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# Re-sampling of the KLX02 deep borehole at Laxemar

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**SKB**

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# Abstract

The project "Re-sampling of the KLX02 borehole at Laxemar" focuses on the origin and changes of deep groundwaters, which are important for understanding the stability of the groundwater surrounding the final repository. The results from the sampling campaign in 1997 down to a depth of 1500m are compared with the results from 1993 sampled in the same borehole. The analytical results and some preliminary calculations are presented.

The changes since the last sampling campaign 4 years ago indicate a high degree of mixing and dynamics in the system. The following conclusions are drawn:

- More changes in the water composition than expected compared with the results from the sampling campaign in 1993

- Larger portions of meteoric water in the upper part of the borehole

- Less glacial water in the intermediate part of the borehole

- More brine water in the lower part of the borehole

The conclusion is that there has been a relatively large change in the groundwater system during the last 4 years in the Laxemar deep borehole. The disturbance removed the effect from the last glaciation and pulled in groundwater, which resulted in a mixture mainly consisting of meteoric and brine waters. The most probable reason is that the annual fluctuation and flow in the open borehole play an important role as a modificator especially for the isotopes. The results show the sensitivity of deep groundwater to changes in the prevailing hydrogeological situation.

# Contents

# 1    Background

The project "Re-sampling of the KLX02 borehole at Laxemar" focuses on the origin and changes of deep groundwaters which are important for understanding the stability of the groundwater surrounding the final repository. The aim is to describe the sampling, present the analytical results and present a preliminary modelling.

KLX02 was drilled in 1992 to a depth of 1,705 m, some 2.5km WSW of the Äspö Hard Rock Laboratory (HRL) on the Laxemar mainland. This borehole represents the deepest borehole drilled within the Research and Development programme managed by Swedish Nuclear Fuel and Waste Management Company (SKB).

Groundwater sampling of the KLX02 borehole was conducted in 1993 on two occasions. The background information concerning the borehole history, the groundwater sampling protocol and the interpretation of the groundwater chemistry from the sampling campaigns in 1993 has been described by Laaksoharju et al. (1994). The results described here are from the sampling campaign in 1997. The objectives for the re-sampling of KLX02 were:

- To compare the changes in the groundwater chemistry since the last sampling campaign in 1993 in order to increase the understanding concerning the effects from natural disturbances on the groundwater composition.

- To establish the composition and origin of deep basement groundwaters.

- To use these data to support the existing hydraulic and hydrogeochemical interpretation of the Laxemar borehole and the Äspö site generally.

- To provide a sound basis for evaluating the stability of deep regional groundwater systems in this part of Sweden.

- To find possible indications of changes in the groundwater chemistry which can indicate a regional flow.

# 2 The sampling tool and conditions

Groundwater sampling of the KLX02 borehole was conducted 1993 on two occasions (Laaksoharju et al, 1995). The first sampling was taken in the open borehole using the so-called Tube sampler (Nurmi and Kukkonen, 1986); the second sampling was carried out using the SKB-packer equipment to isolate pre-determined borehole sections.

The sampling campaign in 1997 was performed with the Tube sampler. This sampler consists of 50 m sections of polyamide tubes (10 mm outer diameter; maximum length 1,700 m) with a hand-operated valve and connector fastened at both ends of each tube. The first string placed in the borehole contained a check-valve; the following tube was connected to the upper part of the tube in the borehole and the hand-operated valves were opened. Several tube strings were connected until the desired measuring depth was achieved. It is important to note that only the water column in the open borehole was sampled; there was no pumping involved. When the tube string was filled with borehole water the individual lengths were isolated by closing the valves and the tubes were subsequently removed; water contained in the 50 m tube lengths (2.5 litre) was poured into flasks for analysis.

The advantage of this technique is that the equipment is convenient, easy and rapid to operate, even at considerable depths. The disadvantage is that the water column collected represents open-hole conditions, i.e. the chemical distribution in the groundwater is controlled by the hydraulic properties of the borehole, which may not always conform to adjacent bedrock conditions. Furthermore, lowering the tube into the open borehole may cause perturbation and mixing of groundwater types around and inside the tube.

The sampling was performed the 25 of September 1997. The sampler was successfully lowered into the borehole to a depth of 1,150–1,200 m where there was a large resistance. After lifting up 75 m of the tube string the resistance disappeared and the equipment could be lowered to a depth of 1,450 m. At this depth a new resistance occurred which could not be passed.

The open-hole conditions may have contributed to a general mixing of groundwater types in the borehole; the degree of mixing depends on the hydraulic properties of the borehole and possibly on groundwater density variations. In KLX02 this risk is considered to be large since the upper part of the borehole represents active recharge. Subsequent raising and lowering of the tube sampler may have also caused groundwater perturbation in the boreholes resulting in the mixing of non-saline and saline water types. Furthermore, it is a known phenomenon for groundwater to undergo significant pH and Eh changes through degassing and oxidation etc. when lifted to the surface; this is believed to be a significant problem when sampling deep boreholes such as KLX02.

# 3 Analytical and sampling protocol

The quantified parameters are major components, pH, tritium, stable isotopes, temperature, the isotopes $^{87}Sr$, $^{34}S$ and $^{14}C$. The sampling protocol in Table 3-1 shows the type and collected samples from KLX02.

The analytical protocols and analytical quality controls of the collected samples used are described by Nilsson (1995). The sampling followed the so-called SKB level 3 for analytical procedures. The approved analytical results were included in the SKB database SICADA.

## Table 3-1 Sampling protocol used at KLXO2

| SNO | KBS nr | Depth (m) | 3H | 2H | 18O | Major Comp | 14C | 87Sr | Bact. | 34S | 37Cl |
|-----|--------|-----------|----|----|-----|-----------|-----|------|-------|-----|------|
| 1 | 2406 | 0-50 | X | X | X | XX | | | | | |
| 2 | 2408 | 50-100 | X | X | X | XX | | | | | |
| 3 | 2413 | 100-150 | X | X | X | XXX | | | | | |
| 4 | 2414 | 150-200 | X | X | X | XXX | | | | | |
| 5 | 2422 | 200-250 | X | X | X | X | XX | X | X | X | |
| 6 | 2415 | 250-300 | X | X | X | XXX | | | | | |
| 7 | 2416 | 300-350 | X | X | X | XXX | | | | | |
| 8 | 2417 | 350-400 | X | X | X | XXX | | | | | |
| 9 | 2421 | 400-450 | X | X | X | X | XX | X | X | X | |
| 10 | 2423 | 450-500 | X | X | X | XX | | | | | |
| 11 | 2424 | 500-550 | X | X | X | XX | | | | | |
| 12 | 2425 | 550-600 | X | X | X | XX | | | | | |
| 13 | 2420 | 600-650 | X | X | X | X | XX | X | X | X | |
| 14 | 2426 | 650-700 | X | X | X | XX | | | | | |
| 15 | 2427 | 700-750 | X | X | X | XX | | | | | |
| 16 | 2428 | 750-800 | X | X | X | XX | | | | | |
| 17 | 2419 | 800-850 | X | X | X | X | XX | X | X | X | |
| 18 | 2429 | 850-900 | X | X | X | XX | | | | | X |
| 19 | 2418 | 900-950 | X | X | X | X | XX | X | X | X | |
| 20 | 2430 | 950-1000 | X | X | X | XX | | | | | X |
| 21 | 2412 | 1000-1050 | X | X | X | X | XX | X | X | X | |
| 22 | 2431 | 1050-1100 | X | X | X | X | | | | | X |
| 23 | 2411 | 1100-1150 | X | X | X | X | XX | X | X | X | |
| 24 | 2432 | 1150-1200 | X | X | X | X | | | | | X |
| 25 | 2410 | 1200-1250 | X | X | X | X | XX | X | X | X | |
| 26 | 2433 | 1250-1300 | X | X | X | X | | | | | X |
| 27 | 2409 | 1300-1350 | X | X | X | X | XX | X | X | X | |
| 28 | 2434 | 1350-1400 | X | X | X | X | | | | | X |
| 29 | 2407 | 1400-1450 | X | X | X | X | XX | X | X | X | |

Gray tagged indicates analyzed samples others represent backup samples.     X = number of bottles

# 4    Results

## 4.1    Scatter Plots

In order to show the general trends of the analytical groundwater data in more detail, x and y scatter plots for the KLX02 data are shown in Figures 4-1 to 4-14. The variables Cl, $HCO_3$, $SO_4$, Na, K, Ca, Mg, $\delta^{18}O$, tritium, $\delta^2H$, $\delta^{87}Sr$, $\delta^{34}S$, $^{14}C$ (pmC) and microbes are plotted against depth. The data from 1997 is compared with data from 1993 except for the $\delta^{87}Sr$, $\delta^{34}S$, $^{14}C$ (pmC) and microbes which show data collected during 1997. The complete chemical data for the sampling campaign conducted in 1997 is presented in Appendix 1.
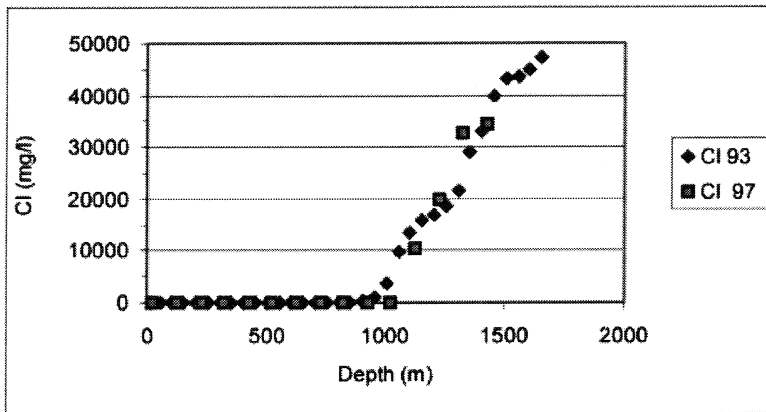


*Figure 4-1. Scatter plot for the KLX02 borehole data shown for Cl versus depth. The data from 1997 is compared with data from 1993.*
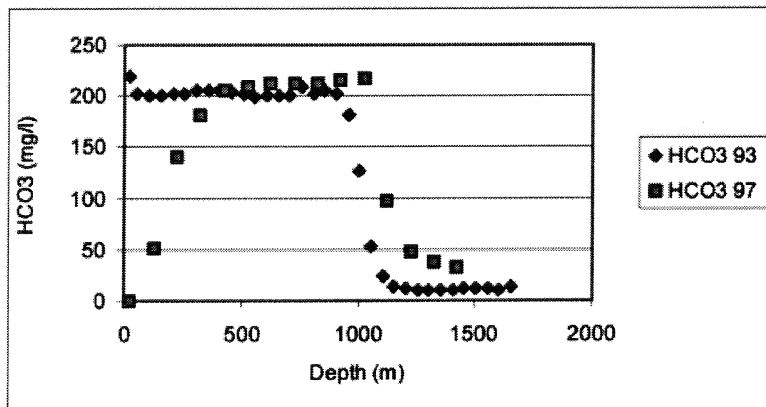


*Figure 4-2. Scatter plot for the KLX02 borehole data shown for $HCO_3$ versus depth. The data from 1997 is compared with data from 1993.*
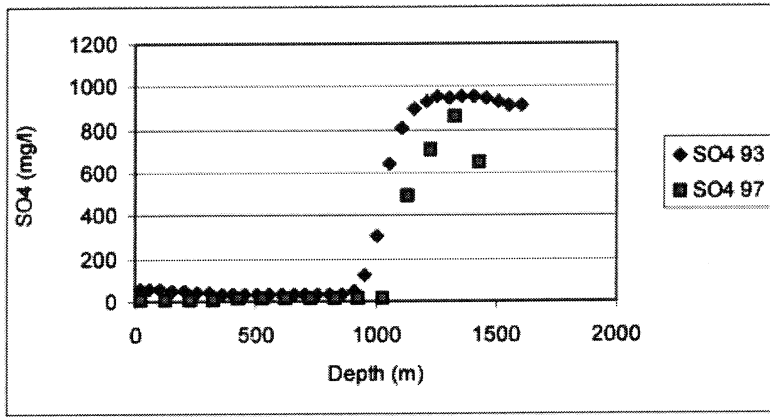
13

**Figure 4-3.** Scatter plot for the KLX02 borehole data shown for $SO_4$ versus depth. The data from 1997 is compared with data from 1993.



**Figure 4-4.** Scatter plot for the KLX02 borehole data shown for Na versus depth. The data from 1997 is compared with data from 1993.



**Figure 4-5** Scatter plot for the KLX02 borehole data shown for K versus depth. The data from 1997 is compared with data from 1993.

**Figure 4-6.** Scatter plot for the KLX02 borehole data shown for Ca versus depth. The data from 1997 is compared with data from 1993.
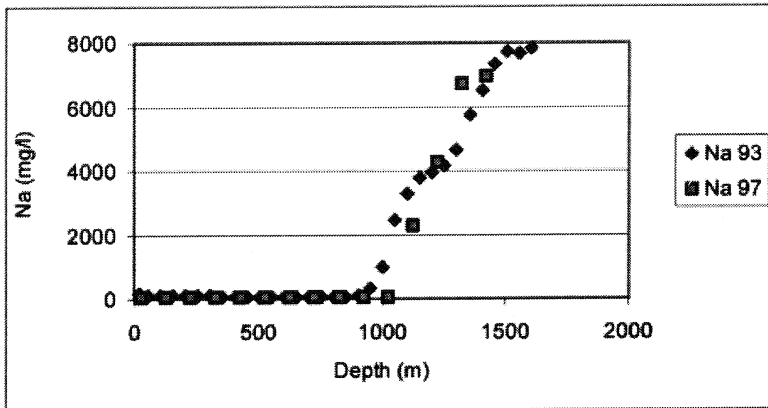


**Figure 4-7.** Scatter plot for the KLX02 borehole data shown for Mg versus depth. The data from 1997 is compared with data from 1993.



**Figure 4-8.** Scatter plot for the KLX02 borehole data shown for $\delta^{18}O$ versus depth. The data from 1997 is compared with data from 1993.
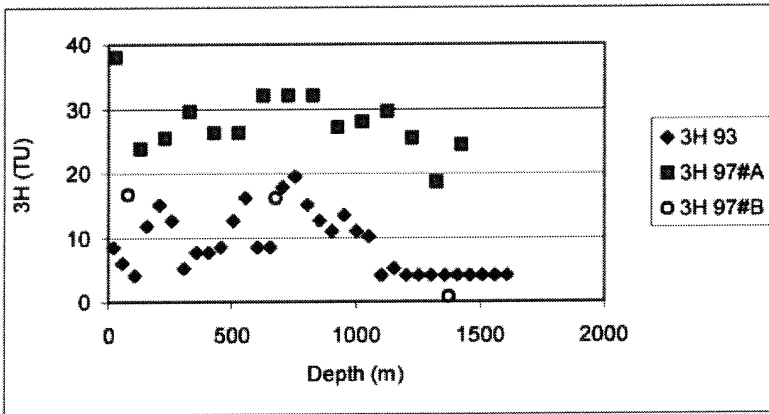
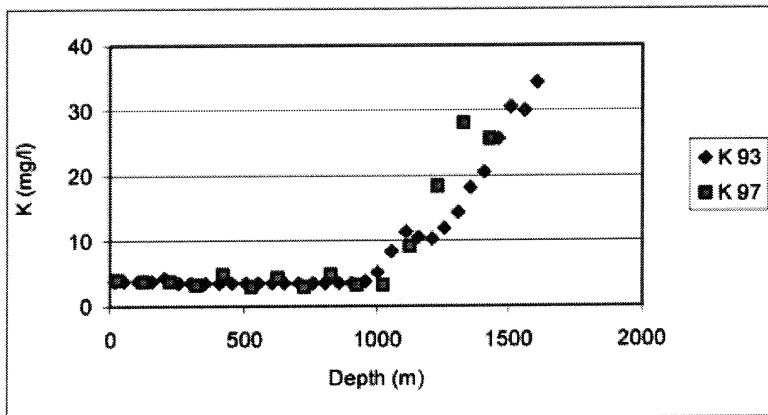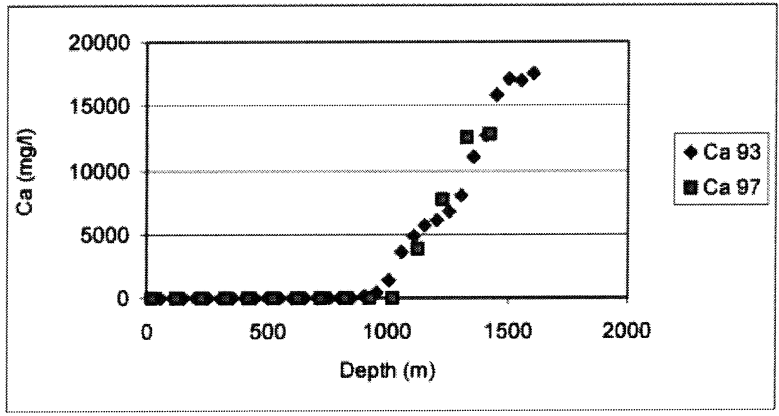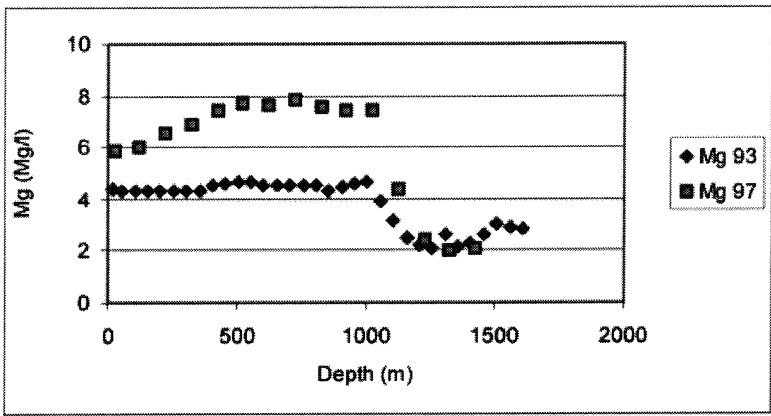*Figure 4-9. Scatter plot for the KLX02 borehole data shown for tritium versus depth. The data from 1997 is compared with data from 1993. The values 3H 97#A from 1997 are uncertain due to analytical problems in the tritium analyses. The samples 3H 97#B are from the 1997 sampling campaign but made by another laboratory.*
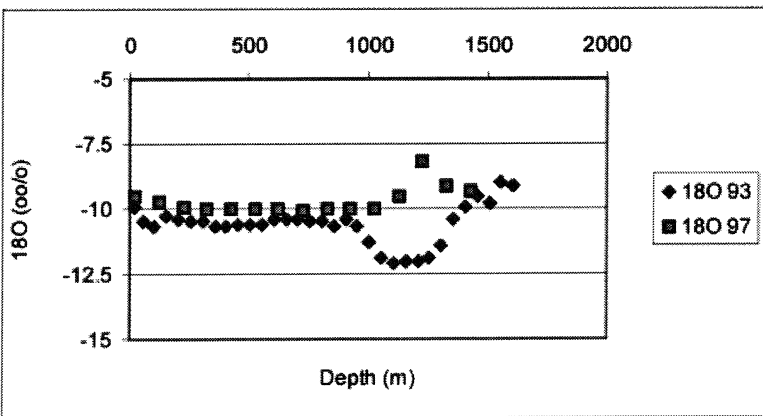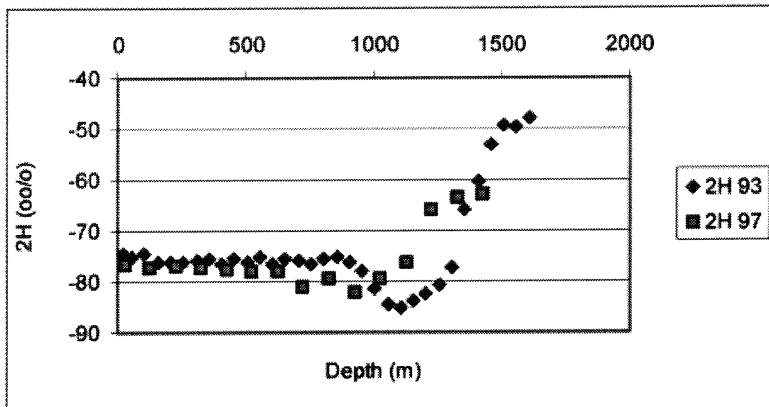


*Figure 4-10. Scatter plot for the KLX02 borehole data shown for $d^2H$ versus depth. The data from 1997 is compared with data from 1993.*



*Figure 4-11. Scatter plot for the KLX02 borehole data shown for $\delta^{34}S$ versus depth.*

16

**Figure 4-12.** Scatter plot for the KLX02 borehole data shown for $\delta^{87}Sr$ versus depth.



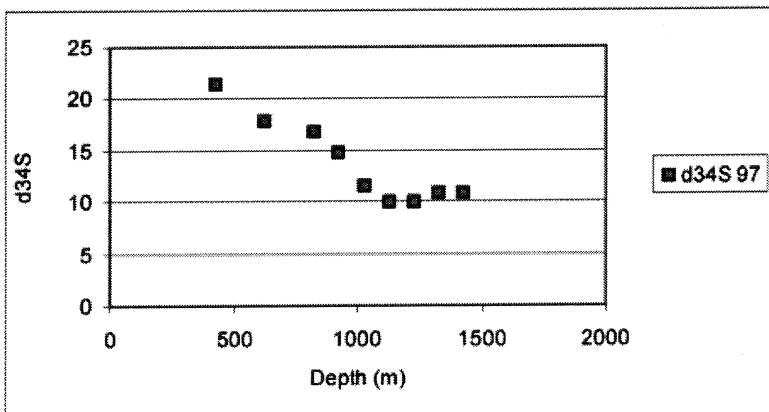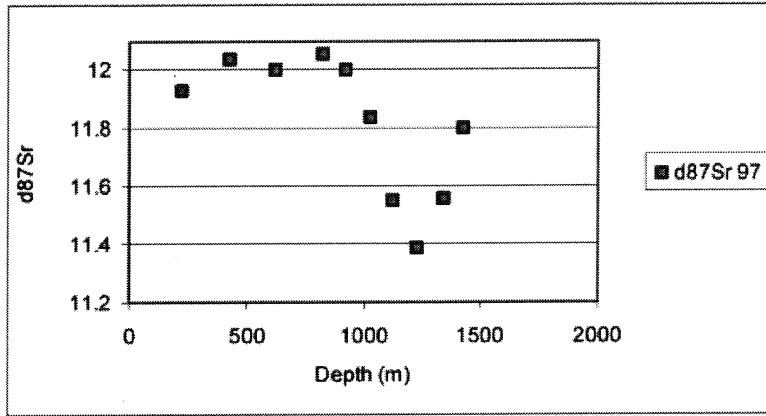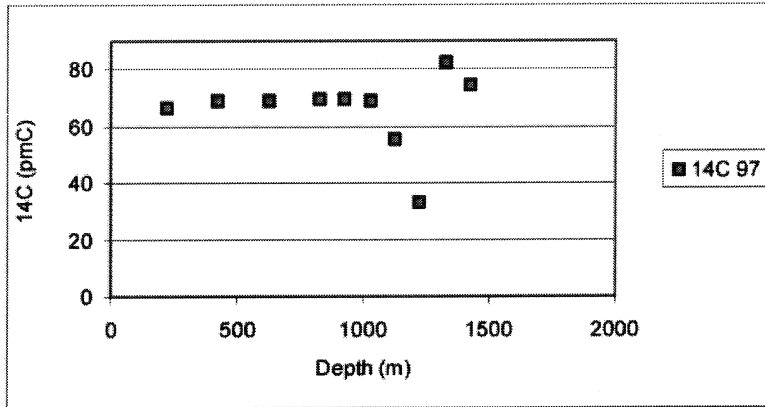**Figure 4-13.** Scatter plot for the KLX02 borehole data shown for $^{14}C$ analysis shown as percent modern carbon (pmC) versus depth.
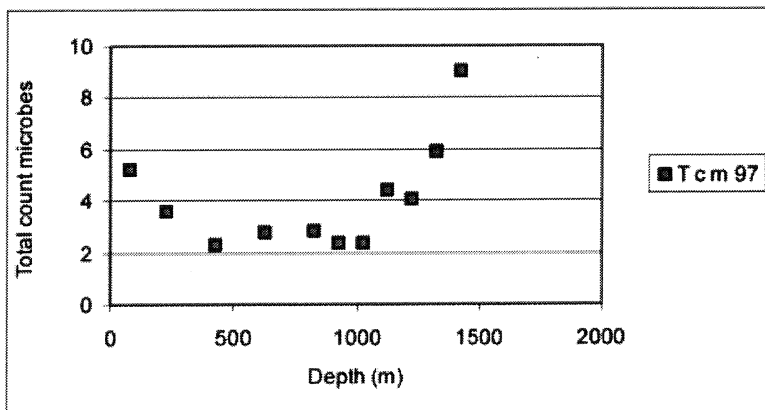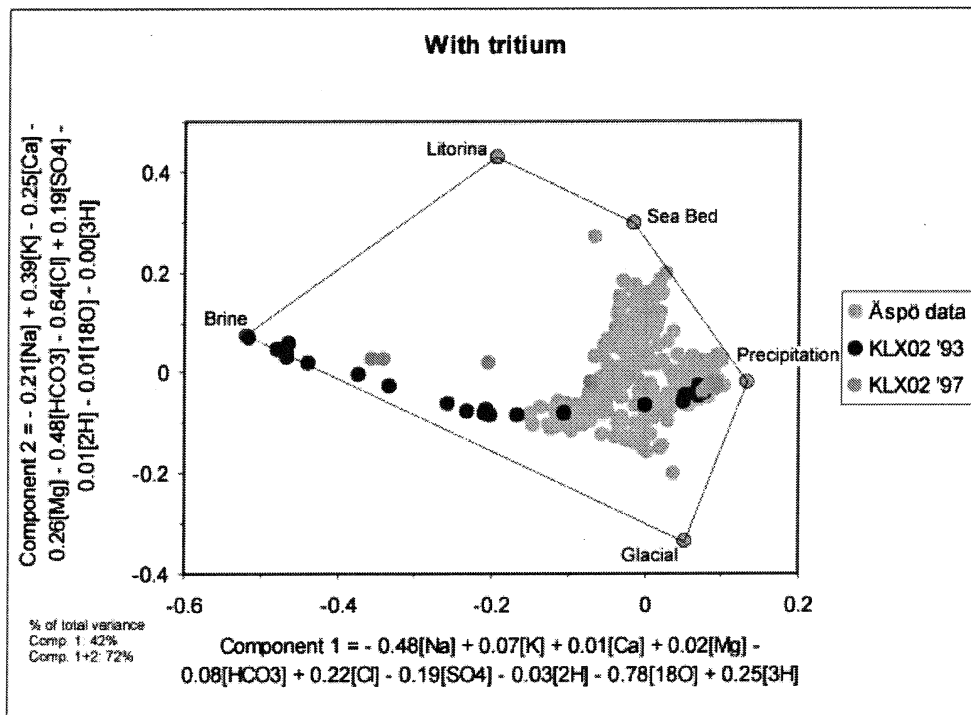


**Figure 4-14.** Scatter plot for the KLX02 borehole data shown for total cell counts for the microbes (*$10^5$*) versus depth.
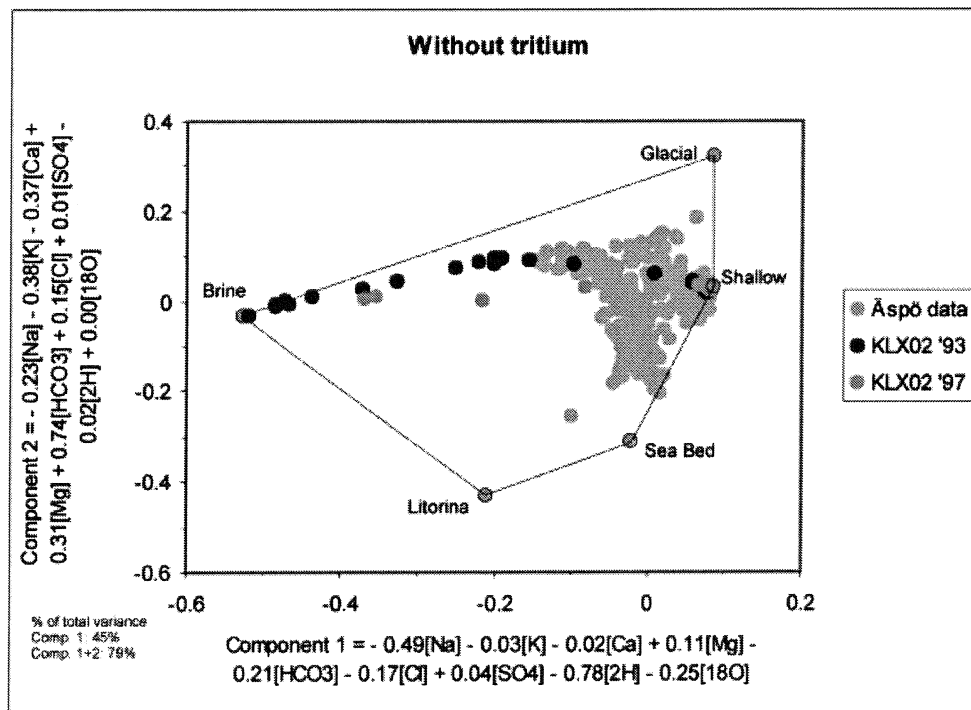
From the major groundwater chemistry, the samples seem to reflect two distinct groupings; one shallow to intermediate *Sodium-Bicarbonate* type to a depth of 1,000 m, and the other of deep origin, a *Calcium-Chloride* type, occurring below 1,000 m. The values for Cl, Na, K and Ca seem to be similar with the values obtained during the last sampling campaign. The $HCO_3$ values in the upper 400 m of the borehole are lower. The $SO_4$ value at 1,500 m is lower than during the previous campaign. The tritium values show a large discrepancy from one campaign to another due to analytical problems. Samples 3H 97#B (Figure 4-9) were sent to a different laboratory than samples 3H 97#A (Figure 4-9) and the difference is more than 20 tritium units. The tritium values 3H 97#A cannot therefore be used for modelling. The Mg values are higher compared to the previous campaign. The $\delta^{18}O$ values and $\delta^2H$ are higher at a depth of 1,000–1,500 m compared with the previous campaign. $\delta^{87}Sr$ plot shows a decrease at 800 m depth down to 1,200 m depth; the signature increases after this depth. The decrease of $\delta^{87}Sr$ and the increase of $\delta^{18}O$ and $\delta^2H$ are associated with the saline interface. The $\delta^{34}S$ values show a value of +21.5‰, at 400 m depth which may indicate a marine signature. Deeper in the groundwater, down to around 1,000 m, there is an almost linear decrease at depths of around 1,100 m to 1,400 m where the $\delta^{34}S$ values stabilise at around +10‰. The $^{14}C$ analysis shown as percent modern carbon shows a homogenous signature at a depth of 450 m to 1,050 m. At the intermediate and lower part of the borehole the pmC values show strong deviations of around 33.5–82.8 which may indicate disturbances at this depth. A small portion of mixed shallow water with deep water may result in large deviations in the pmC values. The total cell counts for the microbial samples show lower values at a depth of 500–1,000 m; higher values are obtained at the shallow and the deep part. The reason for this is unknown but may reflect different microbial populations thriving at different depths and conditions. Microbe culturing could have answered this question but the culturing failed during this mission.

## 4.2   M3

The sampled groundwaters where modelled by M3 (Multivariate Mixing and Mass balance calculations), Laaksoharju et al., (1994) and Laaksoharju and Wallin (eds.), (1997). The M3 model consists of 3 steps where the first step is a standard multivariate analysis (PCA), followed by mixing and finally by mass balance calculations. Here only the first two steps were applied, PCA and mixing calculations. In the PCA plot (Figure 4-15a) all the Äspö site data is compared with data sampled in 1993 and 1997 at KLX02. Because of the known uncertainty of the tritium analyses the PCA plot was recalculated using the same data as in Figure 4-15a but excluding tritium from the PCA analysis (Figure 4-15b).

**With tritium**

Component 2 = - 0.21[Na] + 0.39[K] - 0.25[Ca] - 0.26[Mg] - 0.48[HCO3] - 0.64[Cl] + 0.19[SO4] - 0.01[2H] - 0.01[18O] - 0.00[3H]

0.4
0.2
0
-0.2
-0.4

Litorina
Sea Bed
Brine
Precipitation
Glacial

Äspö data
● KLX02 '93
KLX02 '97

-0.6    -0.4    -0.2    0    0.2

% of total variance
Comp 1: 42%
Comp. 1+2: 72%

Component 1 = - 0.48[Na] + 0.07[K] + 0.01[Ca] + 0.02[Mg] - 0.08[HCO3] + 0.22[Cl] - 0.19[SO4] - 0.03[2H] - 0.78[18O] + 0.25[3H]

*Figure 4-15a.* A principal component plot is used to show the distribution of the Äspö site data in comparison with the data sampled 1993 and 1997 at KLX02. The identified extreme waters are named (see discussion below). The first and second principal components together account for 72% of the variability, or the information of the Äspö site data set. The variables: $Cl$, $HCO_3$, $SO_4$, $Na$, $K$, $Ca$, $Mg$, $\delta^{18}O$, $\delta^{2}H$ and $^{3}H$ were used in the PCA calculation.

**Without tritium**

Component 2 = - 0.23[Na] - 0.38[K] - 0.37[Ca] + 0.31[Mg] + 0.74[HCO3] + 0.15[Cl] + 0.01[SO4] - 0.02[2H] + 0.00[18O]

0.4
0.2
0
-0.2
-0.4
-0.6

Glacial
Shallow
Brine
Sea Bed
Litorina

Äspö data
● KLX02 '93
KLX02 '97

-0.6    -0.4    -0.2    0    0.2

% of total variance
Comp 1: 45%
Comp. 1+2: 79%

Component 1 = - 0.49[Na] - 0.03[K] - 0.02[Ca] + 0.11[Mg] - 0.21[HCO3] - 0.17[Cl] + 0.04[SO4] - 0.78[2H] - 0.25[18O]

*Figure 4-15b.* A principal component plot is used to show the distribution of the Äspö site data in comparison with the data sampled in 1993 and 1997 at KLX02. In this calculation the tritium values have been excluded from the data set. The identified extreme waters are named (see discussion below). The first and second principal components together account for 79% of the variability, or the information of the Äspö site data set. The variables: $Cl$, $HCO_3$, $SO_4$, $Na$, $K$, $Ca$, $Mg$, $\delta^{18}O$ and $\delta^{2}H$ were used in the PCA calculation.

The difference between Figures 4-15 a and b is minor (less than 10%) therefore the model presented in Figure 4-15b was used for further modelling. From the PCA plot (Figure 4-15b) some extreme waters have been identified. These waters are named reference waters. The reference waters are crucial for understanding the origin and evolution of the waters. The closer a sample in the PCA plot is to the reference waters the more similar is the water composition and the more likely is an interrelationship. This is used in the mixing calculations where the distance to the reference water is equivalent to the mixing portion. The selected reference waters identified from the PCA for the current modelling are (the analytical composition is listed in Appendix 1):

- **Brine reference water**, which represents the brine type of water, found in KLX02: 1,631–1,681 m.

- **Glacial reference water** is a precipitation water composition where the stable isotope values ($\delta^{18}O$ = -21 SMOW and $\delta^2H$ = -158 SMOW) were based on measured values of $\delta^{18}O$ in the calcite surface deposits, interpreted as sub-glacial precipitates, collected from different geological formations at the west coast of Sweden (Tullborg and Larson, 1984). The water represents a possible meltwater composition from the last glaciation >13,000 BP.

- **Litorina Sea reference water** is an ancient sea water composition (8,000–2,000 BP) with a Cl concentration of 6,100 mg/l based on analyses of microfossils from the marine sediments in southern Finland (Kankainen, 1986). A similar Cl content was suggested by Sjöberg et al. (1984) based on measurements of interstadial water in postglacial black clays.

- **Sea Bed reference water** is extracted marine *sediment pore water* (Landström et al., 1994) with modelled values for stable isotopes. The major component chemistry in the pores resembled modern Baltic Sea values. Based on this knowledge the modern isotope values measured from the Baltic Sea water were used.

- **Shallow reference water**, which represents the type of water found in HLX06(871103): 45–100 m.

The results from the sampling campaign in 1997 differ from the results obtained in 1993 as shown in the PCA plot (Figure 4-15b). The results from 1997 show many observations associated with Meteoric water and some observations falling more or less along a straight mixing line between the Meteoric and Brine reference waters. The deviation from 1993 towards Glacial water is not obtained with the measured water composition in the present samples.

The results from the M3 mixing calculations based on the data from 1993 and 1997 along the borehole are shown in Figure 4-16. The calculated values are listed in Appendix 1.
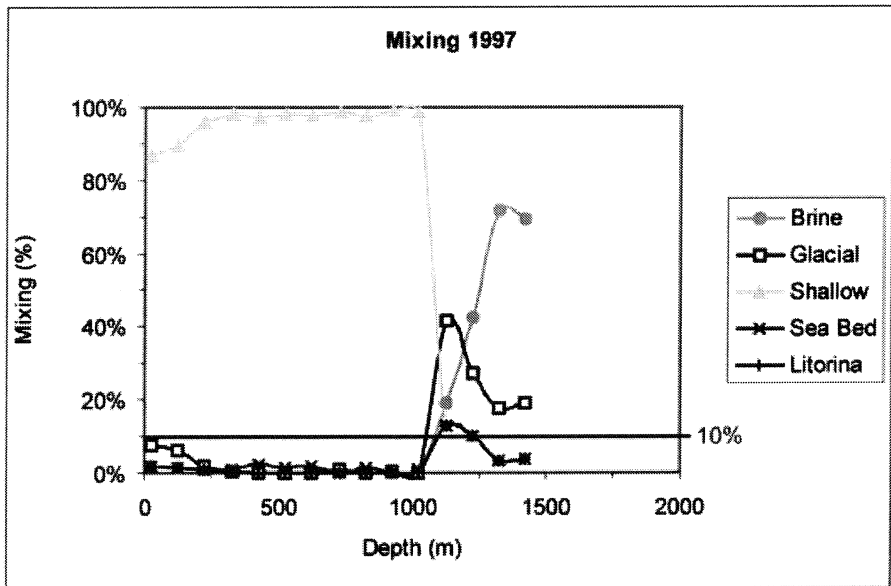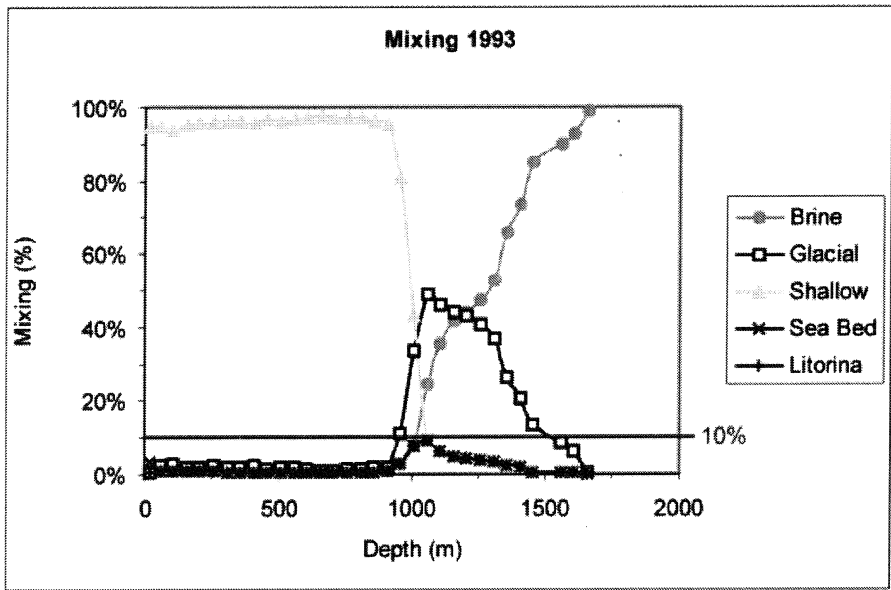
*Figure 4-16.* *The results of M3 mixing calculations obtained on groundwater sampled in 1993 and 1997. The calculated mixing portions of Meteoric, Brine, Glacial, Litorina and Sea Bed are shown against depth. The mixing portions add up to 100% for all the samples. A mixing portion of less than 10% is regarded to be under the detection limit for the M3 method and is therefore uncertain.*

# 5    Discussion

The stability of the deep groundwater system is important for performance assessment. The changes since the last sampling campaign 4 years ago indicate a surprisingly high degree of mixing and dynamics in the system. From the analytical results (Figures 4-1 to 4-14 and Appendix 1) and from M3 modelling (Figures 4-15b and 4-16) the following conclusions are drawn:

- At a depth of 0–1,050 m the major groundwater chemistry of the samples seems to reflect one shallow to intermediate *Sodium-Bicarbonate* type of water. There are indications of influx of shallow groundwater in the upper part of the borehole and the water is partly under-saturated with respect to calcite, which is seen in the low $HCO_3$ and relatively high bacterial content. This water shows a successive evolution due to bacterial activity, calcite dissolution and mixing. The $^{14}C$ analysis shown as percent modern carbon shows a homogenous signature at a depth of 450 m to 1,050 m. The $^{13}C$ analyses show an input of biogenic carbon in combination with low $^{14}C$ values which indicates an input from the dissolved calcite as well. The dissolution of calcite is shown in a low pmC value of 66.3 in the sample taken from 450 m depth. At a depth of 400–1,050 m the samples have a meteoric signature with a homogenous composition both chemically, isotopically (stable isotopes), and bacterially. Unexpectedly, the $d^{34}S$ values show a value of +21.5‰, at 400 m depth which indicates a marine signature which vanishes at larger depths. This has been interpreted as being leached from old marine sediments rich in sulphates residing at the surface alternatively some remnants from fossil seawater which also may be indicated by higher Mg values compared to the samples from 1993. One explanation may be that this water is mixed in at a depth of 1,090 m where previous temperature logging (Laaksoharju et al., 1995) show an anomaly. The $^{18}O$ signature of this water is somewhat higher (-10.0 to -10.1‰) than in the surface water (-9.5 to -9.9‰) which can be associated with a recharge from the west according to the hydrogeological modelling. The open borehole can cause this groundwater to flow upward in the borehole. The portion of meteoric water is generally 10% greater and the penetration depth is 100m deeper in comparison to 1993conditions.

- At the non-saline/saline interface at 1,050 m depth down to 1,450 m the water changes to a *Calcium-Chloride* type of brine water. The portion of brine water at a depth of 1,050–1,450 m is greater in comparison to 1993 conditions. Less glacial water is obtained which is also indicated by higher $\delta^{18}O$ values compared with the values from 1993. At a depth of around 1,200 m $\delta^{18}O$, $\delta^2H$, $\delta^{87}Sr$ and $^{14}C$ values deviate and it is difficult to conclusively provide an answer to this. There are no tracers of Glacial water or a clear deviation from the MWL in the brine component. The bacterial content is high and the chemical variation and isotopical variation is also relatively high. The reason may be ongoing mixing between a meteoric and brine type of water.

The reasons for the relative large disturbances between the 1993 and 1997 sampling campaigns have been evaluated as: changes in the regional flow pattern due to tunnel construction; natural flow conditions which have changed the groundwater composition and; the open hole which acts like a "superconductor" making water mix along the borehole creating new water compositions. The last explanation seems to be the most plausible since the three-component mixture consisting of meteoric, glacial and brine water has been replaced by a two component mixture consisting of meteoric and brine water. Natural annual changes of 1m water column in an open borehole can cause the interface between non-saline and saline groundwater to fluctuate up to 100 m in the borehole. This pumping effect can change the water composition and especially the isotopical signature of the water. In 1997 the saline interface was 100 m deeper in the borehole compared with the situation in 1993. The results show the sensitivity of deep groundwaters which mix and change depending on the prevailing hydrogeological situation.

# Acknowledgements

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# Appendix 1

29

The analytical results from KLX02, the reference water composition and the results from the mixing calculations.

| | Date | Idcode | Secup | Seclow | Mean | SNO | Na (mg/l) | K (mg/l) | Ca (mg/l) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 970925 | KLX02 | 0 | 50 | 25 | 2406 | 61,0 | 4,1 | 29,2 |
| 2 | | KLX02 | 50 | 100 | 75 | 2408 | | | |
| 3 | 970925 | KLX02 | 100 | 150 | 125 | 2413 | 62,6 | 3,8 | 33,6 |
| 4 | 970925 | KLX02 | 200 | 250 | 225 | 2422 | 58,1 | 3,8 | 32,1 |
| 5 | 970925 | KLX02 | 300 | 350 | 325 | 2416 | 53,6 | 3,3 | 34,4 |
| 6 | 970925 | KLX02 | 400 | 450 | 425 | 2421 | 50,8 | 4,9 | 37,2 |
| 7 | 970925 | KLX02 | 500 | 550 | 525 | 2424 | 52,0 | 3,1 | 39,6 |
| 8 | 970925 | KLX02 | 600 | 650 | 625 | 2420 | 51,2 | 4,3 | 39,4 |
| 9 | | KLX02 | 650 | 700 | 675 | 2426 | | | |
| 10 | 970925 | KLX02 | 700 | 750 | 725 | 2427 | 51,6 | 3,1 | 40,1 |
| 11 | 970925 | KLX02 | 800 | 850 | 825 | 2419 | 50,4 | 4,8 | 39,1 |
| 12 | 970925 | KLX02 | 900 | 950 | 925 | 2418 | 50,3 | 3,2 | 38,1 |
| 13 | 970925 | KLX02 | 1000 | 1050 | 1025 | 2412 | 57,5 | 3,2 | 53,4 |
| 14 | 970925 | KLX02 | 1100 | 1150 | 1125 | 2411 | 2277,2 | 9,2 | 3929,0 |
| 15 | 970925 | KLX02 | 1200 | 1250 | 1225 | 2410 | 4285,5 | 18,3 | 7732,6 |
| 16 | 970925 | KLX02 | 1300 | 1350 | 1325 | 2409 | 6762,2 | 28,0 | 12550,0 |
| 17 | 970925 | KLX02 | 1330 | 1350 | 1340 | 2409 | | | |
| 18 | | KLX02 | 1350 | 1400 | 1375 | 2434 | | | |
| 19 | 970925 | KLX02 | 1400 | 1450 | 1425 | 2407 | 6940,8 | 25,7 | 12800,0 |
| 20 | 930803 | Brine Ref. Water | 1631 | 1681 | | | 8500,0 | 45,5 | 19300,0 |
| 21 | | Glacial Ref. Water | | | | | 0,2 | 0,4 | 0,2 |
| 22 | | Litorina Ref. Water | | | | | 3179,8 | 154,1 | 152,0 |
| 23 | | Sea Bed Ref. Water | 3,06 | 3,06 | | | 2144,0 | 91,8 | 103,0 |
| 24 | 871103 | Shallow Ref. Water | 45 | 100 | 72,5 | | 92,0 | 2,0 | 12,3 |

| | Mg (mg/l) | HCO3 (mg/l) | Cl (mg/l) | SO4_S (mg/l) | SO4 (mg/l) | Si (mg/l) | Li (mg/l) | Sr (mg/l) | Sr (USGS) | pH |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 5,85 | 0,0 | 150,32 | 2,04 | 6,12 | 1,53 | 0,02 | 0,32 | | 4,7 |
| 2 | | | | | | | | | | |
| 3 | 5,99 | 51,0 | 119,83 | 2,22 | 6,66 | 1,91 | 0,03 | 0,41 | | 6,0 |
| 4 | 6,54 | 139,0 | 65,94 | 2,73 | 8,19 | 3,12 | -0,01 | 0,33 | 0,28 | 7,3 |
| 5 | 6,91 | 182,0 | 46,09 | 3,51 | 10,53 | 4,77 | 0,02 | 0,29 | | 7,4 |
| 6 | 7,44 | 205,0 | 36,16 | 4,20 | 12,60 | 5,62 | 0,01 | 0,14 | 0,26 | 7,6 |
| 7 | 7,69 | 209,0 | 35,45 | 4,52 | 13,56 | 6,00 | 0,01 | 0,27 | | 7,4 |
| 8 | 7,63 | 212,0 | 35,45 | 4,50 | 13,50 | 6,00 | 0,03 | 0,26 | 0,26 | 7,6 |
| 9 | | | | | | | | | | |
| 10 | 7,84 | 212,0 | 35,45 | 4,62 | 13,86 | 6,12 | 0,03 | 0,31 | | 7,6 |
| 11 | 7,60 | 213,0 | 34,74 | 4,56 | 13,68 | 6,09 | 0,01 | 0,31 | 0,27 | 7,5 |
| 12 | 7,40 | 215,0 | 35,45 | 4,44 | 13,32 | 6,11 | 0,01 | 0,27 | 0,27 | 7,6 |
| 13 | 7,41 | 217,0 | 83,67 | 4,97 | 14,91 | 6,45 | 0,01 | 0,54 | 0,43 | 7,9 |
| 14 | 4,39 | 97,0 | 10423,18 | 163,11 | 489,33 | 4,50 | 1,42 | 74,11 | 92,7 | 7,1 |
| 15 | 2,43 | 47,0 | 19977,77 | 251,78 | 755,34 | 2,65 | 2,48 | 146,88 | 142,57 | 7,0 |
| 16 | 2,01 | 38,0 | 32994,93 | 318,18 | 954,54 | 2,88 | 4,08 | 242,36 | | 6,8 |
| 17 | | | | | | | | | 229,54 | |
| 18 | | | | | | | | | | |
| 19 | 2,07 | 32,0 | 34442,59 | 226,38 | 679,14 | 3,00 | 4,38 | 251,03 | 257,52 | |
| 20 | 2,12 | 14,1 | 47200,00 | | 906,00 | | | | | |
| 21 | 0,10 | 0,1 | 0,50 | | 0,50 | | | | | |
| 22 | 379,63 | 146,0 | 6100,00 | | 527,26 | | | | | |
| 23 | 258,00 | 793,0 | 3383,00 | | 53,10 | | | | | |
| 24 | 2,30 | 249,0 | 12,10 | | 23,50 | | | | | |

| | 2H (SMOW) | 3H 97#A (TU) | 3H 97#B (TU) | 18O (SMOW) | 13-C | 14-C Age | 14-C pmC | 87Sr/86Sr | d 87-Sr |
|---|---|---|---|---|---|---|---|---|---|
| 1 | -76,5 | 38,0 | | -9,5 | | | | | |
| 2 | | | 16,8 | | | | | | |
| 3 | -77,4 | 23,7 | | -9,7 | | | | | |
| 4 | -77,0 | 25,4 | | -9,9 | -18,47 | 3255 | 66,3 | 0,7177 | 11,93 |
| 5 | -77,4 | 29,6 | | -10,0 | | | | | |
| 6 | -77,7 | 26,2 | | -10,0 | -18,15 | 2925 | 69,1 | 0,7177 | 12,04 |
| 7 | -77,8 | 26,2 | | -10,0 | | | | | |
| 8 | -78,1 | 32,1 | | -10,0 | -18,44 | 2950 | 68,9 | 0,7177 | 12,00 |
| 9 | | | 16,2 | | | | | | |
| 10 | -81,2 | 32,1 | | -10,1 | | | | | |
| 11 | -79,3 | 32,1 | | -10,0 | -18,38 | 2870 | 69,6 | 0,7178 | 12,06 |
| 12 | -82,2 | 27,0 | | -10,0 | -18,28 | 2875 | 69,5 | 0,7177 | 12,00 |
| 13 | -79,3 | 27,9 | | -10,0 | -19,29 | 2925 | 69,1 | 0,7176 | 11,84 |
| 14 | -76,2 | 29,6 | | -9,5 | -20,16 | 4655 | 55,7 | 0,7174 | 11,55 |
| 15 | -66,0 | 25,4 | | -8,2 | -20,02 | 8730 | 33,5 | 0,7173 | 11,39 |
| 16 | -63,4 | 18,6 | | -9,1 | -21,49 | 1470 | 82,8 | | |
| 17 | | | | | | | | 0,7174 | 11,56 |
| 18 | | | <0.8 | | | | | | |
| 19 | -62,8 | 24,5 | | -9,3 | -22,33 | 2325 | 74,4 | 0,7176 | 11,80 |
| 20 | -44,9 | 4,2 | | -8,9 | | | | | |
| 21 | -158,0 | 0,0 | | -21,0 | | | | | |
| 22 | -35,0 | 0,0 | | -5,0 | | | | | |
| 23 | -61,0 | 0,0 | | -7,0 | | | | | |
| 24 | -77,0 | 17,0 | | -10,6 | | | | | |

| | 34-S | Total count microbes | Glacial | Brine | Litorina | Sea Bed | Shallow |
|---|---|---|---|---|---|---|---|
| 1 | | | 7,9% | 1,9% | 1,9% | 1,9% | 86,5% |
| 2 | | (5.23+-2.55)*105 | | | | | |
| 3 | | | 6,3% | 1,4% | 1,4% | 1,4% | 89,3% |
| 4 | | (3.59+-0.87)*105 | 1,9% | 0,8% | 0,8% | 0,8% | 95,8% |
| 5 | | | 0,4% | 0,4% | 0,4% | 0,8% | 98,0% |
| 6 | 21,5 | (2.34+-0.39)*105 | 0,2% | 0,2% | 0,2% | 2,2% | 97,2% |
| 7 | | | 0,1% | 0,1% | 0,1% | 1,6% | 98,1% |
| 8 | 17,9 | (2.78+-0.49)*105 | 0,1% | 0,1% | 0,1% | 2,0% | 97,6% |
| 9 | | | | | | | |
| 10 | | | 0,7% | 0,2% | 0,2% | 0,2% | 98,7% |
| 11 | 16,8 | (2.87+-0.66)*105 | 0,2% | 0,2% | 0,2% | 1,7% | 97,8% |
| 12 | 14,8 | (2.41+-0.56)*105 | 0,6% | 0,1% | 0,1% | 0,1% | 99,0% |
| 13 | 11,5 | (2.35+-0.49)*105 | 0,1% | 0,1% | 0,1% | 1,1% | 98,5% |
| 14 | 10,0 | (4.44+-1.88)*105 | 41,5% | 19,0% | 13,2% | 13,2% | 13,2% |
| 15 | 10,0 | (4.06+-1.22)*105 | 27,4% | 42,8% | 9,9% | 9,9% | 9,9% |
| 16 | 10,8 | (5.91+-1.98)*105 | 17,7% | 71,8% | 3,5% | 3,5% | 3,5% |
| 17 | | | | | | | |
| 18 | | | | | | | |
| 19 | 10,8 | (9.04+-3.33)*105 | 19,0% | 69,5% | 3,8% | 3,8% | 3,8% |
| 20 | | | | | | | |
| 21 | | | | | | | |
| 22 | | | | | | | |
| 23 | | | | | | | |
| 24 | | | | | | | |