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KBS-3H

Single-hole interpretation of borehole K08028F01

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Update notice

The original report, dated December 2016, was found to contain an error which have been corrected in this updated version. The corrected error is presented below.

Updated 2019-05

Location	Original text	Corrected text
Appendix 1	WellCAD plot is missing.	WellCAD plot inserted.

Abstract

Methodology development for detailed site investigations is ongoing within the SKB DETUM project which includes development of methodology for site descriptive modelling (SKB 2010). The methodology development process puts strong emphasis on integrated modelling during all phases of modelling. One component in the development is to increase the scope of the current methodology for geological single hole interpretation to also include integration of hydrogeological and hydrogeochemical data. Another important aspect is the demand for increased spatial resolution, primarily in the identification of potential critical structures (related to the FPI criterion). The current work, called geoscientific single-hole interpretation, constitutes a first trial of such integration where the experiences will form basis for definition of a new/updated methodology.

This report presents the single-hole interpretation of the cored borehole K08028F01 which has been drilled underground from the Äspö tunnel to serve as pilot borehole for a planned full scale KBS-3H experimental drift. The interpretation combines the geological core mapping, interpreted geophysical logs, and borehole radar measurements to identify rock units and potential critical structures for canister integrity. The latter includes both continuous single fractures and minor deformation zones that constitute potential risks for either secondary movements as a result of seismic events or inflow of water of such extent that the design premises are not fulfilled. Hydrogeological data have been used in order to identify structural features with increased hydraulic conductivity and hydrogeochemical data have also been used to support the interpretation work.

The single-hole interpretation of the borehole K08028F01 shows that the dominant rock is Ävrö granodiorite (501056). There are four borehole sections of fine-grained granite (511058) evenly distributed along the borehole. Two sections of fine-grained diorite-gabbro (505102) occur in the superficial part of the borehole. There is also a short section of Äspö diorite (501037) in the central part of K08028F01.

Five possible deformation zones (potential critical structures) were identified in K08028F01, denoted DZ1–DZ5. The zones DZ1–DZ4 have been identified with a low confidence of existence (confidence level = 1) and DZ5, at the end of the borehole, which has been identified with a high confidence of existence (confidence level = 3).

The KBS-3H design has been developed jointly by SKB and Posiva since 2002. This report has been prepared within the project phase "KBS-3H – System Design 2011–2016".

Sammanfattning

Metodutveckling för en detaljerad platsundersökning pågår inom SKBs DETUM-projekt och detta arbete inkluderar utveckling av metodik för platsspecifik modellering (SKB, 2010). Det läggs stor vikt på att man använder sig av integrerad modellering i alla steg i processen. Som en del i utvecklingsarbetet ingår att öka omfattningen på den i nuläget s.k. geologiska enhålstolkningen till att i fortsättning även inkludera hydrogeologiska och hydrogeokemiska data. En annan viktig del är att öka den rumsliga upplösningen i tolkningen, framförallt rörande identifikationen av möjliga kritiska strukturer (FPI). Föreliggande arbete utgör ett första test av en integrerad geovetenskaplig enhålstolkning och är tänkt att ligga till grund för en ny/uppdaterad metodik.

Denna rapport behandlar enhålstolkning av kärnborrhålet K08028F01 vilket har borrats under jord från Äspötunneln i syfte att användas som pilotborrhål för en planerad fullskalig experimentell fullortsborrad tunnel inom ramen för projekt KBS-3H. Enhålstolkningen syftar till att utifrån den geologiska karteringen, tolkade geofysiska loggar och borrhålsradarmätningar identifiera olika bergenheters fördelning i borrhålen samt läge och utbredning av möjliga kritiska strukturer, vilket inkluderar både kontinuerliga enskilda sprickor samt mindre deformationszoner som utgör potentiell risk för att säkerhetskraven inte uppfylls, dels genom sekundära rörelser till följd av seismiska händelser eller genom omfattande inflöde av vatten. Hydrogeologiska data har använts för att identifiera strukturer med förhöjd hydraulisk konduktivitet och geokemiska data har använts för att stödja tolkningsarbetet.

Enhålstolkningen visar att berget som omger kärnborrhålet K08028F01 domineras av Ävrögranodiorit (501056). Det förekommer fyra sektioner med finkornig granit (511058) jämnt fördelade längs borrhålet och två sektioner med finkornig diorit-gabbro (505102) förekommer i hålets nedre del. Det finns endast en kortare sektion med Äspödiorit (501037) i den centrala delen av K08028F01.

Fem möjliga deformationszoner eller möjliga kritiska strukturer har identifierats i K08028F01 (DZ1–DZ5). DZ1–DZ4 existens har identifierats med låg konfidens (konfidensnivå = 1) och DZ5, som är belägen längs hålets sista ca 10 m, har identifierats med hög konfidens (konfidensnivå = 3).

KBS-3H är en variant av KBS-3 metoden som utvecklas gemensamt av SKB och Posiva. Denna rapport har utarbetats under projektfasen ”KBS-3H – System Design 2011–2016”.

Contents

1 Introduction

Much of the primary geological, geophysical, hydrogeological and hydrogeochemical borehole data stored in the SKB database SICADA need to be integrated and synthesized before they can be used for modelling in the 3D-CAD system Rock Visualization System (RVS). The end result of this procedure has traditionally been termed geological single-hole interpretation, which consists of integrated series of different geological and geophysical logging data and accompanying descriptive documents (SKB MD 810.003 v.3.0, SKB internal controlling document, cf. Table 1-1).

Methodology development for detailed site investigations is ongoing within the SKB DETUM project which includes development of methodology for site descriptive modelling (SKB 2010). This process puts strong emphasis on integrated modelling during all phases of modelling. One component in the development is to increase the scope of the current methodology for geological single hole interpretation to also include integration of hydrogeological and hydrogeochemical data.

Another important aspect is the demand for increased spatial resolution, primarily in the identification of potential critical structures. A critical structure can be defined as a geological structure that may jeopardize the long-term safety of a canister if it intersects a deposition hole. The term embraces continuous single fractures and minor deformation zones that constitute potential risks for either secondary movement as a result of seismic events or as inflow of water of such extent that the design premises for the deposition hole are not fulfilled. One such potential critical structure is the “Full Perimeter Intersection” (FPI). The term was introduced to represent and account for fractures of unknown size, but being of such extent that their intersection with a tunnel can be traced around the full perimeter of the tunnel face. (cf. Munier 2010). However, it must be emphasized the identification by way of borehole information of individual fractures that might be potentially critical is very limited and the interpretation is hence, more or less, limited to potential minor deformation zones. The current work constitutes a trial of such integration and application of increased spatial resolution where the gained experiences will form basis for possible adjustments of the existing methodology.

The KBS-3H design has been developed jointly by SKB and Posiva since 2002. This report has been prepared within the project phase “KBS-3H – System Design 2011–2016”.

This document reports the results gained from the single-hole interpretation (SHI) of the cored borehole K08028F01, which is one of the activities performed within the KBS-3H project (SKB 2012). The borehole has been drilled underground from the TAS08 tunnel in the Äspö Hard Rock Laboratory (Figure 1-1) and is planned to serve as pilot borehole for a planned full scale KBS-3H experimental drift. The analysis work was carried out in accordance with the steering and controlling documents listed in Table 1-1. The rock type nomenclature (Table 1-2) that has been used is in accordance with method instruction SKB MD 132.004.

Table 1-1. Controlling and steering documents for the performance of the activity. The listed documents are internal unpublished SKB internal documents written in Swedish.

Activity plan	Number	Version
AP TD 3HDEMO-14-056 – Geovetenskaplig enhålstolkning av K08028F01.	AP TD 3HDEMO-14-056	1.0
Method description	**Number**	**Version**
Metodbeskrivning för geologisk enhålstolkning.	SKB MD 810.003	3.0
Instruktion: Regler för bergarters benämningar vid platsundersökning i Oskarshamn.	SKB MD 132.004	1.0

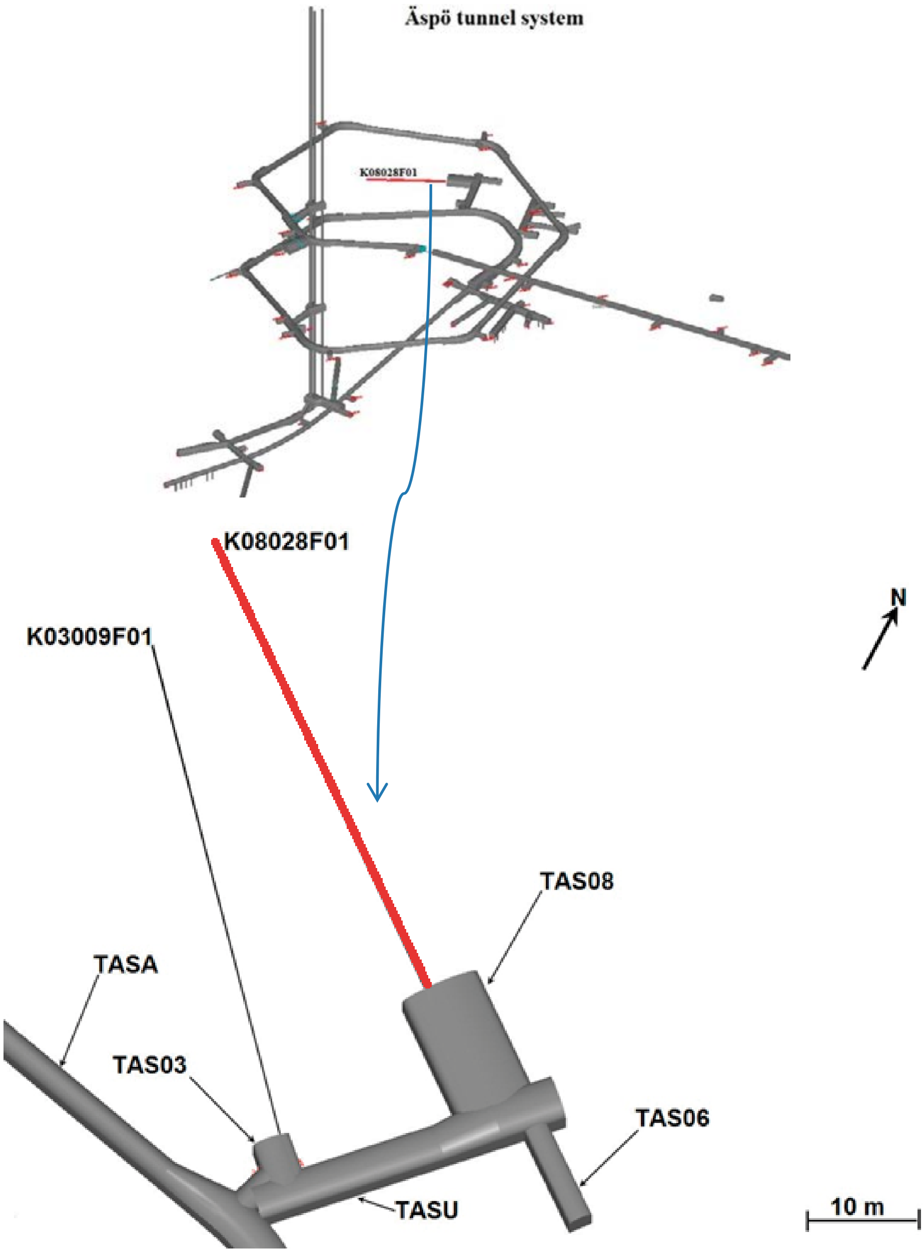

Figure 1-1. *The position of the cored borehole K08028F01(red line) in the TAS08 tunnel located in the interior of the TASU tunnel (part of the Äspö Expansion area at the –410 m level). Overview map at the top and close up below.*

Table 1-2. The rock nomenclature (rock types and rock occurrences) used in the geological borehole mapping, which was made by the Boremap methodology adopted by SKB.

Rock type	Rock code	Rock description
Dolerite	501027	Dolerite
Fine-grained Götemar granite	531058	Granite, fine- to medium-grained, ("Götemar granite")
Coarse-grained Götemar granite	521058	Granite, coarse-grained, ("Götemar granite")
Fine-grained granite	511058	Granite, fine- to medium-grained
Pegmatite	501061	Pegmatite
Granite	501058	Granite, medium- to coarse-grained
Ävrö granite	501044	Granite to quartz monzodiorite, generally porphyritic
Ävrö granodiorite	501056	Granite to granodiorite, sparsely porphyritic to porphyritic
Ävrö quartz monzodiorite	501046	Quartz monzonite to quartz monzodiorite, generally porphyritic
Äspö diorite	501037	Quartz monzodiorite to granodiorite, porphyritic
Quartz monzodiorite	501036	Quartz monzodiorite to granodiorite, equigranular to sparsely porphyritic
Diorite-gabbro	501033	Diorite to gabbro
Fine-grained dioritoid	501030	Intermediate rock, fine-grained
Fine-grained diorite-gabbro	505102	Mafic rock, fine-grained
Gabbroid-dioritoid	508107	Mafic rock, undifferentiated
Mylonite	508004	Mylonite
Sulphide mineralization	509010	Sulphide mineralization
Sandstone	506007	Sandstone
Quartz-dominated hydrothermal vein/segregation	508021	Quartz-dominated hydrothermal vein/segregation
Hybrid rock	505105	Hybrid rock
Breccia	508002	Breccia
Felsic volcanic rock	503076	Felsic volcanic rock

2 Objective and scope

The single-hole interpretation forms an important, intermediate step of synthesis and conceptualization between borehole data and modelling, with identification of major rock units and possible deformation zones along a borehole. The result of the SHI interpretation constitutes a 1D model representation of the dominant rock units and possible deformation zones in the immediate vicinity of the borehole, top serve as input information in the subsequent 3D-modelleing. The traditional work has involved an integrated interpretation of data from the geological mapping of the borehole (Boremap), different borehole geophysical logs and borehole radar data. However, the ongoing methodology development for site descriptive modelling within the SKB DETUM project puts strong emphasis on integrative modelling, including the single-hole interpretation. To gain practical experience as a basis for definition of such new methodology, it was decided to include integration of hydrogeological and hydrogeochemical data in the current interpretation of K08028F01, thereby the notation "geoscientific". Integration of hydrogeological data in the process has to a variable extent been made previously during the interpretation of borehole data from the site investigations for the expansion of SFR (e.g. Petersson et al. 2010) and the characterisation of the uppermost 150 m of the bedrock in proximity of the planned accesses and surface drift areas of the final repository.

The focus of the work lies in establishing an increased resolution of the interpretation, along with an integration of hydrogeological and hydrogeochemical data. The requirement has been to relate to the long-term safety, whereby recognition of potential FPIs, ultimately constituting potential critical structures for canister integrity, and definition of rock units being of possible significance to thermal modelling are emphasized.

An important aspect in the current work has been the required increase in the resolution of the interpretation. During the site descriptive modelling at completion of the site investigations in Forsmark and Laxemar, the single-hole interpretation process focused on the identification of possible major deformation zones (i.e. more extensive structures intercepting the borehole, cf. SKB 2008). One of the basic criteria for identification of possible deformation zones in boreholes during that process was a significant increase of the fracture frequency. To fulfil the design premises during the construction and operation of the final repository by way of detailed site investigations, the degree of detail in the interpretation must be increased to embrace all structures defined as being possibly critical for long-term safety. Given the canister failure criterion associated with the most recent canister design (SKB 2009), the term critical structure where movements exceeding this criterion are to be expected includes continuous single fractures and minor deformation zones with radii exceeding approximately 75 m (Fälth et al. 2010). To recognize potential critical structures in a borehole the focus on scale dependent parameters, such as relative fracture frequency, must be reduced in favour of specific properties that are characteristic to FPIs and which are readily identifiable in borehole data and logs.

In the current interpretation of K08028F01, it was decided to identify all structures that may constitute potential FPIs, and ultimately potential critical structures, which also comprise structures that in the traditional SHI were recognized as possible deformation zones. In the absence of a systematic compilation of distinctive, site specific properties for FPIs, the interpretation largely relied on typical parameters listed by Cosgrove et al. (2006) for large fractures, in addition to the fracture frequency. These parameters include displacement, kinematic indicators, aperture (width for sealed fractures) and transmissivity.

Again, it should be stressed that the possibility to identify single fractures as potential critical structures from borehole information is very limited. Without the existence of a combination of several indicative parameters the confidence in the interpretation would be too low to be of any value for future layout decisions. There is also a significant risk for over interpretation. Thus, the identification of such low confidence structures the identification of critical structures must be focused on minor deformation zones and the identification of less prominent structures of potential critical size is possible first when a tunnel has been driven. This said, it is however projected that with the wealth of information collected during development of the planned repository at Forsmark, the successively gained empirical knowledge base will improve the prospect and capability for making such projections from borehole information.

The subdivision of K08028F01 into rock units was also subjected to a reassessment in terms of resolution. The minimum borehole length of a rock unit has traditionally been in the order of c. 5 m, as defined in (SKB MD 810.003). However, the size of the smallest defined rock unit should depend on the scale at which variations of thermal conductivity are significant for the maximum temperature of the canister. Based on the conclusions of Sundberg et al. (2005) the minimum size of a rock unit has therefore been set to 1–2 m for rock types with anomalous thermal conductivity compared with the predominant rock type(-s).

3 Data used for the single-hole interpretation

The following data have been used in the single-hole interpretation of borehole K08028F01:

- Boremap data from geological mapping (Sigurdsson 2016).
- Generalized geophysical logs and their interpretation (Tiensuu and Heikkinen 2016).
- Radar data and their interpretation (Gustafsson 2016).
- Hydrogeological data (PFL and cross-hole interference tests) (Komulainen and Pöllänen 2016, Hjerne et al. 2016).
- Hydrogeochemical data (Wallin 2016).

As a basis for the geoscientific single-hole interpretation, a combined WellCad plot consisting of the above mentioned data sets was used. The plot consists of 10 main columns and several subordinate columns. The columns include:

1: BH Length: Length along the borehole

2: Rock type
- 2.1: Rock type
- 2.2: Occurrence, Rock type < 1m
- 2.3: Rock type structure
- 2.4: Rock type texture
- 2.5: Rock type grain size
- 2.6: Structure orientation
- 2.7: Rock alteration
- 2.8: Rock alteration intensity

3: Fracture frequency
- 3.1: Open total
- 3.2: Sealed total
- 3.3: Fracture orientation open/sealed
- 3.4: Fracture orientation broken/unbroken
- 3.5: Total fractures

4: Fracture alteration orientation
- 4.1: Open alteration
- 4.2: Sealed alteration
- 4.3: Surface

5: Crush zones and core loss
- 5.1: Crush zone
- 5.2: Piece length (mm)
- 5.3: Core loss

6: Generalized geophysical data
- 6.1: Silicate density
- 6.2: Magnetic susceptibility
- 6.3: Natural gamma radiation
- 6.4: Estimated fracture frequency (fr/m)

7: Fracture orientation and radar
- 7.1: Fracture orientation open/sealed
- 7.2: Radar direct primary/info
- 7.3: Radar dipole primary/info

8: Hydrogeology
  8.1: Pumping T Flow TMoye/Pumping T Flow period
  8.2: Transmissivity Flow logging
  8.3: Test pumping
  8.4: Pumped inflow
  8.5: TD/T Lower limit/T Upper limit

9: Hydrogeochemistry
  9.1: Alkalinity
  9.2: Chloride
  9.3: pH

9: Packers
  9.1: Packer positions

10: OPTV
  10.1: OPTV

The generalized geophysical logs are described below:

Silicate density: This parameter indicates the density of the bedrock after subtraction of the magnetic component. It provides general information on the mineral composition of the rock types. The classification is divided into five groups of silicate density < 2 680 kg/m^3, 2 680–2 730 kg/m^3, 2 730–2 800 kg/m^3, 2 800–2 890 kg/m^3 and > 2 890 kg/m^3 corresponding to the mineral composition of granite, granodiorite, tonalite, diorite and gabbro, respectively (Puranen 1989). The data serve as a support to the classification of rock types.

Magnetic susceptibility: The bedrock has been classified into sections of low (< 10^{-3} SI), medium (10^{-3}–10^{-2} SI), high (10^{-2}–10^{-1} SI), and very high (>10^{-1} SI) magnetic susceptibility. The susceptibility is strongly associated with the magnetite content in the different rock types.

Natural gamma radiation: The bedrock has been classified into sections of low, medium, and high natural gamma radiation. Low radiation may indicate mafic rock types and high radiation may indicate fine-grained granite or pegmatite.

Estimated fracture frequency: This parameter provides an estimate of the fracture frequency (roughly open and partly open fractures) along 5 m sections, calculated from resistivity, SPR, P-wave velocity and caliper data. The estimated fracture frequency is based on a statistical relationship after a comparison has been made between the geophysical logs and the mapped open fracture frequency. The log provides an indication of sections with low and high frequency of fractures.

Separate diagrams of moving averages of open fractures alone, open fractures as well as partly open fractures and crush, the sealed fractures alone, and the total number of sealed fractures and sealed fracture networks, respectively, were available during the interpretation process.

Close inspection of the borehole radar data was carried out during the interpretation process, especially during the identification of possible deformation zones. The occurrence and orientation or alpha angles (between reflector plane and borehole axis) of radar anomalies within the possible deformation zones are commented upon in the text that describes these zones.

The hydrogeological logs are described below:

Pumping T Flow TMoye/Pumping T Flow period: This column display transmissivity, T (m^2/s), evaluated from pumping test in specific sections of the borehole. Blue lines show T for sections where a steady-state evaluation (Moye) was considered to provide the most representative transmissivity value. Red lines show T for sections where a transient evaluation was considered to provide the most representative transmissivity value.

Transmissivity Flow logging: Show transmissivity evaluated for flow anomalies using PFL with a 0.1 m interval.

Temp pumping: Temperature measurement during PFL-logging

Pumped inflow: Inflow during PFL-logging in 1 m and 5 m sections, shown at "sec up" (the upper length coordinate of the section) for each flow anomaly.

TD/T Lower limit/T Upper limit: Evaluated transmissivity from PFL-logging in 1 m and 5 m sections, shown at "sec up" for each flow anomaly. The column also display upper and lower measurement limit for transmissivity with PFL-logging.

In all columns above, the packer positions used during pumping tests are shown as grey areas.

Groundwater sampling for hydrogeochemical analyses was performed at three sections in the borehole, 19–29 m, 30–32 m and 37–39 m. The sampling was made according to the highest sampling standard, Class 5, which includes cations, anions, trace element, REE, stable and radiogenic isotopes. A few hydrogeochemical parameters were analyzed by the Äspö laboratory, but most of the analyses were performed in external laboratories. See Wallin (2016) for more information regarding the hydrogeochemical data analyses.

The data and interpretation products of all the above listed geoscientific investigations have been utilized in the single-hole interpretation carried out. The results from the single-hole interpretation are presented in a WellCad plot (Appendix 1) and are discussed further in this report.

4 Execution

4.1 General

The single-hole interpretation was carried out by a group of geoscientists consisting of geologists, geophysicists, hydrogeologists and hydrogeochemists. All data used (see Chapter 3) are visualized side by side in a borehole composite log constructed using the software WellCad (Figure 3-1). The working procedure is summarized in Figure 4-1 and in the text below.

The first step in the working procedure is to study all types of data related to the character of the rock type and to merge sections of similar rock type into rock units. The traditional minimum length of a single rock unit is c. 5 m and this is proposed to be decreased to 1–2 m in the geoscientific SHI. Each rock unit is defined in terms of the borehole length interval and is provided with a brief description of its character (geology and physical properties) for inclusion in the WellCad plot, see Section 5-1 for examples of descriptive text. The confidence in the interpretation of a rock unit is denoted by three classes: 3 = high, 2 = medium and 1 = low. Confidence level 3 indicates that there is a high possibility that the defined rock unit consists of accurately classified rock types with well-defined properties. Confidence levels 1 and 2 have generally only been used in full face percussion drilled boreholes for which the classification is only based on drill chips and/or geophysical logging data (no drill core is available). However, with the new demands for increased resolution in the SHI-interpretation it is proposed that a decreased confidence level is used also for cored boreholes e.g. in cases when there is a clear discrepancy between the geological mapping and the geophysical logging data.

The second step in the working procedure is to identify potentially critical structures, corresponding to possible minor deformation zones. This is done by inspection of the results of the geological mapping (fracture frequency, aperture, width (thickness), kinematic indicators, alteration, crush zones, etc.) in combination with the geophysical logging data (mainly resistivity, sonic, caliper) and borehole radar reflectors. Hydrogeological data and geophysical fluid logs are used to identify water bearing structures. The borehole section of each identified possible deformation zone is defined in terms of the borehole length interval and is provided with a brief description, which also includes hydrogeochemical information for water bearing structures.

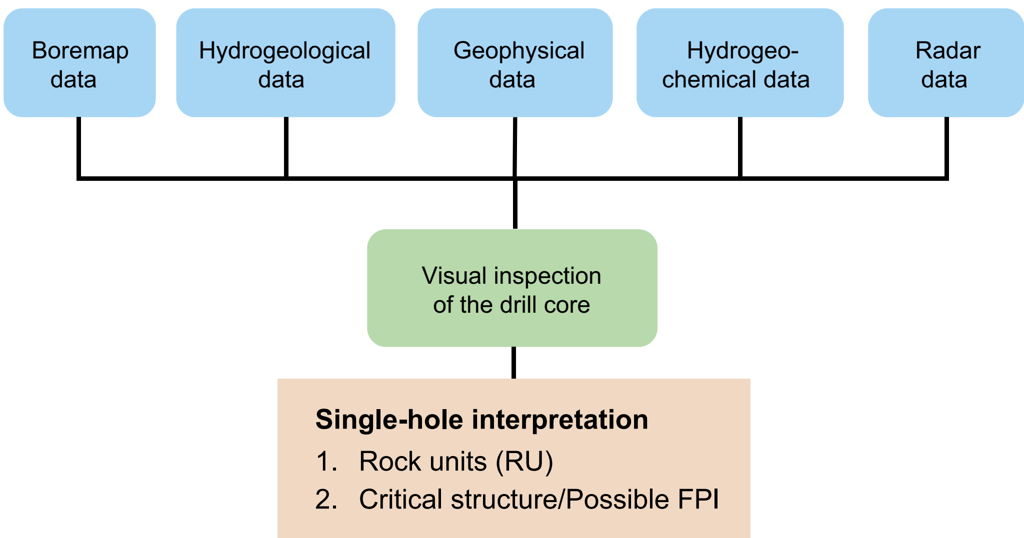

Figure 4-1. *Schematic block-scheme of single-hole interpretation of K08028F01.*

The confidence in the interpretation of potentially critical structures is denoted by three classes: 3 = high, 2 = medium and 1 = low. Confidence level 3 indicates that there is a high possibility that the selected structure constitutes a deformation zone or a potential critical structure, and that this interpretation is based on at least two clear and independent geological or one geological and at least one geophysical or hydrogeological property. Confidence level 2 indicates that there is a possibility that the selected structure constitutes a potential critical structure (i.e. possible minor deformation zone), and that this interpretation is based on at least one significant geological property. The confidence level 1 indicates that there is a possibility that the selected structure constitutes a critical structure, but that this interpretation is based only on one geological, geophysical or hydrogeological property.

The third step in the procedure is to carry out a visual inspection of the drill core. Following the proposed definitions of rock units and deformation zones, the drill cores are physically inspected in order to check the selection of the boundaries between these geological entities. During this process, if judged necessary, the locations of boundaries and confidence levels may be adjusted.

Potential critical structures, with focus on possible minor deformation zones that are brittle, brittle-ductile or ductile in character, have been identified primarily according to the recommendations in Munier et al. (2003) with support of typical parameters for large fractures listed in Cosgrove et al. (2006). If possible, more extensive deformation zones have been subdivided into damage and core zones, respectively (Figures 4-2 and 4-3). The frequencies of open and sealed fractures have been assessed in the identification procedure, but their importance has been reduced in favour of properties that are characteristic for large fractures and identifiable in a borehole, such as anomalous apertures and widths, the occurrence of slickensides and alteration etc. The frequency and properties of partly open fractures are included together with open fractures in the brief description of each zone. The occurrence and properties of anomalies in geophysical data (e.g. amplitude, frequency and width), including radar reflectors, have all assisted in the identification of the potential critical structures. Hydrogeological data have been used in order to identify structural features with increased hydraulic conductivity.

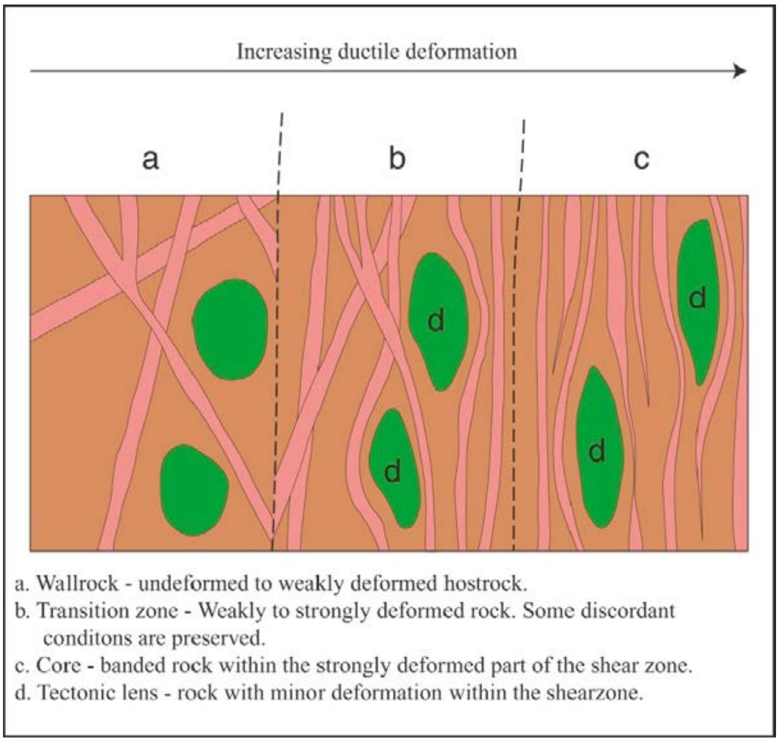

Figure 4-2. Schematic example of a ductile shear zone. Heterogeneous rock which has been deformed under low- to high-grade metamorphic conditions (after Munier et al. 2003).

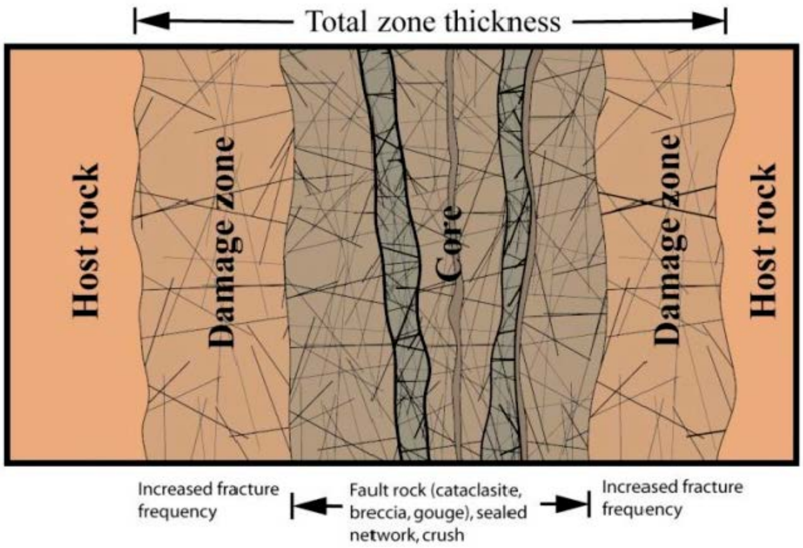

Figure 4-3. *Schematic example of a brittle deformation zone (modified from Munier et al. 2003).*

4.2 Nonconformities

No nonconformities are reported.

5 Results

The detailed result of the geological single-hole interpretation is presented as a print-ready document from the software WellCad (Appendix 1) for K08028F01. All orientations are related to Äspö96 north.

Since the fracture frequency traditionally has been an important parameter for the definition of the possible deformation zones, moving average plots of this parameter are shown for the cored borehole K08028F01 in Figure 5-1. A 5 m window with 1 m steps has been used in the calculation procedure. The moving average diagram for fracture frequency regarding open fractures; open, partly open fractures and crush; sealed fractures; sealed fractures and sealed fracture network, respectively, are shown in the diagram.

5.1 Subdivision of rock units and deformation zones

A summary of the rock unit properties is presented in Table 5-1.

5.1.1 Rock units in K08028F01

The borehole is divided into six different rock units, RU1–RU6. Rock unit 1 occurs in two separate borehole intervals RU1a and RU1b.

2.20–42.36 m

RU1a: Dominated by Ävrö granodiorite (501056) and fine grained granite (511058), with subordinate occurrences of pegmatite (501061). Generally weak oxidation and minor epidotization. Structurally massive with minor sections of foliation as well as rock types showing faint banding. The silicate density is in the range 2 640–2 750 kg/m^3, which indicates a mineral composition that corresponds to granite or granodiorite. The magnetic susceptibility is generally 0.01–0.03 SI. Sections with silicate density < 2 680 kg/m^3 in combination with increased natural gamma radiation and decreased magnetic susceptibility occur at 2.2–6.0 m, 25.0–28.0 m and 31.5–39.5 m, and they correspond to fine-grained granite. Confidence level = 3.

42.36–44.87 m

RU2: Dominated by structurally massive Äspö diorite (501037), with subordinate fine-grained diorite-gabbro (505102). Weak epidotization connected to the fine-grained diorite-gabbro. In the section 42.358–44.000 m the silicate density is in the range 2 660–2 700 kg/m^3, which indicates a mineral composition that corresponds to granite or granodiorite, typical for Ävrö granodiorite. In the section 44.000–44.555 there is a major increase in silicate density (2 820 kg/m^3) in combination with decreased natural gamma radiation and magnetic susceptibility, which is typical for fine-grained diorite-gabbro. Confidence level = 2.

44.87–66.29 m

RU1b: Dominated by Ävrö granodiorite (501056) and fine grained granite (511058), with subordinate occurrences of pegmatite (501061) and fine-grained diorite-gabbro (505102). Weak oxidation and minor epidotization connected to the fine-grained diorite-gabbro. Structurally mainly massive with minor occurrences of foliated rock. The silicate density is mainly in the range 2 630–2 670 kg/m^3, which together with partly increased natural gamma radiation indicates a mineral composition that corresponds to granite. The magnetic susceptibility is generally 0.01–0.03 SI. Along the section 51.8–57.0 m the silicate density is in the range of 2 700–2 770 kg/m^3 in combination with decreased natural gamma radiation, which corresponds to a mineral composition of granodiorite to tonalite. Confidence level = 3.

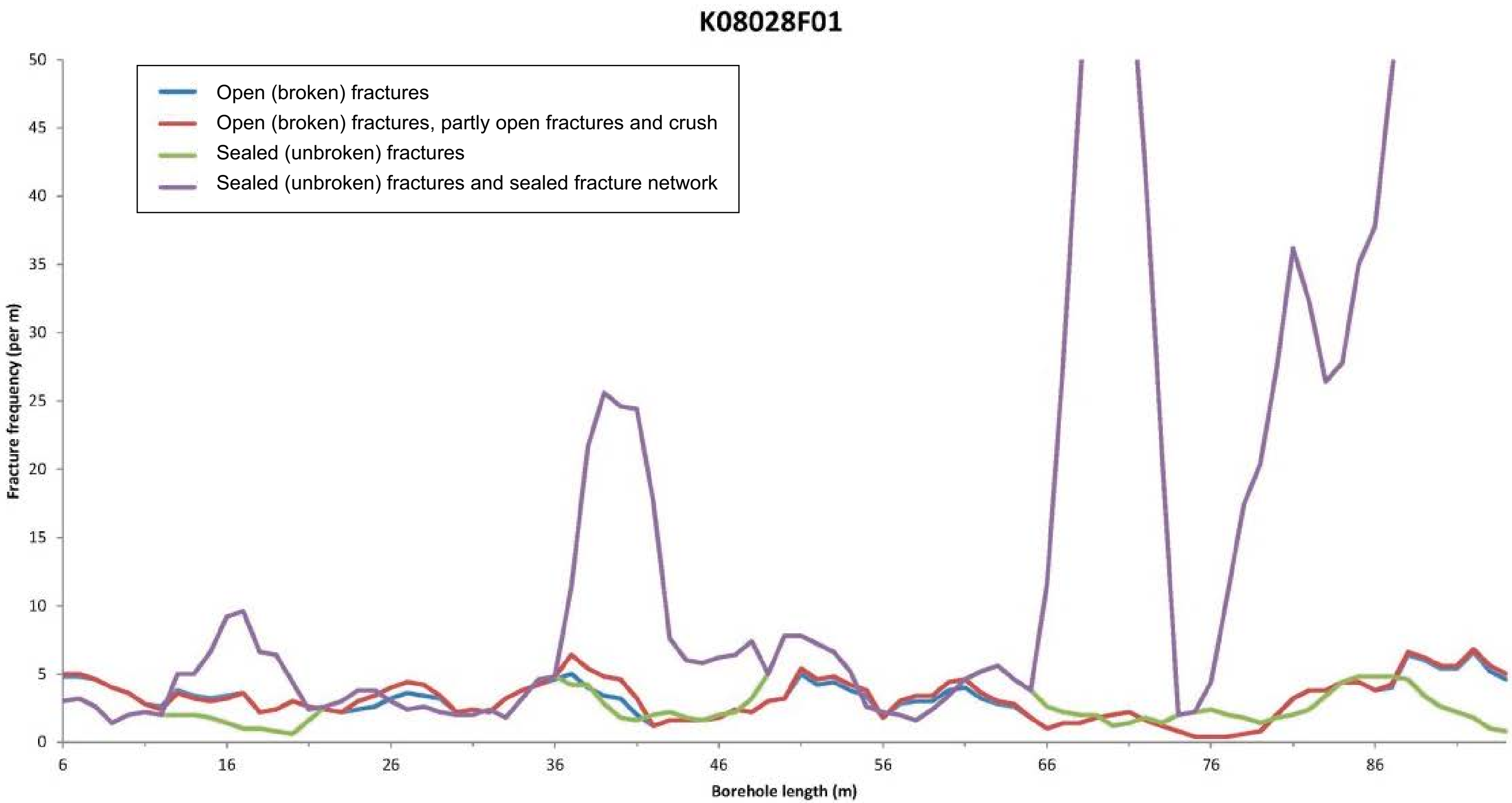

Figure 5-1. *Fracture frequency plot for K08028F01. Moving average using a 5 m window with 1 m steps.*

Table 5-1. Properties of the rock units RU1–RU6 (see Table 1-2 for the rock type nomenclature).

Discipline	Parameter/method Borehole section length (m)	RU1a 2.00–42.36	RU2 42.36–44.87	RU1b 44.87–66.29	RU3 66.29–70.00	RU4 70.00–84.72	RU5 84.72–90.21	RU6 90.21–94.39
Geology	Predominant rock type	501056 and 511058	501037	501056 and 511058	505102	501056 and 511058	505102	501056
	Subordinate rock types	505102	505102	505102	–	501061	501061	501061 and 511058
	Deformation style	Massive. Locally slight foliation and banding	Massive	Massive. Locally slight foliation.	Massive	Massive Locally slight foliation	Massive Locally slight foliation	Massive Locally slight foliation
Geophysics	Silicate density (kg/m^3)	2 640–2 750	2 660–2 700	2 630–2 670	2 800–2 950	2 690–2 750	2 800–2 950	2 640–2 750
	Magnetic susceptibility (SI)	0.010–0.035	0.010–0.020	0.010–0.030	0.0005–0.0010	0.010–0.020	0.0005–0.0010	0.0005–0.0010
	Natural gamma radiation (μR/h)	15–30	15–25	15–30	10–20	15–40	5–50	15–30
Confidence level	(Level 1, 2 or 3)	3	2	3	3	3	3	3
Comment			Matrix richer in mafic minerals than RU1					

66.29–70.00 m

RU3: Dominated by structurally massive, fine-grained diorite-gabbro (505102) with subordinate occurrences of fine-grained granite (511058) and pegmatite (501061). Weak epidotization. The silicate density for the major part of the section is in the range 2 800–2 950 kg/m^3, which indicates a mineral composition corresponding to diorite and gabbro. There is a significant decrease in natural gamma radiation and also in magnetic susceptibility (0.0005–0.0010 SI). Confidence level = 3.

70.00–84.72 m

RU4: Dominated by Ävrö granodiorite (501056) and fine grained granite (511058), with subordinate occurrences of pegmatite (501061). Weak oxidation and minor epidotization. Structurally massive but minor occurrences of foliated rock with weak to medium intensity occur. The silicate density for the major part of the section is in the range 2 690–2 750 kg/m^3, which indicates a mineral composition that corresponds to granite – granodiorite (typical for Ävrö granodiorite). The magnetic susceptibility is fairly constant with an average of c. 0.010 SI and the natural gamma radiation is in the range of 15–25 μR/h. In the section 76.0–80.0 m there is a decrease in the silicate density in combination with increased natural gamma radiation, which indicates fine-grained granite. Confidence level = 3.

84.72–90.21 m

RU5: Dominated by fine-grained diorite-gabbro (505102) with subordinate occurrences of pegmatite (501061) and fine-grained granite (511058). Weak epidotization and minor oxidation. Structurally the rock type is mainly massive with minor occurrences of foliated rock with weak intensity. The silicate density for the major part of the section is in the range 2 800–2 950 kg/m^3. There is a significant decrease in natural gamma radiation and also in magnetic susceptibility (0.0005–0.0010 SI). In the section 87.8–88.4 m there is a major decrease in silicate density in combination with significantly increased natural gamma radiation, which indicates fine-grained granite or pegmatite. Confidence level = 3.

90.21–94.39 m

RU6: Dominated by Ävrö granodiorite (501056). Subordinate rock types comprise pegmatite (501061) and fine-grained granite (511058). Weak epidotization. Structurally the rock type is mainly massive with minor occurrences of foliated rock. The silicate density displays large variations in the range 2 640–2 750 kg/m^3 and the magnetic susceptibility is significantly decreased along the entire section (0.0005–0.0010 SI). This indicates a heterogeneous mineral composition and alteration of magnetite. Confidence level = 3.

5.1.2 Possible deformation zones in K08028F01

Five potential critical structures (possible deformation zones) have been recognized in K08028F01 (denoted DZ1–DZ5). A summary of the deformation zone properties is presented in Table 5-2.

Deformation zones

***DZ1** 37.20–39.00 m, (no zone core identified). Confidence level = 1.*

Brittle deformation. A crush zone at 37.56 m, sealed networks and oxidation. The rock type is mainly fine-grained granite (511058). There is one radar reflector that is interpreted to intersect the borehole section at c. 37.32 m, with an α-angle = 51°. There is a distinct decrease in resistivity in combination with a significant caliper anomaly. There is also a clear gradient in fluid temperature along the section, which indicates in or out flow of water. There are no major anomalies in P- or S-wave velocity. There is a PFL-anomaly at 37.6 m with an evaluated transmissivity of 2.3E−8 m^2/s. Pumping in 37.0–39.0 m resulted in detectable pressure responses in several other sections in K08028F01 and 89.0–100.92 m in the neighbouring K03009F01 some 40 m distant, cf. Figure 1-1. Transient evaluation of the pumping test resulted in a transmissivity of 3.8E−8 m^2/s for the pumped section. Hydrogeochemical data show that the groundwater has a chlorine concentration of 2 378 mg/L and an average conductivity of 774 S/m. The section has the highest alkalinity at 207.2 mg/L and the laboratory pH is 7.63.

DZ2 *49.60–51.60 m (no zone core identified). Confidence level = 1.*

Brittle deformation. A cataclasite, increased fracture frequency, slickensides and oxidation. The rock type is mainly fine-grained granite (511058). There is one radar reflector that is interpreted to intersect the borehole the section at c. 49.76 m, with an α-angle = 31°. There is a clear and sharp decrease in resistivity and magnetic susceptibility at 51.0 m, which corresponds to a single structure. There is also a gradient in fluid temperature along the entire section, however the fluid temperature data are noisy along this part of the borehole. There are no major anomalies in any of the other geophysical logs. There are no indications of flow anomalies from PFL. No pumping test performed.

DZ3 *59.70–63.00 m (no zone core identified). Confidence level = 1.*

Brittle deformation. Fractures with sub-horizontal dip mainly with epidote, chlorite and calcite as fracture fillings and usually with oxidized walls. The main rock type is fine-grained granite (511058). There are no radar reflectors that intersect the borehole along this section. There is a fairly strong gradient in fluid temperature along the entire section; however the fluid temperature data are noisy in this part of the borehole. There are no major anomalies in any of the other geophysical logs. There are no indications of flow anomalies from PFL. No pumping test performed.

DZ4 *69.00–70.00 m (no zone core identified). Confidence level = 1.*

Brittle deformation. The zone is characterized by two cataclasites, sealed network, with fracture width up to 5 mm, epidote fracture filling, slickensides and epidotization. The main rock type is fine-grained diorite-gabbro. There are no radar reflectors that intersect the borehole section. There is a distinct but short wavelength decrease in resistivity seen at 69.3 m and 69.9 m. The magnetic susceptibility is decreased along the entire section. There is also a clear gradient in fluid temperature. There are no major anomalies in any of the other geophysical logs. There are no indications of flow anomalies from PFL. No pumping test performed.

DZ5 *84.00–94.39 m (zone core at 93.30–94.39 m). Confidence level = 3.*

Brittle deformation. characterized by several cataclasites, increased fracture frequency, one fracture with 20 mm width including a 1mm aperture, and three fractures with apertures at 1 mm. Alteration is epidotization of weak intensity with a minor occurrence of oxidation (with medium intensity). The main rock types are fine-grained diorite-gabbro and Ävrö granodiorite. There are two radar reflectors that are interpreted to intersect the borehole section. One reflector intersects at c. 89.02 m, with an α-angle of42°. The other reflector intersects at c. 93.10 m, with an α-angle of 55° and the orientation of this reflector is 253°/71° or 72°/1°. The resistivity and magnetic susceptibility are significantly decreased along the entire section. Both P- and S-wave velocities are partly decreased and there are significant caliper anomalies. The fluid temperature shows a major increase along the section. No indications of flow anomalies from PFL but pumping in 84.0–94.39 m resulted in detectable flow rate and pressure responses in several other sections in K08028F01 and 89.0–100.92 m in K03009F01. Steady-state evaluation of the pumping test resulted in a transmissivity of the pumped section of 1.7E−9 m^2/s.

Table 5-2. Properties of the deformation zones DZ1–DZ5.

Discipline	Parameter/method Borehole section length (m)	DZ1 37.20–39.00	DZ2 49.60–51.60	DZ3 59.70–63.00	DZ4 69.00–70.00	DZ5 84.00–94.39
Geology	**Deformation style**	Brittle	Brittle	Brittle	Brittle	Brittle
	General orientation (strike/dip)	NS/steep to moderate to E	SW-NE/sub-vertical	Sub-horizontal	EW/steep to moderate to S	NE-SW/sub-vertical
	Kinematic interpretation	N/A	Slickensides	N/A	Slickensides	Slickensides
	Fracture character	Crush and sealed network	Cataclasite	Sealed fractures	Cataclasites and sealed network	Cataclasites, fractures and sealed network
	Mineralogy	Epidote, chlorite, calcite, quartz	Calcite, epidote, quartz, chlorite, oxidized walls	Calcite, chlorite, epidote, quartz, oxidized walls	Epidote, chlorite, calcite	Chlorite, epidote, calcite, laumontite, oxidized walls
	Bedrock alteration	Weak oxidation	No alteration	Weak oxidation	Weak epidotisation	Weak epidotization and minor medium oxidation
	Dominant rock type	511058	511058	511058	505102	505102 and 501056
	Criteria for identification	Sealed networks, fracture widths up to 3 mm, one crush, oxidation	Increased frequency of open and sealed fractures, fracture widths up to 2 mm, one fracture with 2 mm aperture, slickensides, one cataclasite	Slightly increased frequency of sub-horizontal, sealed fractures, oxidation	Sealed networks, one 5 mm wide fracture, slickensides, epidotization	Increased frequency of open and sealed fractures, sealed networks, several cataclasites, slicken-sides, one 20 mm wide fracture, apertures up to 2 mm, oxidation, epidotization

Table 5-2. Cont.

Discipline	Parameter/method Borehole section length (m)	DZ1 37.20–39.00	DZ2 49.60–51.60	DZ3 59.70–63.00	DZ4 69.00–70.00	DZ5 84.00–94.39
Geophysics	**Resistivity focused** (anomaly in % from median focused resistivity)	−97 %	−95 %	−50 %	−70 %	−85 %
	Resistivity normal (anomaly in % from median normal resistivity)	not used	not used	not used	not used	not used
	SPR (anomaly in % from median SPR)	not used	not used	not used	not used	not used
	P-wave velocity (anomaly in m/s from mean P-wave velocity)	−220 m/s	−160 m/s	−230 m/s	−50 m/s	−280 m/s
	S-wave velocity (anomaly in m/s from mean S-wave velocity)	−80 m/s	−60 m/s	−60 m/s	70 m/s	−450 m/s
	Caliper abi (anomaly in mm from median borehole diameter)	4.90 mm	0.45 mm	0.00 mm	0.43 mm	0.75 mm
	Fluid temperature (anomaly in deg C with reference to 5 m running average temperature)	0.07 °C	0.08 °C	0.08 °C	0.17 °C	1.19 °C
	Fluid resistivity (anomaly in % from median fluid resistivity)	0 %	−2 %	0 %	3 %	500 %
Hydrogeology	**Transmissivity from PFL (m^2/s)**	2.3E−8 m^2/s	No flow anomalies	No flow anomalies	No flow anomalies	No flow anomalies
	Pressure responses	Several other sections in K08028F01 and 89.0–100.92 m in K03009F01	n.a.	n.a.	n.a.	Several other sections in K08028F01 and 89.0–100.92 m in K03009F01
	Pumping flow rate (l/min)	0.30 l/min	No pumping	No pumping	No pumping	0.031 l/min
	Transmissivity from pumping test (m^2/s)	3.8E−8 m^2/s	n.a.	n.a.	n.a.	1.7E−9 m^2/s
Hydrogeochemistry	**Alkalinity (mg/l)**	207.2 mg/l	n.a.	n.a.	n.a.	n.a.
	Chloride (mg/l)	2 378 mg/l	n.a.	n.a.	n.a.	n.a.
	pH	7.70	n.a.	n.a.	n.a.	n.a.
Confidence level	**Level 1, 2 or 3**	1	1	1	1	3

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Appendix 1

Geoscientific single-hole interpretation of K08028F01

The results from the geoscientific single-hole interpretation of K08028F01 are presented in a WellCAD plot. The WellCAD plot consists of the following columns of indata and interpretations made:

Boremap	1:	Depth (Length along the borehole)
	2:	Rock type
	3:	Rock alteration
	4:	Frequency of sealed fractures
	5:	Frequency of open and partly open fractures
	6:	Crush
Geophysics	7:	Silicate density
	8:	Magnetic susceptibility
	9:	Natural gamma radiation
	10:	Estimated fracture frequency
Hydrogeology	11:	Transmissivity flow logging
	12:	T pumping test steady-state evaluation/T pumping test transient evaluation
Hydrogeochemistry	13:	Alkalinity
	14:	Chloride
	15:	PH
Interpretations	16:	Description: Rock unit
	17:	Stereogram for sealed fractures in rock unit (blue symbols)
	18:	Stereogram for open and partly open fractures in rock unit (red symbols)
	19:	Description: Possible deformation zone
	20:	Stereogram for sealed fractures in possible deformation zone (blue symbols)
	21:	Stereogram for open and partly open fractures in possible deformation zone (red symbols)

Title SINGLE HOLE INTERPRETATION K08028F01 — SIGNED DATA: YES

SKB

Site	ÄSPÖ	Inclination [°]	2.10	Elevation [m.a.s.l.]	-396.57	Strike Reference	ÄSPÖ96
Borehole	K08028F01	Date of mapping	2014-06-30 11:02:00	Drilling Start Date	2014-05-19 14:20:00	Made By	PKM
Diameter [mm]	76	Coordinate System	ÄSPÖ96	Drilling Stop Date	2014-06-12 11:32:00		
Length [m]	94.390	Northing [m]	7450.64	Surveying Date			
Bearing [°]	320.50	Easting [m]	2386.04	Plot Date	2015-03-19 02:01:18		

ROCKTYPE ÄSPÖ
- Fine-grained granite 511058
- Ävrö granodiorite 501056
- Äspö diorite 501037
- Fine-grained diorite-gabbro 505102

ROCK ALTERATION
- Oxidized
- Epidotisized

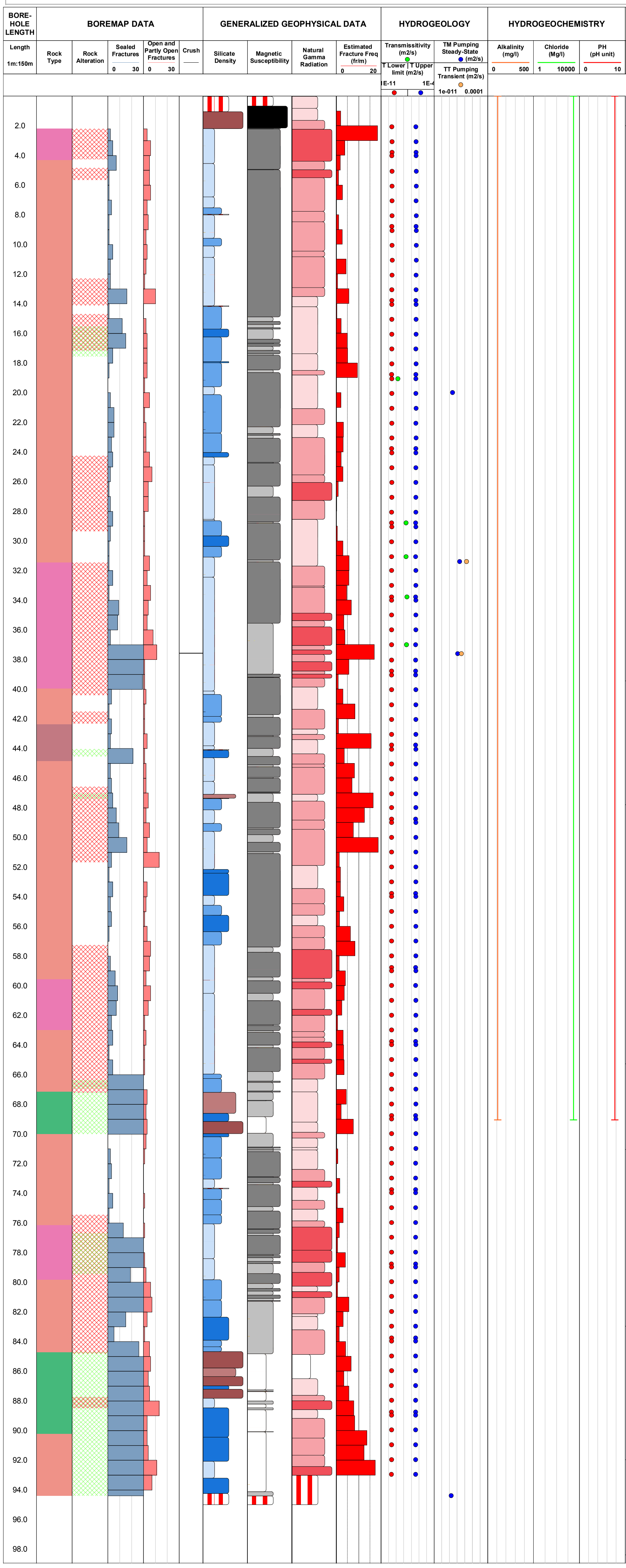
SILICATE DENSITY
- unclassified
- dens<2680
- 2680<dens<2730
- 2730<dens<2800
- 2800<dens<2890
- dens>2890

SUSCEPTIBILITY
- unclassified
- sus<0.001
- 0.001<sus<0.01
- 0.01<sus<0.1
- sus>0.1

NATURAL GAMMA
- unclassified
- gam<10
- 10<gam<20
- 20<gam<30
- gam>30

CONFIDENCE RU
- Probable
- Certain

CONFIDENCE DZ
- Possible
- Certain



ROCK UNIT

Description Rock Unit

2.00

RU1a Dominated by Ävrö granodiorite (501056) and fine grained granite (511058), with subordinate occurrences of pegmatite (501061). Generally weak oxidation and minor epidotization. Structurally massive with minor sections of foliation as well as rock types showing faint banding. The silicate density is in the range 2,640 – 2,750 kg/m3, which indicates a mineral composition that corresponds to granite or granodiorite. The magnetic susceptibility is generally 0.01-0.03 SI. Sections with silicate density < 2,680 kg/m3 in combination with increased natural gamma radiation and decreased magnetic susceptibility occur at 2.2-6.0 m, 25.0-28.0 m and 31.5-39.5 m, and they correspond to fine-grained granite.

42.36

42.36

RU2 Dominated by structurally massive Äspö diorite (501037), with subordinate fine-grained diorite-gabbro (505102). Weak epidotization connected to the fine-grained diorite-gabbro. In the section 42.358-44.000 m the silicate density is in the range 2,660-2,700 kg/m3, which indicates a mineral composition that corresponds to granite or granodiorite, typical for Ävrö granodiorite. In the section 44.000 – 44.555 there is a major increase in silicate density (2,820 kg/m3) in combination with decreased natural gamma radiation and magnetic susceptibility, which is typical for fine-grained diorite-gabbro.

44.87

44.87

RU1b Dominated by Ävrö granodiorite (501056) and fine grained granite (511058), with subordinate occurrences of pegmatite (501061) and fine-grained diorite-gabbro (505102). Weak oxidation and minor epidotization connected to the fine-grained diorite-gabbro. Structurally mainly massive with minor occurrences of foliated rock. The silicate density is mainly in the range 2,630 – 2,670 kg/m3, which together with partly increased natural gamma radiation indicates a mineral composition that corresponds to granite. The magnetic susceptibility is generally 0.01-0.03 SI. Along the section 51.8 – 57.0 m the silicate density is in the range of 2,700-2770 kg/m3 in combination with decreased natural gamma radiation, which corresponds to a mineral composition of granodiorite to tonalite.

66.29

66.29

RU3 Dominated by structurally massive, fine-grained diorite-gabbro (505102) with subordinate occurrences of fine-grained granite (511058) and pegmatite (501061). Weak epidotization. The silicate density for the major part of the section is in the range 2,800-2,950 kg/m3. There is a significant decrease in natural gamma radiation and also in magnetic susceptibility (0.0005-0.0010 SI).

70.00

70.00

RU4 Dominated by Ävrö granodiorite (501056) and fine grained granite (511058), with subordinate occurrences of pegmatite (501061). Weak oxidation and minor epidotization. Structurally massive but minor occurrences of foliated rock with weak to medium intensity occur. The silicate density for the major part of the section is in the range 2,690-2,750 kg/m3, which indicates a mineral composition that corresponds to granite – granodiorite (typical for Ävrö granodiorite). The magnetic susceptibility is fairly constant with an average of c. 0.010 SI and the natural gamma radiation is in the range of 15-25 µR/h. In the section 76.0-80.0 m there is a decrease in the silicate density in combination with increased natural gamma radiation, which indicates fine-grained granite.

84.72

84.72

RU5 Dominated by fine-grained diorite-gabbro (505102) with subordinate occurrences of pegmatite (501061) and fine-grained granite (511058). Weak epidotization and minor oxidation. Structurally the rock type is mainly massive with minor occurrences of foliated rock with weak intensity. The silicate density for the major part of the section is in the range 2,800-2,950 kg/m3. There is a significant decrease in natural gamma radiation and also in magnetic susceptibility (0.0005-0.0010 SI). In the section 87.8-88.4 m there is a major decrease in silicate density in combination with significantly increased natural gamma radiation, which indicates fine-grained granite or pegmatite.

90.21

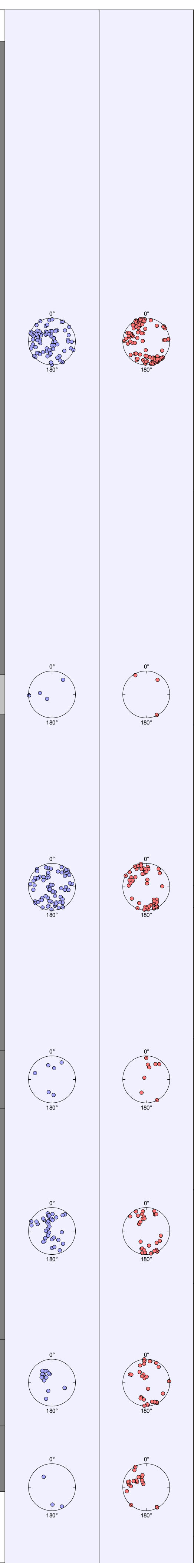
90.21

RU6 Dominated by Ävrö granodiorite (501056). Subordinate rock types comprise Pegmatite (501061) and fine-grained granite (511058). Weak epidotization. Structurally the rock type is mainly massive with minor occurrences of foliated rock. The silicate density displays large variations in the range 2,640-2,750 kg/m3 and the magnetic susceptibility is significantly decreased along the entire section (0.0005-0.0010 SI).

94.39

RU1a, RU2, RU1b, RU3, RU4, RU5, RU6

Rock Unit Sealed Fractures (Projection Wulff) — Rock Unit Open and Partly Open Fractures (Projection Wulff)



POSSIBLE DEFORMATION ZONES

Description Possible Deformation Zone

37.20

DZ1 Characterized by a crush zone at 37,56 m, sealed networks and oxidation. The rock type is mainly fine-grained granite (511058). There is one radar reflector that is interpreted to intersect the borehole section at c. 37.32 m, with an a-angle = 51°. There is a distinct decrease in resistivity in combination with a significant caliper anomaly. There is also a clear gradient in fluid temperature along the section, which indicates in or out flow of water. There are no major anomalies in P- or S-wave velocity. There is a PFL-anomaly at 37.6 m with an evaluated transmissivity of 2.3E-8 m2/s. Pumping in 37.0-39.0 m resulted in detectable pressure responses in several other sections in K08028F01 and 89.0-100.92 m in the neighbouring K03009F01 some 40 m distant, cf. Figure 1-1. Transient evaluation of the pumping test resulted in a transmissivity of 3.8E-8 m2/s for the pumped section. Hydrogeochemical data show that the groundwater has a chlorine concentration of 2378 mg/L and an average conductivity of 774 S/m. The section has the highest alkalinity at 207.2 mg/L and the laboratory pH is 7.63.

39.00

49.60

DZ2 Characterized by a cataclasite, increased fracture frequency, slickensides and oxidation. The rock type is mainly fine-grained granite (511058). There is one radar reflector that is interpreted to intersect the borehole the section at c. 49.76 m, with an a-angle = 31°. There is a clear and sharp decrease in resistivity and magnetic susceptibility at 51.0 m, which corresponds to a single structure. There is also a gradient in fluid temperature along the entire section, however the fluid temperature data are noisy along this part of the borehole. There are no major anomalies in any of the other geophysical logs. There are no indications of flow anomalies from PFL. No pumping test performed.

51.60

59.70

DZ3 Characterized by fractures with sub-horizontal dip mainly with epidote, chlorite and calcite as fracture fillings and usually with oxidized walls. The main rock type is fine-grained granite (511058). There are no radar reflectors that intersect the borehole along this section. There is a fairly strong gradient in fluid temperature along the entire section; however the fluid temperature data are noisy in this part of the borehole. There are no major anomalies in any of the other geophysical logs. There are no indications of flow anomalies from PFL. No pumping test performed.

63.00

69.00

DZ4 The zone is characterized by two cataclasites, sealed network, with fracture width up to 5 mm, epidote fracture filling, slickensides and epidotization. The main rock type is fine-grained diorite-gabbro. There are no radar reflectors that intersect the borehole section. There is a distinct but short wavelength decrease in resistivity seen at 69.3 m and 69.9 m. The magnetic susceptibility is decreased along the entire section. There is also a clear gradient in fluid temperature. There are no major anomalies in any of the other geophysical logs. There are no indications of flow anomalies from PFL. No pumping test performed.

70.00

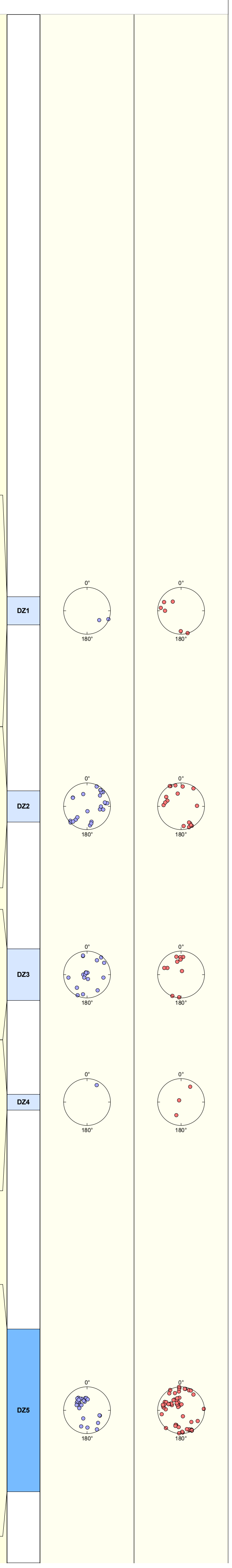
84.00

DZ5 The zone is characterized by several cataclasites, increased fracture frequency, one fracture with 20 mm width including a 1mm aperture, and three fractures with apertures at 1 mm. Alteration is epidotization of weak intensity with a minor occurrence of oxidation (with medium intensity). The main rock types are fine-grained diorite-gabbro and Ävrö granodiorite. There are two radar reflectors that are interpreted to intersect the borehole section. One reflector intersects at c. 89.02 m, with an a-angle of42°. The other reflector intersects at c. 93.10 m, with an a-angle of 55° and the orientation of this reflector is 253°/71° or 72°/1°. The resistivity and magnetic susceptibility are significantly decreased along the entire section. Both P- and S-wave velocities are partly decreased and there are significant caliper anomalies. The fluid temperature shows a major increase along the section. No indications of flow anomalies from PFL but pumping in 84.0-94.39 m resulted in detectable flow rate and pressure responses in several other sections in K08028F01 and 89.0-100.92 m in K03009F01. Steady-state evaluation of the pumping test resulted in a transmissivity of the pumped section of 1.7E-9 m2/s.

94.39

DZ1, DZ2, DZ3, DZ4, DZ5

Possible Deformation Zone Sealed Fractures (Projection Wulff) — Possible Deformation Zone Open and Partly Open Fractures (Projection Wulff)



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SKB is responsible for managing spent nuclear fuel and radioactive waste produced by the Swedish nuclear power plants such that man and the environment are protected in the near and distant future.

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