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Oskarshamn site investigation

Laboratory data from the site investigation programme for the transport properties of the rock

Boreholes KSH01A, KSH02A and KLX02A

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Geosigma AB

February 2005

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Abstract

In this report the results gained from laboratory investigations of diffusivity and sorption characteristics at the time for data storage Simpevarp/Laxemar 1.2 is presented. These measurements are part of the discipline-specific programme "Transport Properties of the Rock" within the SKB site investigations. As diffusivity and sorption measurements are time-consuming and still in progress, there are only matrix porosity data from KSH01A, KSH02A and KLX02A that are presented in this document.

Sammanfattning

Denna rapport redovisar de resultat som erhållits från laboratoriemätningar av diffusion- och sorptionsegenskaper vid tidpunkten för datafrys Simpevarp/Laxemar 1.2. Mätning av dessa parametrar ingår som delar i programmet för ”Bergets transportegenskaper” inom SKB:s platsundersökningar. Då mätningar av genomdiffusion och batchsorption är tidskrävande och ännu pågår, redovisas i detta dokument endast resultat av matrisporositets mätningar för KSH01A, KSH02A och KLX02A.

Contents

1 Introduction

This document reports data gained by the laboratory investigations of diffusivity and sorption characteristics within the discipline-specific programme "Transport Properties of the Rock" which is one of the activities performed within the site investigation at Oskarshamn. The work was carried out during the period of November 2003 to October 2004, in accordance with activity plan AP PS 400-03-041 and AP PS 400-03-093.

The rock samples for the laboratory measurements were taken from borehole KSH01A, KSH02A and KLX02A by Johan Byegård, Eva Gustavsson and Henrik Widestrand, Geosigma AB.

Samples were taken at every 20 meters of the rock core and are therefore representing the heterogeneity of bedrocks in the Simpevarp and the Laxemar area, which mainly consists of Ävrögranite, quartsmonzodiorite and dioritoid.

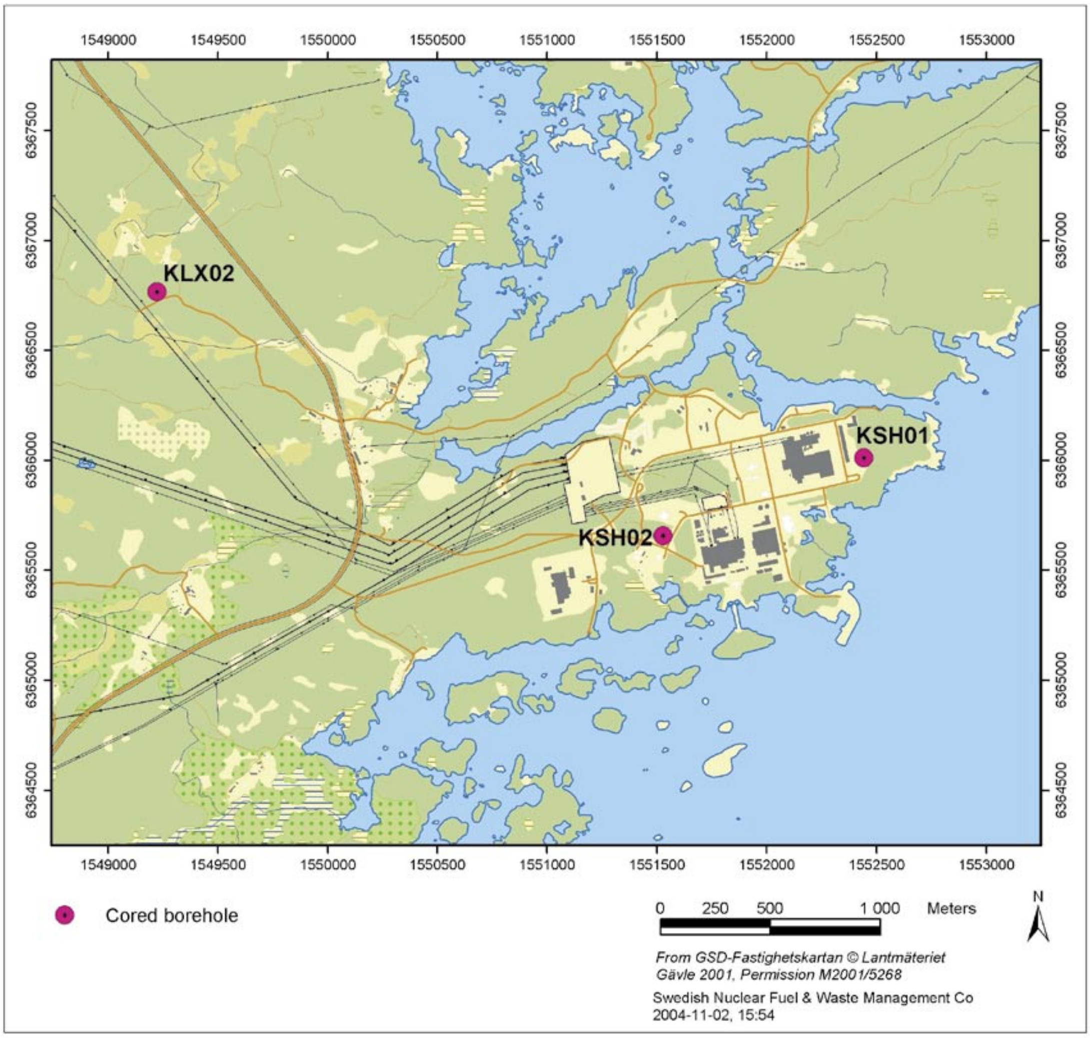

Figure 1-1. *Map of boreholes KSH01A, KSH02A and KLX02A.*

2 Objective and scope

The purpose of this work is to report data from the laboratory investigations of Transport Properties of the Rock, which are available for data storage Simpevarp/Laxemar 1.2.

Laboratory measurements on rock samples and drill cores provide direct information on the retardation properties of the rock matrix and the fracture materials. The parameters that are determined are the matrix porosity, porosity distribution and diffusivity of the rock materials, and the sorption coefficients for a number of combinations of rock materials, radionuclides and groundwater compositions. The measurements are performed on rock cores or crushed rock from several different parts of the candidate rock volume. Major rock types, minor rock types, different fracture types and fracture zones from the Simpevarp area and the Laxemar area are represented in the total sample collection.

About 350 rock samples are included in the laboratory investigations, but as sorption and diffusivity measurements are time-consuming and still on-going experiments, there are only matrix porosity data from KSH01, KSH02 and KLX02 that are reported in this document. A small number of preliminary data from diffusivity measurements can be presented, but no results from sorption measurements are delivered. Electrical resistivity data, for calculating effective diffusivity, are presented in two separate reports /Löfgren and Neretnieks, 2004; Löfgren, 2001/. Laboratory measurements of ^{14}C-PMMA (porosity) and He-gas diffusion are not performed at this moment.

Brief descriptions of the laboratory methods, relevant for the data presentation in this document, are given in Chapter 3. Strategy for the use of laboratory methods can be found in a separate report, SKB R-03-20 /Byegård et al. 2003/. Matrix porosity data tables delivered to SICADA are presented in Appendix 1.

As the laboratory work is in progress, there are no analyses or interpretations included in this report. A final report will be produced in during autumn 2005.

3 Laboratory measurements

3.1 General

Sample preparation and water porosity measurements were done at Swedish National Testing and Research Institute (SP). Through-diffusion measurements are performed at Chalmers University of Technology (CTH). Controlling documents are SKB MD 540.001 and SKB MD 540.002 (SKB internal documents).

3.2 Matrix porosity

Information of the porosity is produced in the laboratory measurements as supporting data in the diffusion experiments. The porosity of the rock matrix can be determined in several different ways by means of laboratory measurements on slices of rock cores. The most common method and the method used in this investigation, is the water saturation technique which is determined according to standard methods.

3.3 Through-diffusion measurements

Matrix diffusivity measurements are carried out by measuring how quickly an added substance diffuses through a piece of a drill core, so-called through-diffusion measurements /Ohlsson and Neretnieks, 1995; Byegård et al. 1998/. The measurement is normally performed on a 1–5 cm thick sawn-out slice of a drill core placed in a measurement cell. One side of the core piece is in contact with a synthetic groundwater and the other is in contact with a synthetic groundwater tagged with the radionuclide to be studied. Samples are then taken on the untagged side, and the effective diffusion coefficient De for the rock matrix can be calculated based on the concentration increase on the untagged side.

More detailed description of through-diffusion experiments can be found in SKB MD 540.001 (SKB internal document).

4 Results

4.1 Matrix porosity

203 rock samples were sent to Swedish National Testing and Research Institute (SP) for matrix porosity measurements. The length of the sample varies from 0.5 to 5 centimetres. Data gained from the laboratory measurements are presented in Appendix 1 (field note no Simpevarp 93, field note no Simpevarp 165, field note no Simpevarp 237). The uncertainty of a single reported porosity value is 0.09%, given with a coverage factor of 2.

4.2 Through diffusion, preliminary results

Through diffusion experiments on rock samples from KSH01 and KSH02 are in progress at Chalmers. In this report some preliminary results are being reported from experiments where sufficient number of data points has been collected. The data are presented as a scaled accumulated amount of tracer in the target cell C_r as a function of time. The effective diffusivity D_e and the rock capacity factor α were fitted to the experimental data using Equation 1:

$$C_r = \frac{D_e t}{l^2} - \frac{\alpha}{6} - \frac{2\alpha}{\pi^2}\sum_{n=1}^{\infty}\frac{(-1)^n}{n^2}\exp\left\{-\frac{D_e n^2 \pi^2 t}{l^2 \alpha}\right\}, \qquad (1)$$

where t is the experimental time after injection of tracer and l is the length of the rock sample.

The latter part of the experimental data was also fitted to a simplified linear form of Equation 1, i.e.

$$C_r = \frac{D_e t}{l^2} - \frac{\alpha}{6}. \qquad (2)$$

In Figure 4-1 and 4-2 examples of experimental through diffusion data are presented together with the result from successful model calculations using Equation 1.

The obtained effective diffusivities and the rock capacity factors for these and other preliminary evaluated data are tabulated in Table 4-1. At this stage no error estimates of the fitted parameters D_e and α are being reported. Furthermore, the discussion of the results and an evaluation of the method and the diffusion model are left for the future when the final results will be reported.

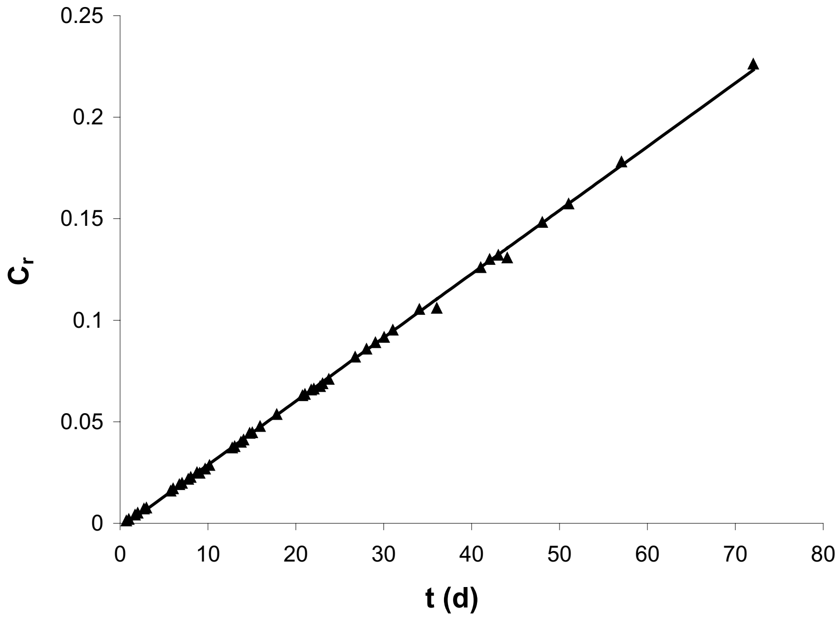

Figure 4-1. *Preliminary data of measured C_r values (▲) as a function of time from a HTO through diffusion experiment on a 0.5 cm thick sample from KSH01A (KSH01A-891.77–891.78). The solid line represents calculated C_r values using Eq 1 with D_e and α optimized for a fit to the experimental data.*

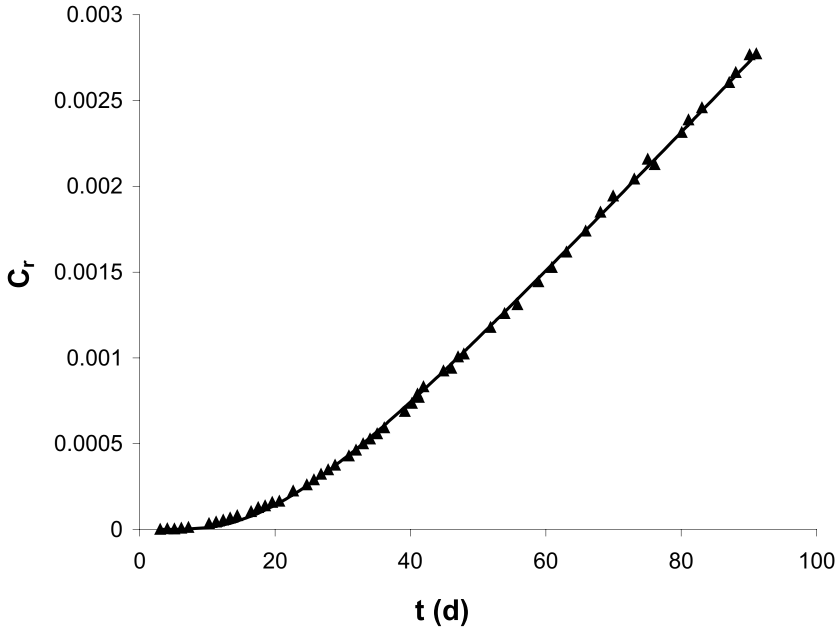

Figure 4-2. *Preliminary data of measured C_r values (▲) as a function of time from a HTO through diffusion experiment on a 1.0 cm thick sample from KSH02A (KSH02A-474.47–474.48). The solid line represents calculated C_r values using Eq 1 with D_e and α optimized for a fit to the experimental data.*

Table 4-1. Preliminary results from trough diffusion experiments of rock samples from KSH01A and KSH02A. D_e, the effective diffusivity and α, the rock capacity factor were obtained from least square fits of experimental data to Eq 1 and Eq 2 (the linear form).

SKB ID	Sample thickness (mm)	D_e from Eq 1 (m^2/s)	D_e from Eq 2 (m^2/s)	α from Eq 1	α from Eq 2
KSH01A-891.66–891.67	5	1.26E–12	1.27E–12	1.31E–02	1.51E–02
KSH01A-891.77–891.78	5	1.01E–12	1.01E–12	1.52E–02	1.78E–02
KSH01A-891.88–891.89	5	1.11E–12	1.11E–12	1.00E–02	1.06E–02
KSH01A-39.58–39.63	30	1.94E–15	1.97E–15	2.37E–05	2.48E–05
KSH01A-140.67–140.72	30	2.08E–15	2.12E–15	3.17E–05	3.30E–05
KSH01A-219.35–219.40	30	2.15E–15	2.05E–15	3.39E–05	2.83E–05
KSH01A-940.80–940.85	30	4.28E–13	4.16E–13	8.85E–03	7.98E–03
KSH02A-480.00–480.05	30	2.45E–15	2.45E–15	4.70E–05	4.56E–05
KSH02A-660.08–660.13	28	1.99E–15	2.08E–15	3.18E–05	3.59E–05
KSH02A-474.46–474.47	5	7.40E–14	7.38E–14	4.67E–03	4.57E–03
KSH02A-474.47–474.48	10	4.96E–14	4.91E–14	5.84E–03	5.56E–03
KSH02A-474.6–474.65	50	3.43E–15	3.42E–15	1.74E–05	1.71E–05
KSH02A-474.78–474.79	10	8.59E–13	8.82E–13	1.78E–02	2.31E–02

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Appendix A

Matrix porosity data measured by water saturation technique

Table A-1. KSH01A.

idcode	secup	seclow	rock_type	total_porosity
KSH01A	19.96	19.99	Quartzmonzodiorite	0.47
KSH01A	39.59	39.62	Quartzmonzodiorite	0.10
KSH01A	59.12	59.15	Quartzmonzodiorite	0.08
KSH01A	76.65	76.68	Quartzmonzodiorite	0.12
KSH01A	99.71	99.74	Quartzmonzodiorite	0.08
KSH01A	121.41	121.44	Quartzmonzodiorite	0.08
KSH01A	140.68	140.71	Quartzmonzodiorite	0.34
KSH01A	160.72	160.75	Quartzmonzodiorite	0.10
KSH01A	181.47	181.50	Quartzmonzodiorite	0.13
KSH01A	200.11	200.14	Quartzmonzodiorite	0.08
KSH01A	219.36	219.39	Dioritoid	0.08
KSH01A	222.72	222.73	Dioritoid	0.15
KSH01A	222.73	222.76	Dioritoid	0.08
KSH01A	239.96	239.99	Dioritoid	0.19
KSH01A	261.08	261.11	Quartzmonzodiorite	1.59
KSH01A	280.23	280.26	Quartzmonzodiorite	0.45
KSH01A	295.41	295.44	Quartzmonzodiorite	0.13
KSH01A	317.78	317.81	Quartzmonzodiorite	0.08
KSH01A	340.88	340.91	Quartzmonzodiorite	0.08
KSH01A	362.55	362.58	Granite	0.12
KSH01A	378.98	379.01	Dioritoid	0.08
KSH01A	398.75	398.78	Dioritoid	0.13
KSH01A	420.78	420.81	Dioritoid	0.41
KSH01A	440.23	440.26	Dioritoid	0.75
KSH01A	460.00	460.05	Dioritoid	0.20
KSH01A	478.20	478.25	Dioritoid	0.07
KSH01A	500.30	500.35	Dioritoid	0.24
KSH01A	520.75	520.80	Dioritoid	0.15
KSH01A	539.00	539.05	Dioritoid	0.10
KSH01A	559.90	559.95	Dioritoid	0.07
KSH01A	580.87	580.92	Dioritoid	0.13
KSH01A	598.65	598.70	Dioritoid	0.13
KSH01A	620.22	620.27	Dioritoid	0.41
KSH01A	640.55	640.60	Ävrögranite	0.17
KSH01A	661.06	661.11	Ävrögranite	0.12
KSH01A	680.20	680.25	Granite	0.05
KSH01A	699.00	699.05	Granite	0.02
KSH01A	720.24	720.29	Granite	0.20
KSH01A	760.75	760.80	Quartzmonzodiorite	0.12
KSH01A	779.19	779.24	Ävrögranite	0.19

idcode	secup	seclow	rock_type	total_porosity
KSH01A	800.40	800.45	Dioritoid	0.58
KSH01A	820.08	820.13	Ävrögranite	0.47
KSH01A	840.70	840.75	Ävrögranite	0.35
KSH01A	859.15	859.20	Ävrögranite	0.30
KSH01A	880.50	880.55	Ävrögranite	0.39
KSH01A	891.66	891.67	Ävrögranite	0.58
KSH01A	891.67	891.68	Ävrögranite	0.54
KSH01A	891.69	891.72	Ävrögranite	0.45
KSH01A	891.72	891.77	Ävrögranite	0.43
KSH01A	891.77	891.78	Ävrögranite	0.48
KSH01A	891.78	891.79	Ävrögranite	0.60
KSH01A	891.80	891.83	Ävrögranite	0.44
KSH01A	891.83	891.88	Ävrögranite	0.42
KSH01A	891.88	891.89	Ävrögranite	0.48
KSH01A	891.89	891.90	Ävrögranite	0.44
KSH01A	891.91	891.94	Ävrögranite	0.46
KSH01A	898.60	898.65	Ävrögranite	0.35
KSH01A	919.65	919.70	Ävrögranite	0.24
KSH01A	940.80	940.85	Ävrögranite	0.32
KSH01A	960.77	960.82	Quartzmonzodiorite	0.35
KSH01A	980.40	980.45	Quartzmonzodiorite	0.25
KSH01A	981.43	981.46	Quartzmonzodiorite	0.29
KSH01A	981.46	981.49	Quartzmonzodiorite	0.29
KSH01A	981.50	981.53	Quartzmonzodiorite	0.27
KSH01A	999.45	999.50	Quartzmonzodiorite	0.22

Table A-2. KSH02A.

idcode	secup	seclow	rock_type	total_porosity
KSH02A	19.96	19.99	Dioritoid	0.05
KSH02A	39.96	39.99	Dioritoid	0.07
KSH02A	60.18	60.21	Dioritoid	0.20
KSH02A	80.01	80.04	Dioritoid	0.12
KSH02A	99.91	99.94	Dioritoid	0.53
KSH02A	119.96	119.99	Dioritoid	0.10
KSH02A	140.16	140.19	Dioritoid	0.08
KSH02A	148.09	148.10	Dioritoid	0.38
KSH02A	148.11	148.12	Dioritoid	0.15
KSH02A	148.12	148.15	Dioritoid	0.07
KSH02A	148.16	148.21	Dioritoid	0.06
KSH02A	148.21	148.22	Dioritoid	0.00
KSH02A	148.23	148.24	Dioritoid	0.05
KSH02A	148.24	148.27	Dioritoid	0.08
KSH02A	148.28	148.33	Dioritoid	0.02
KSH02A	148.34	148.35	Dioritoid	0.05
KSH02A	148.36	148.39	Dioritoid	0.05

idcode	secup	seclow	rock_type	total_porosity
KSH02A	148.39	148.44	Dioritoid	0.03
KSH02A	159.96	159.99	Dioritoid	0.20
KSH02A	179.96	179.99	Dioritoid	0.10
KSH02A	219.66	219.69	Dioritoid	0.12
KSH02A	239.96	239.99	Dioritoid	0.07
KSH02A	259.83	259.86	Dioritoid	0.05
KSH02A	280.01	280.04	Dioritoid	0.07
KSH02A	299.95	299.98	Dioritoid	0.34
KSH02A	339.94	339.97	Dioritoid	0.10
KSH02A	360.06	360.09	Dioritoid	0.68
KSH02A	419.96	419.99	Dioritoid	0.84
KSH02A	459.69	459.72	Dioritoid	0.27
KSH02A	474.46	474.47	Dioritoid	0.61
KSH02A	474.47	474.48	Dioritoid	0.40
KSH02A	474.56	474.59	Dioritoid	0.42
KSH02A	474.60	474.65	Dioritoid	0.10
KSH02A	474.65	474.66	Dioritoid	0.30
KSH02A	474.66	474.67	Dioritoid	0.20
KSH02A	474.68	474.71	Dioritoid	0.20
KSH02A	474.71	474.76	Dioritoid	0.31
KSH02A	474.77	474.78	Dioritoid	0.59
KSH02A	474.78	474.79	Dioritoid	0.47
KSH02A	474.80	474.83	Dioritoid	0.18
KSH02A	474.86	474.91	Dioritoid	0.42
KSH02A	480.01	480.04	Dioritoid	0.19
KSH02A	500.01	500.04	Dioritoid	1.33
KSH02A	539.86	539.89	Dioritoid	0.20
KSH02A	560.06	560.09	Quartzmonzodiorite	0.21
KSH02A	580.11	580.14	Quartzmonzodiorite	0.07
KSH02A	599.35	599.36	Granite	0.32
KSH02A	599.36	599.37	Granite	0.28
KSH02A	599.37	599.40	Granite	0.19
KSH02A	599.41	599.46	Granite	0.20
KSH02A	599.46	599.47	Granite	0.23
KSH02A	599.47	599.48	Granite	0.26
KSH02A	599.48	599.51	Granite	0.19
KSH02A	599.52	599.57	Granite	0.24
KSH02A	599.57	599.58	Granite	0.40
KSH02A	599.58	599.59	Granite	0.25
KSH02A	599.59	599.62	Granite	0.29
KSH02A	599.62	599.67	Granite	0.24
KSH02A	600.01	600.04	Granite	0.17
KSH02A	639.89	639.92	Granite	0.30
KSH02A	660.09	660.12	Dioritoid	0.09
KSH02A	680.16	680.19	Dioritoid	0.31
KSH02A	685.98	685.99	Quartzmonzodiorite	0.38

idcode	secup	seclow	rock_type	total_porosity
KSH02A	685.99	686.00	Quartzmonzodiorite	0.25
KSH02A	686.00	686.03	Quartzmonzodiorite	0.10
KSH02A	686.04	686.09	Quartzmonzodiorite	0.08
KSH02A	686.09	686.10	Quartzmonzodiorite	0.19
KSH02A	686.10	686.11	Quartzmonzodiorite	0.25
KSH02A	686.11	686.14	Quartzmonzodiorite	0.12
KSH02A	686.15	686.20	Quartzmonzodiorite	0.04
KSH02A	686.20	686.21	Quartzmonzodiorite	0.10
KSH02A	686.21	686.22	Quartzmonzodiorite	0.05
KSH02A	686.22	686.25	Quartzmonzodiorite	0.05
KSH02A	686.26	686.31	Quartzmonzodiorite	0.05
KSH02A	700.01	700.04	Granite	0.20
KSH02A	720.01	720.04	Dioritoid	0.10
KSH02A	740.01	740.04	Dioritoid	1.15
KSH02A	760.17	760.20	Dioritoid	0.14
KSH02A	779.82	779.85	Dioritoid	0.25
KSH02A	819.91	819.94	Dioritoid	0.42
KSH02A	840.01	840.04	Dioritoid	0.02
KSH02A	859.96	859.99	Dioritoid	0.21
KSH02A	880.01	880.04	Dioritoid	0.15
KSH02A	900.01	900.04	Dioritoid	0.17
KSH02A	920.01	920.04	Dioritoid	0.13
KSH02A	940.01	940.04	Dioritoid	0.13
KSH02A	959.96	959.99	Dioritoid/pegmatite	0.12
KSH02A	979.96	979.99	Dioritoid/pegmatite	0.20

Table A-3. KLX02A.

idcode	secup	seclow	rock_type	total_porosity
KLX02A	201.89	201.92	Ävrögranite	0.30
KLX02A	216.69	216.70	Ävrögranite	0.35
KLX02A	216.70	216.71	Ävrögranite	0.23
KLX02A	216.71	216.74	Ävrögranite	0.13
KLX02A	216.74	216.79	Ävrögranite	0.15
KLX02A	216.79	216.80	Ävrögranite	0.44
KLX02A	216.80	216.81	Ävrögranite	0.28
KLX02A	216.81	216.84	Ävrögranite	0.19
KLX02A	216.84	216.89	Ävrögranite	0.16
KLX02A	216.89	216.90	Ävrögranite	0.43
KLX02A	216.91	216.92	Ävrögranite	0.33
KLX02A	216.92	216.95	Ävrögranite	0.21
KLX02A	216.95	217.00	Ävrögranite	0.19
KLX02A	220.11	220.14	Ävrögranite	0.36
KLX02A	235.02	235.05	Ävrögranite	0.36
KLX02A	235.05	235.08	Ävrögranite	0.39
KLX02A	235.08	235.11	Ävrögranite	0.39

idcode	secup	seclow	rock_type	total_porosity
KLX02A	239.88	239.91	Ävrögranite	0.28
KLX02A	258.96	258.99	Ävrögranite	0.23
KLX02A	280.01	280.04	Ävrögranite	0.19
KLX02A	299.79	299.82	Ävrögranite	0.21
KLX02A	320.04	320.07	Ävrögranite	0.13
KLX02A	339.95	339.98	Ävrögranite	0.17
KLX02A	387.78	387.81	Diorite/Gabbro	0.21
KLX02A	420.02	420.05	Ävrögranite	0.25
KLX02A	440.21	440.24	Ävrögranite	0.15
KLX02A	459.69	459.72	Ävrögranite	0.38
KLX02A	480.02	480.05	Ävrögranite	0.40
KLX02A	499.95	499.98	Ävrögranite	0.25
KLX02A	519.63	519.66	Ävrögranite	0.21
KLX02A	540.03	540.06	Ävrögranite	0.29
KLX02A	560.72	560.75	Ävrögranite	0.43
KLX02A	579.77	579.80	Ävrögranite	0.30
KLX02A	600.19	600.22	Ävrögranite	0.27
KLX02A	620.79	620.82	Ävrögranite	0.34
KLX02A	639.93	639.96	Ävrögranite	0.42
KLX02A	680.83	680.86	Ävrögranite	0.27
KLX02A	682.34	682.37	Dioritoid	0.06
KLX02A	682.37	682.40	Dioritoid	0.06
KLX02A	682.40	682.43	Dioritoid	0.12
KLX02A	700.15	700.18	Dioritoid	1.49
KLX02A	839.39	839.42	Diorite/Gabbro	0.15
KLX02A	859.70	859.73	Ävrögranite	0.42
KLX02A	880.95	880.98	Diorite/Gabbro	1.12
KLX02A	898.04	898.07	Diorite/Gabbro	0.04
KLX02A	921.15	921.18	Diorite/Gabbro	0.07
KLX02A	938.42	938.45	Ävrögranite	0.39
KLX02A	959.56	959.59	Ävrögranite	0.32
KLX02A	979.92	979.95	Ävrögranite	0.41
KLX02A	998.20	998.23	Ävrögranite	0.25