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Forsmark site investigation

Hydrochemical logging in KFM08A

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October 2005

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This report concerns a study which was conducted for SKB. The conclusions and viewpoints presented in the report are those of the authors and do not necessarily coincide with those of the client.

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Abstract

Hydrochemical logging or so called tube sampling has been performed in the core drilled borehole KFM08A. The method is a fast and simple sampling technique to obtain information about the chemical composition of the water column along an open borehole. The equipment consists of an approximately 1,000 m long polyamide tube divided into units of 50 m.

The water content in each tube unit constituted one sample in most cases. Each second sample was analysed. Two samples (100–200 m and 450–550 m) were concatenated from two tube units in order to allow analyses of all SKB chemical class 3 isotope options. The content of remaining flushing water from core drilling was acceptable (< 20%) down to 200 m and isotope determinations were included for the first two samples. From 400 m and downwards, the amount of flushing water was relatively constant around 40%, the highest amount being 44% in the tube unit from section 560–610 m.

The relative charge balance error did not exceed the acceptable level ($\pm 5\%$) in any of the eight samples analysed. However, due to high flushing water content in the samples, the obtained analysis data from this activity will be less useful for chemical modelling work.

Sammanfattning

Hydrokemisk loggning, eller så kallad slangprovtagning, har utförts i det kärnborrade borrhålet KFM08A. Metoden är snabb och enkel att använda för att erhålla information om den kemiska sammansättningen hos grundvattnet längs ett öppet borrhål. Utrustningen består av en cirka 1 000 m lång polyamidslang uppdelad i enheter om vardera 50 m.

Innehållet i en slangenhet utgjorde i de flesta fall ett prov och vartannat prov analyserades. Två prov (från sektionerna 100–200 m samt 450–550 m) bestod av sammanslaget vatten från två slangenheter för att ge tillräcklig vattenvolym för analys av samtliga isotoptillval enligt SKB kemiklass 3. Halten kvarvarande spolvatten från kärnboringen var acceptabel (< 20 %) ner till cirka 200 m och isotopanalyser utfördes på de två översta proverna enligt tillval SKB klass 3. Från 400 m och nedåt var spolvattenhalten relativt konstant runt 40 %. Det högsta värdet, från slangenheten 560–610 m, uppgick till 44 %.

Det relativa jonbalansfelet överskred inte acceptabelt värde ($\pm 5\%$) i något av de åtta analyserade proverna. På grund av den höga spolvattenhalten är dock erhållna analysdata från aktiviteten mindre användbara för hydrokemisk modellering.

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1 Introduction

This document reports performance and results of the activity “Hydrochemical logging in KFM08A” within the site investigation programme at Forsmark /1/. The controlling documents for the activity are listed in Table 1-1. Both activity plan and method description are SKB’s internal controlling documents. The fieldwork was carried out in May 2005. The obtained data from the activity are reported to the database SICADA, where they are traceable by the Activity Plan number.

Borehole KFM08A is the eighth deep telescopic borehole drilled at the Forsmark site investigation /2/. The location of KFM08A and the other drilled deep telescopic boreholes within the investigation area are shown in Figure 1-1. Figure 1-2 displays a zooming in towards drill site DS8 with KFM08A and nearby situated percussion drilled boreholes in soil and rock. Borehole KFM08A is inclined 60° from the horizontal plane in the direction towards north-west. The borehole section 0–102.26 m is percussion drilled and has a stainless steel casing with the internal diameter 200 mm, whereas section 102.26–1,001.19 m is core drilled with a diameter of 77.3 mm. The design of borehole KFM08A is presented in Appendix 1.

KFM08A is an SKB chemistry-type telescopic borehole, see method descriptions MD 620.003, Method description for drilling cored boreholes, and 610.003, Method description for percussion drilling, (both are SKB’s internal controlling documents. An SKB chemical type of borehole requires cleaning procedures of all equipment to be used in the borehole, during and after drilling, according to level 2 in the cleaning instructions in MD 600.004 (Instruktion för rengöring av borrhålsutrustning och viss markbaserad utrustning). The activities/investigations performed in KFM08A prior to the hydrochemical logging are listed in Table 1-2.

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

Activity plan	Number	Version
Hydrokemisk loggning i KFM08A	AP PF 400-05-059	1.0
Method descriptions	Number	Version
Metodbeskrivning för hydrokemisk loggning	SKB MD 422.001	1.0
Instruktion för rengöring av borrhålsutrustning och viss markbaserad utrustning	SKB MD 600.004	1.0

Table 1-2. Activities performed in KFM08A prior to the hydrochemical logging.

Activities performed	Date of completion	Length or section (m)	Comment
Percussion drilling	2004-12-15	0–100.55	
Core drilling	2005-03-31	100.55–1,001.19	HFM22 served as the source of flushing water for drilling the cored part of KFM08A. HFM22 is a SKB chemical type of percussion drilled borehole /2, 3, 4/.
Flushing water treatment	–	–	Automatic dosing of Uranine was used during drilling of KFM08A. In this way no in-line storage tank was needed after the UV-system /2/.
Microbe control was not performed	–	–	–
Water sampling, SKB class 3	2005-02-02	100.0–203.51	Sampling during drilling Sample no 8786
BIPS-logging	2005-05-10	102–980	/5/
Differential flow logging	2005-05-20	100–920	/6/
Geophysical logging	2005-05-29	102.5–195.	/7/
Hydrochemical logging	2005-05-30	0–910	Presented in this report.



Figure 1-1. The investigation area at Forsmark (approximately the area inside the black square) including the candidate area selected for more detailed investigations. The collarings of the deep telescopic boreholes, KFM01A to KFM08B, are marked with red circles. The projection of the boreholes on the horizontal plane at top of casing is also shown in the figure.

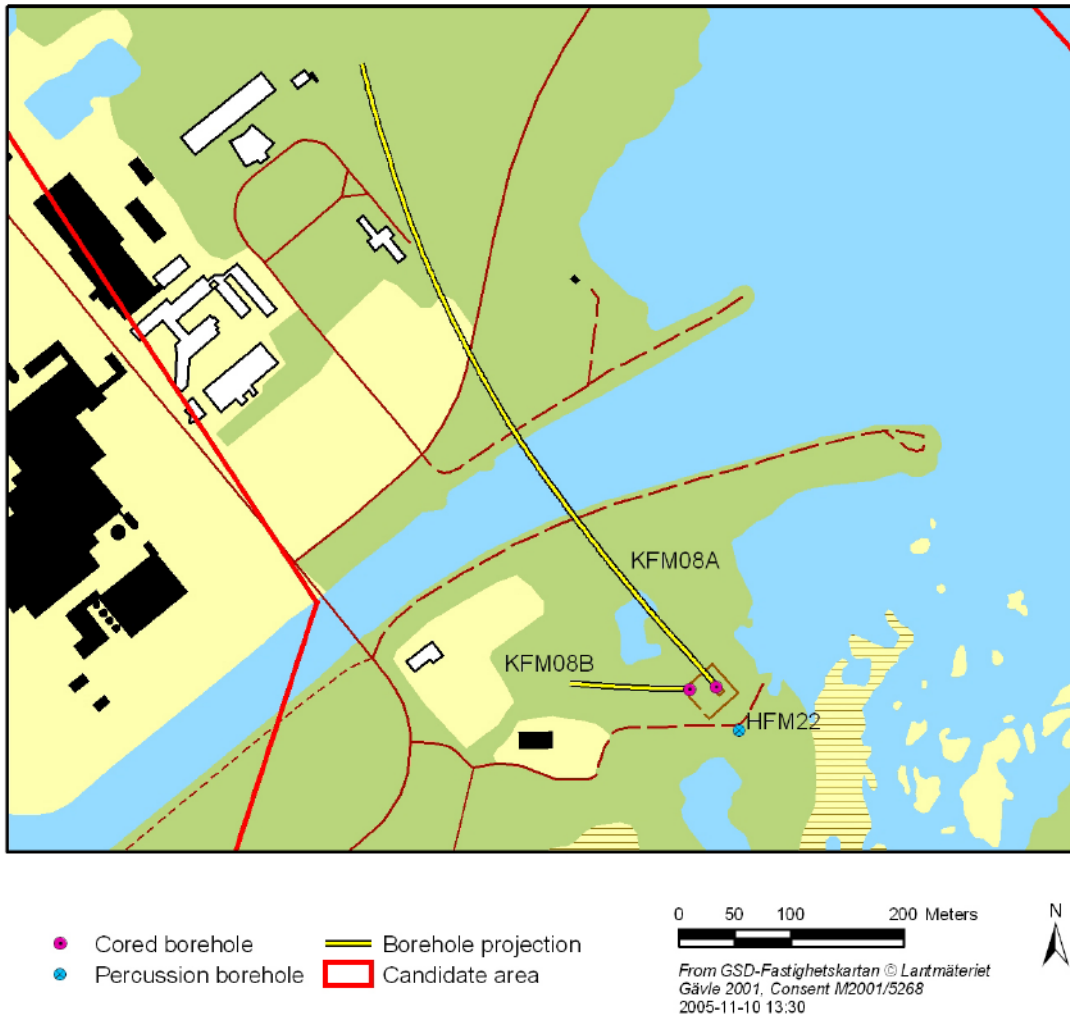


Figure 1-2. Location of the telescopic borehole KFM08A and the percussion borehole HFM22 at drill site DS8.

2 Objective and scope

Hydrochemical logging is one of the basic investigation methods conducted in telescopic and cored boreholes drilled at the site investigations. The method is performed in order to obtain an overview of the initial chemical composition of the water column along an open borehole. The sampling technique is fast and simple, also for boreholes of considerable lengths. However, due to the often very high flushing water contents in newly drilled boreholes in Forsmark, the method has been omitted in a few of the previous boreholes. Two main reasons for performing the activity in KFM08A can still be recognised:

- It is an advantage if all core drilled boreholes are investigated in the same way to enable comparison of the groundwater situation after drilling and its successive development with time.
- The chemical data from hydrochemical logging are regarded as less representative and not suitable for chemical modelling work but may still give useful information about the borehole situation just after drilling and the representativeness of later samples.

The analysis program is carried out according to SKB chemistry class 3 including isotope options (tritium, deuterium and oxygen-18). However, if the content of remaining flushing water from core drilling exceeds 20% in a sample the isotope determinations are omitted.

3 Sampling equipment

For the hydrochemical logging an approximately 1,000 m long polyamide tube, composed of units of 50 m length, was used. The equipment is described in the method description SKB MD 422.001. Metal couplings and manual shut off valves are mounted at both ends of each tube unit. The external and internal diameters of the tube units are 10 and 8 mm, respectively. A weight and a non-return valve are mounted at the lower end of the tube array to keep it stretched in the borehole and to prevent water outflow when the equipment is lifted to the ground surface. A schematic illustration of the equipment used for the hydrochemical logging is given in Figure 3-1.

The water content in each tube unit constitutes one sample and the volume of each sample will amount to at least two litres.

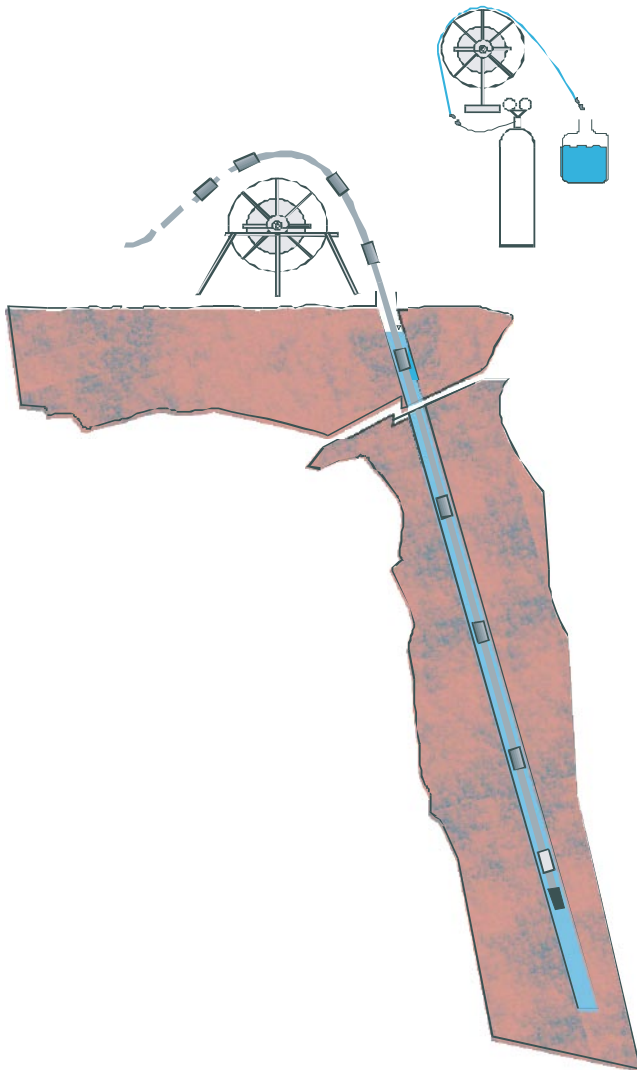


Figure 3-1. Equipment for hydrochemical logging in boreholes. A non-return valve and a weight are mounted at the lower end of the tube array. Each tube unit is 50 m long.

4 Performance

4.1 Hydrochemical logging

Sampling of the telescopic borehole KFM08A was performed on the 30th of May 2005 according to the activity plan AP PF 400-05-059 and in compliance with the method description SKB MD 422.001.

The hydrochemical logging was carried out to 910 m borehole length. The tube array could not be lowered all the way down to the bottom of the borehole because the borehole deviates upwards, i.e. flattens out, towards depth, thus making the frictional resistance to exceed the gravitational force on the equipment. The lowering of the tubes started at 08:07 and the retrieval at 11:37. The tube units were emptied using pressurized nitrogen gas and the water was portioned into several plastic bottles to be analysed by different laboratories. In most cases one tube unit constituted one sample. However, SKB samples number 8897 and 8903 were concatenated from two tube units in order to obtain a large enough volume to allow analyses of all SKB class 3 isotope options.

The groundwater level in the borehole, which was checked before as well as after completed logging, was measured at 3.91 m and 4.24 m from top of casing. The upper tube unit was therefore not completely filled with sample water.

4.2 Sample treatment and chemical analysis

An overview of sample treatment and analysis routines is given in Appendix 2. The routines are applicable independent of sampling object or sampling method. The samples collected at the hydrochemical logging of KFM08A were assigned SKB numbers 8895 to 8910. The samples 8898 to 8910 were not sent for isotope determinations due to their high flushing water content (more than 25%). A scheme showing filled sample portions at the logging occasion is given in Table 4-1.

Table 4-1. Overview of samples collected at the hydrochemical logging in KFM08A. Filled cells represent collected samples. Dark grey cells represent collected reserve samples.

Sample information			Collected sample portions										
Tube unit	Length (m)	SKB no	Cond, pH, alk	Major constit	Br-/I-	Anions	Ura-nine	³ H	δ ² H/ δ ¹⁸ O	δ ³⁷ Cl	⁸⁷ Sr	C-iso-topes	δ ³⁴ S
1	10 60	8895											
2	110	8896											
3 and 4	210	8897											
5	260	8898											
6	310	8899						x	x	x	x	x	
7	360	8900											
8	410	8901						x	x	x	x	x	
9	460	8902											
10 and 11	560	8903						x	x	x	x	x	x
12	610	8904											
13	660	8905						x	x	x	x	x	
14	710	8906											
15	760	8907						x	x	x	x	x	
16	810	8908											
17	860	8909						x	x	x	x	x	
18	910	8910											

x = samples were collected but not analysed due to high flushing water content.

4.3 Data handling

The following routines for quality control and data management are generally applied for hydrogeochemical analysis data, independent of sampling method or sampling object.

Several components are determined by more than one method and/or laboratory. Moreover, control analyses by an independent laboratory are performed as a standard procedure on each fifth or tenth collected sample.

All analytical results were stored in the SICADA database, where they are traceable by the Activity Plan number. The applied hierarchy path “Hydrochemistry/Hydrochemical investigation/Analyses/Water in the database” contains two types of tables, raw data tables and primary data tables (final data tables).

Data on **basic water analyses** are inserted into raw data tables for further evaluation. The evaluation results in a final reduced data set for each sample. These data sets are compiled in a primary data table named “water_composition”. The evaluation is based on:

- Comparison of the results from different laboratories and/or methods. The analyses are repeated if a large disparity is noted (generally more than 10%).
- Calculation of charge balance errors. Relative errors within $\pm 5\%$ are considered acceptable (in surface waters $\pm 10\%$).

$$\text{Relative error (\%)} = 100 \times \frac{\sum \text{cations(equivalents)} - \sum \text{anions(equivalents)}}{\sum \text{cations(equivalents)} + \sum \text{anions(equivalents)}}$$

- General expert judgement of plausibility based on earlier results and experiences.

All results from special analyses of **trace metals** and **isotopes** are inserted directly into primary data tables. In those cases where the analyses are repeated or performed by more than one laboratory, a “best choice” notation will indicate those results which are considered most reliable.

An overview of the data management is given in Figure 4-1.

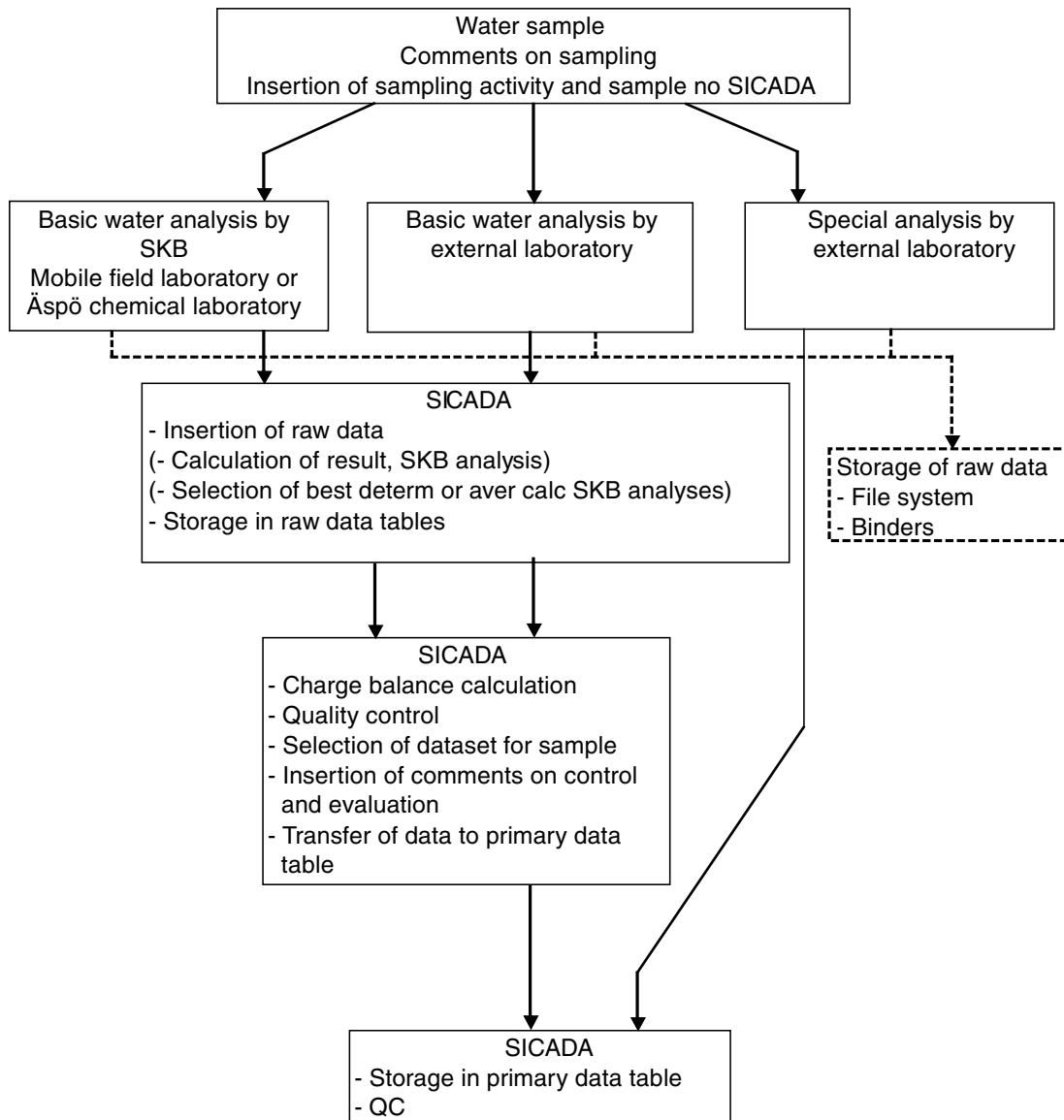


Figure 4-1. Overview of data management for hydrogeochemical data.

4.4 Nonconformities

The activity was performed according to the controlling documents for the activity with one deviation. Due to flattening out of the deeper parts of the borehole, the hydrochemical logging could be performed only down to 910 m borehole length instead of 996 m as planned.

5 Results

The results from the chemical analysis of hydrochemical logging in KFM08A are presented in Appendices 3 and 4. Available isotope data at the time of printing this report are included. No isotope determinations will be available below 200 m borehole length since the flushing water content exceeds 25%. Diagrams showing the flushing water content and the electrical conductivity along the borehole are presented in Figures 5-1 and 5-2. The data are plotted at the mid-length of each tube unit.

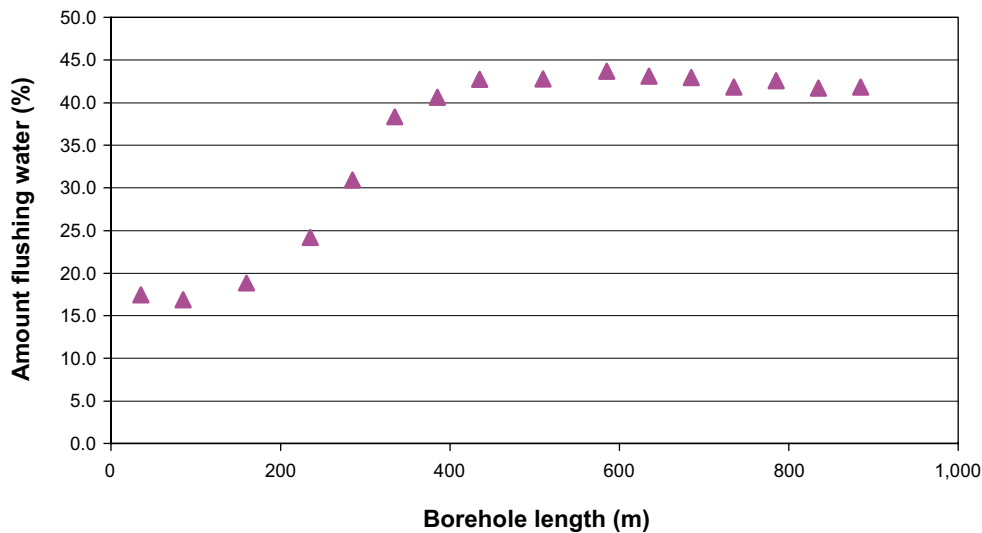


Figure 5-1. Amount of remaining flushing water versus borehole length in KFM08A.

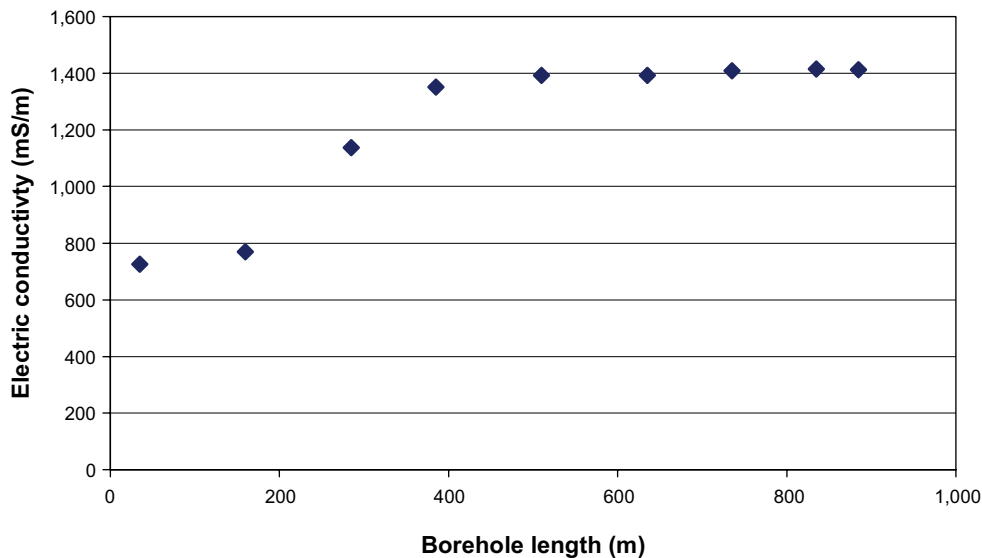


Figure 5-2. Electrical conductivity versus borehole length in KFM08A.

The charge balance errors give an indication of the quality and uncertainty of the analytical data for major constituents. The relative charge balance errors are calculated for the selected sets of data, see Appendix 3. Errors within $\pm 5\%$ are considered acceptable. This limit is not exceeded for any of the samples.

6 Summary and conclusions

The hydrochemical logging of KFM08A was conducted without major problems. However, samples were not collected below 910 m, because the lower part of the borehole was too flat to allow lowering of the equipment beyond 910 m borehole length. The main conclusions that can be drawn from the hydrochemical logging are:

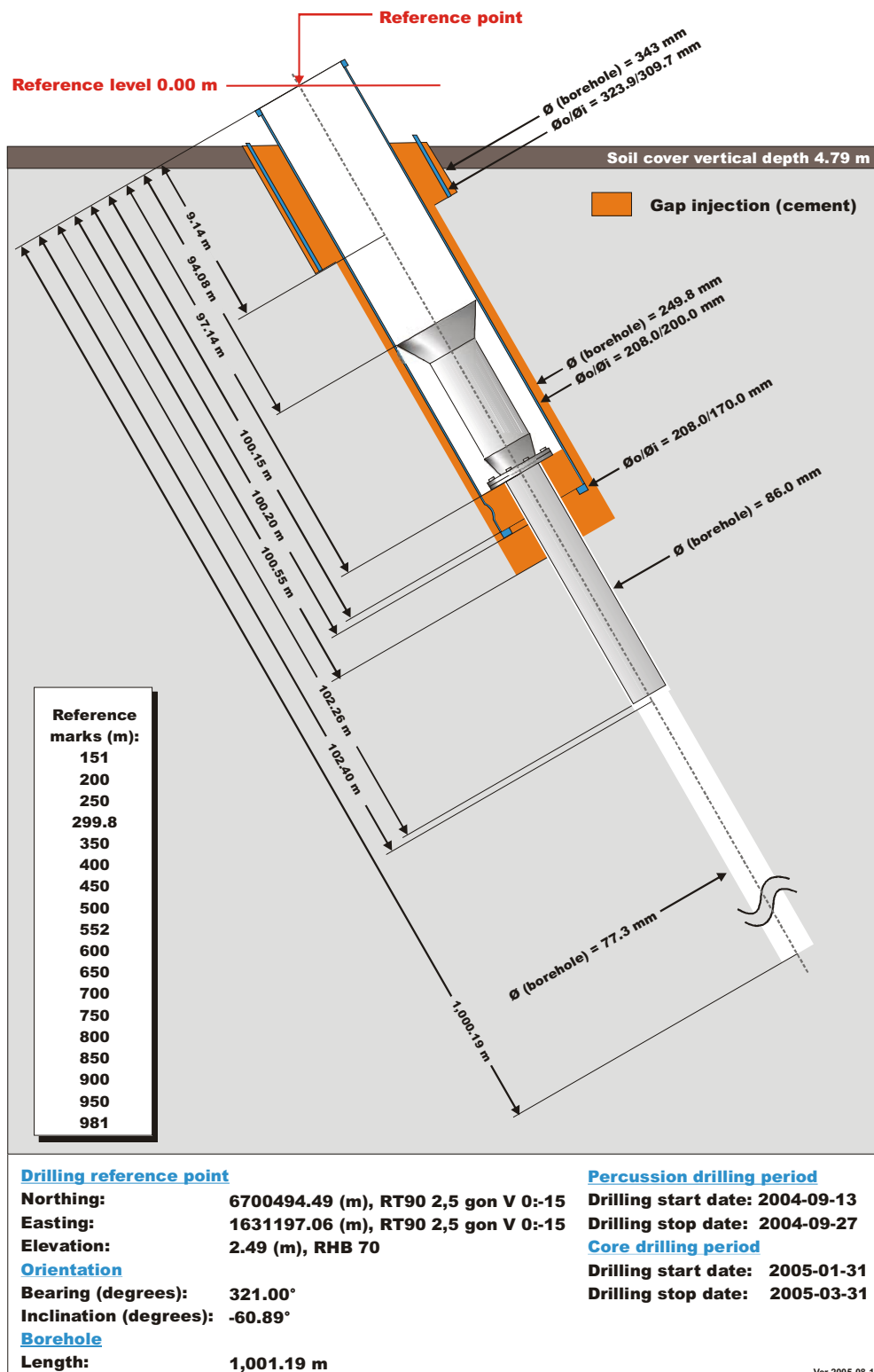
- The amount of remaining flushing water in the water column along the borehole was quite high, especially below 350 m where it levelled out at around 40%.
- According to the differential flow logging, a major water yielding zone is located at about 686 m. This zone is neither indicated by the flushing water content nor by the salinity (electrical conductivity).
- A back-calculation predicts a chloride concentration of 5,760 mg/L in the water yielding zone at 686 m, which is quite reasonable. The variables used for the calculation are; chloride concentration (4,860 mg/L) at the logging occasion, chloride concentration of the flushing water (3,660 mg/L) and the percentage of flushing water (43%).
- The charge balance errors did not exceed the acceptable limit of $\pm 5\%$ for any of the eight analysed samples. This indicates that the analyses of the major components are consistent.

7 References

- /1/ **SKB, 2001.** Site investigations. Investigation methods and general execution programme. SKB TR-01-29, Svensk Kärnbränslehantering AB.
- /2/ **Claesson L-Å, Nilsson G, 2005.** Forsmark site investigation. Drilling of the telescopic borehole KFM08A and the core drilled borehole KFM08B at drill site DS8. SKB P-05-173, Svensk Kärnbränslehantering AB.
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Design of cored borehole KFM08A

Technical data Borehole KFM08A



Sampling and analysis methods

Table A2-1. Sample handling routines and analysis methods.

Component group	Component/element	Sample container (material)	Volume (mL)	Filtering	Preparation/conservation*	Analysis method	Analysis within – or delivery time to lab
Anions 1.	HCO ₃ pH(lab) cond (lab)	Plastic	250	No	No	Titration Pot. meas, Cond. meas	The same day – maximum 24 hours
Anions 2	Cl, SO ₄ , Br ⁻ , F ⁻ , I ⁻	Plastic	100	Yes (not in the field)	No	Titration (Cl ⁻) IC (Cl ⁻ , SO ₄ , Br ⁻ , F ⁻) ISE (F ⁻)	Not critical (month)
	Br, I	Plastic	100	Yes (not in the field)	No	ICP MS	Not critical (month)
Cations, Si and S according to SKB class 3	Na, K, Ca, Mg, S(tot), Si(tot), Li, Sr	Plastic (at low conc acid washed bottles)	100	Yes (not in the field)	Yes (not in the field, 1 mL HNO ₃)	ICP-AES ICP-MS	Not critical (month)
Cations, Si and S according to SKB class 4 and 5	Na, K, Ca, Mg, S(tot), Si(tot), Fe, Mn, Li, Sr	Plastic (Acid washed)	100	Yes (immediately in the field)	Yes (1 mL HNO ₃)	ICP-AES ICP-MS	Not critical (month)
Fe(II), Fe(tot)	Fe(II), Fe(tot)	Plastic (Acid washed)	500	Yes	Yes (5 mL HCl)	Spectrophotometry Ferrozine method	As soon as possible the same day
Hydrogen sulphide	HS ⁻	Glass (Winkler)	About 120x2	No	Ev 1 mL 1 M NaOH+ 1 mL 1M ZnAc	Spectrophotometry	Immediately or if conserved, a few days
Nutrient salts	NO ₂ , NO ₃ +NO ₂ , NH ₄ , PO ₄	Plastic	250	No	No	Spectrophotometry	Maximum 24 hours
Environmental metals	Al, As, Ba, B, Cd, Co, Cr, Cu, Hg, Mo, Ni, P, Pb, V, Zn	Plastic	100	Yes	Yes (1 mL HNO ₃)	ICP-AES ICP-MS	Not critical (month)
Lantanoids, U, Th and so on	Sc, Rb, Y, Zr, I, Sb, Cs, La, Hf, Ti, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, U, Th	Plastic	100	Yes	Yes (1 mL HNO ₃)	ICP-AES ICP-MS	Not critical (month)

Component group	Component/element	Sample container (material)	Volume (mL)	Filtering	Preparation/conservation*	Analysis method	Analysis within – or delivery time to lab
Dissolved organic Carbon, dissolved inorganic Carbon	DOC, DIC	Plastic	100 25	Yes	Frozen, transported in isolated bag	UV oxidation, IR Carbon analyser Shimadzu TOC5000	Short transportation time
Total organic Carbon	TOC	Plastic	250 25	No	Frozen, transported in isolated bag	UV oxidation, IR Carbon analyser Shimadzu TOC5000	Short transportation time
Environmental isotopes	$\delta^2\text{H}$, $\delta^{18}\text{O}$	Plastic	100	No	–	MS	Not critical (month)
Tritium	^3H (enhanced.)	Plastic (dry bottle)	500	No	–	LSC	Not critical (month)
Chlorine-37	$\delta^{37}\text{Cl}$	Plastic	100	No	–	ICP MS	Not critical (month)
Carbon isotopes	$\delta^{13}\text{C}$, pmC (^{14}C)	Glass (brown)	100×2	No	–	(A)MS	A few days
Sulphur isotopes	$\delta^{34}\text{S}$	Plastic	500–1,000	No	–	Combustion, ICP MS	No limit
Strontium-isotopes	$^{87}\text{Sr}/^{86}\text{Sr}$	Plastic	100	No	–	TIMS	Days or week
Uranium and Thorium isotopes	^{234}U , ^{235}U , ^{238}U , ^{232}Th , ^{230}Th	Plastic	50	No	–	Chemical separat. Alfa/gamma spectrometry, ICP-MS	No limit
Boron isotopes	$^{10}\text{B}/^{11}\text{B}$	Plastic	100	Yes	Yes (1 mL HNO_3)	ICP – MS	No limit
Radon and Radium isotopes	^{222}Rn , ^{226}Ra	Plastic	500	No	No	EDA, RD-200	Immediate transport
Dissolved gas (con- tent and composition)	Ar, N_2 , CO_2 , O_2 , CH_4 , H_2 , CO , C_2H_2 , C_2H_4 , C_2H_6 , C_3H_8	Cylinder of stain- less steel	200	No	No	GC	Immediate transport
Colloids	Filter series and frac- tionation (see below)	Polycarbonate filter	0.45, 0.2 and 0.05 μm	–	N_2 atmosphere	ICP-AES ICP-MS	Immediate transport
Humic and fulvic acids	Fractionation	Fractions are collected in plastic bottles	100	–	N_2 atmosphere	UV oxidation, IR (DOC)	Immediate transport
Archive samples with acid	–	Plast (washed in acid)	100×2 **	Yes	Yes (1 mL HNO_3)	–	Storage in freeze con- tainer
Archive samples without acid	–	Plastic	250×2 **	Yes	No	–	Storage in freeze con- tainer
Carbon isotopes in humic and fulvic acids	$\delta^{13}\text{C}$, pmC (^{14}C)	DEAE cellulose (anion exchanger)	–	–	–	(A)MS	A few days

* Suprapur acid is used for conservation of samples.

** Minimum number, the number of archive samples can vary depending on how many similar samples that are collected at the same occasion.

*** Full name and address is given in Table A2-3.

Abbreviations and definitions:

IC	Ion chromatograph
ISE	Ion selective electrode
ICP-AES	Inductively Coupled Plasma Atomic Emission Spectrometry
ICP-MS	Inductively Coupled Plasma Mass Spectrometry
INAA	Instrumental Neutron Activation Analysis
MS	Mass Spectrometry
LSC	Liquid Scintillation Counting
(A)MS	(Accelerator) Mass Spectrometry
GC	Gas Chromatography

Table A2-2. Reporting limits and measurement uncertainties.

Component	Method	Detection limit	Reporting limit or range	Unit	Measurement uncertainty ²	“Total” uncertainty ³
HCO ₃	Alkalinity titration	0.2	1	mg/L	4%	< 10%
Cl ⁻	Mohr titration	5	70	mg/L	5%	< 10%
Cl ⁻	IC	0.2	0.5		6%	10%
SO ₄	IC	0.2	0.5	mg/L	6%	15%
Br ⁻	IC	0.2	0.7	mg/L	9%	20%
Br ⁻	ICP	–	0.001–0.010 ¹		15%	
F ⁻	IC	0.2	0.6	mg/L	10%	20%
F ⁻	Potentiometri	–	–		–	–
I ⁻	ICP	–	0.001–0.010 ¹	mg/L	15%	20%
Na	ICP	–	0.1	mg/L	4%	10%
K	ICP	–	0.4	mg/L	6%	15%
Ca	ICP	–	0.1	mg/L	4%	10%
Mg	ICP	–	0.09	mg/L	4%	10%
S(tot)	ICP	–	0.160	mg/L	10%	15%
Si(tot)	ICP	–	0.03	mg/L	4%	15%
Sr	ICP	–	0.002	mg/L	4%	15%
Li	ICP	–	0.2–2 ¹	µg/L	10%	20%
DOC	See Table 1	–	0.5	Mg/L	8%	30%
TOC	See Table 1	–	0.5	Mg/L	10%	30%
δ ² H	MS	–	2	‰ SMOW ⁴	1.0‰	–
δ ¹⁸ O	MS	–	0.1	‰ SMOW ⁴	0.2‰	–
³ H	LSC	–	0.8 or 0.1	TU ⁵	0.8 or 0.1 TU	–
δ ³⁷ Cl	ICP MS	–	0.2‰ (20 mg/L)	‰ SMOC ⁶	–	–
δ ¹³ C	A (MS)	–	> 20 mg Carbon	‰ PDB ⁷	–	–
pmC (¹⁴ C)	A (MS)	–	> 20 mg kol	PmC ⁸	–	–
δ ³⁴ S	ICP MS	–	0.2‰	‰ CDT ⁹	0.2‰	–
⁸⁷ Sr/ ⁸⁶ Sr	MS	–	–	No unit (ratio) ¹⁰	0.000020	–
¹⁰ B/ ¹¹ B	ICP MS	–	–	No unit (ratio) ¹⁰	0.0020	–
²³⁴ U, ²³⁵ U, ²³⁸ U, ²³² Th, ²³⁰ Th	Alfa spectr	–	0.05	Bq/L	0.05 Bq/L	Right order of magnitude
²²² Rn, ²²⁶ Rn	LSC	–	0.1	Bq/L	0.05 Bq/L	

1. Reporting limits at salinity ≤ 0.4% (520 mS/m) and ≤ 3.5% (3,810 mS/m) respectively.
2. Measurement uncertainty reported by consulted laboratory, generally 95% confidence interval.
3. Estimated total uncertainty by experience (includes effects of sampling and sample handling).
4. Per mill deviation¹² from SMOW (Standard Mean Oceanic Water).

5. TU = Tritium Units, where one TU corresponds to a Tritium/hydrogen ratio of 10^{-18} (1 Bq/L Tritium = 8.45 TU).
6. Per mill deviation¹² from SMOC (Standard Mean Oceanic Chloride).
7. Per mill deviation¹² from PDB (the standard PeeDee Belemnite).
8. The following relation is valid between pmC (percent modern carbon) and Carbon-14 age:

$$\text{pmC} = 100 \times e^{((1950-y-1.03t)/8274)}$$
 where y = the year of the C-14 measurement and t = C-14 age.
9. Per mill deviation¹² from CDT (the standard Canyon Diablo Troilite).
10. Isotope ratio without unit.
11. The following expressions are applicable to convert activity to concentration, for uranium-238 and thorium-232:
 1 ppm U = 12.4 Bq/kg²³⁸U
 1 ppm Th = 3.93 Bq/kg²³²Th
12. Isotopes are often reported as per mill deviation from a standard. The deviation is calculated as:

$$\delta^i = 1,000 \times (K_{\text{sample}} - K_{\text{standard}}) / K_{\text{standard}}$$
 where K = the isotope ratio and ⁱI = ²H, ¹⁸O, ³⁷Cl, ¹³C or ³⁴S etc.

Appendix 3

Water composition, compilation of basic water analysis data

Idcode	Secup m	Seclow m	Sample no	Date	Charge Bal %	Na mg/L	K mg/L	Ca mg/L	Mg mg/L	HCO ₃ ⁻ mg/L	Cl ⁻ mg/L	SO ₄ ²⁻ mg/L	SO ₄ -S mg/L	Br ⁻ mg/l	F ⁻ mg/L	I ⁻ mg/L	Si mg/L	Li mg/L	Sr mg/L	pH	EICond mS/m	DrillWater %
KFM08A	10	60	8895	2005-05-30	-0.4	948	18.7	505	44.5	218	2,220	203	77.3	13.4	1.06	0.066	7.2	0.036	4.87	7.6	726	18
KFM08A	60	110	8896	2005-05-30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17
KFM08A	110	210	8897	2005-05-30	-1.3	980	20.7	536	46.0	255	2,340	236	86.5	13.4	0.99	0.061	8.0	0.039	5.53	7.6	770	19
KFM08A	210	260	8898	2005-05-30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	24
KFM08A	260	310	8899	2005-05-30	1.7	1,310	19.7	1,160	46.0	124	3,850	190	69.9	27.9	0.95	0.12	5.6	0.043	12.1	7.4	1,140	31
KFM08A	310	360	8900	2005-05-30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	38
KFM08A	360	410	8901	2005-05-30	-2.7	1,370	20.1	1,360	47.2	43.7	4,760	164	64.8	41.3	0.93	0.17	4.6	0.045	15.8	7.0	1,350	41
KFM08A	410	460	8902	2005-05-30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	43
KFM08A	460	560	8903	2005-05-30	-2.0	1,400	20.2	1,390	46.9	25.6	4,810	167	61.0	41.1	0.90	0.17	4.5	0.044	15.9	6.7	1,390	43
KFM08A	560	610	8904	2005-05-30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	44
KFM08A	610	660	8905	2005-05-30	-1.7	1,420	20.4	1,420	46.7	22.2	4,860	165	63.5	41.8	0.93	0.17	4.6	0.046	16.1	6.5	1,390	43
KFM08A	660	710	8906	2005-05-30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	43
KFM08A	710	760	8907	2005-05-30	-1.0	1,450	20.1	1,450	46.5	19.5	4,870	164	62.3	45.7	0.92	0.18	4.7	0.045	16.2	6.5	1,410	42
KFM08A	760	810	8908	2005-05-30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	43
KFM08A	810	860	8909	2005-05-30	-1.7	1,440	20.1	1,440	45.9	20.3	4,870	160	61.2	43.2	0.95	0.17	4.8	0.044	16.4	6.5	1,420	42
KFM08A	860	910	8910	2005-05-30	-	-	-	-	-	21.9	-	-	-	-	-	-	-	-	-	-	-	42

Appendix 4

Isotopes, compilation of H-, O-, B-, S-, Cl-, Sr- and C-isotopes

Idcode	Secup m	Seclow m	Sample no	Date	$\delta^2\text{H}$ ‰ SMOW	^3H TU	$\delta^{18}\text{O}$ ‰ SMOW	$^{10}\text{B}/^{11}\text{B}$ no unit	$\delta^{34}\text{S}$ ‰ CDT	$\delta^{37}\text{Cl}$ ‰ SMOC	$^{87}\text{Sr}/^{86}\text{Sr}$ no unit	$\delta^{13}\text{C}$ ‰ PDB	^{14}C pmC
KFM08A	10	60	8895	2005-05-30	A	A	A	A	-	A	A	A	A
KFM08A	110	210	8897	2005-05-30	A	A	A	A	A	A	A	A	A