inferred volcanic origin (rock code 103076) occurs in the length interval 491.53–496.33 metres. Two additional such occurrences are found in the length interval 123.6–124.1 metres. The rock is equigranular, dark grey in colour and all contacts are parallel with the tectonic foliation. Except for a faint banding and the grain-size, there are no textural or structural macroscopic features that unambiguously point towards a volcanic origin of the rock.

Aplites in KFM01D have been separated into two types on the basis of their tectonic character. Those that show a distinct fabric were mapped as 'aplitic metagranite' (rock code 101058), whereas more massive occurrences were registered as 'aplite' (rock code 1062). Individual occurrences are typically less than one decimetre in borehole width, with a few aplitic meta-granites that ranges up to 5 decimetres. One occurrence of aplitic metagranite at 660.72–663.78 metres adjusted length exceeds 3 metres in width.

A few centimetre-wide occurrences of skarn-like material (rock code 108019) are concentrated into the interval between 102 and 105 metres. Individual occurrences are distinguished by their visible content of epidote and reddish feldspar or/and probable garnet. Other frequent components are quartz and magnetite. In addition, there are a few minor occurrences of granite, granodiorite, quartz diorite, 'granitoid' and 'mafic igneous rock' in KFM01D. None of them appears to fit into the bedrock nomenclature defined by SKB MD 132.005. Instead they were coded as 1058 (unspecified granite), 1056 (unspecified granodiorite), 1038 (unspecified quartz diorite), 1051 (unspecified granitoid) and 5102 (unspecified mafic igneous rock). A minor occurrence of medium-grained metagranodiorite (rock code 101056) occurs at 235.84–236.00 metres adjusted length. Quartz-dominated segregations or veins were coded as 8021.

5.2 Ductile structures

Most rocks in KFM01D are characterized by composite L-S fabrics. The predominant component varies throughout the borehole. Some of the pegmatitic granites, the fine- to medium-grained metagranitoid (rock code 101051) and the fine to medium-grained granite (rock code 111058) intruded, however, after the development of the foliation, and are massive or show a weak mineral lineation. The intensity of the deformational fabric in KFM01D is mostly faint to weak, and more rarely medium. It must, however, be emphasized that the distinctness of a fabric does not necessarily reflect the amount of strain. Nor does the fact that a rock may appear massive always implicate that they actually are unaffected by strain. It is, for example, often difficult to distinguish tectonic fabric visually in the pegmatites and some of the fine-grained mafic rocks. Likewise do the intervals affected by static recrystallization appear rather massive, since the fabric in the precursor has been obliterated. The structural orientation in KFM01D is rather variable throughout the borehole, though the majority are moderately dipping and strikes roughly between ESE and SSE (Figure 5-1). None of the linear fabrics have been possible to register with the present methodology, but the general impression is that they are gently to moderately dipping.

Twenty-two narrow zones of more intense ductile and brittle-ductile deformation have been registered in KFM01D. Eighteen of them are registered as ductile shear zones and four as brittle-ductile shear zone. The zones occur sporadically throughout KFM01D and the borehole length of individual zones is generally less than one decimetre, with a few ranging up to nine decimetres. The protolith in the zones seems mainly to be a highly deformed and grain-size reduced variety of the metagranite (rock code 101057), and amphibolites (rock code 102017), but also the intermediate metavolcanic rock (rock code 103076) have been affected. The shear zones in KFM01D are all more or less parallel with the local tectonic foliation (Figure 5-1).

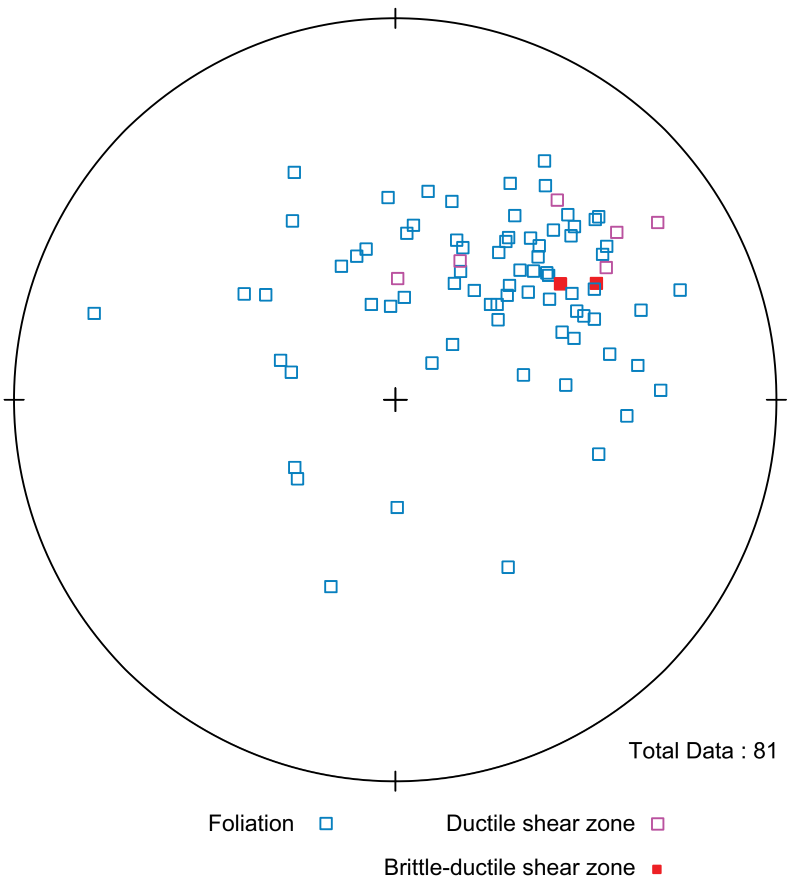

Figure 5-1. *Lower hemisphere, equal area stereographic projection showing poles to ductile and brittle-ductile structures in KFM01D.*

5.3 Alteration

Besides the albitization as discussed in section 5.1, the most common alteration encountered in KFM01D is varying degrees of oxidation or red pigmentation of feldspars by sub-microscopic hematite. It is generally restricted to three more intensely fractured intervals, with laumontite-bearing (176–185 and 685–689 metres) and adularia-bearing (771–777 metres) fracture assemblages. Totally, about 3.4% of the mapped interval of KFM01D has been affected by oxidation. Normally this oxidation is faint to weak in intensity, and more rarely medium to strong.

Other types of alterations within KFM01D include chloritization, epidotization and an alteration that gives the rock a slightly darker, blurred appearance (mapped as 'sassuritization' in Boremap). Individual occurrences are typically less than one decimetre in borehole length, with a few ranging up to four decimetre. The widest occurrence is an interval of weak epidotization that has affected an amphibolite at 150.55–151.71 metres adjusted length.

5.4 Fractures

5.4.1 Fracture frequencies and orientations

The total number of open (broken fractures with aperture > 0), partly open (unbroken fractures with aperture > 0) and sealed fractures (broken and unbroken fractures with aperture = 0) registered *outside crush zones and sealed networks* during the Boremap-logging of KFM01D amounts to 1,635, i.e. about 2.3 fractures/metres. Of these are 431 open, 37 partly open and 1,167 sealed. This separation into open, partly open or sealed fractures is made on the basis of the degree of weathering of the fracture surface and the fit of the fracture planes. It should be emphasized that there is a certain degree of uncertainty in these judgements. In addition, there are two calcite sealed fractures , 7 and 17 centimetres wide, respectively (at 179.67–179.84 and 772.00–772.07 metres adjusted length), that were mapped as 'carbonate-dominated hydrothermal vein' (rock code 8022).

Totally, there are 18 sealed networks and 5 breccias (or brecciated intervals) registered in the mapped interval. The distinction between breccia and sealed network is not straight forward, but normally zones with none or minor rotation of individual rock fragments has been mapped as sealed network. Significant fractures that differ markedly (e.g. in aperture or infilling mineralogy) from the majority of fractures within the sealed networks are mapped separately. The total length of all sealed networks in KFM01D amount to 2.3 metres. The piece length (i.e. the distance between individual fractures) within these networks is typically about 1.3 cm, but ranges up to 3.5 cm. The breccias are concentrated into four intervals of the borehole: 179.84–179.86, 488.85–488.94, 688.49–688.52 and 694.62–694.66 metres adjusted length. Individual occurrences range up to 4 centimetres in width. Except for the registered breccias, no displacements have been noted during the mapping of KFM01D. One gently dipping crush zone occurs at 488.99–489.00 metres adjusted length in KFM01D.

Throughout the borehole, the frequency of open and sealed fractures varies rather coherently, with an increased number of open fractures in intervals with concentrations of sealed fractures (Appendix 1). Similar to some of the other deep boreholes in the area e.g. KFM07A; /Petersson et al. 2005c/, there is an abrupt decrease in the fracture frequency below ~200 metres borehole length. Three distinct intervals with increased fracture frequency occur below that level: 410–421, 487–497 and 674–699 metres adjusted length. All three intervals are dominated by sealed fractures, many included in sealed fracture networks.

It is reasonable to expect that mechanical discontinuities, such as lithological contacts, should be the locus of fracture formation more frequently than within a homogeneous rock. For this reason we have noted the proportion of fractured amphibolite contacts. About 23% of the contacts in the mapped interval of KFM01D are fractured. This can be compared with other cored boreholes from the Forsmark drilling programme, in which 22–42% of the contacts are fractured /Petersson et al. 2006ab and references therein/.

Inferred core discing occurs at the following lengths along KFM01D: 154.85–154.92, 168.64–168.73, 462.20–462.22, 554.26–554.27 and 796.41–796.49 metres. Three of these intervals appear to be initial signs of core discing and do not actually breaks the core. None of the intervals exceed 9 cm in width, and the typical dimension of individual discs range between 5 and 17 mm. The fractures are all planar to slightly saddle-shaped.

5.4.2 Fracture mineralogy

Chlorite and/or calcite are found in slightly more than 70% of the total number of the registered fractures in KFM01D. Other infilling minerals, in order of decreasing abundance, include adularia, quartz, sub-microscopic hematite, clay minerals, laumontite, biotite, pyrite, prehnite and, more rarely, white feldspar, unspecified sulphides, epidote, iron hydroxide, apophyllite and magnetite. In addition, there are two fractures with unknown mineral filling. Analyses by XRD of similar material from the previously mapped cored boreholes in the area have revealed that most such filling are mineral mixtures, or in some cases, feldspars, apophyllite or analcime /Sandström et al. 2004/. There are also 126 fractures that are virtually free from visible mineral coatings. These are mostly open, though there are also sealed fractures with no *visible* mineral sealing.

The various clay minerals are more or less restricted to open fractures. Fractures with clay minerals are found throughout the borehole. Clay minerals registered in fractures at greater depths are typically corrensite and illite, often intimately associated with chlorite. Other minerals preferably found in open and partly open fractures are iron hydroxide and apophyllite (mapped as X1). Except for one occurrence of iron hydroxide at 451.20 metres adjusted length and one of apophyllite at 373.91 metres adjusted length, both minerals are restricted to fractures that occur above 153 metres length.

Pyrite is frequent in both sealed and open fractures. The presence of other sulphides, registered as ‘unspecified sulphides’, is rare and restricted to four fractures. Also hematite is spread rather equally between open or sealed fractures.

All other minerals, as well as oxidized walls, are preferentially associated with fractures inferred to be sealed. A typical mineral assemblage, commonly found both in individual fractures and sealed fracture networks consists of adularia together with calcite, chlorite, and locally hematite and quartz. However, the exact assemblage varies locally. A number of very thin (<< 1 mm), sealed fractures are typically only revealed by their oxidized walls. Several of these thin fractures are sealed by a mineral inferred to be hematite, but it might well be hematite-stained laumontite or adularia. This interpretation is based on the fact the hematite within KFM01D typically occurs in two main varieties: (1) thin, reddish coatings, preferentially found in flat lying fractures, and (2) staining of various silicates, such as adularia and laumontite.

Another less common, but yet characteristic assemblages, mainly found in the sealed fractures is laumontite + calcite + chlorite ± quartz. The vast majority of the laumontite-bearing fractures are restricted in rather narrow length intervals at 176–188, 408–421, 489–492, 672–690 metres. Prehnite is with few exceptions limited to thin, sealed fractures found within amphibolites and related rocks. Subsequent EDS-analysis of some of these fractures has revealed that most of the light greenish minerals inferred to be prehnite in fact are epidote (B. Sandström, written communication).

White feldspar is mainly registered in a few fractures throughout the borehole. The term is used for white or colourless adularia as well as suspected albite. Biotite is found in fractures inferred to be late-, rather than post-metamorphic. These fractures are typically mono-mineralic or include chlorite or quartz.

References

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SKB, 2005. Preliminary site description. Forsmark area – version 1.2. SKB R-05-18, Svensk Kärnbränslehantering AB.

Appendix 1

WellCAD image

Title	LEGEND FOR FORSMARK	KFM01D	Appendix: 1

Site FORSMARK
Borehole KFM01D
Plot Date 2006-06-21 21:12:36
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 TYPE
- Oxidized
- Chloritisized
- Epidotisized
- Weathered
- Tectonized
- Sericitisized
- Quartz dissolution
- Silicification
- Argillization
- Albitization
- Carbonatization
- Saussuritization
- Steatitization
- Uralitization
- Laumontitization
- Fract zone alteration

MINERAL
- Biotite
- Epidote
- Hematite
- Calcite
- Chlorite
- Quartz
- Pyrite
- Clay Minerals
- Laumontite
- Iron Hydroxide

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

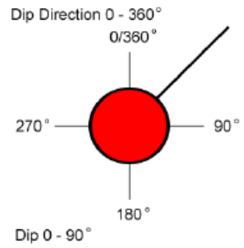
ROUGHNESS
- Planar
- Undulating
- Stepped
- Irregular

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

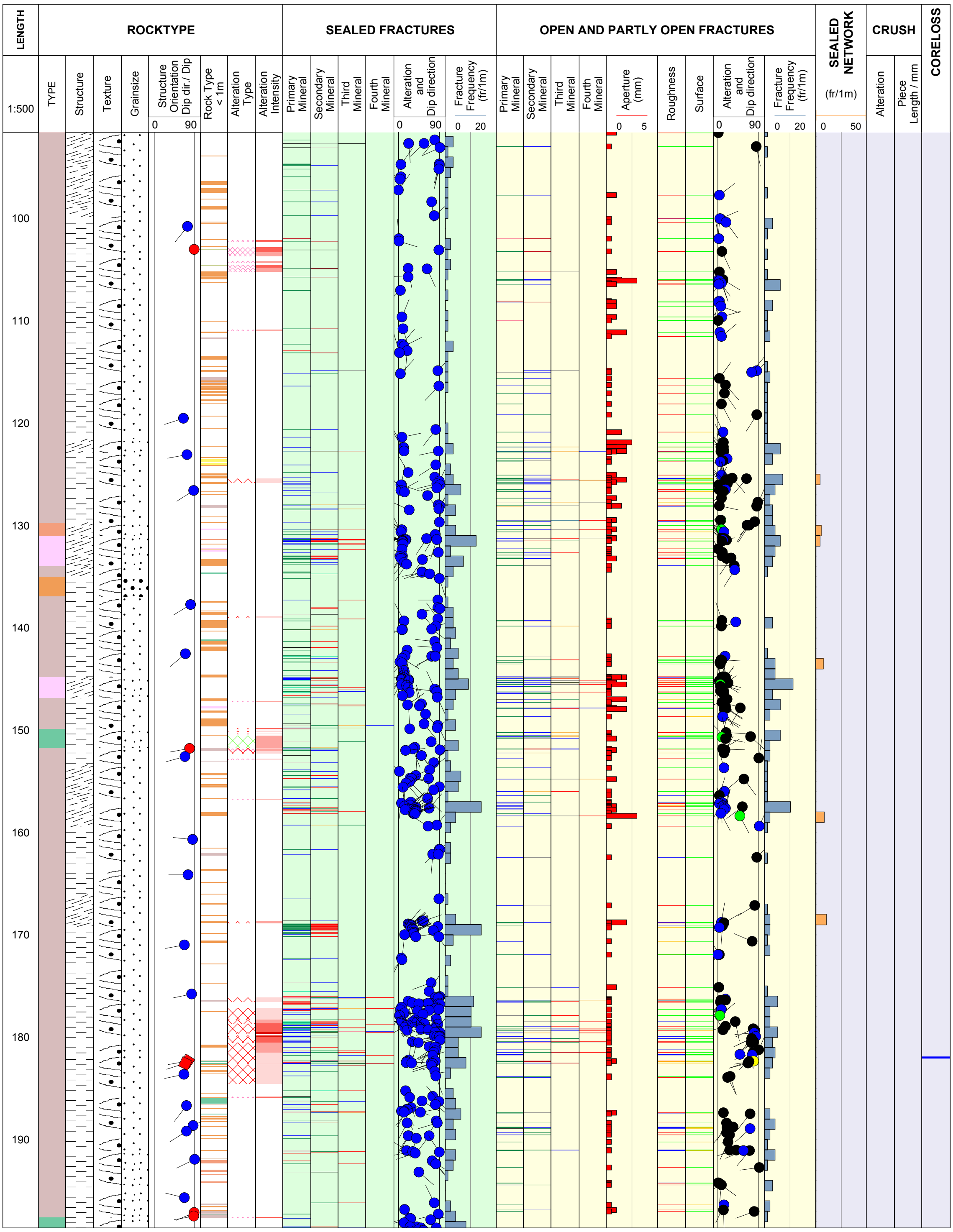


Page 1

Title GEOLOGY IN KFM01D **Appendix: 1**

SKB

Site	FORSMARK	**Coordinate System**	RT90-RHB70
Borehole	KFM01D	**Northing [m]**	6699542.07
Diameter [mm]	76	**Easting [m]**	1631404.52
Length [m]	800.240	**Elevation [m.a.s.l.]**	2.95
Bearing [°]	35.03	**Drilling Start Date**	2005-11-21 07:00:00
Inclination [°]	-54.89	**Drilling Stop Date**	2005-12-05 14:30:00
Date of coremapping	2006-03-28 13:20:00	**Plot Date**	2006-06-21 21:12:36
Rocktype data from	p_rock	**Signed data**	



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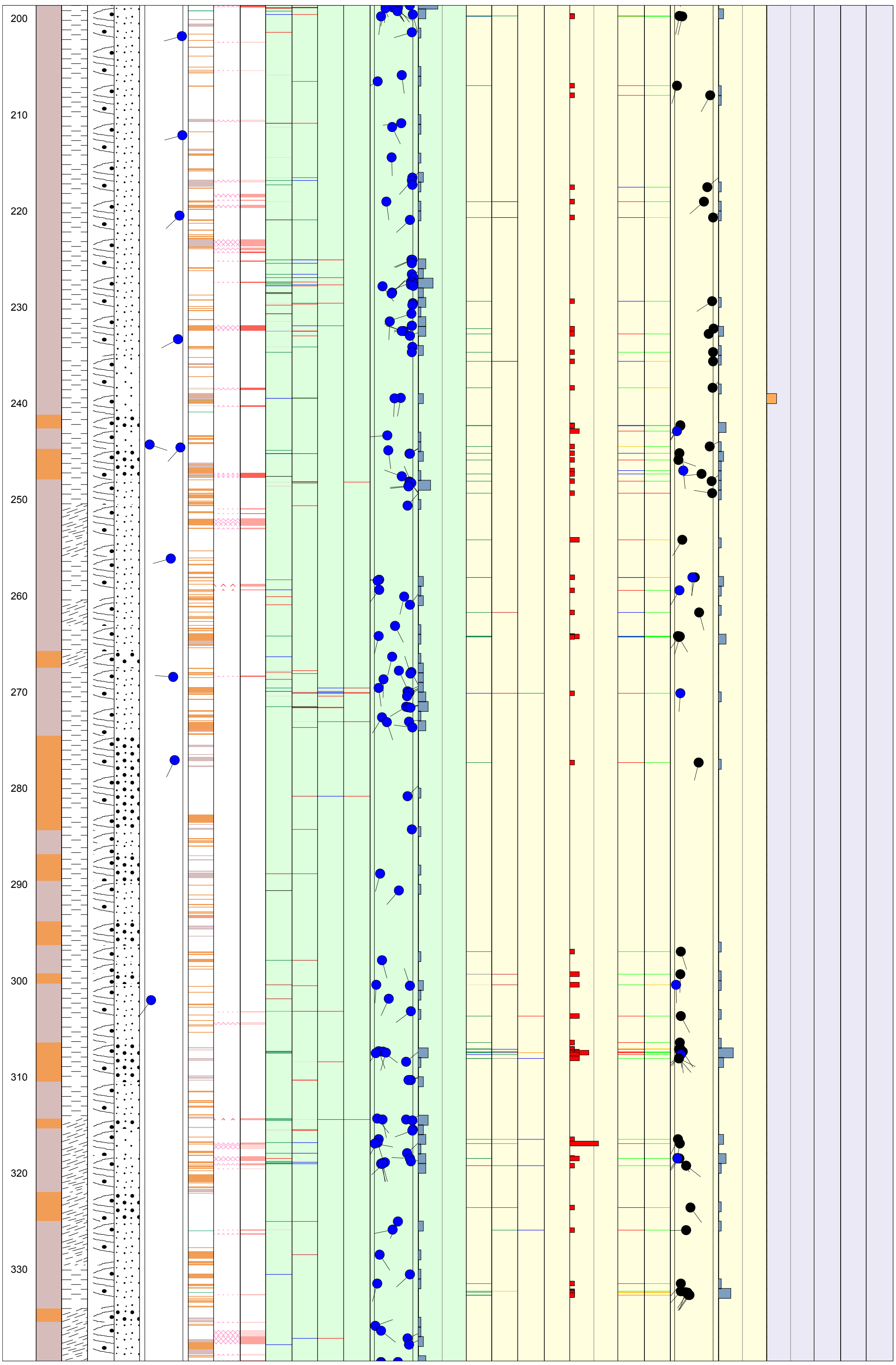

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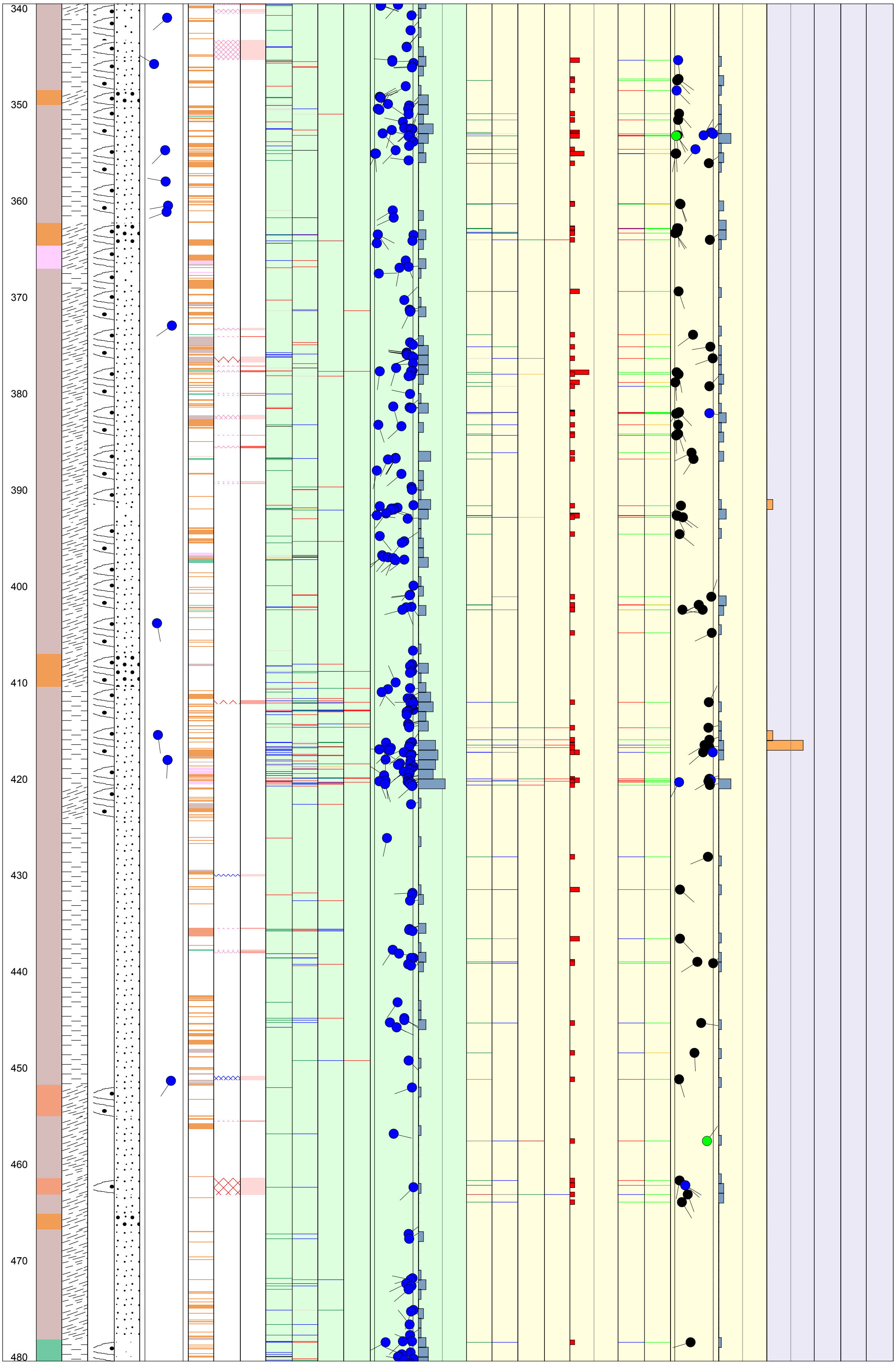

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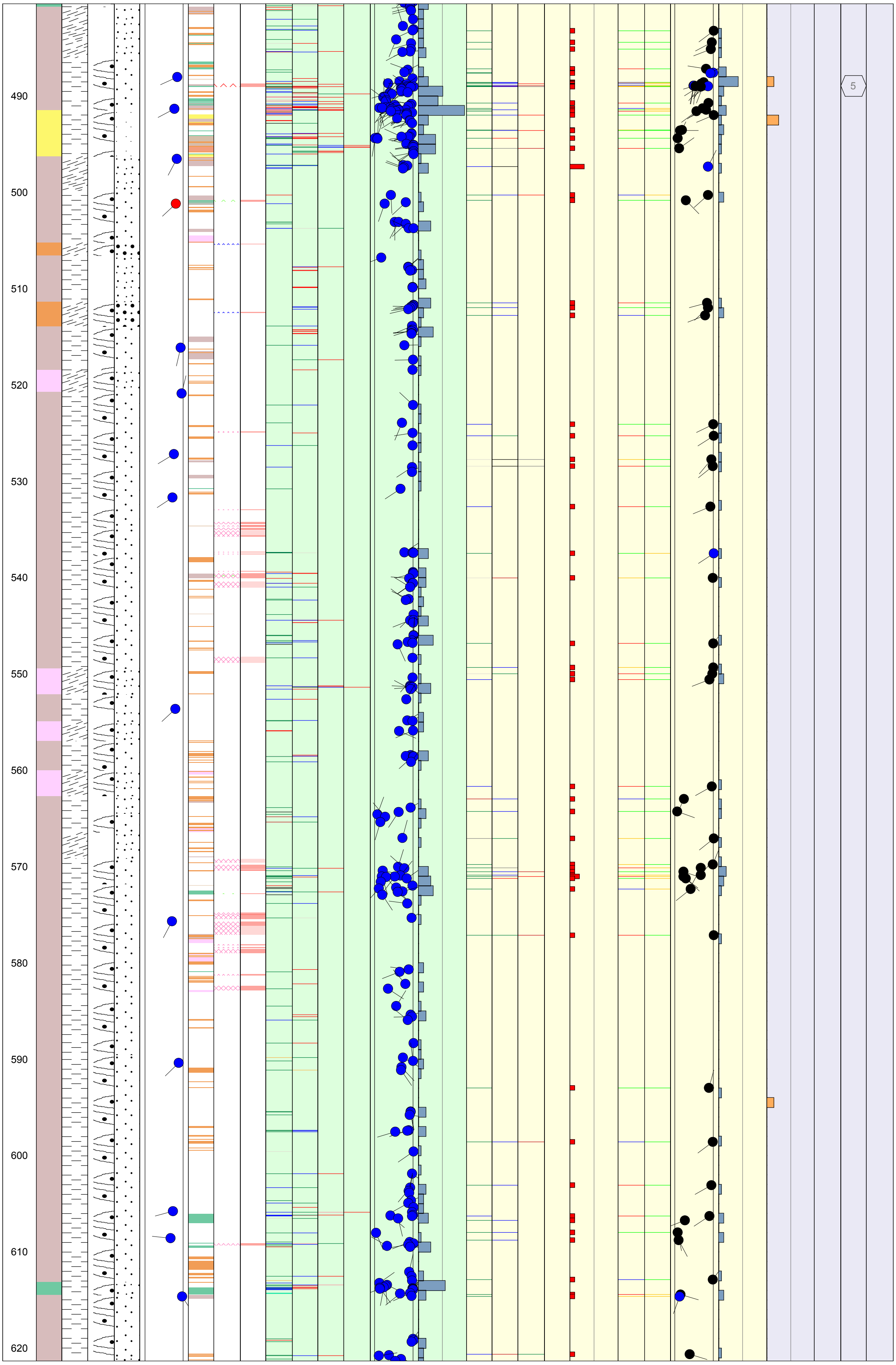

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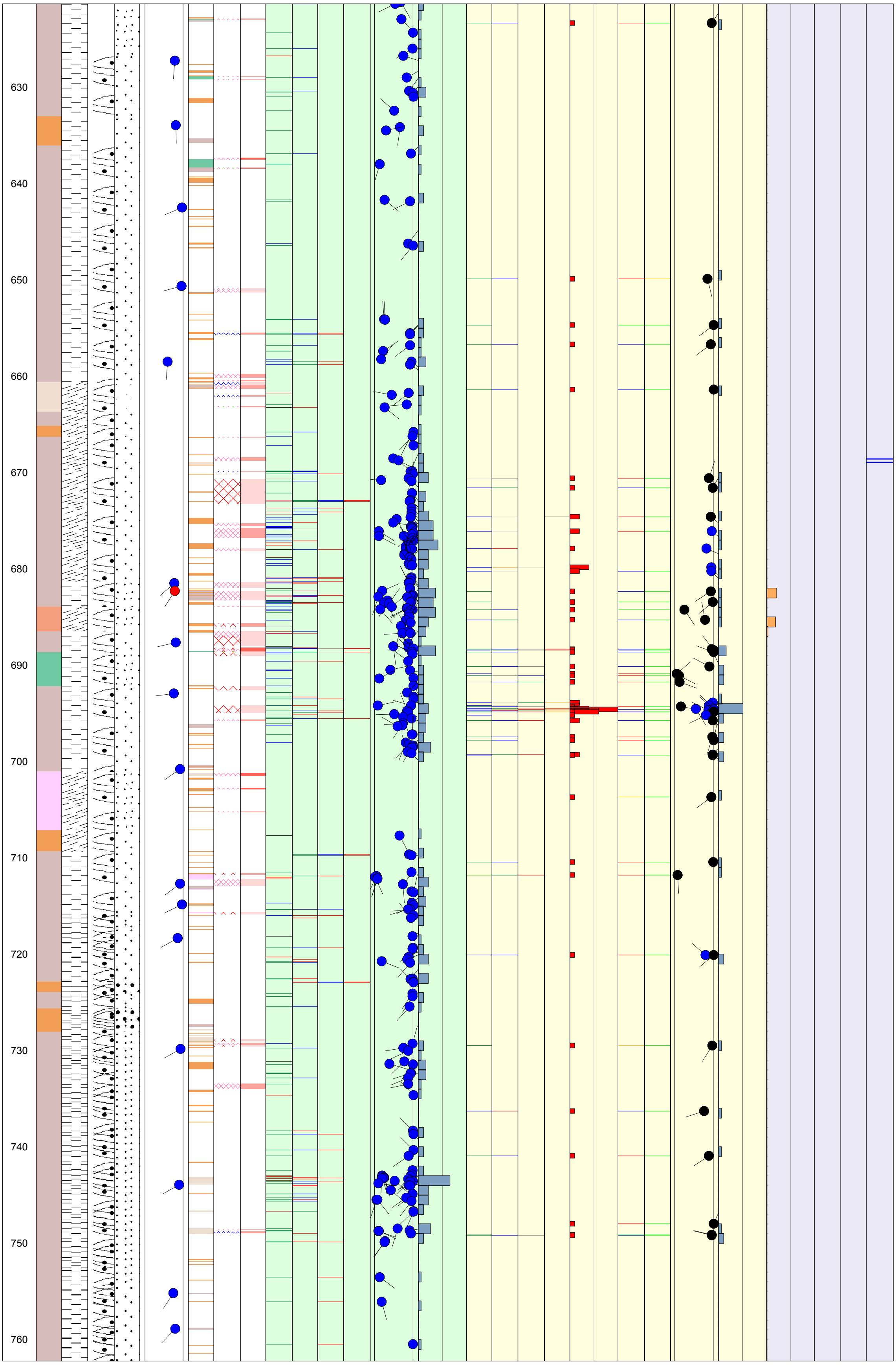

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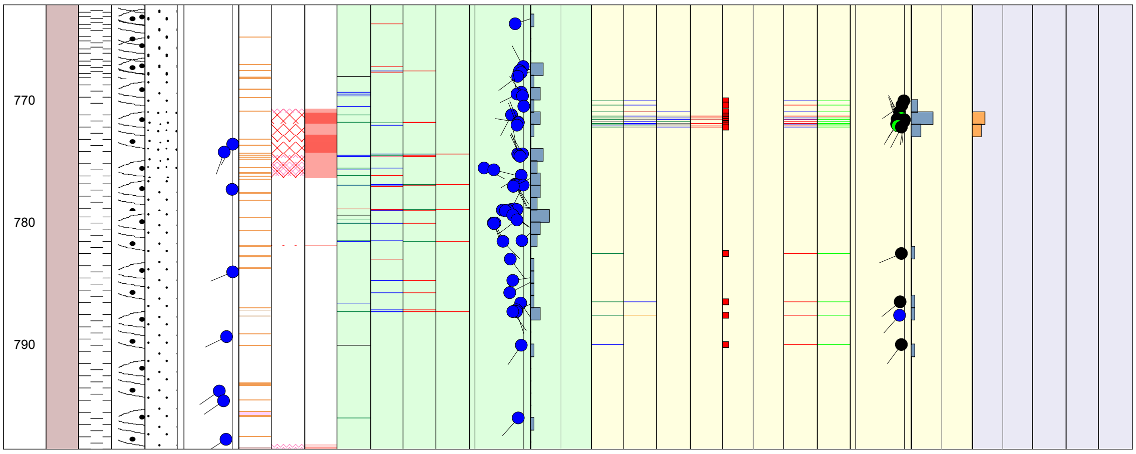
770
780
790

Appendix 2

Borehole diameters

Hole Diam T – Drilling: Borehole diameter

KFM01D, 2005-12-18 13:44:00–2006-02-18 10:49:00 (0.000–800.240 m)

Sub Secup (m)	Sub Seclow (m)	Hole Diam (m)	Comment
89.770	91.480	0.0860	
91.480	800.240	0.0758	

Printout from SICADA 2006-06-07 16:24:01.

Appendix 3

Downhole deviation measurements

Maxibor T – Borehole deviation: Maxibor

KFM01D, 2006-02-21 00:00:00 (3.000–798.000 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	6699542.07	1631404.52	–2.95	RT90-RHB70	–54.90	35.03	0.0000	0.0000	0.0000	
3.00	6699543.48	1631405.51	–0.49	RT90-RHB70	–54.90	35.03	0.0000	0.0000	0.0000	
6.00	6699544.89	1631406.50	1.96	RT90-RHB70	–54.74	35.10	1.7300	0.0000	0.0000	
9.00	6699546.31	1631407.50	4.41	RT90-RHB70	–54.60	35.05	3.4600	0.0000	0.0100	
12.00	6699547.73	1631408.50	6.86	RT90-RHB70	–54.47	34.97	5.1900	0.0000	0.0200	
15.00	6699549.16	1631409.50	9.30	RT90-RHB70	–54.39	35.02	6.9400	0.0000	0.0500	
18.00	6699550.59	1631410.50	11.74	RT90-RHB70	–54.39	35.06	8.6800	0.0000	0.0700	
21.00	6699552.02	1631411.50	14.18	RT90-RHB70	–54.42	35.02	10.4300	0.0000	0.1000	
24.00	6699553.45	1631412.50	16.62	RT90-RHB70	–54.53	34.99	12.1800	0.0000	0.1200	
27.00	6699554.87	1631413.50	19.06	RT90-RHB70	–54.60	35.00	13.9200	0.0000	0.1400	
30.00	6699556.30	1631414.50	21.50	RT90-RHB70	–54.77	34.99	15.6600	0.0000	0.1600	
33.00	6699557.72	1631415.49	23.95	RT90-RHB70	–54.91	34.99	17.3900	0.0000	0.1700	
36.00	6699559.13	1631416.48	26.41	RT90-RHB70	–54.96	35.00	19.1100	0.0000	0.1600	
39.00	6699560.54	1631417.47	28.87	RT90-RHB70	–54.94	34.96	20.8300	–0.0100	0.1600	
42.00	6699561.95	1631418.45	31.32	RT90-RHB70	–54.94	34.90	22.5600	–0.0100	0.1600	
45.00	6699563.37	1631419.44	33.78	RT90-RHB70	–54.99	34.81	24.2800	–0.0100	0.1600	
48.00	6699564.78	1631420.42	36.23	RT90-RHB70	–55.02	34.71	26.0000	–0.0200	0.1500	
51.00	6699566.19	1631421.40	38.69	RT90-RHB70	–55.12	34.73	27.7200	–0.0300	0.1500	
54.00	6699567.60	1631422.38	41.15	RT90-RHB70	–55.08	34.80	29.4400	–0.0400	0.1300	
57.00	6699569.01	1631423.36	43.61	RT90-RHB70	–55.06	34.76	31.1500	–0.0500	0.1200	
60.00	6699570.42	1631424.34	46.07	RT90-RHB70	–55.02	34.83	32.8700	–0.0500	0.1200	

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
63.00	6699571.84	1631425.32	48.53	RT90-RHB70	–55.04	34.83	34.5900	–0.0600	0.1100	
66.00	6699573.25	1631426.30	50.99	RT90-RHB70	–55.02	34.86	36.3100	–0.0700	0.1000	
69.00	6699574.66	1631427.29	53.45	RT90-RHB70	–54.97	34.83	38.0300	–0.0700	0.1000	
72.00	6699576.07	1631428.27	55.90	RT90-RHB70	–54.88	34.85	39.7500	–0.0800	0.0900	
75.00	6699577.49	1631429.26	58.36	RT90-RHB70	–54.80	34.79	41.4800	–0.0800	0.0900	
78.00	6699578.91	1631430.24	60.81	RT90-RHB70	–54.78	34.84	43.2100	–0.0900	0.1000	
81.00	6699580.33	1631431.23	63.26	RT90-RHB70	–54.83	35.01	44.9400	–0.1000	0.1000	
84.00	6699581.74	1631432.22	65.71	RT90-RHB70	–54.95	35.17	46.6700	–0.1000	0.1100	
87.00	6699583.15	1631433.22	68.17	RT90-RHB70	–54.96	35.17	48.3900	–0.0900	0.1000	
90.00	6699584.56	1631434.21	70.62	RT90-RHB70	–54.93	35.25	50.1100	–0.0900	0.1000	
93.00	6699585.97	1631435.20	73.08	RT90-RHB70	–54.89	35.31	51.8400	–0.0800	0.1000	
96.00	6699587.38	1631436.20	75.53	RT90-RHB70	–54.87	35.31	53.5600	–0.0700	0.1000	
99.00	6699588.78	1631437.20	77.99	RT90-RHB70	–54.86	35.32	55.2900	–0.0600	0.1000	
102.00	6699590.19	1631438.20	80.44	RT90-RHB70	–54.84	35.31	57.0100	–0.0600	0.1000	
105.00	6699591.60	1631439.19	82.89	RT90-RHB70	–54.82	35.32	58.7400	–0.0500	0.1000	
108.00	6699593.01	1631440.19	85.35	RT90-RHB70	–54.81	35.31	60.4700	–0.0400	0.1100	
111.00	6699594.42	1631441.19	87.80	RT90-RHB70	–54.79	35.31	62.2000	–0.0300	0.1100	
114.00	6699595.84	1631442.19	90.25	RT90-RHB70	–54.77	35.29	63.9300	–0.0200	0.1200	
117.00	6699597.25	1631443.19	92.70	RT90-RHB70	–54.74	35.28	65.6600	–0.0100	0.1300	
120.00	6699598.66	1631444.19	95.15	RT90-RHB70	–54.70	35.28	67.3900	–0.0100	0.1300	
123.00	6699600.08	1631445.19	97.60	RT90-RHB70	–54.67	35.31	69.1200	0.0000	0.1400	
126.00	6699601.49	1631446.20	100.04	RT90-RHB70	–54.64	35.34	70.8600	0.0100	0.1600	
129.00	6699602.91	1631447.20	102.49	RT90-RHB70	–54.61	35.33	72.6000	0.0200	0.1700	
132.00	6699604.33	1631448.21	104.94	RT90-RHB70	–54.58	35.34	74.3300	0.0300	0.1800	
135.00	6699605.74	1631449.21	107.38	RT90-RHB70	–54.55	35.33	76.0700	0.0400	0.2000	
138.00	6699607.16	1631450.22	109.83	RT90-RHB70	–54.54	35.34	77.8100	0.0400	0.2200	
141.00	6699608.58	1631451.22	112.27	RT90-RHB70	–54.53	35.36	79.5500	0.0500	0.2400	
144.00	6699610.00	1631452.23	114.71	RT90-RHB70	–54.50	35.36	81.2900	0.0600	0.2600	

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
147.00	6699611.42	1631453.24	117.15	RT90-RHB70	–54.47	35.33	83.0300	0.0700	0.2800	
150.00	6699612.85	1631454.25	119.60	RT90-RHB70	–54.45	35.33	84.7800	0.0800	0.3000	
153.00	6699614.27	1631455.26	122.04	RT90-RHB70	–54.43	35.32	86.5200	0.0900	0.3200	
156.00	6699615.69	1631456.27	124.48	RT90-RHB70	–54.41	35.30	88.2700	0.1000	0.3500	
159.00	6699617.12	1631457.27	126.92	RT90-RHB70	–54.38	35.27	90.0100	0.1100	0.3700	
162.00	6699618.54	1631458.28	129.36	RT90-RHB70	–54.36	35.23	91.7600	0.1200	0.4000	
165.00	6699619.97	1631459.29	131.79	RT90-RHB70	–54.32	35.21	93.5100	0.1200	0.4300	
168.00	6699621.40	1631460.30	134.23	RT90-RHB70	–54.27	35.19	95.2600	0.1300	0.4600	
171.00	6699622.83	1631461.31	136.67	RT90-RHB70	–54.22	35.18	97.0100	0.1300	0.4900	
174.00	6699624.27	1631462.32	139.10	RT90-RHB70	–54.16	35.15	98.7600	0.1400	0.5300	
177.00	6699625.70	1631463.33	141.53	RT90-RHB70	–54.11	35.15	100.5200	0.1400	0.5600	
180.00	6699627.14	1631464.34	143.96	RT90-RHB70	–54.06	35.13	102.2800	0.1400	0.6000	
183.00	6699628.58	1631465.36	146.39	RT90-RHB70	–54.03	35.13	104.0400	0.1500	0.6500	
186.00	6699630.02	1631466.37	148.82	RT90-RHB70	–53.99	35.10	105.8000	0.1500	0.6900	
189.00	6699631.47	1631467.39	151.25	RT90-RHB70	–53.91	35.08	107.5700	0.1500	0.7400	
192.00	6699632.91	1631468.40	153.67	RT90-RHB70	–53.82	35.05	109.3300	0.1500	0.7900	
195.00	6699634.36	1631469.42	156.09	RT90-RHB70	–53.74	35.04	111.1000	0.1500	0.8500	
198.00	6699635.82	1631470.44	158.51	RT90-RHB70	–53.68	35.02	112.8800	0.1500	0.9100	
201.00	6699637.27	1631471.46	160.93	RT90-RHB70	–53.62	34.98	114.6500	0.1500	0.9700	
204.00	6699638.73	1631472.48	163.34	RT90-RHB70	–53.51	34.95	116.4300	0.1500	1.0400	
207.00	6699640.19	1631473.50	165.75	RT90-RHB70	–53.41	34.92	118.2200	0.1500	1.1100	
210.00	6699641.66	1631474.52	168.16	RT90-RHB70	–53.31	34.88	120.0100	0.1400	1.1900	
213.00	6699643.13	1631475.55	170.57	RT90-RHB70	–53.22	34.85	121.8000	0.1400	1.2700	
216.00	6699644.60	1631476.57	172.97	RT90-RHB70	–53.12	34.84	123.6000	0.1300	1.3600	
219.00	6699646.08	1631477.60	175.37	RT90-RHB70	–53.05	34.80	125.4000	0.1300	1.4500	
222.00	6699647.56	1631478.63	177.77	RT90-RHB70	–53.00	34.77	127.2000	0.1200	1.5500	
225.00	6699649.04	1631479.66	180.17	RT90-RHB70	–52.98	34.72	129.0000	0.1100	1.6500	
228.00	6699650.53	1631480.69	182.56	RT90-RHB70	–52.96	34.69	130.8100	0.1000	1.7500	

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
231.00	6699652.01	1631481.72	184.96	RT90-RHB70	–52.93	34.67	132.6200	0.0900	1.8500	
234.00	6699653.50	1631482.75	187.35	RT90-RHB70	–52.89	34.66	134.4300	0.0800	1.9600	
237.00	6699654.99	1631483.78	189.74	RT90-RHB70	–52.86	34.64	136.2400	0.0700	2.0600	
240.00	6699656.48	1631484.81	192.13	RT90-RHB70	–52.84	34.64	138.0500	0.0500	2.1700	
243.00	6699657.97	1631485.84	194.52	RT90-RHB70	–52.81	34.62	139.8600	0.0400	2.2700	
246.00	6699659.46	1631486.87	196.91	RT90-RHB70	–52.77	34.60	141.6700	0.0300	2.3800	
249.00	6699660.96	1631487.90	199.30	RT90-RHB70	–52.69	34.56	143.4900	0.0200	2.5000	
252.00	6699662.46	1631488.93	201.69	RT90-RHB70	–52.61	34.51	145.3100	0.0000	2.6100	
255.00	6699663.96	1631489.96	204.07	RT90-RHB70	–52.56	34.49	147.1300	–0.0200	2.7300	
258.00	6699665.46	1631490.99	206.45	RT90-RHB70	–52.51	34.47	148.9500	–0.0300	2.8500	
261.00	6699666.97	1631492.03	208.83	RT90-RHB70	–52.47	34.46	150.7800	–0.0500	2.9800	
264.00	6699668.47	1631493.06	211.21	RT90-RHB70	–52.44	34.46	152.6100	–0.0700	3.1000	
267.00	6699669.98	1631494.10	213.59	RT90-RHB70	–52.39	34.44	154.4300	–0.0900	3.2300	
270.00	6699671.49	1631495.13	215.97	RT90-RHB70	–52.30	34.40	156.2700	–0.1100	3.3600	
273.00	6699673.00	1631496.17	218.34	RT90-RHB70	–52.17	34.40	158.1000	–0.1300	3.5000	
276.00	6699674.52	1631497.21	220.71	RT90-RHB70	–52.01	34.41	159.9400	–0.1500	3.6400	
279.00	6699676.05	1631498.25	223.07	RT90-RHB70	–51.83	34.39	161.7900	–0.1700	3.7900	
282.00	6699677.58	1631499.30	225.43	RT90-RHB70	–51.68	34.29	163.6400	–0.1900	3.9500	
285.00	6699679.11	1631500.35	227.79	RT90-RHB70	–51.52	34.18	165.5000	–0.2100	4.1200	
288.00	6699680.66	1631501.39	230.14	RT90-RHB70	–51.38	34.13	167.3700	–0.2400	4.3000	
291.00	6699682.21	1631502.45	232.48	RT90-RHB70	–51.29	34.11	169.2400	–0.2700	4.4800	
294.00	6699683.76	1631503.50	234.82	RT90-RHB70	–51.20	34.13	171.1100	–0.3000	4.6700	
297.00	6699685.32	1631504.55	237.16	RT90-RHB70	–51.13	34.16	172.9900	–0.3300	4.8600	
300.00	6699686.87	1631505.61	239.49	RT90-RHB70	–51.07	34.17	174.8800	–0.3600	5.0600	
303.00	6699688.43	1631506.67	241.83	RT90-RHB70	–51.01	34.17	176.7600	–0.3900	5.2600	
306.00	6699690.00	1631507.73	244.16	RT90-RHB70	–50.95	34.16	178.6500	–0.4200	5.4600	
309.00	6699691.56	1631508.79	246.49	RT90-RHB70	–50.88	34.16	180.5400	–0.4500	5.6700	
312.00	6699693.13	1631509.85	248.82	RT90-RHB70	–50.82	34.15	182.4300	–0.4700	5.8800	

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315.00	6699694.69	1631510.92	251.14	RT90-RHB70	–50.79	34.16	184.3300	–0.5000	6.0900	
318.00	6699696.26	1631511.98	253.47	RT90-RHB70	–50.78	34.14	186.2200	–0.5300	6.3100	
321.00	6699697.83	1631513.05	255.79	RT90-RHB70	–50.76	34.11	188.1200	–0.5600	6.5200	
324.00	6699699.40	1631514.11	258.11	RT90-RHB70	–50.71	34.07	190.0200	–0.5900	6.7400	
327.00	6699700.98	1631515.17	260.44	RT90-RHB70	–50.64	34.04	191.9200	–0.6200	6.9600	
330.00	6699702.55	1631516.24	262.76	RT90-RHB70	–50.56	34.02	193.8200	–0.6600	7.1800	
333.00	6699704.13	1631517.31	265.07	RT90-RHB70	–50.49	34.01	195.7200	–0.6900	7.4100	
336.00	6699705.72	1631518.37	267.39	RT90-RHB70	–50.43	34.00	197.6300	–0.7300	7.6400	
339.00	6699707.30	1631519.44	269.70	RT90-RHB70	–50.36	33.99	199.5400	–0.7600	7.8700	
342.00	6699708.89	1631520.51	272.01	RT90-RHB70	–50.32	33.98	201.4600	–0.8000	8.1100	
345.00	6699710.48	1631521.58	274.32	RT90-RHB70	–50.29	33.95	203.3700	–0.8300	8.3500	
348.00	6699712.07	1631522.65	276.63	RT90-RHB70	–50.26	33.95	205.2900	–0.8700	8.5900	
351.00	6699713.66	1631523.72	278.93	RT90-RHB70	–50.23	33.93	207.2000	–0.9000	8.8300	
354.00	6699715.25	1631524.79	281.24	RT90-RHB70	–50.21	33.92	209.1200	–0.9400	9.0700	
357.00	6699716.84	1631525.87	283.55	RT90-RHB70	–50.16	33.88	211.0400	–0.9800	9.3200	
360.00	6699718.44	1631526.94	285.85	RT90-RHB70	–50.08	33.85	212.9600	–1.0200	9.5600	
363.00	6699720.04	1631528.01	288.15	RT90-RHB70	–49.96	33.82	214.8900	–1.0600	9.8200	
366.00	6699721.64	1631529.08	290.45	RT90-RHB70	–49.85	33.78	216.8200	–1.1000	10.0700	
369.00	6699723.25	1631530.16	292.74	RT90-RHB70	–49.78	33.76	218.7500	–1.1400	10.3400	
372.00	6699724.86	1631531.24	295.03	RT90-RHB70	–49.72	33.75	220.6900	–1.1800	10.6100	
375.00	6699726.47	1631532.31	297.32	RT90-RHB70	–49.66	33.74	222.6300	–1.2300	10.8800	
378.00	6699728.09	1631533.39	299.61	RT90-RHB70	–49.62	33.76	224.5700	–1.2700	11.1500	
381.00	6699729.70	1631534.47	301.89	RT90-RHB70	–49.61	33.78	226.5100	–1.3100	11.4200	
384.00	6699731.32	1631535.55	304.18	RT90-RHB70	–49.61	33.78	228.4600	–1.3600	11.7000	
387.00	6699732.93	1631536.63	306.46	RT90-RHB70	–49.62	33.80	230.4000	–1.4000	11.9800	
390.00	6699734.55	1631537.72	308.75	RT90-RHB70	–49.64	33.82	232.3400	–1.4400	12.2500	
393.00	6699736.16	1631538.80	311.03	RT90-RHB70	–49.68	33.85	234.2900	–1.4800	12.5300	
396.00	6699737.77	1631539.88	313.32	RT90-RHB70	–49.72	33.87	236.2300	–1.5200	12.8000	

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399.00	6699739.38	1631540.96	315.61	RT90-RHB70	–49.75	33.88	238.1700	–1.5600	13.0700	
402.00	6699740.99	1631542.04	317.90	RT90-RHB70	–49.77	33.87	240.1000	–1.6000	13.3400	
405.00	6699742.60	1631543.12	320.19	RT90-RHB70	–49.80	33.88	242.0400	–1.6400	13.6100	
408.00	6699744.21	1631544.20	322.48	RT90-RHB70	–49.82	33.87	243.9800	–1.6800	13.8700	
411.00	6699745.82	1631545.28	324.77	RT90-RHB70	–49.83	33.90	245.9100	–1.7200	14.1400	
414.00	6699747.42	1631546.36	327.06	RT90-RHB70	–49.84	33.91	247.8500	–1.7600	14.4000	
417.00	6699749.03	1631547.44	329.36	RT90-RHB70	–49.86	33.92	249.7800	–1.7900	14.6700	
420.00	6699750.63	1631548.52	331.65	RT90-RHB70	–49.86	33.93	251.7200	–1.8300	14.9300	
423.00	6699752.24	1631549.60	333.94	RT90-RHB70	–49.87	33.94	253.6500	–1.8700	15.1900	
426.00	6699753.84	1631550.68	336.24	RT90-RHB70	–49.88	33.93	255.5800	–1.9100	15.4500	
429.00	6699755.45	1631551.75	338.53	RT90-RHB70	–49.88	33.91	257.5200	–1.9400	15.7200	
432.00	6699757.05	1631552.83	340.82	RT90-RHB70	–49.87	33.92	259.4500	–1.9800	15.9800	
435.00	6699758.66	1631553.91	343.12	RT90-RHB70	–49.84	33.93	261.3800	–2.0200	16.2400	
438.00	6699760.26	1631554.99	345.41	RT90-RHB70	–49.79	33.93	263.3200	–2.0600	16.5100	
441.00	6699761.87	1631556.07	347.70	RT90-RHB70	–49.69	33.93	265.2500	–2.0900	16.7700	
444.00	6699763.48	1631557.16	349.99	RT90-RHB70	–49.59	33.94	267.1900	–2.1300	17.0400	
447.00	6699765.09	1631558.24	352.27	RT90-RHB70	–49.48	33.94	269.1400	–2.1700	17.3200	
450.00	6699766.71	1631559.33	354.55	RT90-RHB70	–49.34	33.93	271.0900	–2.2000	17.6000	
453.00	6699768.33	1631560.42	356.83	RT90-RHB70	–49.24	33.91	273.0400	–2.2400	17.8900	
456.00	6699769.96	1631561.51	359.10	RT90-RHB70	–49.11	33.89	275.0000	–2.2800	18.1900	
459.00	6699771.59	1631562.61	361.37	RT90-RHB70	–48.99	33.86	276.9600	–2.3200	18.4900	
462.00	6699773.22	1631563.71	363.63	RT90-RHB70	–48.91	33.87	278.9300	–2.3600	18.8000	
465.00	6699774.86	1631564.80	365.90	RT90-RHB70	–48.82	33.85	280.9000	–2.4000	19.1100	
468.00	6699776.50	1631565.90	368.15	RT90-RHB70	–48.72	33.81	282.8800	–2.4400	19.4300	
471.00	6699778.14	1631567.01	370.41	RT90-RHB70	–48.62	33.79	284.8500	–2.4800	19.7500	
474.00	6699779.79	1631568.11	372.66	RT90-RHB70	–48.52	33.75	286.8400	–2.5300	20.0800	
477.00	6699781.44	1631569.21	374.91	RT90-RHB70	–48.45	33.71	288.8200	–2.5700	20.4100	
480.00	6699783.10	1631570.32	377.15	RT90-RHB70	–48.42	33.67	290.8100	–2.6200	20.7500	

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483.00	6699784.76	1631571.42	379.40	RT90-RHB70	–48.40	33.64	292.8000	–2.6700	21.0900	
486.00	6699786.41	1631572.52	381.64	RT90-RHB70	–48.39	33.62	294.7900	–2.7100	21.4300	
489.00	6699788.07	1631573.63	383.88	RT90-RHB70	–48.37	33.61	296.7900	–2.7600	21.7600	
492.00	6699789.73	1631574.73	386.12	RT90-RHB70	–48.35	33.58	298.7800	–2.8100	22.1000	
495.00	6699791.39	1631575.83	388.37	RT90-RHB70	–48.32	33.55	300.7700	–2.8600	22.4500	
498.00	6699793.06	1631576.94	390.61	RT90-RHB70	–48.28	33.53	302.7700	–2.9100	22.7900	
501.00	6699794.72	1631578.04	392.85	RT90-RHB70	–48.24	33.51	304.7600	–2.9700	23.1300	
504.00	6699796.39	1631579.14	395.08	RT90-RHB70	–48.20	33.49	306.7600	–3.0200	23.4800	
507.00	6699798.05	1631580.24	397.32	RT90-RHB70	–48.17	33.45	308.7600	–3.0700	23.8300	
510.00	6699799.72	1631581.35	399.56	RT90-RHB70	–48.14	33.43	310.7600	–3.1300	24.1800	
513.00	6699801.40	1631582.45	401.79	RT90-RHB70	–48.10	33.40	312.7600	–3.1900	24.5300	
516.00	6699803.07	1631583.55	404.02	RT90-RHB70	–48.08	33.37	314.7600	–3.2400	24.8900	
519.00	6699804.74	1631584.66	406.26	RT90-RHB70	–48.06	33.34	316.7700	–3.3000	25.2400	
522.00	6699806.42	1631585.76	408.49	RT90-RHB70	–48.02	33.31	318.7700	–3.3600	25.6000	
525.00	6699808.09	1631586.86	410.72	RT90-RHB70	–47.98	33.29	320.7700	–3.4200	25.9600	
528.00	6699809.77	1631587.96	412.95	RT90-RHB70	–47.96	33.26	322.7800	–3.4800	26.3200	
531.00	6699811.45	1631589.06	415.17	RT90-RHB70	–47.96	33.24	324.7900	–3.5400	26.6800	
534.00	6699813.13	1631590.16	417.40	RT90-RHB70	–47.93	33.22	326.8000	–3.6100	27.0400	
537.00	6699814.81	1631591.27	419.63	RT90-RHB70	–47.90	33.18	328.8100	–3.6700	27.4000	
540.00	6699816.50	1631592.37	421.85	RT90-RHB70	–47.84	33.16	330.8200	–3.7400	27.7700	
543.00	6699818.18	1631593.47	424.08	RT90-RHB70	–47.79	33.15	332.8300	–3.8000	28.1400	
546.00	6699819.87	1631594.57	426.30	RT90-RHB70	–47.75	33.11	334.8400	–3.8700	28.5100	
549.00	6699821.56	1631595.67	428.52	RT90-RHB70	–47.70	33.06	336.8600	–3.9400	28.8800	
552.00	6699823.25	1631596.77	430.74	RT90-RHB70	–47.65	33.01	338.8800	–4.0100	29.2500	
555.00	6699824.95	1631597.87	432.96	RT90-RHB70	–47.60	32.97	340.9000	–4.0800	29.6300	
558.00	6699826.64	1631598.98	435.17	RT90-RHB70	–47.55	32.94	342.9200	–4.1500	30.0100	
561.00	6699828.34	1631600.08	437.39	RT90-RHB70	–47.47	32.88	344.9400	–4.2200	30.3900	
564.00	6699830.05	1631601.18	439.60	RT90-RHB70	–47.40	32.84	346.9700	–4.3000	30.7800	

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567.00	6699831.75	1631602.28	441.81	RT90-RHB70	–47.36	32.84	349.0000	–4.3800	31.1700	
570.00	6699833.46	1631603.38	444.01	RT90-RHB70	–47.33	32.84	351.0300	–4.4600	31.5600	
573.00	6699835.17	1631604.48	446.22	RT90-RHB70	–47.28	32.80	353.0600	–4.5300	31.9600	
576.00	6699836.88	1631605.59	448.42	RT90-RHB70	–47.22	32.75	355.0900	–4.6100	32.3500	
579.00	6699838.59	1631606.69	450.62	RT90-RHB70	–47.17	32.71	357.1300	–4.6900	32.7500	
582.00	6699840.31	1631607.79	452.82	RT90-RHB70	–47.13	32.69	359.1700	–4.7800	33.1500	
585.00	6699842.03	1631608.89	455.02	RT90-RHB70	–47.10	32.66	361.2100	–4.8600	33.5600	
588.00	6699843.75	1631609.99	457.22	RT90-RHB70	–47.08	32.65	363.2500	–4.9500	33.9600	
591.00	6699845.47	1631611.10	459.42	RT90-RHB70	–47.08	32.63	365.2900	–5.0300	34.3700	
594.00	6699847.19	1631612.20	461.61	RT90-RHB70	–47.06	32.60	367.3300	–5.1200	34.7800	
597.00	6699848.91	1631613.30	463.81	RT90-RHB70	–47.04	32.58	369.3700	–5.2000	35.1800	
600.00	6699850.63	1631614.40	466.01	RT90-RHB70	–47.01	32.55	371.4100	–5.2900	35.5900	
603.00	6699852.36	1631615.50	468.20	RT90-RHB70	–46.97	32.52	373.4600	–5.3800	36.0000	
606.00	6699854.08	1631616.60	470.39	RT90-RHB70	–46.95	32.50	375.5000	–5.4700	36.4100	
609.00	6699855.81	1631617.70	472.59	RT90-RHB70	–46.93	32.47	377.5500	–5.5600	36.8300	
612.00	6699857.54	1631618.80	474.78	RT90-RHB70	–46.91	32.44	379.6000	–5.6500	37.2400	
615.00	6699859.27	1631619.90	476.97	RT90-RHB70	–46.87	32.40	381.6400	–5.7400	37.6600	
618.00	6699861.00	1631621.00	479.16	RT90-RHB70	–46.83	32.38	383.6900	–5.8400	38.0700	
621.00	6699862.73	1631622.10	481.35	RT90-RHB70	–46.80	32.35	385.7400	–5.9300	38.4900	
624.00	6699864.47	1631623.20	483.53	RT90-RHB70	–46.76	32.32	387.7900	–6.0300	38.9100	
627.00	6699866.20	1631624.30	485.72	RT90-RHB70	–46.72	32.29	389.8500	–6.1300	39.3400	
630.00	6699867.94	1631625.39	487.90	RT90-RHB70	–46.69	32.27	391.9000	–6.2300	39.7600	
633.00	6699869.68	1631626.49	490.09	RT90-RHB70	–46.65	32.24	393.9600	–6.3200	40.1900	
636.00	6699871.42	1631627.59	492.27	RT90-RHB70	–46.60	32.20	396.0100	–6.4300	40.6200	
639.00	6699873.17	1631628.69	494.45	RT90-RHB70	–46.56	32.16	398.0700	–6.5300	41.0500	
642.00	6699874.91	1631629.79	496.62	RT90-RHB70	–46.52	32.11	400.1300	–6.6300	41.4800	
645.00	6699876.66	1631630.89	498.80	RT90-RHB70	–46.49	32.07	402.1900	–6.7400	41.9100	
648.00	6699878.41	1631631.98	500.98	RT90-RHB70	–46.47	32.04	404.2600	–6.8400	42.3500	

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
651.00	6699880.16	1631633.08	503.15	RT90-RHB70	–46.45	32.03	406.3200	–6.9500	42.7900	
654.00	6699881.92	1631634.17	505.33	RT90-RHB70	–46.41	32.02	408.3800	–7.0600	43.2300	
657.00	6699883.67	1631635.27	507.50	RT90-RHB70	–46.35	32.02	410.4500	–7.1700	43.6700	
660.00	6699885.43	1631636.37	509.67	RT90-RHB70	–46.30	32.01	412.5200	–7.2800	44.1100	
663.00	6699887.18	1631637.47	511.84	RT90-RHB70	–46.25	31.98	414.5900	–7.3900	44.5600	
666.00	6699888.94	1631638.57	514.01	RT90-RHB70	–46.20	31.95	416.6600	–7.5000	45.0100	
669.00	6699890.71	1631639.67	516.17	RT90-RHB70	–46.16	31.97	418.7300	–7.6100	45.4600	
672.00	6699892.47	1631640.77	518.33	RT90-RHB70	–46.13	31.97	420.8100	–7.7200	45.9100	
675.00	6699894.23	1631641.87	520.50	RT90-RHB70	–46.10	32.01	422.8800	–7.8300	46.3600	
678.00	6699896.00	1631642.97	522.66	RT90-RHB70	–46.05	32.01	424.9600	–7.9400	46.8200	
681.00	6699897.76	1631644.07	524.82	RT90-RHB70	–46.00	32.01	427.0400	–8.0500	47.2800	
684.00	6699899.53	1631645.18	526.98	RT90-RHB70	–45.98	32.00	429.1200	–8.1600	47.7400	
687.00	6699901.30	1631646.28	529.13	RT90-RHB70	–45.98	32.00	431.2000	–8.2700	48.2000	
690.00	6699903.07	1631647.39	531.29	RT90-RHB70	–45.94	31.93	433.2900	–8.3800	48.6700	
693.00	6699904.84	1631648.49	533.45	RT90-RHB70	–45.93	31.87	435.3700	–8.4900	49.1300	
696.00	6699906.61	1631649.59	535.60	RT90-RHB70	–45.89	31.90	437.4500	–8.6100	49.6000	
699.00	6699908.38	1631650.70	537.76	RT90-RHB70	–45.85	31.91	439.5400	–8.7200	50.0600	
702.00	6699910.15	1631651.80	539.91	RT90-RHB70	–45.78	31.89	441.6200	–8.8400	50.5300	
705.00	6699911.93	1631652.91	542.06	RT90-RHB70	–45.72	31.82	443.7100	–8.9500	51.0100	
708.00	6699913.71	1631654.01	544.21	RT90-RHB70	–45.68	31.77	445.8000	–9.0700	51.4800	
711.00	6699915.49	1631655.11	546.35	RT90-RHB70	–45.65	31.75	447.9000	–9.1900	51.9600	
714.00	6699917.28	1631656.22	548.50	RT90-RHB70	–45.64	31.75	449.9900	–9.3100	52.4400	
717.00	6699919.06	1631657.32	550.64	RT90-RHB70	–45.62	31.73	452.0800	–9.4300	52.9200	
720.00	6699920.84	1631658.42	552.79	RT90-RHB70	–45.59	31.72	454.1800	–9.5500	53.4000	
723.00	6699922.63	1631659.53	554.93	RT90-RHB70	–45.55	31.70	456.2700	–9.6700	53.8800	
726.00	6699924.42	1631660.63	557.07	RT90-RHB70	–45.52	31.70	458.3700	–9.7900	54.3700	
729.00	6699926.21	1631661.74	559.21	RT90-RHB70	–45.50	31.68	460.4700	–9.9200	54.8500	
732.00	6699927.99	1631662.84	561.35	RT90-RHB70	–45.47	31.67	462.5700	–10.0400	55.3400	

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
735.00	6699929.79	1631663.95	563.49	RT90-RHB70	–45.43	31.62	464.6700	–10.1600	55.8300	
738.00	6699931.58	1631665.05	565.63	RT90-RHB70	–45.38	31.57	466.7700	–10.2900	56.3200	
741.00	6699933.37	1631666.15	567.76	RT90-RHB70	–45.33	31.50	468.8700	–10.4100	56.8100	
744.00	6699935.17	1631667.25	569.90	RT90-RHB70	–45.29	31.44	470.9800	–10.5400	57.3000	
747.00	6699936.97	1631668.36	572.03	RT90-RHB70	–45.25	31.41	473.0900	–10.6800	57.8000	
750.00	6699938.77	1631669.46	574.16	RT90-RHB70	–45.22	31.37	475.1900	–10.8100	58.3000	
753.00	6699940.58	1631670.56	576.29	RT90-RHB70	–45.17	31.32	477.3000	–10.9500	58.8000	
756.00	6699942.39	1631671.66	578.42	RT90-RHB70	–45.10	31.27	479.4100	–11.0800	59.3000	
759.00	6699944.20	1631672.76	580.54	RT90-RHB70	–45.01	31.24	481.5300	–11.2200	59.8100	
762.00	6699946.01	1631673.86	582.66	RT90-RHB70	–44.92	31.22	483.6400	–11.3600	60.3200	
765.00	6699947.83	1631674.96	584.78	RT90-RHB70	–44.86	31.20	485.7600	–11.5000	60.8400	
768.00	6699949.64	1631676.06	586.90	RT90-RHB70	–44.83	31.19	487.8800	–11.6500	61.3600	
771.00	6699951.46	1631677.16	589.01	RT90-RHB70	–44.81	31.18	490.0100	–11.7900	61.8800	
774.00	6699953.29	1631678.26	591.13	RT90-RHB70	–44.78	31.16	492.1300	–11.9300	62.4000	
777.00	6699955.11	1631679.36	593.24	RT90-RHB70	–44.75	31.14	494.2500	–12.0800	62.9200	
780.00	6699956.93	1631680.46	595.35	RT90-RHB70	–44.73	31.12	496.3800	–12.2200	63.4500	
783.00	6699958.76	1631681.57	597.46	RT90-RHB70	–44.71	31.11	498.5100	–12.3700	63.9700	
786.00	6699960.58	1631682.67	599.58	RT90-RHB70	–44.69	31.09	500.6300	–12.5100	64.5000	
789.00	6699962.41	1631683.77	601.68	RT90-RHB70	–44.67	31.09	502.7600	–12.6600	65.0300	
792.00	6699964.23	1631684.87	603.79	RT90-RHB70	–44.65	31.08	504.8900	–12.8100	65.5500	
798.00	6699967.89	1631687.08	608.01	RT90-RHB70	–44.62	31.10	509.1500	–13.1000	66.6200	

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Appendix 4

Length reference marks

Reference Mark T – Reference mark in drillhole

KFM01D, 2006-02-15 14:00:00–2006-02-15 21:30:00 (150.000–750.000 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
150.00	400.00	300	450	25.0	0	JA		150,79/150,89
200.00	400.00	300	450	25.0	0	JA		201,06/201,16
250.00	400.00	300	450	28.0	0	JA		251,31/251,41
300.00	400.00	300	450	28.0	0	JA		301,57/301,67
350.00	400.00	300	450	30.0	0	JA		351,82/351,92
400.00	400.00	300	450	30.0	0	JA		402,07/402,17
450.00	400.00	300	450	30.0	0	JA		452,32/452,42
500.00	400.00	300	450	30.0	0	JA		502,58/502,68
550.00	400.00	300	450	29.0	0	JA		552,83/552,93
600.00	400.00	300	450	28.0	0	JA		603,09/603,19
650.00	400.00	300	450	29.0	0	JA		653,35/653,45
700.00	400.00	300	450	29.0	0	JA		703,59/703,69
750.00	400.00	300	450	29.0	0	JA		753,86/753,96

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