

P-05-33

Forsmark site investigation

Hydrochemical logging in KFM06A

Cecilia Berg, Geosigma AB

January 2005

Svensk Kärnbränslehantering AB

Swedish Nuclear Fuel
and Waste Management Co
Box 5864

SE-102 40 Stockholm Sweden

Tel 08-459 84 00

+46 8 459 84 00

Fax 08-661 57 19

+46 8 661 57 19



ISSN 1651-4416

SKB P-05-33

Forsmark site investigation

Hydrochemical logging in KFM06A

Cecilia Berg, Geosigma AB

January 2005

Keywords: Core drilled borehole, Groundwater, Water sampling, Chemical analyses, AP-PF 400-04-102.

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

A pdf version of this document can be downloaded from www.skb.se

Abstract

Hydrochemical logging, or so called tube sampling, has been performed in the inclined telescopic borehole KFM06A which is core drilled between 100–1,000 m borehole length. This is a fast and simple sampling technique to obtain information on 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 length.

In most cases the water content of one tube unit constituted one sample and each second tube unit/sample was analysed. Three samples (95–195 m, 395–495 m and 795–895 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 after drilling was acceptable (below 20%) down to 250 m and the SKB class 3 isotopes were determined in the first three samples. Beneath 250 m the flushing water content increased, and the highest measured amount was 69% in the sample from 795–895 m.

In this borehole, nitrogen flushing from the bottom of the borehole replaced mammoth pumping as a method to eliminate flushing water and the water column was exchanged four times. From the hydrochemical logging results it can be concluded that the flushing water problem remains also when applying the new method.

The relative charge balance error did not exceed the acceptable level of $\pm 5\%$ in any of the nine samples analysed. Due to the high amount of remaining flushing water, the analysis data obtained from the hydrochemical logging will, however, be less useful for chemical modelling work.

Sammanfattning

Hydrokemisk loggning, eller så kallad slangprovtagning, har utförts i det lutande teleskopborrhålet KFM06A som är kärnborrat mellan 100–1 000 m borrhålslängd. 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.

I de flesta fall utgjorde innehållet i en slangenhet ett prov och vartannat prov analyserades. Tre prov (95–195 m, 395–495 m samt 795–895 m) bestod av vatten från två slangenheter för att ge tillräcklig vattenvolym för analys av samtliga isotoptillval enligt SKB kemi-klass 3. Halten av kvarvarande spolvatten från borrningen var acceptabel (under 20 %) ner till 250 m och isotoperna bestämdes i de tre första proven enligt SKB klass 3 tillvalet. Under 250 m ökade spolvattenhalten och högsta värdet uppgick till 69 % i provet från 795–895 m.

I detta borrhål användes spolning med kvävgas från botten av hålet som metod för att eliminera spolvatten och vattenpelaren omsattes fyra gånger i stället för mammut pumpning som i tidigare borrhål. Av resultaten från den hydrokemiska loggningen dras slutsatsen att även med den nya metoden kvarstår problemen med spolvattnet.

Det relativa jonbalansfelet överskred inte gränsen för godkännande på $\pm 5\%$ i något av de nio analyserade proven. På grund av den höga spolvattenhalten i proverna är erhållna analysdata från aktiviteten dock inte fullt ut användbara för hydrokemisk modellering.

Contents

1	Introduction	7
2	Objective and scope	9
3	Sampling equipment	11
4	Performance	13
4.1	Hydrochemical logging	13
4.2	Sample treatment and chemical analysis	13
4.3	Data handling	15
4.4	Nonconformities	16
5	Results	17
6	Conclusions	19
7	References	21
	Appendix 1	23
	Appendix 2	25
	Appendix 3	31
	Appendix 4	32

1 Introduction

This document reports the performance and the results of hydrochemical logging in KFM06A, which is one of the activities performed within the site investigation at Forsmark /1/. The work was carried out in accordance with activity plan SKB PF 400-04-102. In Table 1-1 controlling documents for performing this activity are listed. Both activity plan and method descriptions are SKB's internal controlling documents. The data are reported to SICADA in field note no Forsmark 410.

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

Activity plan	Number	Version
Hydrokemisk loggning I KFM06A	AP PF 400-04-102	1.0
Method descriptions	Number	Version
Metodbeskrivning för hydrokemisk loggning	SKB MD 422.001	1.0

Borehole KFM06A is the sixth deep telescopic borehole drilled at the site investigations in the Forsmark area /2/. The location of the drill sites within the site investigation area is shown in Figure 1-1, drill site DS6 included. Figure 1-2 presents a zooming in towards drill site DS6 with KFM06A, KFM06B and nearby situated percussion drilled boreholes in soil and rock. Borehole KFM06A is inclined 60° from the horizontal plane. The borehole section 0–100 m is percussion drilled and cased with a stainless steel casing with the internal diameter 200 mm, whereas section 100–1,000.64 m is core drilled with a diameter of 77 mm. The borehole is of the so called SKB chemical type, see method descriptions MD 620.003 (Method description for drilling cored boreholes) and 610.003 (Method description for percussion drilling). A borehole being of SKB chemical type entails 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 (Instruction for cleaning borehole equipment and certain surface equipment). Basic borehole information is given in Table 1-2 below. The design of the borehole is presented in Appendix 1.

Table 1-2. Previous activities in borehole KFM06A.

Activities performed	Date of completion	Length (m)	Comment
Percussion drilling	2003-11-21	100.75	
Core drilling	2004-09-21	100–1,000.64	HFM16 served as source of flushing water for core drilling the cored part of KFM06A. HFM16 is a SKB chemical type of borehole /3, 4/.
N ₂ -flushing of borehole and additional pumping	2004-09-21	0–1,000.64	477.5 m ³ of borehole water was exchanged.
Differential flow logging	2004-10-21	102–1,000.64	
BIPS-logging	2004-11-02	102–994.00	
Hydrochemical logging	2004-10-28	0–995	Described in this report.

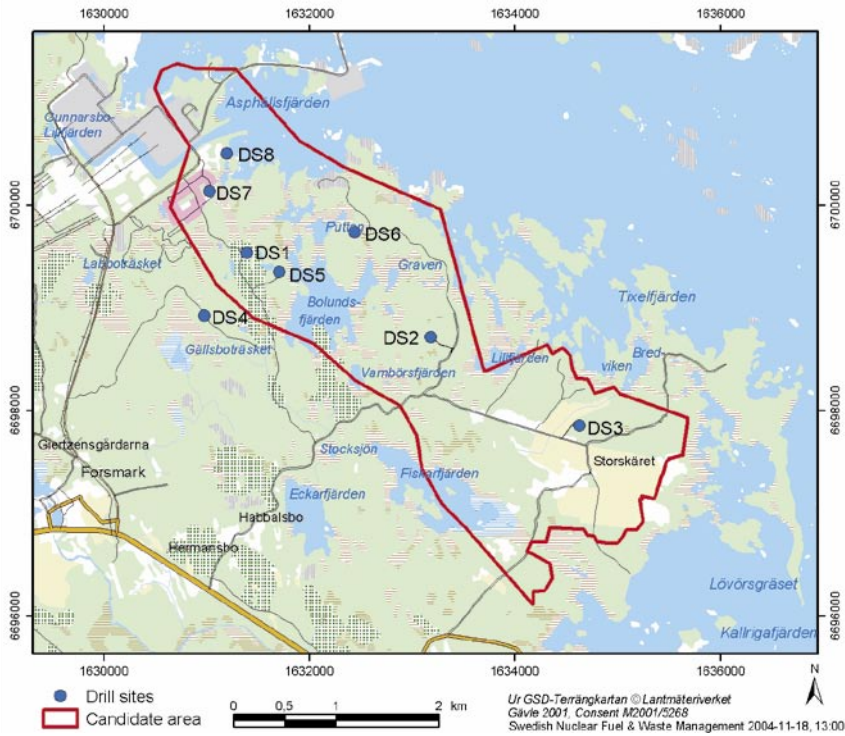


Figure 1-1. The investigation area at Forsmark (approximately the area inside the black square) including the candidate area selected for more detailed investigations. The eight drill sites (DS1-8) for deep boreholes are marked with blue circles. KFM06A is located within drill site DS6.

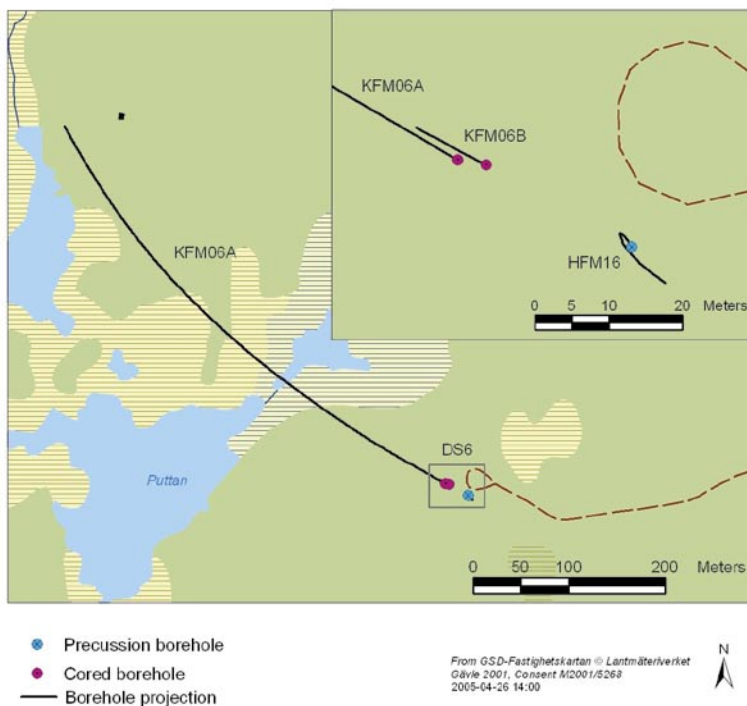


Figure 1-2. Locations of the core drilled telescopic boreholes KFM06A and KFM06B (both are inclined 60°) as well as the percussion borehole HFM16 at drill site DS6. The boreholes are projected to the horizontal plane at ground surface.

2 Objective and scope

Hydrochemical logging is performed in order to obtain an overview of the initial chemical composition of the water column along the open borehole KFM06A shortly after completed drilling. The technique used for sampling is fast and simple even at great depths.

The analysis program is carried out according to SKB chemistry class 3 including isotope options. However, if the content of drilling water in a sample exceeds 20%, the isotope determinations are omitted.

3 Sampling equipment

For the hydrochemical logging an approximately 1,000 m long polyamide tube, divided into units of 50 m, was used. The equipment is described in the method description SKB MD 422.001.

A schematic illustration of the equipment is shown in Figure 3-1. The length of each tube unit is given in Table 3-1. The tube units are connected with metal couplings and manual shut off valves are mounted at both ends of each unit. The external and internal diameters of the tube units are 10 and 8 mm respectively. The water content in each tube unit constitutes one sample and the volume of each sample will amount to at least two litres. A check valve and a weight are mounted at the bottom of the tube array to prevent water outflow and to keep it stretched in the borehole.

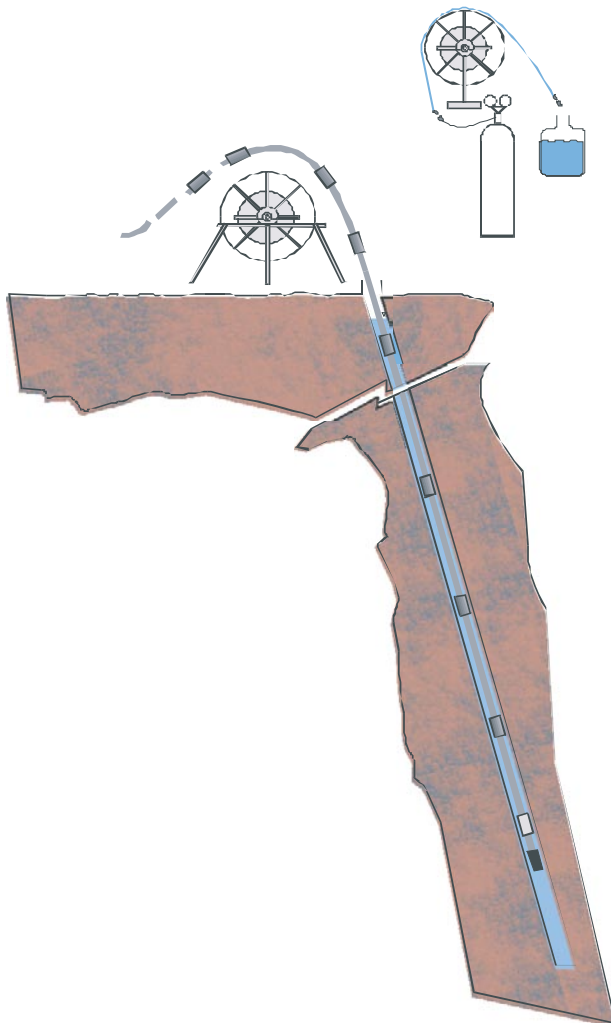


Figure 3-1. Equipment for hydrochemical logging in boreholes. At the lower end of the tube array there is a non-return valve and a weight connected. Each tube unit is 50 m long.

Table 3-1. Length of tube units.

Unit	Length (m)
1	49.71
2	50.08
3	49.77
4	49.28
5	49.97
6	50.01
7	49.85
8	49.87
9	49.57
10	49.72
11	49.67
12	50.25
13	50.62
14	49.70
15	49.22
16	49.20
17	49.30
18	49.63
19	49.62
20	49.87
Sum:	994.91
Coupling length:	2.812
Weight length:	0.817
Total tube length:	998.539

4 Performance

4.1 Hydrochemical logging

Sampling of the telescopic borehole KFM06A was performed according to the activity plan AP PF 400-04-102 and following the method description SKB MD 422.001.

The hydrochemical logging was performed on the 28:th of October to a length of 995 m. The tube array was not lowered all the way down to the bottom at 1,000.64 m in order to decrease the risk of getting stuck and also to avoid suspending drilling debris sedimented at the bottom of the borehole. The lowering of the tubes started at 08:56 and the retrieval of the tube units started at 12:56. The first tube unit at the top of the array was lowered to 45 m of its length. This resulted in a tube that was not completely filled with sample water. The tube units were emptied using pressurized nitrogen gas and the water was portioned into plastic bottles to be analysed at different laboratories. In most cases one tube unit constitutes one sample. However, SKB samples number 8697, 8700 and 8709 were concatenated from two tube units in order to allow analyses of all SKB chemical class 3 isotope options.

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. An overview showing the filled sample portions at the logging occasion is given in Table 4-1. The sample portions SKB number 8700 to 8711 intended for isotope analyses were not sent to the laboratories for isotope determination due to their high amount of remaining flushing water from drilling (above 20%). The data from the hydrochemical logging are stored in the database SICADA in field note no Forsmark 410. The SKB sample numbers are 8695–8711.

Table 4-1. Overview of samples collected at the hydrochemical logging in KFM06A. 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	Uranine	³ H	$\delta^2\text{H}/\delta^{18}\text{O}$	$\delta^{37}\text{Cl}$	⁸⁷ Sr	C isotopes	$\delta^{34}\text{S}$	Left overs
1	0-45	8695												
2	95	8696												
3 and 4	195	8697												
5	245	8698												
6	295	8699												
7 and 8	395	8700						X	X	X	X	X	X	
9	445	8701												
10	495	8702						X	X	X	X			
11	545	8703												
12	595	8704						X	X	X	X			
13	645	8705												
14	695	8706												
15	745	8707						X	X	X	X			
16	795	8708												
17 and 18	895	8709						X	X	X	X	X	X	
19	945	8710												
20	995	8711						X	X	X	X	X	X	

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

The uppermost tube unit was not completely filled; see Section 4.1 and sample portions for ³⁷Cl and ⁸⁷Sr could not be filled.

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 are stored in the SICADA database. 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.

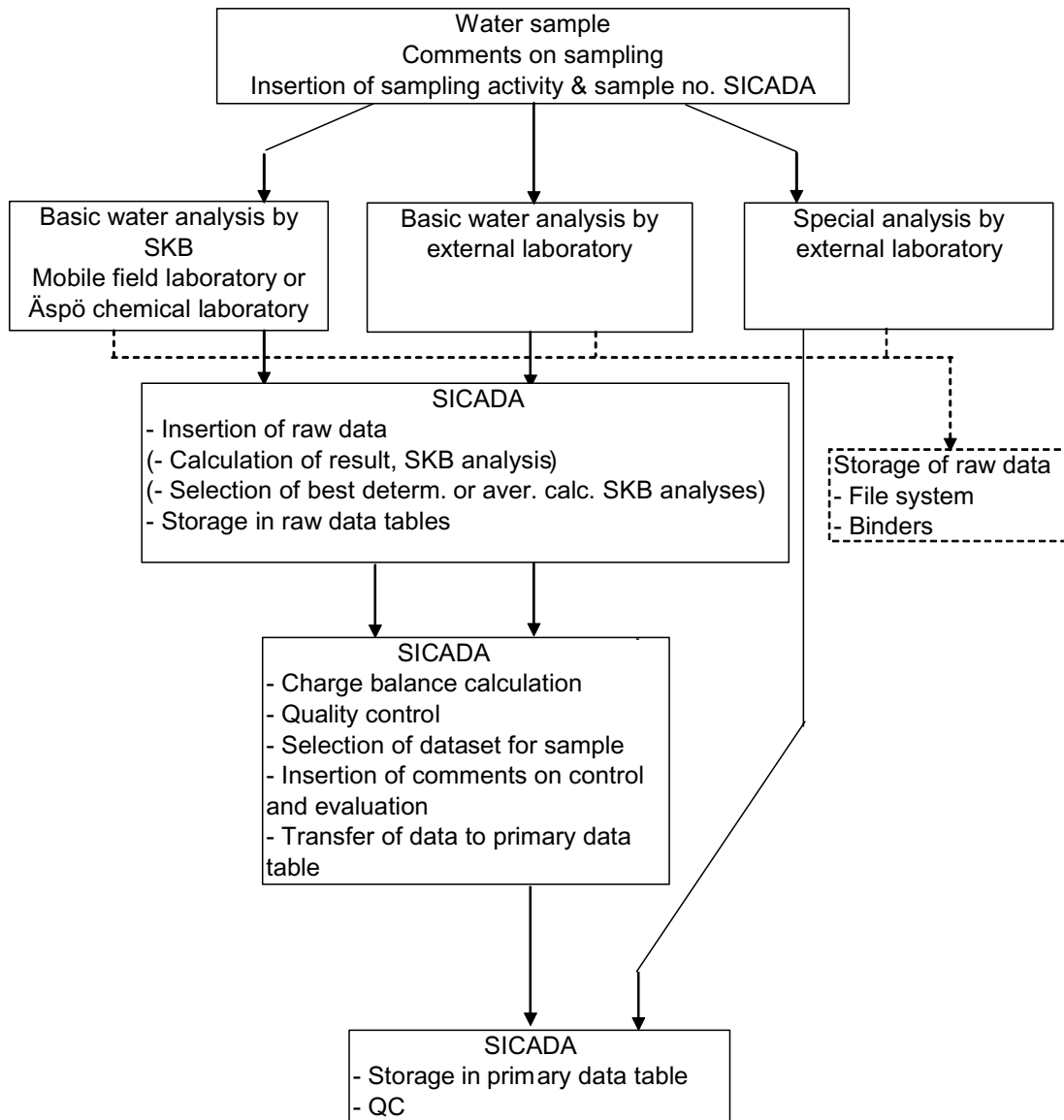


Figure 4-1. Overview of data management for hydrogeochemical data.

4.4 Nonconformities

The activity was performed according to the controlling documents for the activity without any deviations that can affect the quality of the data.

5 Results

The analysis results from the hydrochemical logging in KFM06A are presented in Appendices 3 and 4. Diagrams showing the flushing water content and the electric conductivity along the borehole at the time of the hydrochemical logging are presented in Figures 5-1 and 5-2. The results have been plotted for the mid-point of each tube unit. Since the flushing water content exceeds 20% from approximately 300 m and downwards to the bottom of the borehole, no isotope determinations are available beneath that borehole length.

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

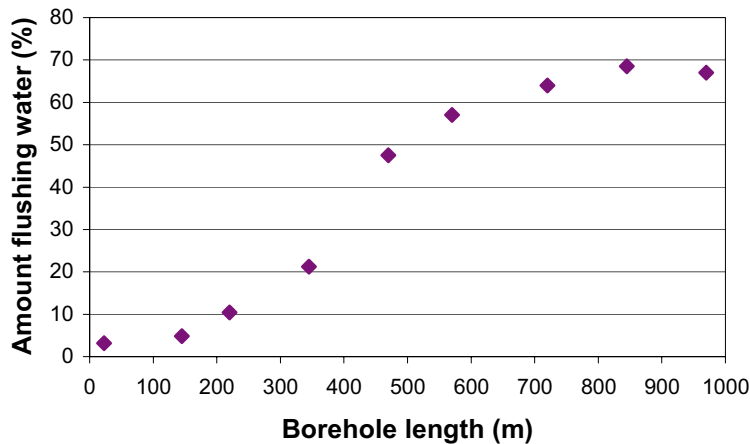


Figure 5-1. Flushing water content versus borehole length.

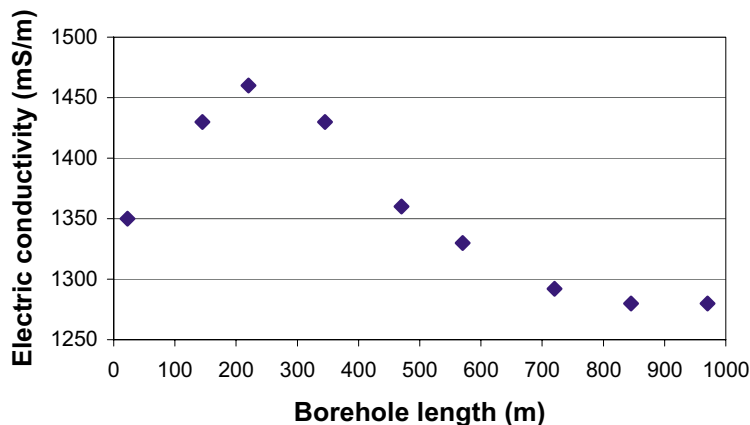


Figure 5-2. Electric conductivity versus borehole length.

6 Conclusions

The hydrochemical logging in KFM06A revealed a high amount of flushing water in the water column along the borehole. Accordingly, the chemical data obtained, will be less useful for chemical modelling work. The main conclusions that can be drawn from the activity are:

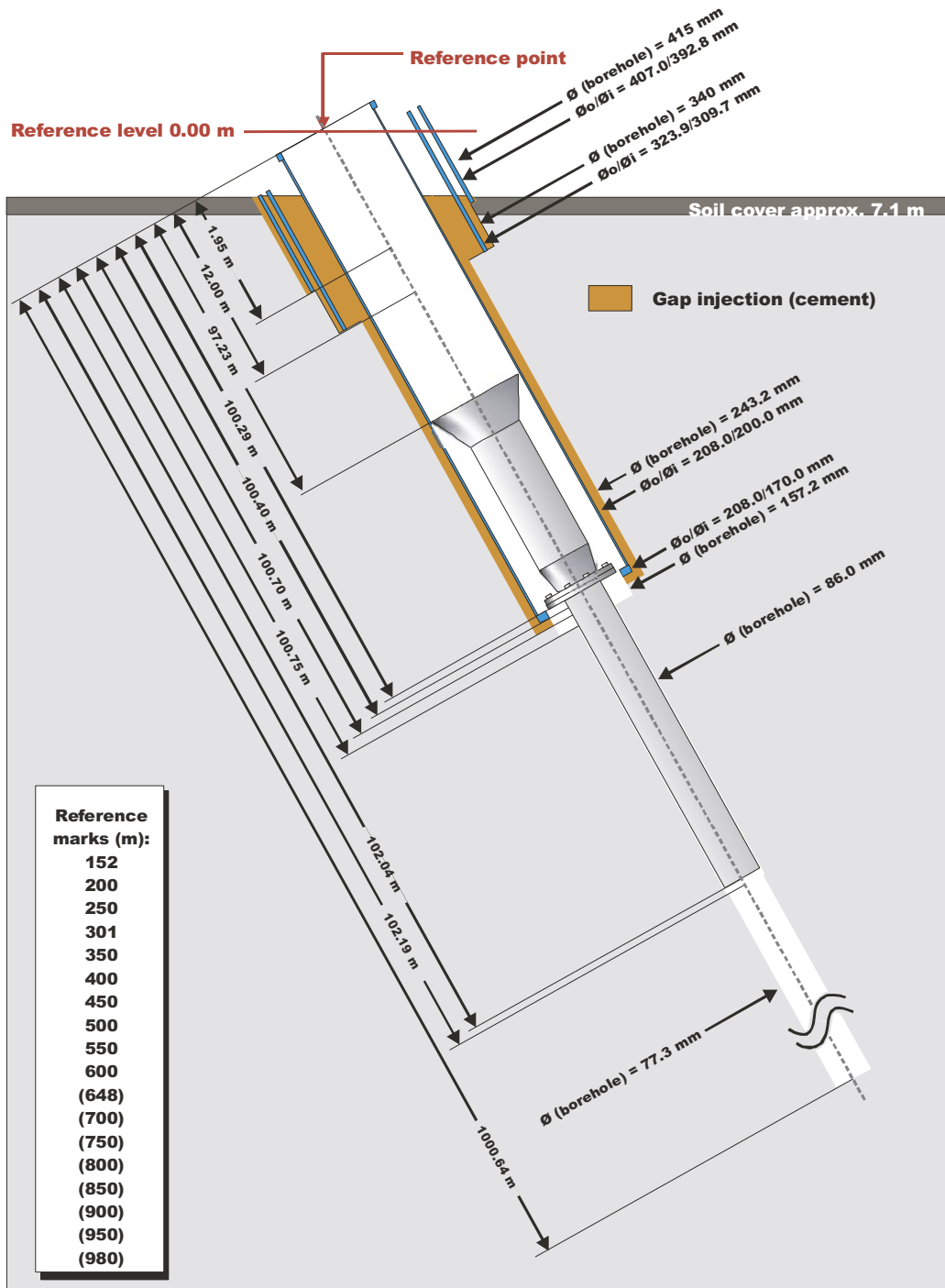
- The amount of remaining flushing water was below 25% in the upper part of the borehole, i.e. the first 400 m borehole length. The content showed a steady increase versus depth along the borehole and ended at just below 70% in the last sample. The electric conductivity trend verifies this condition.
- The charge balance error did not exceed the acceptable limit of $\pm 5\%$ in any data set.

7 References

- /1/ **SKB, 2001.** Generellt genomförande program för platsundersökningar. SKB R-01-10, Svensk Kärnbränslehantering AB.
- /2/ **Claesson L-Å, Nilsson G, 2004.** Forsmark site investigation. Drilling of the telescopic borehole KFM06A and the percussion drilled borehole KFM06B at drill site DS6. SKB P-05-50 (in progress), Svensk Kärnbränslehantering AB.
- /3/ **Claesson L-Å, Nilsson G, 2004.** Forsmark site investigation. Drilling of a monitoring well, HFM16, at drilling site DS6. SKB P-04-94. Svensk Kärnbränslehantering AB.
- /4/ **Nilsson D, 2004.** Forsmark site investigation. Sampling and analyses of groundwater from percussion drilled boreholes. Results from the percussion boreholes HFM09 to HFM19 and the percussion drilled part of KFM06A. SKB P-04-92. Svensk Kärnbränslehantering AB.

Technical data

Borehole KFM06A



Northing: 6699732.88 (m), RT90 2,5 gon V 0:-15
Easting: 1632442.51 (m), RT90 2,5 gon V 0:-15
Elevation: 4.10 (m), RHB 70
Orientation
Bearing (degrees): 300.92°
Inclination (degrees): -60.25°
Borehole
Length: 1000.64 m

Percussion drilling period
Drilling start date:
Drilling stop date:
Core drilling period
Drilling start date: 2004-06-14
Drilling stop date: 2004-09-21

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	Laboratory***	Analysis within – or delivery time to lab.
Anions 1.	HCO ₃ pH (lab) cond (lab)	Plastic	250	Yes (not in the field)	No	Titration Pot. meas, Cond. meas	Mobile field lab. AnalyCen	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 ⁻)	Äspö:s chemistry lab. AnalyCen	Not critical (month)
	Br, I	Plastic	100	Yes (not in the field)	No	ICP MS	Paavo Ristola OY Analytica AB,	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	Analytica AB, AnalyCen	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	Analytica AB, AnalyCen	Not critical (month)
Fe(II), Fe(tot)	Fe(II), Fe(tot)	Plastic (Acid washed)	500	Yes	Yes (5 mL HCl))	Spectrophotometry Ferrozine method	Mobile field lab.	As soon as possible the same day
Hydrogen sulphide	HS ⁻	Glass (Winkler)	About 120×2	No	Ev 1 mL 1 M NaOH+ 1 mL 1M ZnAc	Spectrophotometry	AnalyCen Äspö:s chemistry lab.	Immediately or if conserved, a few days
Nutrient salts	NO ₂ , NO ₃ +NO ₂ , NH ₄ , PO ₄	Plastic	250	No	No	Spectrophotometry	Äspö:s chemistry lab. AnalyCen	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	Analytica AB, AnalyCen	Not critical (month)

Component group	Component/element	Sample container (material)	Volume (mL)	Filtering	Preparation/Conservation*	Analysis method	Laboratory***	Analysis within – or delivery time to lab.
Lantanoids, U, Th and so on	Sc, Rb, Y, Zr, I, Sb, Cs, La, Hf, Tl, 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	SGAB Analytica, AnalyCen	Not critical (month)
Dissolved organic Carbon, dissolved inorganic Carbon	DOC, DIC	Plastic	250 25	Yes	Frozen, transported in isolated bag	UV oxidation, IR Carbon analysator Shimadzu TOC5000	Paavo Ristola OY Dept. of System ecology, SU	Short transportation time
Total organic Carbon	TOC	Plastic	250 25	No	Frozen, transported in isolated bag	UV oxidation, IR Carbon analysator Shimadzu TOC5000	Paavo Ristola OY Dept. of System ecology, SU	Short transportation time
Environmental isotopes	$\delta^2\text{H}$, $\delta^{18}\text{O}$	Plastic	100	No	– –	MS	IFE	Not critical (month)
Tritium,	^3H (enhanced)	Plastic (dry bottle)	500	No	–	LSC	Univ. of Waterloo	Not critical (month)
Chlorine-37	$\delta^{37}\text{Cl}$	Plastic	100	No	–	ICP MS		
Carbon isotopes	$\delta^{13}\text{C}$, pmC (^{14}C)	Glass (brown)	100×2	No	–	(A)MS	Univ. of Waterloo	A few days
Sulphur isotopes	$\delta^{34}\text{S}$	Plastic	500–1,000	Yes	–	Combustion, ICP MS	IFE	No limit
Strontium-isotopes	$^{87}\text{Sr}/^{86}\text{Sr}$	Plastic	100	Yes	–	TIMS	IFE	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	IFE	No limit
Boron isotopes	$^{10}\text{B}/^{11}\text{B}$	Plastic	100	Yes	Yes (1 mL HNO ₃)	ICP – MS	Analytica AB	No limit
Radon and Radium isotopes	^{222}Rn , ^{226}Ra	Plastic	500	No	No	EDA, RD-200	IFE	Immediate transport
Dissolved gas (content and composition)	Ar, N ₂ , CO ₂ , O ₂ , CH ₄ , H ₂ , CO, C ₂ H ₂ , C ₂ H ₄ , C ₂ H ₆ , C ₃ H ₈	Cylinder of stainless steel	200	No	No	GC	Paavo Ristola OY	Immediate transport

Component group	Component/element	Sample container (material)	Volume (mL)	Filtering	Preparation/Conservation*	Analysis method	Laboratory***	Analysis within – or delivery time to lab.
Colloids	Filter series and fractionation (see below)	Polycarbonate filter	0.45, 0.2 and 0.05 µm	–	N ₂ atmosphere	ICP-AES ICP-MS	Analytica AB	Immediate transport
Humic and fulvic acids	Fractionation	Fractions are collected in plastic bottles	250	–	N ₂ atmosphere	UV oxidation, IR (DOC)	Paavo Ristola OY	Immediate transport
Archive samples with acid	–	Plast (washed in acid)	100×2 **	Yes	Yes (1 mL HNO ₃)	–	–	Storage in freeze container
Archive samples without acid	–	Plastic	250×2 **	Yes	No	–	–	Storage in freeze container
Carbon isotopes in humic and fulvic acids	δ ¹³ C, pmC (¹⁴ C)	DEAE cellulose (anion exchanger)	–	–	–	(A)MS	The Ångström laboratory, Uppsala	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 tab. 1	–	0.5	Mg/L	8%	30%
TOC	See tab. 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 ¹³	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:

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

Table A2-3. Participant laboratories.

Äspö water chemical laboratory (SKB)
Mobile field laboratory, Forsmark (SKB)

Inainöörtoimisto
Paavo Ristola Oy
Teollisuus-ja
Voimalaitoskemia
Rajantorpantie 8, C-talo
01600 Vantaa
FINLAND

Dept. of System ecology
Stockholm University
10691 Stockholm

Analytica AB
Aurorum 10
977 75 Luleå
(Nytorpsvägen 16
Box 511
183 25 Täby)

Environmental Isotope Laboratory
Dep. Of earth sciences
University of Waterloo
Waterloo, Ontario
N2L 3G1 CANADA

Institutt for energiteknik (IFE)
Instituttveien 18
P.O Box 40
2027 Kjeller
NORGE

AnalyCen Nordic AB
Box 905
531 19 Lidköping

The Ångström laboratory
Box 534
Se-751 21 Uppsala

Water composition, compilation of basic water analysis data

Compilation January 2005

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	Si mg/L	Fe mg/L	Mn mg/L	Li mg/L	Sr mg/L	pH	EiCond mS/m	Flushing water %	I ⁻ mg/L
KFM06A	0	45	8695	2004-10-28	-0.09	1760	29.0	790	193	111	4380	348	118	19.3	1.25	5.50	0.11	1.53	0.049	6.35	7.31	1350	3.2	0.029
KFM06A	45	95	8696	2004-10-28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	xxx	-
KFM06A	95	195	8697	2004-10-28	-0.32	1890	31.4	848	205	114	4730	372	124	20.3	0.80	5.69	0.355	1.61	0.052	6.86	7.17	1430	4.8	0.052
KFM06A	195	245	8698	2004-10-28	-0.29	1900	31.0	891	193	107	4790	381	123	20.9	0.40	5.56	1.13	1.62	0.052	7.44	7.22	1460	10.4	0.055
KFM06A	245	295	8699	2004-10-28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	xxx	-
KFM06A	295	395	8700	2004-10-28	-0.92	1810	28.2	945	179	98.3	4790	348	115	22.5	0.40	5.17	2.74	1.55	0.048	8.36	7.16	1430	21.2	0.062
KFM06A	395	445	8701	2004-10-28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	xxx	-
KFM06A	445	495	8702	2004-10-28	-0.60	1630	23.7	1030	135	81.5	4550	279	94.0	25.0	0.95	4.59	4.69	1.31	0.043	9.81	7.09	1360	47.5	0.071
KFM06A	495	545	8703	2004-10-28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	xxx	-
KFM06A	545	595	8704	2004-10-28	-1.98	1540	22.1	1020	115	74.1	4490	249	82.3	25.7	0.75	4.4	5.45	1.15	0.04	10.0	7.06	1330	57.0	0.074
KFM06A	595	645	8705	2004-10-28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	xxx	-
KFM06A	645	695	8706	2004-10-28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	xxx	-
KFM06A	695	745	8707	2004-10-28	-2.45	1470	21.4	1050	99	67.4	A	223	73.7	26.0	0.80	4.42	5.82	1.03	0.039	10.4	7.1	1292	64.0	0.077
KFM06A	745	795	8708	2004-10-28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	xxx	-
KFM06A	795	895	8709	2004-10-28	-2.37	1430	21.2	1050	93.5	65.1	4370	210	70.3	25.8	0.75	4.51	6.27	0.99	0.036	10.4	7.0	1280	68.5	0.075
KFM06A	895	945	8710	2004-10-28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	xxx	-
KFM06A	945	995	8711	2004-10-28	-1.94	1420	21.2	1050	91	66.5	4310	203	68.6	26.1	0.80	4.61	6.50	0.975	0.036	10.4	7.11	1280	67.0	0.075

-- = Archive sample.

A = results will be reported later.

xx = No result due to analytical problems.

xxx = Result not in SICADA.

< "value" = result below detection limit.

ChargeBal % = Relative charge balance error %.

SICADA: water_composition.

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

Compilation January 2005

Idcode	Secup m	Seclow m	Sample no	Date	Time	$\delta^2\text{H}$ dev SMOW	^3H TU	$\delta^{18}\text{O}$ dev SMOW	$^{10}\text{B}/^{11}\text{B}$ no unit	$\delta^{34}\text{S}$ dev CDT	$\delta^{37}\text{Cl}$ dev SMOC	$^{87}\text{Sr}/^{86}\text{Sr}$ no unit	$\delta^{13}\text{C}$ dev PDB	^{14}C pmC
KFM06A	0	45	8695	2004-10-28	08:56–12:56	-71.4	2.40	-9.50	0.2395	–	–	–	–	–
KFM06A	95	195	8697	2004-10-28	08:56–12:56	-72.1	1.50	-9.70	0.2390	25.5	-0.14	0.718360	-5.97	A
KFM06A	195	245	8698	2004-10-28	08:56–12:56	-72.9	2.90	-9.70	0.2389	–	-0.07	0.718236	–	–

– = Not analysed.

A = Results will be reported later.

x = No result due to sampling problems.

xx = No result due to analytical problems.

SICADA: h_o_isotopes, b_s_cl_sr_isotopes, c_s_isotopes.