Analysis of groundwater from deep boreholes in Fjällveden

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Stockholm, Sweden 1983-03-29

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This report concerns a study which was conducted for SKBF/KBS. The conclusions and viewpoints presented in the report are those of the author(s) and do not necessarily coincide with those of the client.

A list of other reports published in this series during 1983 is attached at the end of this report. Information on KBS technical reports from 1977-1978 (TR 121), 1979 (TR 79-28), 1980 (TR 80-26), 1981 (TR 81-17) and 1982 (TR 82-28) is available through SKBF/KBS.

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SUMMARY

Groundwater from three boreholes at an investigation site in Fjällveden has been sampled and analyzed. This is part of a larger programme of geological, geophysical and hydrogeological investigations aimed at finding a suitable site for a high level radioactive waste repository.

Four water-bearing levels in each of the boreholes FJ2 and FJ4, and two levels in borehole FJ8, have been sampled. The sampling depths range from 106 down to 562 m. Prior to sampling, the water-bearing section is isolated between packer sleeves. The water is then pumped to the surface where sensitive parameters such as redox potential, pH, sulphide and oxygen content are measured electrochemically on the flowing water in a system isolated from the air. Water, filter and gas samples are sent to several laboratories for further analysis.

The present report is a presentation of the results of the groundwater analyses. The reliability of the results is discussed but there is no evaluation in relation to geology and hydrogeology. This report presents the basic results from the groundwater analyses to be further evaluated by experts in different fields.

CONTENTS

ANALYSIS OF GROUNDWATER FROM DEEP BOREHOLES IN FJÄLLVEDEN

1 INTRODUCTION

Groundwater from three boreholes in Fjällveden has been sampled and analyzed. The sampling levels were chosen on the basis of hydrological measurements in the boreholes. Sampling was carried out by Sveriges Geologiska AB. Personnel from IPK and VIAK performed the field measurements and sampling. Several laboratories participated in the water analysis (see below). Supplementary sampling in additional boreholes in Fjällveden is in progress. The results will be reported at a later time.

The boreholes were pumped out with a gas lift prior to the hydrological investigation and immediately before the equipment for water sampling was lowered to the first sampling level. On the latter occasion, three such gas lift pumpings - called mammoth pumpings - were performed in a row. Iodide (NaI, 0.01 mmol/l) was added to the drilling water during drilling to enable any residual drilling water to be traced in the groundwater. The selected fracture zones were sealed off by packers spaced at a distance of 2.7 m.

Sampling took place from the middle of June to the middle of October, 1982. Four levels were sampled in each of the boreholes FJ2 and FJ4, and two levels in FJ8. Depth is given both as vertical depth (depth) and/or borehole length (length). It is always vertical depth that is given, unless otherwise specified in the table heading.

The work was carried out in periods of 14 days - lowering and start of the sampling pump, 4 days off and 9 days field measurements. When the supply of water is adequate, approximately 4.5 cubic metres of water can be pumped up during one period.

The present report consists primarily of a presentation of the results of the groundwater analyses. The reliability of the results is subjected to some scrutiny. There is, however, no evaluation in relation to geology or hydrology. The material in this report will be further analyzed by experts in different fields.

The geology and hydrology of the test area will be described in KBS TR 83-52.

A general description of the chemistry of groundwater from great depths in granite and gneiss has previously been published by G Jacks (KBS TR 88). The same author has also described the chemistry of groundwater in Blekinge (KBS TR 79-07), where Sternö is situated. The results of analyses of the groundwater from the Finnsjö area are presented in KBS TR 82-23 and from Gideå in KBS TR 83-17. A geochemical evaluation of fracture minerals and the relation between fracture minerals and groundwater composition in Finnsjön has been published by E-L Tullborg and co-workers (KBS TR 82-20). The relationship between pH and carbonate content in deep groundwaters has been discussed by Bert Allard in KBS TR 82-25. The expected groundwater composition and its importance for the final storage of radioactive waste have been discussed in KBS TR 90 and the final report KBS-2 Volume 2 (Handling and Final Storage of Unreprocessed Spent Nuclear Fuel, Technical Volume). Hydrology and groundwater age are also taken up in the latter report.

2 SAMPLING

2.1 Drilling water

Some of the drilling water that is used in the core drilling of the sampling holes can penetrate into rock fractures and contaminate the groundwater there. In order to get rid of the drilling water to as great an extent as possible prior to sampling, three mammoth pumpings (using nitrogen gas) are performed immediately prior to installation of the sampling equipment.

The sampling equipment (2.2) is lowered to the chosen level and allowed to work for 3-4 days before sampling begins. Periodic sampling during a period of 8-9 days makes it possible to follow changes in the composition of the water that might derive from drilling water or some other source of contamination. The changes may also be due to the incursion of water from different aquifers.

Water from percussion-drilled boreholes has been used as drilling water. The drilling water was filtered through mechanical filters of cellulose (18 CMC 3-2), which are supposed to retain particles with diameters larger than 5 μm. The filtered drilling water was then analyzed. The results for the boreholes in question are presented at the bottom of the respective tables (tables 5-8).

Before the drilling water was used, it was "marked" by the addition of sodium iodide (0.01 mmol/l in the drilling water) in order to make sure that it would be possible to trace any drilling water that may have contaminated the sampled water. Unfortunately, it has been found that both the drilling water and sampled groundwater can have considerable contents of natural iodide (KBS TR 83-17). Chloride, for example, is always accompanied by small quantities of bromide and iodide. If we assume 3×10^{-4} mg I per mg Cl, which is a value that has been observed in connection with water sampling at Stripa, chloride concentrations of 100-200 mg/l correspond to iodide concentrations of 0.03-0.06 mg/l, which in turn would be erroneously interpreted as a drilling water contamination of 2-5%. The drilling water contamination given for FJ2, 506 m should for this reason be 2-4% too high, and the drilling water contamination in the first sample (No. 231) in FJ4, 420 m can probably be explained by the high salt content. The drilling waters used in Fjällveden were not analyzed for iodide prior to marking, which brings an additional uncertainty to the drilling water contaminations given in table 8.

2.2 Sampling equipment

The boreholes are core-drilled with a diameter of 56 mm. The 2.7 m long sampling zone is sealed off by rubber packers that are expanded to a pressure that is 0.8-1 MPa above the groundwater pressure. The sampling pump is positioned immediately above the sealed-off zone. The intake is from the upper part of the zone. The pump, which is made of steel and furnished with teflon seals, has a maximum capacity of 0.12 l/stroke, equivalent to 330 l/d. The water flow available for sampling decreases if the flow of water in the measured rock is lower than the capacity of the pump. A schematic illustration of the sampling pump and packers is shown in Fig. 1.

The water is pumped up through teflon-lined iron pipes to a test chamber of stainless steel on the ground surface. The test chamber is equipped with electrodes and measuring cells for recording pH, Eh (glassy carbon), Eh (platinum), pS and the oxygen content and conductivity of the water. The test chamber is also equipped with valves for the extraction of water samples.

As of September, the equipment has been augmented with an extra measuring chamber of glass with two Eh electrodes of the same kind as those in the test chamber (glassy carbon and platinum). In order to give these electrodes plenty of time to stabilize, they are not calibrated and they are only cleaned when the level is changed.

2.3 Procedure

Work at the boreholes is conducted in periods of 14 days. On the last day of a period, the sampling equipment is set up at the level that is to be sampled during the following period, and the sampling pump is started. The personnel then go home for 4 days off while the sampling pump works. Sampling then proceeds for 10 consecutive days. There have been some disruptions in the programme, as is evident from the notes to the table in 2.4.

2.4 Water flow during sampling

The water flow at different levels is shown in the table below. The pumped-up water volume has also been calculated. "Prior" refers to the approximate quantity of water pumped up from the level before sampling started, and "Sampl." to the quantity of water during the sampling period.

BH	Depth m	Mean flow l/day	Prior m^3	Sampl. m^3	Total m^3	Notes
FJ2	106	270	0.2	1.5	1.7	1
	293	245	-	2.2	-	2
	409	265	-	1.6	-	3
	506	190	1.1	1.7	2.8	
FJ4	131	315	1.9	2.5	4.4	
	272	320	1.9	2.6	4.5	
	349	335	2.0	2.7	4.7	
	420	260	0.2	1.6	1.8	4
FJ8	402	250	0.0	1.8	1.8	5
	562	145	0.9	1.3	2.2	

Note 1 Due to delays at the borehole, sampling started the day after lowering.

Note 2 The pump ran for about seven days prior to sampling, but unfortunately there was no pressure in the packers when the personnel returned after their leave. It is therefore probable that water leaked into the sampling zone.

Note 3 Due to difficulties in connection with lowering, the pump was not started until 14 h before the start of the measuring period. The pressure in the packers was lost again in that time, so water may have leaked into the sampling zone.

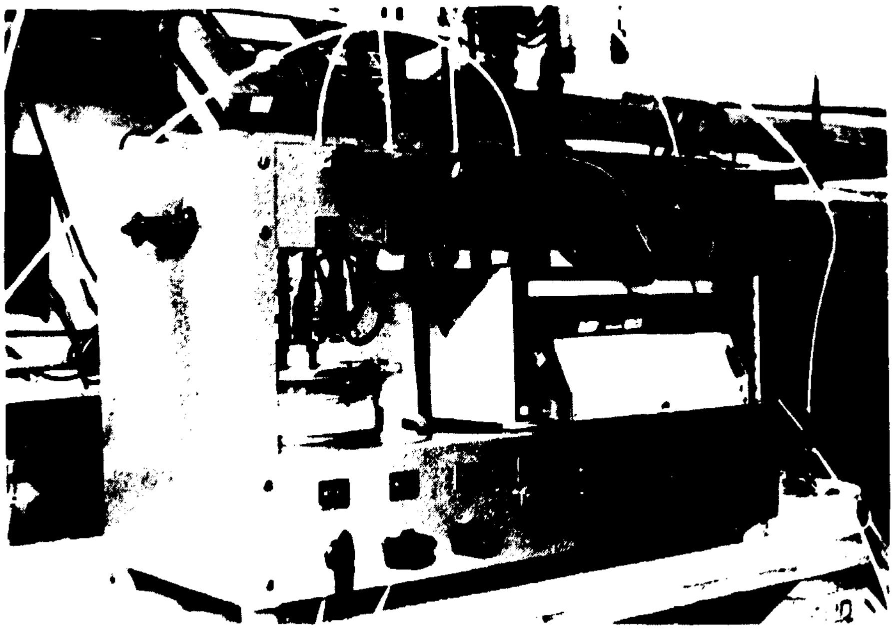
Note 4 Here again, difficulties were encountered in connection with lowering. The sampling zone, which is only sealed off by a single packer, goes from the bottom of the borehole at 585 m to 420 m. The sampling pump started the day before the measurements.

Note 5 The pump was started 2.5 hours before the readings began. The 1st sampling was done 24 hours later.

3 FIELD MEASUREMENTS

The field measurements are recorded in tables 1-3, the E^0 values obtained from the field calibrations in table 4 and the field values obtained during water sampling in table 5.

The photograph below shows the field equipment with test chamber, measuring equipment and valves for water sampling.



3.1 Calibrations

Each calibration has been assigned a calibration number. Measurements made after the calibration have the same number.

All calibration solutions are freshly prepared from concentrate and deaerated distilled water, except the one used for calibration of the conductivity cell

Three buffer solutions with pH 4, 7 and 10 are used for calibration of the pH electrode. Quinhydrone is added to the buffer solutions with pH 4 and 7 for simultaneous calibration of the Eh electrodes. Concentrate diluted to solutions that are 0.01 and 0.05 molar with respect to sulphide ion is used for calibration of the sulphide electrode. The E^o values obtained are presented in table 4.

The oxygen probe is calibrated against air-saturated distilled water and the conductivity cell against 0.01 and 0.1 mol/l KCl.

3.2 Measurement results

Each measuring occasion is identified with a calibration number, borehole designation, length of borehole (core length) as well as day and time. The vertical depths corresponding to the borehole lengths are shown in the table below.

Bore-hole	Length m	Depth m	Bore-hole	Length m	Depth m	Bore-hole	Length m	Depth m
FJ2	123	106	FJ4	151	131	FJ8	470	402
	342	293		317	272		666	562
	483	409		410	349			
	605	506		496	420			

Owing to the fact that it takes some time after each calibration before the water in the test chamber is representative of the borehole water and before the Eh and pS values have stabilized, no measurement results have been included until at least 24 hours after the calibration - in general, from and including the second day after calibration. Nor are values included that have been obtained from obviously unsuccessful measurements owing to problems encountered in the field.

Due to a fault in the measuring equipment at FJ4, pH values were only obtained from the measurements during the first days on the upper level.

Stable measurement results were not obtained from the extra Eh electrodes that were connected before the test chamber until voltmeters with higher internal resistance were procured. The values measured with the extra electrodes are marked "ex" in table 3.

3.3 Temperature measurement

The temperature is measured in the test chamber to permit calibration and calculation of the electrode potentials.

Owing to the relatively slow rate of water turnover in the test chamber, the temperature measured is not representative of the groundwater. It is therefore not reported.

3.4 Measurement of pH, Eh and pS

The system often seems to need to remain undisturbed for about a week before the Eh and pS values are more or less stable. The pH value stabilizes much faster.

The calibrations show that adjustments must be made fairly frequently, probably because a deposit builds up on electrodes and probes. The optimum time between two calibrations would therefore appear to be between 5 and 10 days. The electrodes were usually cleaned when they were lowered to a new level as well as before calibrations 203, 204, 207, 208, 304, 305, 306, 403 and 406.

Due to an amplifier malfunction, almost all pH values for FJ4 are lacking.

3.5 Oxygen measurement with probe

When the oxygen probe was recalibrated, it was found that the measuring error was 5-25% - in the negative direction, as a rule. In seven cases, errors greater than 40% were found, and the probe had to be cleaned and the membrane changed. Values before such a major adjustment are not reported.

It appears as if the oxygen probe has to be recalibrated more frequently than is possible according to 3.4 in order for reliable results to be obtained.

Despite the difficulties encountered in oxygen measurement, the field values often show good correlation with pS; high oxygen content - high pS (low sulphide content).

3.6 Measurement of conductivity

Calibration was only done at the beginning of each level. The conductivity measurements were consistently stable.

4 MAIN COMPONENTS OF THE WATER

Each sampling occasion has been assigned a unique sampling number, which is the same for all samples taken on the same occasion ("Nr." in the tables).

The main components were analyzed by SGAB's water laboratory in Uppsala and by Hydroconsult in Stockholm. Some control analyses were performed by IVL (the Swedish Institute for Water and Air Polution Research) in Stockholm and IMLAB in Linköping. The analysis results are reported in tables 5-8. The table below shows which laboratory carried out the analyses and which method was used. Where there are two analyses of the same parameter, the mean value is reported.

	SGAB	H-con.		SGAB	H-con.
pH	*	*	HCO_3	g	b
cond.	*	*	Cl	i	h
Turb.		*	F	i	k
Ca	a	b	SO_4	i	
Mg	a		PO_4		f
Na	a	c	NO_3		f
K	a	c	NO_2		f
Mn	a	d	NH_4		f
Fe(II)	e		SiO_2	m	m
Fe-tot	a		S	n	
Al	a		I	o	
Cu	a		TOC	p	q
Sr	a				

*	Conventional according to Swedish Standard (SS)
a	Optical emission with ICP (own design)
b	Titrimetric with EDTA according to SS
c	Emission with flame
d	Atomic absorption
e	Colorimetric with o-phenanthroline according to Standard Methods
f	Colorimetric according to SS
g	Specially designed titrator
h	Titration according to Mohr (SS), high concentrations only
i	Ion chromatograph, for chloride, low concentrations only
k	Potentiometrically according to SS
m	Colorimetrically with methylene blue according to Standard Methods
n	Potentiometrically
o	Colorimetrically, higher concentrations also potentiometrically
p	Carbon analyzer from Carlo-Erba
q	Carbon analyzer from Oceanographic

Drilling water was analyzed by SGAB. The analyses are presented at the bottom of tables 5, 6 and 8.

The field values obtained simultaneously with the water sampling and the laboratory analyses of the same parameters are presented in table 5. Note that the field values, which are measured during water sampling, are often not representative of the borehole. Sampling may, for example, have been done immediately after a calibration.

The date is given for both the sampling day and the day the samples were received at the laboratories. In both cases, the date is given with the number of the week followed by the number of the day of the week. (Day 1 is Monday.)

All determinations of metal ions are presented in table 6, while table 8 shows TOC, turbidity and the negative ions that do not contain nitrogen.

The parameters that contain nitrogen are compiled in table 7. The analysis results are given as the concentration of the ion and the concentration of nitrogen.

"Drilling water residue" (table 8) is the percentage fraction of the original iodide concentration in the drilling water (2.1) that has turned up in the groundwater. No correction is made for the water's natural iodide content (2.1).

4.1 Sampling

The water samples were taken through a valve in immediate connection with the test chamber. On each sampling occasion, a new tube, kept well protected from dust, was attached to the valve. The free and untouched end of the tube was inserted down to the bottom of the sample bottle. At least two bottle volumes of sample water were allowed to run over before the bottle was sealed, without any air having been trapped inside. The samples were kept in a refrigerator awaiting transport (4.2).

4.1.1 Unpreserved samples for analysis of negative ions etc. were taken in bottles of borosilicate glass (1 litre) with a ground, filled stopper held in place with a steel clip.

In order to keep the ground surface moist so that no air can leak through, the bottles were stored and transported upside-down.

4.1.2 Preserved samples for analysis of metal ions were taken in acid-washed polyethylene bottles (250 ml).

The samples were preserved with 2.5 ml of concentrated hydrochloric acid (super-pure). The acid was added through a dispenser below the sample surface immediately before the sample bottle was sealed. Hydrochloric acid was chosen as a preservative because iron(II) was to be determined.

4.2 Transport of samples

The samples were packed in specially-made insulated boxes with frozen blocks. The boxes were mailed "express" on the afternoon of the sampling day and delivered to the laboratory the following morning. No water sampling took place on Fridays and Saturdays, since the samples could then not be received by the laboratory until Monday or Tuesday. The Sunday samples were sent together with the Monday samples.

4.3 Sampling levels

Field analyses representative of the borehole are presented in tables 1-3, while the field analyses in table 5 are only representative of the sampling occasion.

Except for the redox-sensitive parameters, the analysis results are, as a rule, strikingly consistent within the levels in FJ2 and FJ8. In FJ2, 106m, as well as in all of FJ4, pronounced trends are found in the concentrations of anions and cations, least pronounced in FJ4, 272m where only iron, phosphate and nitrogen-containing ions change.

There is a possibility that water has leaked into the sampling zone due to a pressure loss in the packers immediately before the start of sampling at levels FJ2, 293m and 409m. No appreciable effect of the leakage is noticeable. The analyses within the levels are uniform and without any trend.

The highest salt concentrations are found in FJ2, 506m and in the first sampled water from FJ4, 420m.

4.4 pH

pH was determined directly in the field and by both laboratories (table 10). The field values are systematically around 5% higher than the laboratory values. A similar difference has been noted in many groundwaters. There is also a small systematic difference between the laboratories, which may be attributable to the fact that Hydroconsult, which notes the lower value, thermostated its samples at 25°C before measurement.

The differences within the levels are small, as a rule. The highest pH values were measured at the deep levels.

4.5 Conductivity

Conductivity was also measured both in the field and at two laboratories. As a rule, the field value is slightly higher than the laboratory values, but the differences are relatively small. An exception from this rule is FJ4, 420m, where the field value is only about half the laboratory values, which agree closely with each other. The conductivity meter in the field was probably set wrong.

4.6 Organic carbon (TOC)

No parameter exhibits such large differences between the laboratories as TOC - SGAB's results are often more than twice Hydroconsult's results. Control analysis at two Swedish laboratories comes closer to verifying SGAB's high results, while analysis at a laboratory in the United States, which specializes in the determination of humic and fulvic acids, confirmed Hydroconsult's low values. The mean value is reported to only one decimal place (table 8).

The normal concentration lies between 4 and 8 mg/l in FJ2 and FJ4, while it is only about 3 mg/l in FJ8. The levels FJ4, 349m and 420m have very high concentrations at the start of the pumping period, after which the concentrations gradually decline to normal values. Other ions exhibit similar trends at these two levels.

4.7 Negative ions

The negative ions are compiled in tables 7 and 8. The results generally show good consistency within the sampling zones. Where trends occur (4.3), the change is verified by other ions.

Very high nitrogen concentrations, mainly as nitrate, are found in the two middle samples in FJ4, 131m. They have no counterpart in any equally pronounced change in any of the cations analyzed. Agreement between the laboratories' N analyses is good for these two samples. pH and conductivity are determined in the same sample bottle. Normal values are reported by both laboratories.

4.8 Positive ions

The positive ions are compiled in table 6. The concentrations generally differ very little between water samples from the same level. Where trends do exist (4.3), they are verified by changes in several ion concentrations.

4.8.1 Lanthanum, neodymium and ytterbium were determined in the same samples as strontium. In all cases, the concentrations were below the detection limit (< 0.005 mg/l).

5 PARTICULATE MATTER

The particulate matter was subjected to several different types of analyses (5.1-5.5).

5.1 Chemical composition

The water was filtered through a membrane filter (Millipore, pore diameter 0.45 µm) installed directly after the test chamber. The filtered volume was between 300 and 2300 ml. The total concentration on the membrane was determined by X-ray fluorescence at SGU's (the Geological Survey of Sweden) laboratory in Luleå. The concentrations are presented in table 9 as mg/l of filtered sample. The sample volume is also given in the table. The quantity of copper, strontium, lanthanum, neodymium and ytterbium was, with the exception of samples Nos. 260 and 282 (where 1 and 2 µg Sr, respectively, was obtained), below the detection limit (1, 1, 3, 2 and 2 µg respectively).

There is a clear correlation between high volume and low concentration, which is natural since the amount of filtrate that can pass a filter is normally dependent on the amount of particles that stay on the filter. The iron and sulphur concentrations also covary, which is not unexpected either.

5.2 Turbidity

Turbidity (table 8) was determined for all samples except those from FJ2, 106m and FJ4, 420m.

5.3 Particle distribution

The particle distribution within the range 2-80 µm was determined at all levels. The determination was performed by VIAK's water pollution research laboratory in Stockholm.

NOTE! It is the length of the borehole and not its vertical depth that is indicated on the curves.

5.4 Humic and fulvic acids

The two deepest levels in the boreholes were analyzed. The determination was performed at Batelle, USA, through combined dialysis and gel film chromotography (GFC). The method, which fractionates the sample into humic acids and four molecular weight fractions of fulvic acid, is described by Means et al 1977 (Limnol. Oceanogr., 22, 957-965). Sodium tetraborate (pH 9.1) was used on recommendation by Swift and Posner 1971 (J. Soil Science, 22, 237-249).

Owing to the samples' low content of organic matter, they were first concentrated ten times before analysis. No loss of volatile organic matter was found in connection with the concentration process.

Level	No.	>1000	700-100	300-700	<300
FJ2, 409m	260	28	63	8	1
FJ2, 506m	266	18	63	15	4
FJ4, 349m	229	48	47	5	0
FJ4, 420m	234	53	37	9	1
FJ8, 402m	285	12	67	18	3
FJ8, 562m	292	23	46	17	14

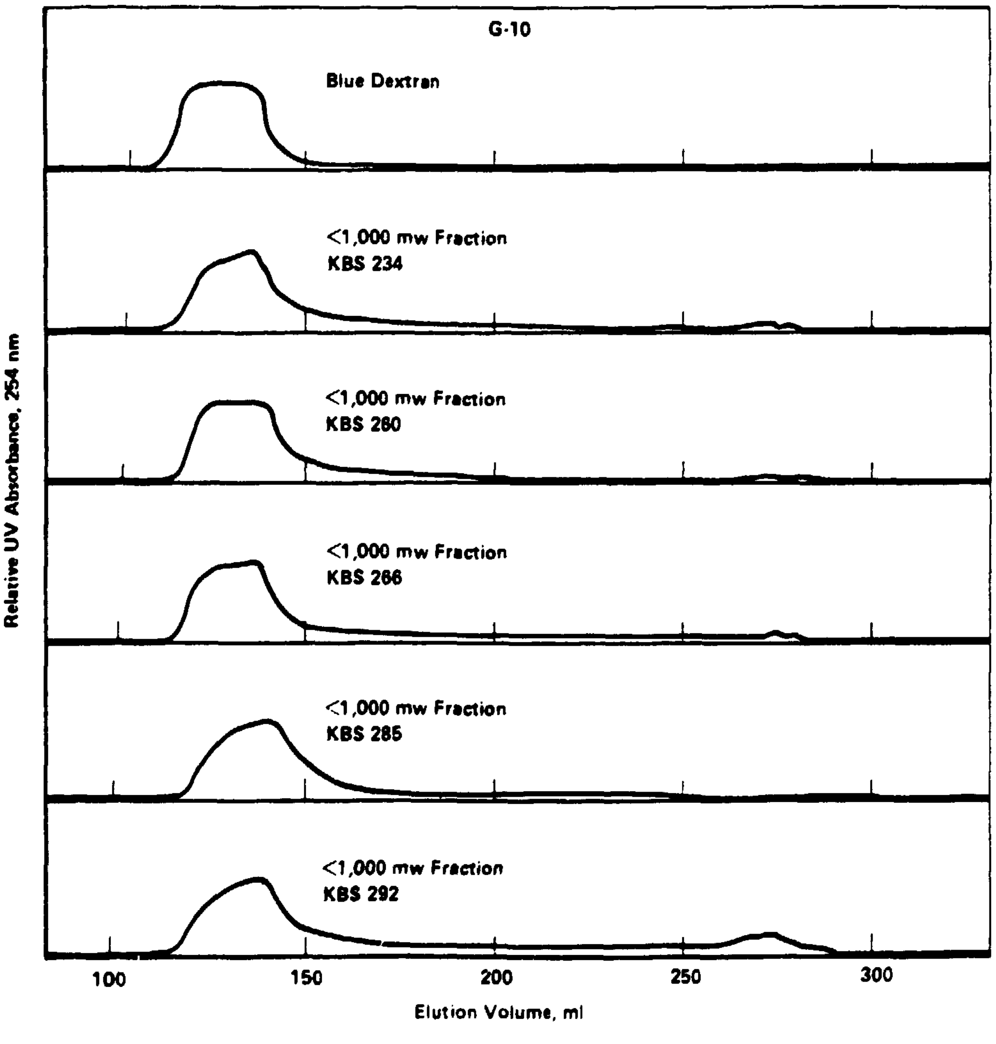
No humic acids were present in the samples. The samples' contents of different molecular weight fractions of fulvic-acid-like substances are shown in the table below. The eluates' UV absorbance, recorded continuously at 254 nm, is shown on the next page.

According to Means, the results strongly indicate that the most important organic constituents are hydrophilic polymer substances with low to medium molecular weights - probably fulvic acids or similar substances, which are the predominant substances in natural water.

6 ISOTOPE ANALYSIS

Isotope analysis of light substances in the water is done mainly to permit calculations of the age and origin of the water. The heavy radioactive substances are determined primarily because the natural background concentrations are of great interest for the KBS project.

The analyses were carried out at the following laboratories:
Laboratory for Isotope Geology, Stockholm (6.1, 6.3)
Institute for Radiohydrometry, Neuherberg, West Germany (6.2, 6.4)
Mass Spectrometry Laboratory, Uppsala University (6.4)
Studsvik Energiteknik, Nyköping, Sweden (6.5)



6.1 Carbon isotopes

Prior to the determination that is used for dating by means of the carbon-14 method, the water's contents of carbon dioxide and carbonate have to be concentrated. It is thereby of the utmost importance that the concentrate not be contaminated by chemicals or contact with air.

6.1.1 Sample preparation is done in the field. A polyethylene barrel holding 130 l and filled from the beginning with nitrogen is filled with water. Hydrochloric acid is added to disintegrate carbonates present in the water. A nitrogen gas stream is then used to drive the carbon dioxide over to a wash bottle containing sodium hydroxide.

6.1.2 Groundwater age is presented in the table below as "Age BP" and age after correction for C-13 content as "Age BP, corr".

Bore-hole	Depth m	Nr	Age BP	Age BP corr	C13 o/oo
FJ2	106	252	4635	4725	-19.5
FJ2	293	256	11010	10960	-28.0
FJ2	409	260	4145	4235	-19.3
FJ2	506	267	13665	13920	- 9.5
FJ4	131	215	3795	3950	-15.3
FJ4	272	222	3345	3475	-17.0
FJ4	349	229	5375	5535	-15.0
FJ4	420	234	6660	6850	-13.3
FJ8	402	285	3880	3980	-18.7
FJ8	562	292	3890	3975	-19.9

6.2 Deuterium and oxygen

The analyses can furnish information on the climatic conditions prevailing at the time of infiltration.

Bore-hole	Depth m	Nr	H-2 (D)	O-18 (D)	O-18 (S)
FJ2	106	252	-80.5	-11.33	-11.24
FJ2	293	256			-11.31
FJ2	409	260			-11.35
FJ2	506	267			-14.11
FJ4	131	216			-11.50
FJ4	272	222	-82.6	-11.54	-11.57
FJ4	349	229	-81.6	-11.45	-11.73
FJ4	420	234	-84.7	-11.69	-11.88
FJ8	402	285	-79.3	-11.22	-11.21
FJ8	562	292	-77.8	-10.94	-11.16

The concentrations in the table refer to deviations in per mill from SMOW (Standard Mean Oceanic Water). The analyses were performed in West Germany (D) and in Sweden (S).

6.3 Tritium

Owing to its short half-life (about 12 years), tritium is an important isotope in hydrologic studies. The amount of tritium in the atmosphere has increased drastically due to nuclear weapons testing. The tritium content of rain water has increased by more than ten times, which makes it possible to determine whether "young" water is present in a groundwater sample.

The tritium concentration is given in the tables in the unit TU, which is the number of tritium atoms per 10^{18} hydrogen atoms.

No tritium determination has been carried out on the drilling water used here.

Nr	Bore-hole	Depth m	Tr TU
256	FJ2	293	19
260	FJ2	409	19
267	FJ2	506	<3
215	FJ4	131	9
222	FJ4	272	21
229	FJ4	349	12
234	FJ4	420	6
285	FJ8	402	8
292	FJ8	562	10

6.4 Uranium, thorium, radium and radon

The natural concentration of these elements in the groundwater is of great interest for the project. The analyses are presented in table 10. The concentrations for U, Ra and Rn are given in Bq/l. The following relationships apply:

39.4 μg U per Bq
2.74×10^{-5} μg Ra-226 per Bq
1.76×10^{-10} μg Rn-222 per Bq

7 GAS ANALYSIS

Helium was determined in the gas that spontaneously leaves the water on its passage through a Horst bottle. The analysis was carried out by AGA SpecialGas, Lidingö, Sweden. No gas sample was taken from FJ4, 349m.

In the table below, besides the percentage content of helium in the gas phase, the amount of water that has passed through the Horst bottle and the obtained gas volume are also given. This enables the reader to form his own rough idea of the quantity of dissolved gases in the water. The helium content of the water has not been calculated, since degassing is dependent on a number of uncontrolled parameters. We know, for example, that temperature variations of >20°C occur in the tent where the borehole opens out and the sampling equipment is located.

BH	Depth m	No.	Helium %	Water volume l	Gas volume m^3	Notes
FJ2	106	252	0.099	218	90	
	293	256	0.002	217	120	
	409	260	0.008	103	145	
	506	267	1.1	19	190	
FJ4	131	215		122	185	2
	272	222	0.004	240		1
	420	234	0.005	195		1
FJ8	402	285	0.003	185	90	
	562	292	0.004	84		1

Note 1 Data on gas volume lacking.

Note 2 Gas analysis lacking.

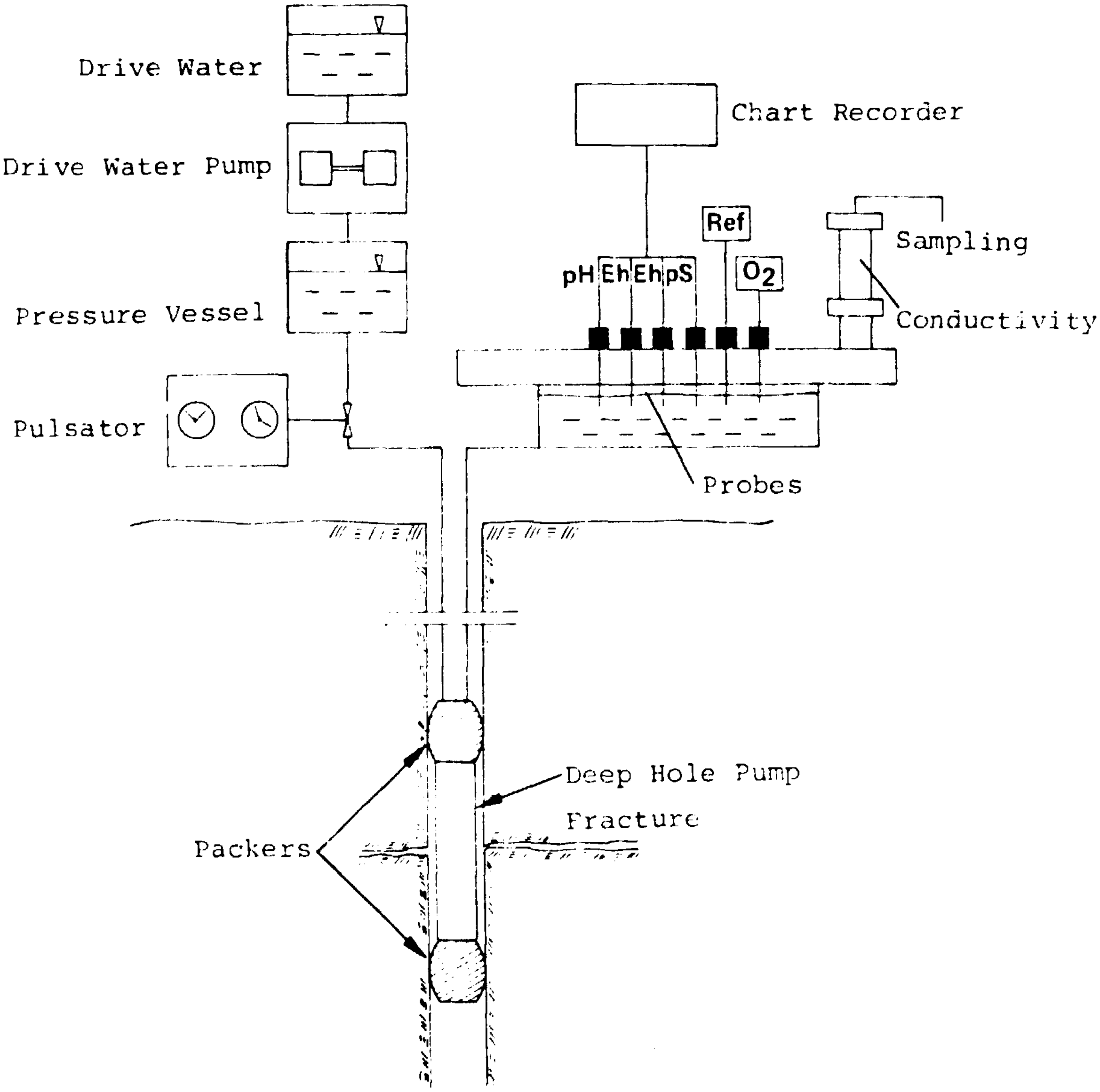


Figure 1. Schematic illustration of sampling equipment

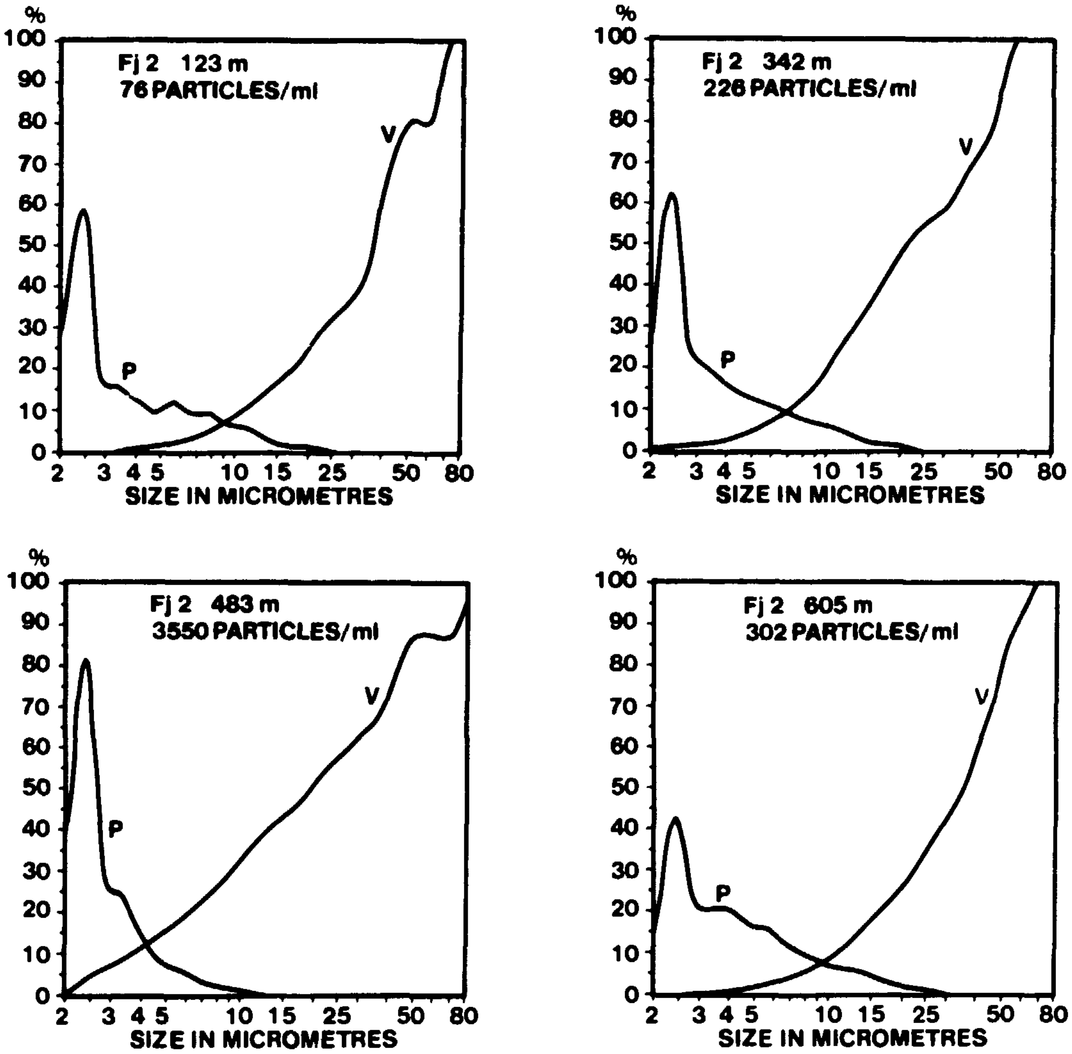


Figure 2a. Particle size distribution analysis in the region 2-80 μm. An HIAC PA 500 instrument is used. P represents the percent of the total number of particles with a certain particle size. V represents the percent of the total numer particle volume less than a certain particle size.

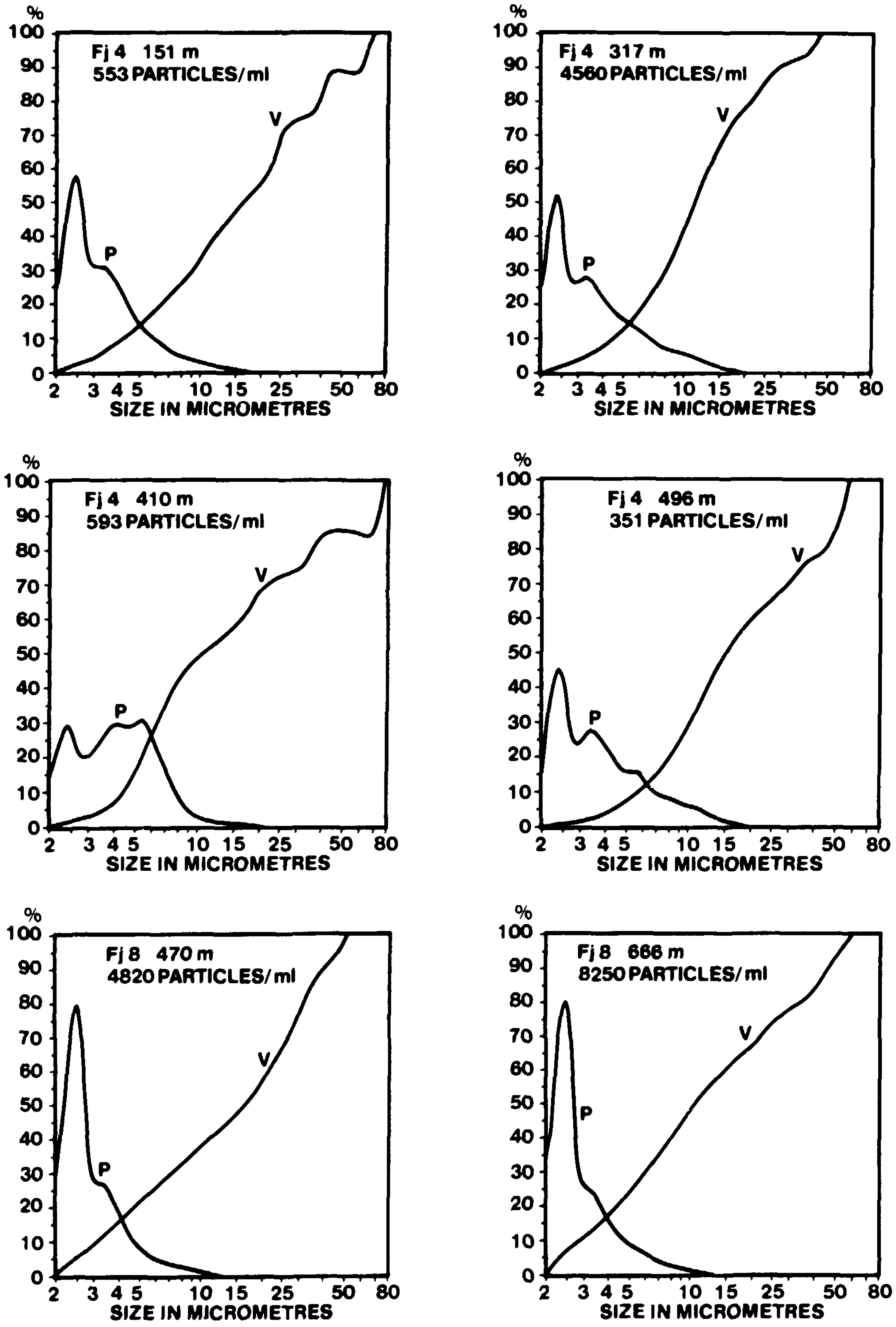


Figure 2b. Particle size distribution analysis in the region 2-80 µm. An HIAC PA 500 instrument is used. P represents the percent of the total number of particles with a certain particle size. V represents the percent of the total particle volume less than a certain particle size.

Table 1

FJÄLLVEDEN - Field measurements

Cali- bration nr	Bore- hole	Hole- length m	Date ww-d	Time	Conduc- tivity mS/m	Oxy- gen mg/l	pH	Eh,C mV	Eh,Pt mV	pS
301	FJ2	123								
			34-6	830	26.9	.00	8.0	- 59	4	13.0
			34-6	1030	26.9	.00	8.0	- 62	1	12.6
			34-6	1230	26.9	.00	8.0	- 65	- 2	12.3
			34-6	1330	26.9	.00	8.0	- 66	- 3	12.2
			34-6	1530	26.9	.00	8.0	- 69	- 5	12.0
			34-7	745	27.0	.00	8.2	- 88	- 16	11.2
			34-7	930	27.0	.00	8.1	- 88	- 18	11.1
			34-7	1130	27.0	.00	8.1	- 89	- 20	11.0
			34-7	1230	27.0	.00	8.2	- 88	- 20	11.1
			34-7	1330	27.0	.00	8.1	- 83	- 11	11.9
304	FJ2	342								
			36-4	1600	27.5	.04	7.1	- 4	81	20.0
			36-5	730	27.1	.02	7.2	- 17	80	18.5
			36-5	900	27.3	.00	7.2	- 20	76	18.2
305	FJ2	342								
			36-7	700	27.0		7.2	- 22	71	16.9
			36-7	900	27.3		7.1	- 27	63	16.3
			36-7	1140	27.4		7.1	- 31	58	15.5
			36-7	1330	27.4		7.1	- 36	51	15.1
			36-7	1450	27.4		7.1	- 38	50	14.8
306	FJ2	342								
			37-2	650	27.5	.05	7.3	- 42	87	21.3
			37-2	730	27.3	.10	7.3	- 43	87	21.3
308	FJ2	483								
			38-6	700	29.2	.02	7.5	- 92	14	17.7
			38-6	900	29.2	.02	7.5	- 95	11	17.5
			38-6	1130	29.4	.02	7.5	-103	14	17.4
			38-6	1240	29.5	.02	7.5	-106	18	17.4
			38-6	1500	29.5	.02	7.5	-116	13	17.2
			38-7	645	30.0	.02	7.5	-115	- 13	15.7
			38-7	845	30.0	.02	7.5	-119	- 15	15.6
			38-7	1100	30.0	.02	7.5	-118	- 18	15.4
			38-7	1200	30.0	.02	7.5	-119	- 19	15.3
309	FJ2	483								
			39-2	545	30.9	.00	7.5	- 87	19	17.4
			39-2	645	30.9	.00	7.5	- 88	18	17.3
			39-2	750	30.9	.00	7.5	- 89	17	17.2
311	FJ2	605								
			40-3	715	71.1	.00	8.8	-184	-119	13.0
			40-3	920	71.7	.03	8.8	-188	-121	12.7
			40-3	1145	71.5	.03	8.8	-101	-123	12.5
			40-3	1305	71.8	.03	8.8	-109	-123	12.3
			40-3	1510	72.0	.02	8.8	-105	-123	12.1
			40-4	800	72.9	.02	8.9	-105	-122	11.1
			40-4	1015	73.5	.00	8.8	-103	-117	11.0
			40-4	1215	73.4	.03	8.8	-107	-124	10.9
			40-4	1430	73.7	.01	8.8	-111	-125	10.8
			40-4	1545	73.9	.01	8.8	-109	-126	10.7
			40-5	735	74.9	.02	8.8	-109	-129	10.4
			40-5	905	74.9	.01	8.8	-110	-128	10.4
312	FJ2	605								
			40-7	710	76.5	.10	8.9	- 29	- 21	19.8
			40-7	900	76.4	.10	8.9	- 29	- 20	20.0
			40-7	1025	77.0	.10	8.9	- 33	- 25	19.6
			40-7	1140	77.2	.10	8.9	- 35	- 27	19.5
			40-7	1250	77.2	.20	8.9	- 17	- 11	20.0
313	FJ2	605								
			41-2	755	78.9	.10	8.9	- 13	- 12	19.9
			41-2	1000	79.0	.10	8.9	- 20	- 20	19.6
			41-2	1100	78.9	.10	8.9	- 21	- 23	19.5

Table 2

FJÄLLVEDEN - Field measurements

Calibration nr	Borehole	Hole-length m	Date ww-d	Time	Conductivity mS/m	Oxygen mg/l	pH	Eh, C mV	Eh, Pt mV	pS
202	FJ4	151								
			26-3	730	34.0		7.9	- 6	32	19.9
			26-3	945	34.0		7.8	2	41	20.1
			26-3	1140	34.3		7.8	2	41	20.0
			26-3	1230	34.5		7.8	1	42	19.9
			26-3	1335	34.6		7.7	2	44	19.9
			26-3	1435	34.5		7.8	11	48	20.1
			26-4	730	34.5		7.7	40	113	21.8
			26-4	836	34.5		7.7	21	118	21.8
			26-4	1035	34.9		7.7	35	120	21.7
			26-4	1225	35.0		7.8	34	116	21.6
			26-4	1300	35.1			34	113	21.7
			26-4	1410	35.1			36	107	21.8
			26-4	1510	35.1			35	108	21.8
203	FJ4	151								
			26-6	1200	33.4	.00		24	54	19.2
			26-6	1420	33.4	.00		21	50	19.1
			26-6	1600	33.0	.00		15	43	19.0
			26-7	735	32.9	.00		29	61	19.0
			26-7	830	33.0	.00		28	63	19.0
204	FJ4	151								
			27-1	1300	35.0	.04		- 83	- 62	13.2
			27-1	1430	35.1	.05		- 87	- 64	12.6
			27-1	1600	35.[illegible]	.04		- 85	- 61	12.4
			27-1	1700	35.3	.04		- 83	- 59	12.4
			27-1	1800	35.4	.04		- 88	- 62	12.1
			27-2	1200	35.3	.04		- 82	- 57	12.4
206	FJ4	317								
			28-3	645	33.4	.00		- 76	- 17	13.1
			28-3	800	33.4	.00		- 79	- 18	13.0
			28-3	900	33.4	.00		- 81	- 19	13.0
			28-3	1200	33.4	.01		- 84	- 23	12.8
			28-3	1320	33.5	.01		- 85	- 25	12.7
			28-3	1430	33.5	.02		- 86	- 26	12.7
			28-3	1530	33.5	.02		- 88	- 26	12.7
			28-4	650	33.4	.00		-125	-115	12.6
207	FJ4	317								
			28-6	1225	33.1	.04		- 24	- 16	19.4
			28-6	1400	33.2	.04		- 25	- 14	18.8
			28-6	1500	33.3	.04		- 21	- 11	18.9
			28-6	1635	33.3			- 20	- 12	18.9
			28-7	750	33.6			- 28	- 19	18.0
			28-7	920	33.7			- 26	- 17	17.8
208	FJ4	317								
			29-2	645	34.0	.00		- 75	3	14.6
			29-2	815	34.0	.01		- 83	1	14.5
			29-2	845	34.0	.02		- 85	1	14.5
			29-2	1000	33.9	.03		- 90		14.4
209	FJ4	410								
			30-1	835	38.1	.00		-178	- 17	11.6
			30-1	910	38.1	.00		-178	- 17	11.6
211	FJ4	410								
			30-6	635	31.2	.00		-115	- 64	11.4
			30-6	800	31.2	.03		-118	- 67	11.3
			30-6	1000	31.1	.03		-122	- 70	11.3
			30-6	1210	31.2	.05		-130	- 76	11.2
			30-6	1400	31.1	.05		-130	- 77	11.2
			30-7	800	31.5	.00		-156	- 85	11.3
			30-7	900	31.5	.00		-161	- 85	11.3
			30-7	930	31.5	.00		- 75	- 87	11.3
212	FJ4	410								
			31-1	1405	32.0	.00		-100	- 89	13.1
			31-1	1530	32.0	.00		- 99	- 89	13.0
			31-2	745	31.8	.00		-109	- 84	12.5
			31-2	745	31.8	.00		-109	- 84	12.5
			31-2	840	31.9	.00		-109	- 84	12.5
			31-2	930	31.9	.01		-109	- 85	12.5
			31-2	1030	31.9	.03		-110	- 86	12.4
			31-2	1130	32.0	.04		-109	- 87	12.3

Table 3

FJÄLLVEDEN - Field measurements

Calibration nr	Borehole	Hole-length m	Date ww-d	Time	Conductivity mS/m	Oxygen mg/l	pH	Eh,C mV	Eh,C ex mV	Eh,Pt mV	Eh,Pt ex mV	pS
214	FJ4	496										
			34-6	755	20.0			-171	- 28	-140	- 43	11.5
			34-6	930	20.0			-173	- 39	-144	- 39	11.4
			34-6	1145	19.9			-173	- 36	-149	- 47	11.4
			34-6	1400	19.6			-174	-219	-156	-227	11.2
			34-6	1500	19.5			-174	-220	-157	-228	11.2
			34-6	1600	19.5			-174	-221	-158	-228	11.2
			34-7	740	18.1			-194	-231	-163	-235	10.9
			34-7	900	18.2			-195	-233	-165	-237	10.9
215	FJ4	496										
			35-1	1130	17.5	.03		-160	-122	-154	-142	12.6
			35-1	1340	17.5	.05		-164	-126	-158	-148	12.4
			35-1	1600	17.5	.05		-165	-128	-159	-155	12.2
			35-1	1740	17.4	.02		-166	-129	-159	-160	12.2
			35-2	800	17.5	.00		-167	-134	-159	- 70	11.9
			35-2	955	17.5	.00		-171	-140	-162	-102	11.7
			35-2	1100	17.5	.02		-171	-141	-163	-110	11.7
			35-2	1245	17.5	.02		-173	-141	-164	-117	11.6
			35-2	1330	17.5	.02		-173	-145	-165	-123	11.6
402	FJ8	470										
			38-7	730	23.8	.01	8.4	-109	- 65	-102	- 82	16.4
			38-7	850	23.5	.01	8.4	-109	- 67	-103	- 85	16.3
			38-7	930	23.8	.03	8.4	-109	- 66	-103	- 85	16.3
			38-7	1205	23.8	.02	8.4	-110	- 75	-103	- 94	16.3
403	FJ8	470										
			39-1	1510	23.9	.01	8.6	-118	- 86	-113	-114	13.9
			39-1	1630	23.9	.01	8.5	-119	- 87	-113	-116	13.9
			39-2	745	23.9	.00	8.6	-119	- 96	-113	-133	13.6
			39-2	930	23.9	.00	8.5	-121	- 99	-115	-137	13.5
			39-2	1030	23.9	.01	8.5	-121	-101	-116	-139	13.5
			39-2	1215	23.9	.01	8.5	-123	-105	-117	-143	13.4
			39-2	1440	23.9	.01	8.5	-124	-108	-119	-147	13.3
405	FJ8	666										
			40-2	1230	24.0	.01	8.9	-153	-156	-140	-174	12.7
			40-2	1530	24.0	.01	8.9	-154	-159	-142	-180	12.6
			40-3	750	24.0	.01	9.0	-155	-176	-141	-203	12.4
			40-3	930	24.0	.01	9.0	-157	-178	-142	-205	12.4
			40-3	1100	24.0	.02	8.9	-158	-181	-144	-208	12.3
			40-3	1315	24.0	.01	8.9	-159	-184	-145	-211	12.3
			40-3	1530	24.0	.00	9.0	-160	-187	-144	-214	12.3
			40-4	750	24.0	.00	9.0	-169	-201	-140	-225	12.2
			40-4	1000	24.0	.00	9.0	-171	-204	-141	-228	12.2
			40-4	1200	24.0	.01	9.0	-173	-205	-143	-229	12.1
			40-4	1410	24.0	.01	9.0	-175	-206	-143	-230	12.1
			40-4	1550	24.0	.00	9.0	-177	-207	-143	-230	12.1
			40-5	750	24.0	.00	9.1	-198	-211	-141	-235	12.1
			40-5	900	24.0	.00	9.1	-199	-212	-141	-235	12.1
			40-2	1405	24.0	.01	8.9	-154	-158	-142	-177	12.6
406	FJ8	666										
			40-6	1140	24.0	.00	9.0	-136	-145	-128	-161	13.0
			40-6	1400	24.0	.00	9.0	-138	-150	-129	-167	12.9
			40-6	1525	24.0	.00	9.0	-138	-151	-129	-170	12.9
			40-7	740	24.0	.00	9.0	-142	-165	-131	-192	12.5
			40-7	845	24.0	.00	9.0	-142	-165	-131	-190	12.4
407	FJ8	666										
			41-1	1300	24.0	.03	8.9	-141	-168	-132	-188	12.4
			41-1	1500	24.0	.02	8.9	-141	-169	-132	-189	12.3
			41-1	1600	24.0	.02	8.9	-141	-162	-132	-184	12.3
			41-2	750	24.0	.02	8.9	-143	-184	-132	-207	12.1
			41-2	935	24.0	.02	8.9	-143	-186	-132	-209	12.1
			41-2	1120	24.0	.03	8.9	-144	-188	-133	-211	12.1
			41-2	1430	24.0	.02	8.9	-143	-190	-134	-213	12.0
			41-3	800	24.1	.01	8.9	-141	-199	-129	-223	12.0
			41-3	915	24.1	.04	8.8	-141	-201	-130	-224	12.0

Table 4

FJÄLLVEDEN - E^{0}-values

Bore-hole	Hole-length m	Cali-bration nr	Date ww-d	Glass pH4 mV	Glass pH7 mV	Glass pH10 mV	C pH4 mV	C pH7 mV	Pt pH4 mV	Pt pH7 mV	Ag.S 0.01M mV	Ag.S 0.05M mV
FJ2	123											
		301	34-4	391	396	400	283	259	278	256	-841	-835
		302	34-7	385	388	395	259	257	256	257	-845	-835
FJ2	342											
		304	36-2	384	384	382	258	263	253	256	-822	-824
		305	36-5	380	378	383	262	265	259	261	-819	-814
		306	36-7	390	392	399	252	253	251	250	-829	-822
FJ2	483											
		307	37-2	382	384	391	263	255	253	248	-820	-810
		308	38-4	379	383	387	258	257	255	255	-809	-805
		309	38-7	378	376	407	265	259	256	259	-823	-813
		310	39-2	484	482	390	264	259	258	256	-817	-809
FJ2	605											
		311	40-1	385	384	376	251	257	249	254	-820	-823
		312	40-5	381	382	383	254	251	254	254	-824	-827
		313	40-7	381	381	380	263	260	254	255	-827	-832
		314	41-2	377	377	376	278	267	257	259	-844	-836
FJ4	151											
		201	25-2	392	395	389	250	249	246	247	-859	-852
		202	26-1	389	383	383	251	253	244	248	-836	-827
		203	26-5	383	381	397	252	254	251	253	-821	-824
		204	26-7	453	470	483	259	257	255	256	-809	-816
FJ4	317											
		205	27-3	375	389	364	254	253	254	252	-827	-824
		206	28-1	438	463	481	256	248	255	252	-838	-826
		207	28-4	542	563	535	259	258	256	256	-835	-833
		208	28-7	605	630	645	246	246	242	243	-807	-816
FJ4	410											
		209	29-3	563	592	610	250	251	250	251	-835	-822
		210	30-1	806	761	810	244	244	243	244	-839	-830
		211	30-4	342	528	575	251	237	249	243	-845	-825
		212	30-7	233	409	558	251	240	250	240	-868	-854
FJ4	496											
		213	31-4	629	665	682	245	245	244	243	-878	-857
		214	34-4	434	437	448	225	252	229	252	-825	-807
		215	34-7	554	578	604	256	252	258	252	-841	-824
		216	35-2	562	592	619	260	249	267	250	-150	- 47
FJ8	470											
		401	38-2	394	413	400	253	282	253	282	-895	-873
		402	38-5	384	386	388	264	246	269	244	-838	-846
		403	38-7	388	390	392	251	250	247	249	-840	-846
FJ8	666											
		404	39-3	390	396	401	253	252	250	250	-836	-840
		405	40-1	393	402	405	255	250	252	247	-853	-841
		406	40-5	60	404	731	259	256	258	256	-836	-829
		407	40-7	391	402	408	258	254	256	254	-838	-829
		408	41-3	382	409	394	257	255	253	254	-831	-831

Table 5a

FJALLVEDEN - Field measurements and corresponding laboratory values

Bore-hole	Depth m	Hole-length m	Nr	Date sampling yy-ww-d	Date lab ww-d	pH field	pH lab	Eh, C field mV	EH, Pt field mV	pS field	S2- lab mg/l	Cond field mS/m	Cond lab mS/m	Oxygen field mg/l
FJ2	106	123												
			239	82-34-4	34-5	7.7	6.9	70	65	22.3	.05	26	23	30
			240	82-34-6	35-2	8.0	7.7	- 66	- 3	12.2	.08	27	27	< 02
			251	82-34-7	35-2	8.1	7.7	- 08	- 20	11.1	06	27	27	< 02
			252	82-35-1	35-2	8.0	7.7	2	15	17.2	.06	27	27	.05
FJ2	293	342												
			253	82-36-2	36-3		7.1				03		25	< 02
			254	82-36-3	36-4	7.1	6.9	29	94	22.8	03	27	25	30
			255	82-36-4	36-5	7.1	6.9	2	81	20.6	.04	28	25	
			256	82-37-1	37-2	7.3	7.0	- 20	92	22.5	.08	27	26	20
FJ2	409	483												
			257	82-38-4	38-5	7.2	7.2	85	80	23.1	.01	27	25	70
			258	82-38-6	39-2	7.5	7.3	-140	-207	17.4	.03	30	28	02
			259	82-38-7	39-2	7.5	7.4	-118	- 18	15.4	.03	30	28	02
			260	82-39-1	39-2	7.4	7.4	- 60	43	20.1	.02	30	27	05
			261	82-39-2	39-4	7.5	7.4	- 88	18	17.3	.03	31	28	< 02
FJ2	506	605												
			262	82-40-1	40-2	8.6	8.6	- 55	9	22.3	.02	66	63	.40
			263	82-40-2	40-3	8.7	8.6	-125	- 25	20.9	.04	69	65	.20
			264	82-40-3	40-4	8.8	8.6	-105	-123	12.4	.11	72	68	03
			265	82-40-4	40-5	8.8	8.7	-107	-124	10.9	.11	73	71	03
			266	82-40-7	41-2	8.9	8.8	- 34	- 26	19.5	.01	77	73	10
			267	82-41-1	41-2	8.9	8.8	25	35	21.3	.01	78	74	30
			268	82-41-2	41-4	8.9	8.7	- 20	- 20	19.6	< 01	79	72	.10
			905				8.1						30	
			907				8.2						29	

Table 5b

FJALLVEDEN - Field measurements and corresponding laboratory values

Bore-hole	Depth m	Hole-length m	Nr	Date sampling yy-ww-d	Date lab ww-d	pH field	pH lab	Eh, C field mV	EH, Pt field mV	pS field	S2- lab mg/l	Cond. field mS/m	Cond. lab mS/m	Oxygen field mg/l
FJ4	131	151												
			211	82-26-2	26-3	7.9	7.7	2	22	20.8	.04	34	33	
			212	82-26-3	26-4	7.8	7.7	1	42	19.9	.04	35	34	
			213	82-26-4	26-5	7.7	7.5	36	107	21.8	.02	35	34	
			214	82-26-7	27-2		7.5				.05	33	32	.05
			215	82-27-1	27-2		8.2	- 83	- 62	13.2	.05	35	35	04
			216	82-27-2	27-3		7.8	- 34	- 8	14.7	.05	34	34	03
FJ4	272	317												
			217	82-28-1	28-2		7.6				.03	33	30	10
			218	82-28-2	29-3		7.6	- 47	- 23	13.6	.02	33	32	03
			219	82-28-3	28-4		7.5	- 86	- 26	12.7	.04	34	32	02
			220	82-28-4	28-5		7.5				02	33	32	
			221	82-28-7	29-2		7.5				< 01	34	33	
			222	82-27-1	29-2		7.5			15.2	.01	34	33	04
			223	82-29-2	29-3		7.4	- 70		14.4	.03	34	33	.02
FJ4	349	410												
			224	82-30-1	30-2		7.6			21.5	.05	37	37	50
			225	82-30-2	30-3		7.6	41	47	18.9	.13	37	36	20
			226	82-30-3	30-4		8.1	- 29	- 18	12.8	.14	36	36	10
			227	82-30-4	30-5		8.2	- 73	- 54	11.3	.20	35	35	06
			228	82-30-7	31-2		8.3	- 85	-101	17.9	.05	32	32	03
			229	82-31-1	31-2		8.3	- 79	- 95	13.3	.04	32	32	< 02
			230	82-31-2	31-3		8.0	-110	- 86	12.4	.04	32	32	03
FJ4	420	496												
			231	82-34-4	34-5		6.8			14.0	.05	32	62	08
			232	82-34-6	35-2		7.7	-174	-156	11.2	.13	20	37	02
			233	82-34-7	35-2		8.3	-125	-120	14.4	.13	18	34	07
			234	82-35-1	35-2		8.4	-160	-154	12.6	13	18	33	03
			235	82-35-2	35-3		8.5	-172	-164	11.6	01	18	33	02
			904				8.1						29	
			906				8.1						30	

Table 5c

FJALLVEDEN - Field measurements and corresponding laboratory values

Bore-hole	Depth m	Hole-length m	Nr	Date sampling yy-ww-d	Date lab ww-d	pH field	pH lab	Eh,C field mV	EH,Pt field mV	pS field	S^{2-} lab mg/l	Cond. field mS/m	Cond. lab mS/m	Oxygen field mg/l
FJ8	402	470												
			281	82-38-3	38-4	8.0	7.6	- 53	- 45	18.2	.05	23	22	06
			282	82-38-4	38-5	8.0	7.7	- 5	- 10	21.0	.03	23	22	20
			283	82-38-5	39-2	8.3	7.9	- 77	- 91	16.8	.01	23	22	04
			284	82-38-7	39-3	8.4	7.7	-109	-103	16.3		24	22	03
			285	82-39-1	39-3	8.6	8.0	-117	-111	14.0	.01	24	22	.02
			286	82-39-2	39-4	8.5	7.7	-121	-116	13.5	.02	24	22	< 02
FJ8	562	666												
			287	82-40-1	40-2	8.6	7.7	-134	-127	13.7	.02	24	22	02
			288	82-40-2	40-3	8.9	7.7	-153	-140	12.7	.09	24	22	< 02
			289	82-40-3	40-4	8.7	7.7	-159	-145	12.3	.08	24	22	< 02
			290	82-40-4	40-5	9.0	7.7	-174	-143	12.1	.08	24	22	< 02
			291	82-40-7	41-2	8.7	7.7	-106	-108	14.0	.01	24	22	04
			292	82-41-1	41-2	8.9	7.9	-139	-130	12.5	.01	24	22	.03
			293	82-41-2	41-2	8.9	7.8	-144	-133	12.1	<.01	24	22	03
			908				7.3						24	
			909				7.5						23	

Table 6a

FJÄLLVEDEN - Metal ions

Bore-hole	Depth m	Nr	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	Mn mg/l	Fe2+ mg/l	Fe-tot mg/l	Al mg/l	Cu mg/l	Sr mg/l
FJ2	106											
		239	23	3.9	27	2.4	.33	1.6	2.0	.03	<.005	.124
		240	22	3.9	35	2.3	.22	1.0	1.1	.02	<.005	.128
		251	18	3.2	37	2.4	.18	1.0	1.1	<.01	<.005	.180
		252	18	3.0	37	2.4	.18	.95	1.1	<.01	<.005	.125
FJ2	293											
		253	20	3.2	26	2.3	.54	5.1	12			
		254	19	3.3	27	2.3	.49	6.2	10			
		255	18	3.3	26	2.3	.56	5.7	12			.125
		256	19	3.3	26	2.3	.49					.122
FJ2	409											
		257	21	3.8	28	2.4	.48	8.0	9.9	<.01	<.005	.125
		258	21	3.6	31	2.5	.45	7.0	7.1			
		259	22	3.6	32	2.6	.40	6.3	6.4			
		260	21	3.4	33	2.6	.46	6.5	7.0	<.01	.005	.125
		261	21	3.6	34	2.6	.40	4.7	5.5			
FJ2	506											
		262	13	1.2	113	1.2	.08	.42	.83			
		263	13	1.2	117	1.2	.08	.32	.83			
		264	13	1.3	122	1.2	.07	.42	.52			
		265	13	1.0	125	1.0	.07	.40	.48	<.01	<.005	.125
		266	12	.9	130	1.0	.06	.24	.33			
		267	12	.8	130	1.0	.06	.22	.34	<.01	<.005	.133
		268	12	1.2	129	1.0	.06	.42	.42			
		905	31	5.0	26	4.7	.06		.10			
		907	13	2.9	49	2.6	.10		.27			

Table 6b

FJÄLLVEDEN - Metal ions

Bore-hole	Depth m	Nr	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	Mn mg/l	Fe2+ mg/l	Fe-tot mg/l	Al mg/l	Cu mg/l	Sr mg/l
FJ4	131											
		211	25	3.3	47	2.8	.19	3.6	4.7			
		212	30	3.6	41	2.8	.26	5.6	6.4			
		213	33	3.8	35	2.7	.32	5.4	7.3	.10	<.005	.192
		214	33	4.5	30	2.6	.30	1.8	5.8			
		215	15	2.2	65	3.0	.10	1.1	1.3	.10	<.005	.145
		216	15	2.5	62	3.0	.10	1.6	2.0			
FJ4	272											
		217	28	3.6	38	2.8	.24	6.1	7.0			
		218	28	3.7	38	2.7	.24	6.1	7.3			
		219	28	3.8	38	2.7	.25	6.5	7.5			
		220	28	3.8	38	2.6	.25	6.4	7.3	.05	<.005	.212
		221	28	3.7	39	2.7	.27	6.4	7.8			
		222	28	3.9	38	2.7	.30	8.1	10	.14	<.005	.168
		223	29	3.9	37	2.7	.29	8.2	9.8			
FJ4	349											
		224	15	1.5	72	2.0	.10	1.6	2.7			
		225	13	1.3	72	1.8	.07	1.3	2.3			
		226	11	.9	71	1.7	.04	.35	.70			
		227	10	.8	71	1.6	.04	.21	.45	.14	<.005	.092
		228	17	2.4	54	2.3	.07	.99	1.0			
		229	17	2.3	54	2.4	.09	1.37	1.4	<.01	<.005	.142
		230	17	2.3	56	2.5	.09	1.78	1.8			
FJ4	420											
		231	21	2.0	100	2.8	.28	3.3	11.0	.07	<.005	.175
		232	13	1.8	68	2.1	.11	2.3	2.3	.01	<.005	.107
		233	13	1.8	62	2.0	.10	1.6	1.6	<.01	<.005	.105
		234	14	2.0	62	2.0	.09	1.2	1.4	<.01	<.005	.113
		235	14	2.2	62	2.0	.09	1.3	1.3	<.01	<.005	.115
		904	13	2.7	50	2.7	.10		.90			
		906	32	4.8	28	4.7	.06		.07			

Table 6c

FJALLVEDEN - Metal ions

Bore-hole	Depth m	Nr	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	Mn mg/l	Fe2+ mg/l	Fe-tot mg/l	Al mg/l	Cu mg/l	Sr mg/l
FJ8	402											
		281	25	4.2	13	3.1	.16	3.5	3.8			
		282	25	4.4	13	3.1	.14	2.1	2.5	<.01	<.005	.091
		283	25	4.6	13	3.2	.15	2.4	3.0			
		284	25	4.6	13	3.2	.15					
		285	25	4.6	13	3.2	.15	2.2	2.9			
		286	25	4.6	13	3.1	.15	2.4	2.9			
FJ8	562											
		287	26	4.2	13	3.0	.16	2.8	3.7			
		288	26	4.2	13	3.0	.16	2.8	3.1			
		289	26	4.2	13	3.0	.15	2.8	3.1			
		290	26	4.2	13	3.0	.15	2.7	3.1	<.01	<.005	.091
		291	26	4.1	13	3.0	.15	2.6	2.9			
		292	26	4.0	14	2.9	.15	2.7	3.2	<.01	<.005	.093
		293	26	4.2	13	3.0	.15	2.5	3.1			
		908	32	4.3	10	3.7	.35		.06			
		909	29	4.0	10	3.7	.33		.07			

Table 7a

FJÄLLVEDEN - Nitrogen containing ions

Bore-hole	Depth m	Nr	NO2 mg/l	NO3 mg/l	NH4 mg/l	NO2-N mg/l	NO3-N mg/l	NH4-N mg/l	Sum-N mg/l
FJ2	106								
		239	.004	.045	.115	.001	.010	.089	.101
		240	.005	.020	.085	.002	.005	.066	.072
		251	.007	.015	.080	.002	.003	.062	.068
		252	<.002	.030	.090	<.001	.007	.070	.077
FJ2	293								
		253	.004	.040	.070	.001	.009	.054	.065
		254	<.002	.040	.065	<.001	.009	.050	.060
		255	<.002	.025	.075	<.001	.006	.058	.064
		256	.005	.020	.055	.002	.005	.043	.049
FJ2	409								
		257	.007	.030	.050	.002	.007	.039	.048
		258	<.002	.060	.050	<.001	.014	.039	.053
		259	<.002	.060	.055	<.001	.014	.043	.057
		260	<.002	.065	.040	<.001	.015	.031	.046
		261	.005	.035	.065	.002	.008	.050	.060
FJ2	506								
		262	.004	.040	.015	.001	.009	.012	.022
		263	.005	.030	.010	.002	.007	.006	.016
		264	<.002	.030	.010	<.001	.007	.008	.015
		265	<.002	.055	.010	<.001	.012	.008	.021
		266	<.002	.020	.010	<.001	.005	.008	.013
		267	<.002	.030	.010	<.001	.007	.008	.015
		268	<.002	.045	.050	<.001	.010	.039	.050

Table 7b

FJÄLLVEDEN - Nitrogen containing ions

Bore-hole	Depth m	Nr	NO2 mg/l	NO3 mg/l	NH4 mg/l	NO2-N mg/l	NO3-N mg/l	NH4-N mg/l	Sum-N mg/l
FJ4	131								
		211	.005	.040	.120	.002	.009	.093	.104
		212	.005	.055	.110	.002	.012	.085	.099
		213	.095	4.500	.125	.029	1.017	.097	1.143
		214	.520	1.570	.230	.158	.355	.179	.692
		215	.007	.060	.120	.002	.014	.093	.109
		216	.027	.025	.260	.008	.006	.202	.216
FJ4	272								
		217	.015	.770	.075	.005	.174	.058	.237
		218	.015	.065	.135	.005	.015	.105	.124
		219	.009	.065	.150	.003	.015	.116	.134
		220	.030	.015	.045	.009	.003	.035	.047
		221	.025	.040	.020	.008	.009	.016	.032
		222	.030	.030	.120	.009	.007	.093	.109
		223	.020	.060	.115	.006	.014	.089	.109
FJ4	349								
		224	.012	.025	.010	.004	.006	.008	.017
		225	.050	.080	.010	.015	.018	.008	.041
		226	.004	.010	.020	.001	.002	.016	.019
		227	.004	.025	.025	.001	.006	.019	.026
		228	.004	.035	.075	.001	.008	.058	.067
		229	.009	.030	.085	.003	.007	.066	.076
		230	.004	.045	.065	.001	.010	.050	.062
FJ4	420								
		231	.011	.020	.005	.003	.005	.004	.012
		232	.012	.020	.020	.004	.005	.016	.024
		233	.009	.025	.035	.003	.006	.027	.036
		234	.007	.040	.050	.002	.009	.039	.050
		235	.007	.015	.065	.002	.003	.050	.056

Table 7c

FJALLVEDEN - Nitrogen containing ions

Bore-hole	Depth m	Nr	NO2 mg/l	NO3 mg/l	NH4 mg/l	NO2-N mg/l	NO3-N mg/l	NH4-N mg/l	Sum-N mg/l
FJ8	402								
		281	<.002	.040	.015	<.001	.009	.012	.021
		282	<.002	.015	.010	<.001	.003	.008	.012
		283	<.002	.045	.010	<.001	.010	.008	.019
		284	<.002	.040	.005	<.001	.009	.004	.014
		285	<.002	.055	.010	<.001	.012	.008	.021
		286	.005	.020	.015	.002	.005	.012	.018
FJ8	562								
		287	.004	.045	.015	.001	.010	.012	.023
		288	.004	.020	.010	.001	.005	.008	.014
		289	.004	.025	.010	.001	.006	.008	.015
		290	.012	.015	.015	.004	.003	.012	.019
		291	.004	.020	.010	.001	.005	.008	.014
		292	.005	.015	.010	.002	.003	.008	.013
		293	.010	.030	.020	.003	.007	.016	.025

Table 8a

FJALLVEDEN - Remaining anions and other parameters

Borehole	Depth m	Nr	HCO3 mg/l	Cl mg/l	F mg/l	SO4 mg/l	PO4 mg/l	SiO2 mg/l	TOC mg/l	Turb. NTU	Drilling water residue, 1%
FJ2	106										
		239	130	8	.3	10	.045	14	6		7.9%
		240	160	6	.7	7.5	.050	13	5		2.2%
		251	160	5	.7	6.1		13	5		1.7%
		252	160	5	.7	6.1	.045	13	5		2.0%
FJ2	290										
		253	150	8	.6	4.0	.14	13	6		7.9%
		254	140	8	.6	3.2	.16	13	6	2.5	8.7%
		255	140	8	6	5.2	.18	13	6	1.3	10.2%
		256	144	8	.6	10	.18	14	8	2.4	8.7%
FJ2	407										
		257	157	7	.7	.2	.22	13	5	13	7.1%
		258	171	8	.9	.2	.18	13	5	9.7	8.7%
		259	173	8	.9	.2	.18	13	6	6.0	8.7%
		260	170	8	.9	.2	.20	13	6	28	7.9%
		261	175	9	.9	.2	.14	13	4		8.7%
FJ2	506										
		262	97	140	4.7	.2	.090	9.5	5	2.3	7.1%
		263	95	150	4.8	<.1	.070	9.4	4	1.9	5.5%
		264	92	160	5.0	<.1	.080	9.2	4	5	[illegible] 5%
		265	90	170	5.2	.1	.070	9.0	4	8	5.5%
		266	85	170	5.5	.2	.055	9.5	4	7	3.9%
		267	83	170	5.5	.2	.050	9.2	4	7	3.9%
		268	81	170	5.4	.2	.055	9.4	4	5	5.5%
		705	180	4	7	7.9		15			
		707	178	4	.9	7.5		15			

Table 8b

FJÄLLVEDEN - Remaining anions and other parameters

Bore-hole	Depth m	Nr	HCO3 mg/l	Cl mg/l	F mg/l	SO4 mg/l	PO4 mg/l	SiO2 mg/l	TOC mg/l	Turb. NTU	Drilling water residue, I%
FJ4	131										
		211	200	8	.6	8	.045	7.5	7	3.3	5.5%
		212	194	10	.6	10	.070	8.0	7	6.9	4.9%
		213	185	10	.6	14	.050	8.5	7	6.3	4.3%
		214	178	10	.6	10	.010	10	7	6.3	4.4%
		215	218	6	1.0	7	.025	5.8	6	3.3	6.0%
		216	207	7	.9	8	.010	6.7	5	2.4	5.2%
FJ4	272										
		217	192	9	.6	8	.085	8.3	8	6.8	4.1%
		218	190	9	.6	7	.075	8.3	8	9.4	4.4%
		219	193	9	.6	7	.075	8.4	7	6.0	4.4%
		220	191	9	.6	5	.130	8.5	8	11	4.1%
		221	196	9	.5	5	.055	8.1	7	6.9	4.7%
		222	196	9	.5	7	.045	8.2	7	2.2	4.4%
		223	196	9	.6	7	.035	8.4	7	5.1	4.4%
FJ4	349										
		224	205	13	1.9	<.1	.29	7.8	40	4.5	7.6%
		225	200	13	2.2	<.1	.31	7.7	30	4.6	7.9%
		226	195	13	2.5	<.1	.26	7.5	20	5.2	7.7%
		227	194	11	2.7	<.1	.24	7.5	15	5.7	7.9%
		228	194	5	1.1	2.6	.115	6.7	6	1.5	3.4%
		229	195	5	1.0	3.6	.105	6.6	6	2.4	3.3%
		230	197	1	1.0	3.4	.070	6.7	7	2.2	4.3%
FJ4	420										
		231	110	220	3.8	.2	.030	5.5	50		4.8%
		232	162	30	2.5	3.7	.050	5.4	25		2.2%
		233	185	14	2.0	3.8	.070	6.1	15		1.3%
		234	198	8	1.7	3.9	.060	6.2	8		.7%
		235	203	6	1.6	3.5	.060	6.2	7		.6%
		904	184	4	.9	7.3		14			
		906	184	4	.7	7.9		15			

Table 8c

FJÄLLVEDEN - Remaining anions and other parameters

Bore-hole	Depth m	Nr	HCO3 mg/l	Cl mg/l	F mg/l	SO4 mg/l	PO4 mg/l	SiO2 mg/l	TOC mg/l	Turb. NTU	Drilling water residue, I%
FJ8	402										
		281	123	4	1.0	7.5	.015	7.8	3	4.4	5.5%
		282	123	4	1.0	7	.015	7.9	4	26	5.5%
		283	128	4	1.0	6.5	.020	8.0	3	20	6.3%
		284	128	4	1.0	6	.020	8.3		22	
		285	130	4	1.0	6.5	.025	8.4	3	22	5.5%
		286	130	4	1.0	6	.020	8.4	3	6.7	5.5%
FJ8	562										
		287	128	4	.9	6	.025	8.2	3	11	5.5%
		288	130	4	.9	6	.030	8.2	3	6.0	5.5%
		289	130	4	.9	6	.040	8.2	3	11.5	5.5%
		290	130	4	.9	6	.045	8.7	3	9.0	4.7%
		291	132	4	.9	6	.050	8.4	3	11	3.9%
		292	130	4	.9	5	.050	8.5	3	11	4.7%
		293	129	4	.9	5	.055	8.5	3	8.5	7.1%
		908	140	3	.4	6.9		18			
		909	137	3	.4	7.0		17			

FJÄLLVEDEN - Particulated matter

Bore-hole	Depth m	Nr	Sample ml	S, prt mg/l	Fe, prt mg/l	Al, prt mg/l
FJ2	106	239	1900	.002	.074	.075
FJ2	106	252	1700	.003	.032	.112
FJ2	293	255	500	.006	.128	.300
FJ2	293	256	500	.012	.118	.220
FJ2	409	257	350	.026	.371	.237
FJ2	409	260	1650	.002	.019	.039
FJ2	506	265	2000	003	.019	.032
FJ2	506	267	950	.004	.103	.021
FJ4	131	213	600	012	.133	.267
FJ4	131	215	850	.002	.032	.118
FJ4	272	220	350	.023	1.829	.157
FJ4	272	222	425	.009	.089	329
FJ4	349	227	300	.047	.270	.667
FJ4	349	229	2250	002	.027	.017
FJ4	420	231	1200	.018	.242	.258
FJ4	420	234	1950	.007	.118	.042
FJ8	402	282	2250	.012	.356	.008
FJ8	562	290	2250	.004	.016	004
FJ8	562	292	2250	.004	.013	.002

Table 10

FJÄLLVEDEN - Uranium, thorium, radium and radon

Bore- hole	Depth m	Nr	Th ug/l	U Bq/l	Ra-226 Bq/l	Rn-222 Bq/l
FJ2	106	252	(2.6+0.6)E-2	(1.4+0.4)E-2	(5.5+0.8)E-3	201+5
FJ2	293	256	(9.2+4.5)E-2	(6.1+3.2)E-3	(5.5+1.0)E-3	266+5
FJ2	409	260	(1.2+0.4)E-1	< 2.3 E-3	< 5.8 E-3	120+5
FJ2	506	267	< 2.6 E-1	< 5.1 E-3	(3.5+0.3)E-3	305+6
FJ4	131	215	< 1.2 E-2	(9.3+0.5)E-2	< 3.9 E-3	151+5
FJ4	272	222	(4.4+1.8)E-3	(7.7+0.5)E-2	< 3.0 E-3	240+5
FJ4	349	229	(1.9+0.6)E-2	(1.6+0.3)E-2	(8.5+1.3)E-3	166+5
FJ4	420	234	(2.5+0.6)E-2	< 4.8 E-3	< 1.1 E-3	189+5
FJ8	402	285	< 3.8 E-2	(2.8+0.4)E-2	(2.9+0.6)E-3	144+5
FJ8	562	292	< 6.9 E-2	(1.1+0.3)E-2	(3.1+0.8)E-3	107+5

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