

Forsmark site investigation

Drill hole KFM04A

Determination of porosity by water saturation and density by buoyancy technique

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June 2004

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Keywords: AP PF 400-04-59, Field note no Forsmark 303, Rock mechanics, Petro physics, Density, Porosity.

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

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Abstract

The density and porosity has been determined on 15 specimens (each divided in two pieces) from drill hole KFM04A, Forsmark, Sweden. The specimens were collected from three levels of the drill hole: at c 110, 580 and 816 m. The investigated rock types are mapped as granodiorite and fine-grained granite (< 200 m) respectively medium-grained granite (580 and 810 m). The results for dry density varied between 2,650–2,720 kg/m³, for wet density between 2,650–2,720 kg/m³ and for porosity between 0.1 and 0.4%.

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1 Introduction

This report presents laboratory determinations of porosity and density of drill core samples from Forsmark, Sweden. The test program, which is part of the currently performed site investigations for a deep repository, was conducted in compliance with activity plan AP PF 400-04-59 (SKB internal controlling document).

The specimens were sampled from the drill core of borehole KFM04A in the Forsmark area by Thomas Janson, Tyréns, and Urban Åkesson, Swedish National Testing and Research Institute (SP) on January 20th 2004. Specimens were taken from three levels of the rock core: level 1 between 108 and 110 m, level 2 between 580 and 581 m and level 3 between 816 and 817 m. The samples were selected based on the preliminary core logging, and with the strategy to primarily investigate the properties of the dominant rock types. The rock cores were transported by SP from Forsmark and arrived at SP on May 3rd 2003. The testing commenced in May 2004 and ended in June 2004.

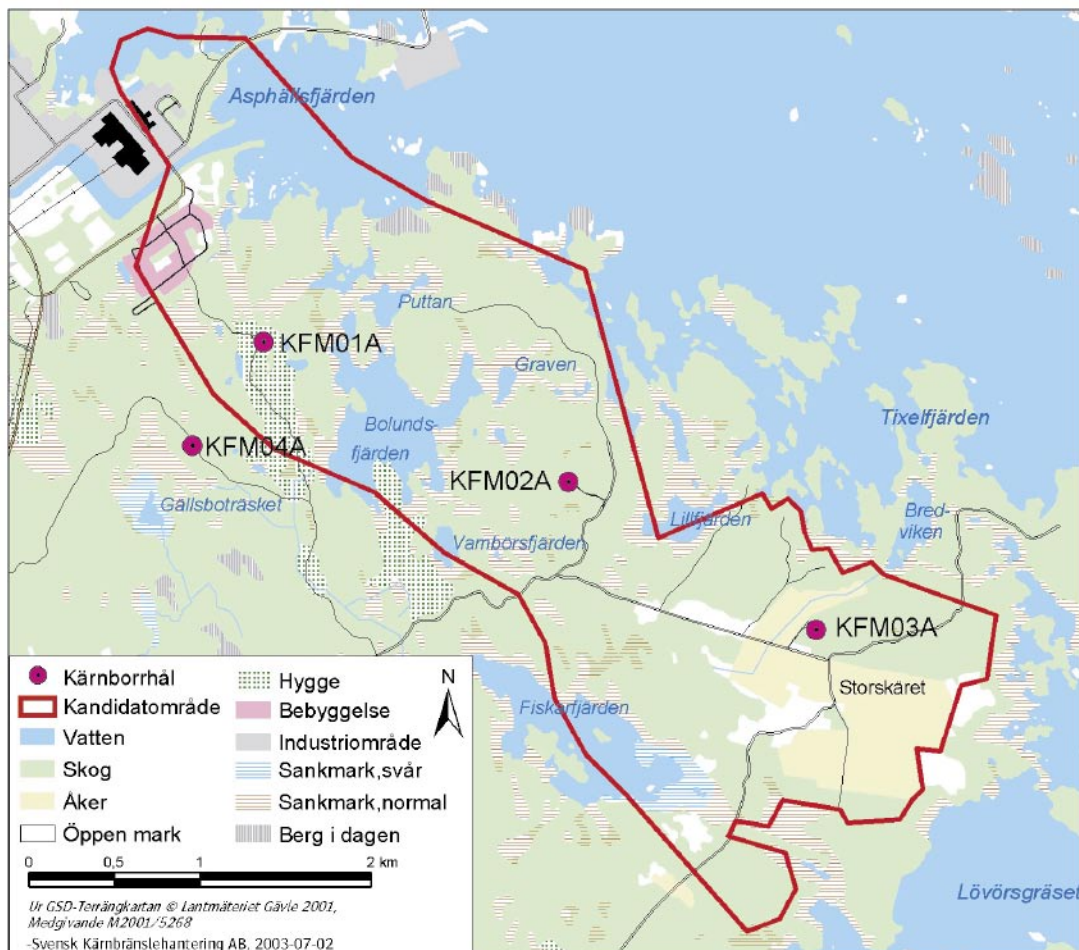


Figure 1-1. Location of drill hole KFM04A at the Forsmark site.

2 Objective and scope

The purpose of the testing is to determine the density and porosity of intact rock core samples. The parameters are used in the rock mechanics and thermal site descriptive model, which will be established for the candidate area selected for site investigations at Forsmark.

The samples were collected from the drill core of borehole KFM04A at Forsmark, which is a telescopic borehole of SKB-chemical type, inclined 60° from the horizontal plane and with a borehole length of c 1,000 m. The samples in this report are taken at three different levels.

3 Equipment

The following equipment was used for the analyses:

- Thermometer (inv no 100877) for measurements of water temperature. Calibrated 2004-03-11. Uncertainty of measurement $\pm 0.4^{\circ}\text{C}$.
- Scale (inv no 102291) for weight measurements. Calibrated 2003-08-12. Uncertainty of measurement ± 0.2 g.
- Heating chamber (inv no 102289) for drying the specimens. Calibrated 2003-08-22. Uncertainty of measurement $\pm 5^{\circ}\text{C}$.
- A covered plastic box filled with water for water saturation of the samples.
- A desiccator for cooling samples.

Uncertainty of method as expanded uncertainty with covering factor 2 (95% confidence interval):

Density ± 4 kg/m³

Porosity $\pm 0.09\%$

Water absorption $\pm 0.05\%$

4 Execution

Determination of the porosity and density was made in accordance with SKB's method description SKB MD 160.002e, version 1.9 (SKB internal controlling document). This includes determination of density in accordance with ISRM 1979, volume 16, number 2, water saturation by EN 13755 and in compliance with Activity plan AP PF 400-04-59 (internal controlling document of SKB). The department of Building Technology and Mechanics (BM) at SP performed the test.

4.1 Description of the samples

Specimens were sampled from 3 levels in drill hole KFM04A. Core drilling of the borehole started at a borehole length of c 100 m. Sampling level 1 ranges between 108 and 110 m, level 2 between 580 and 581 m and level 3 between 816 and 817 m. Table 4-1 presents the rock type and identification marks of the specimens.

Table 4-1. Rock type and identification marks (rock-type classification according to Boremap).

Identification	Sampling depth (Seclow)	Rock type
KFM04A-90V-1	108.87	granodiorite and fine-grained granite
KFM04A-90V-2	108.93	granodiorite and fine-grained granite
KFM04A-90V-3	108.99	granodiorite and fine-grained granite
KFM04A-90V-4	109.05	granodiorite and fine-grained granite
KFM04A-90V-5	109.76	granodiorite and fine-grained granite
KFM04A-90V-7	580.75	medium-grained granite
KFM04A-90V-8	580.81	medium-grained granite
KFM04A-90V-9	580.87	medium-grained granite
KFM04A-90V-10	580.93	medium-grained granite
KFM04A-90V-11	581.00	medium-grained granite
KFM04A-90V-13	816.29	medium-grained granite
KFM04A-90V-14	816.35	medium-grained granite
KFM04A-90V-15	816.40	medium-grained granite
KFM04A-90V-16	816.46	medium-grained granite
KFM04A-90V-17	816.70	medium-grained granite

4.2 Testing

The execution procedure followed the prescription in SKB MD 160.002, version 1.9 (SKB internal controlling document) and the activities described in Table 4-2 were performed:

Table 4-2. The sequence for activities applied for execution of the commission.

Activity No	Activity
1	The specimens were cut according to the marks on the rock cores. Every specimen was cut in two pieces, marked A and B and about 25 mm thick each. The same specimens were used to test the thermal properties heat conductivity and heat capacity with the TPS method.
2	The specimens were photographed in JPEG-format.
3	The specimens were water saturated in normal air pressure for at least seven days. The temperature of the water used for water saturation was 21.1°C and the density of the water was 998 kg/m ³ .
4	The specimens were weighed submerged in tapwater (see Appendix 3)
5	The specimens were surface dried with a towel and weighed.
6	The water saturated density was determined (see Appendix 3)
7	The samples were sent from SP Building and Mechanics to SP Fire Technology for measurement of thermal properties.
8	The samples were sent back from SP Fire Technology to SP Building and Mechanics.
9	The specimens were dried in a heating chamber at 105°C during one week after water saturation.
10	The specimens were transported to a desiccator for cooling.
11	The dry density and porosity were determined (see Appendix 3).

The samples were tested at two occasions. Level 1 was measured during the period May 13th to June 10th 2004 and levels 2 and 3 between June 14th to June 28th 2004.

4.3 Nonconformities

None.

5 Results

Data resulting from this activity are stored in the SKB database SICADA under field note no Forsmark 303.

Protocols, calculations and photos are presented in Appendix 1–3.

A summary of the results of the porosity and density determinations is presented in Tables 5-1, 5-2 and 5-3 as well as in Figures 5-1, 5-2 and 5-3 below.

Table 5-1. Summary of the results of porosity, dry density and wet density determinations of the specimens from level 1, secrow 108 to 110 m. The result for each specimen is a mean value of subsample A and B.

Specimen	Sampling depth, according to the marks on the drill-core boxes (Secrow) (m)	Porosity (%)	Dry density (kg/m ³)	Wet density (kg/m ³)
KFM04A-90V-1	108.87	0.1	2,720	2,720
KFM04A-90V-2	108.93	0.1	2,720	2,720
KFM04A-90V-3	108.99	0.1	2,720	2,720
KFM04A-90V-4	109.05	0.1	2,720	2,720
KFM04A-90V-5	109.76	0.1	2,710	2,710
Mean value		0.1	2,720	2,720
Standard deviation		0.01	5	5

Table 5-2. Summary of the results of porosity, dry density and wet density determinations of the specimens from level 2, secrow 580 to 581 m. The result for each specimen is a mean value of subsample A and B.

Specimen	Sampling depth, according to the marks on the drill-core boxes (Secrow) (m)	Porosity (%)	Dry density (kg/m ³)	Wet density (kg/m ³)
KFM04A-90V-7	580.75	0.4	2,650	2,650
KFM04A-90V-8	580.81	0.3	2,650	2,650
KFM04A-90V-9	580.87	0.3	2,650	2,660
KFM04A-90V-10	580.93	0.3	2,650	2,660
KFM04A-90V-11	581.00	0.3	2,660	2,660
Mean value		0.3	2,650	2,650
Standard deviation		0.03	4	4

Table 5-3. Summary of the results of porosity, dry density and wet density determinations of the specimens from level 3, seclow 816 m to 817 m. The result for each specimen is a mean value of subsample A and B.

Specimen	Sampling depth, according to the marks on the drill-core boxes (Seclow) (m)	Porosity (%)	Dry density (kg/m ³)	Wet density (kg/m ³)
KFM04A-90V-13	816.29	0.3	2,650	2,660
KFM04A-90V-14	816.35	0.4	2,660	2,660
KFM04A-90V-15	816.40	0.3	2,650	2,660
KFM04A-90V-16	816.46	0.3	2,650	2,660
KFM04A-90V-17	816.70	0.3	2,660	2,660
Mean value		0.3	2,650	2,660
Standard deviation		0.04	2	2

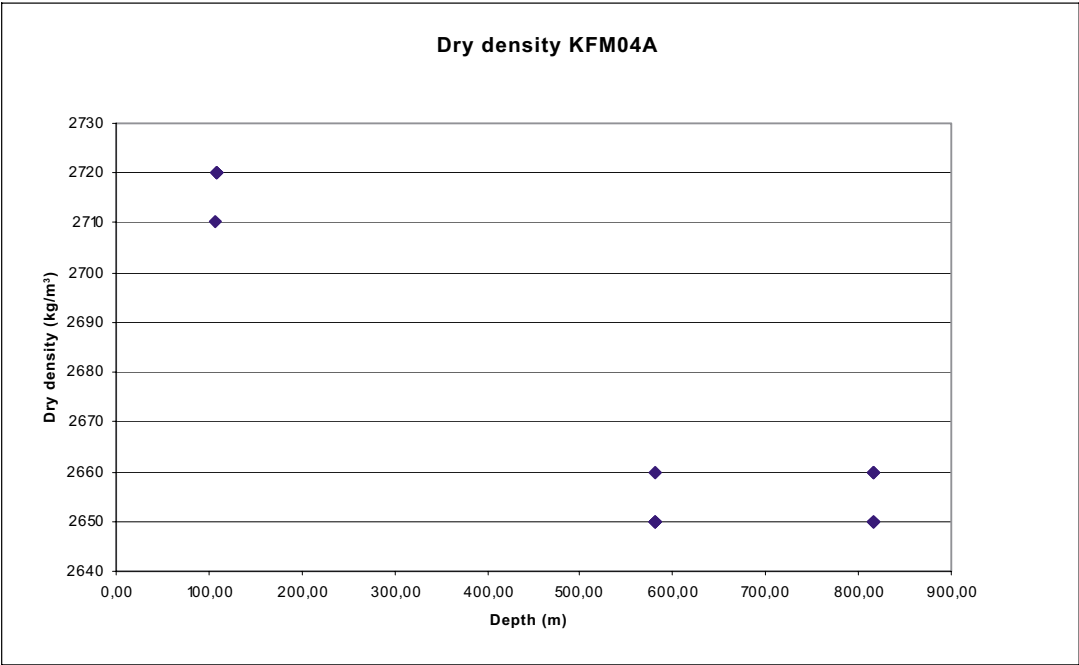


Figure 5-1. Density (dry) versus sampling depth.

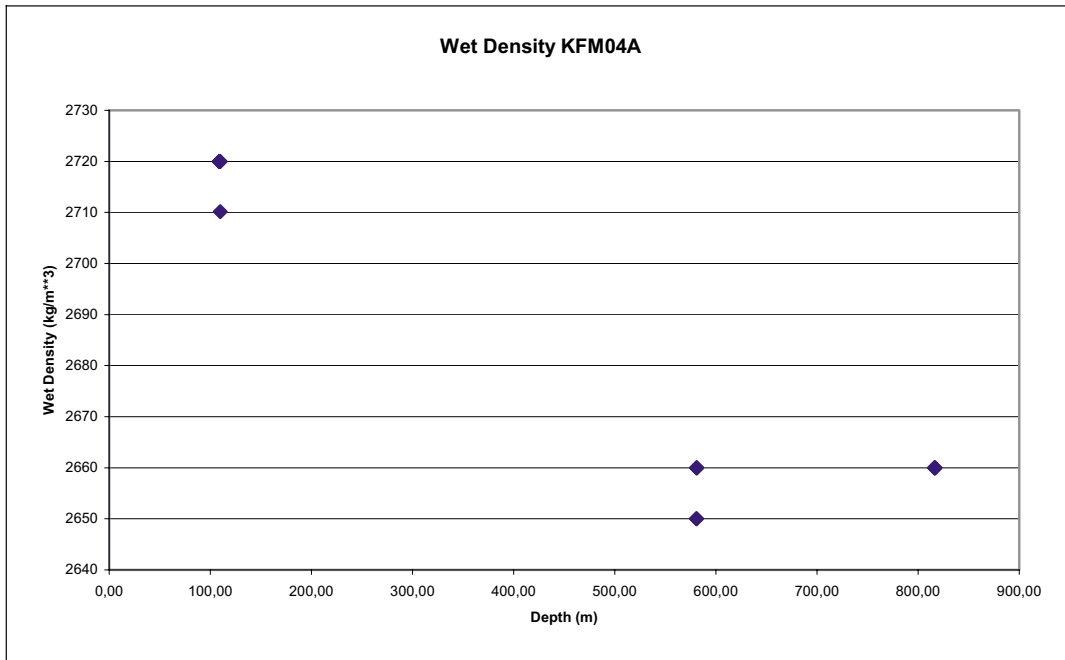


Figure 5-2. Density (wet) versus sampling depth.

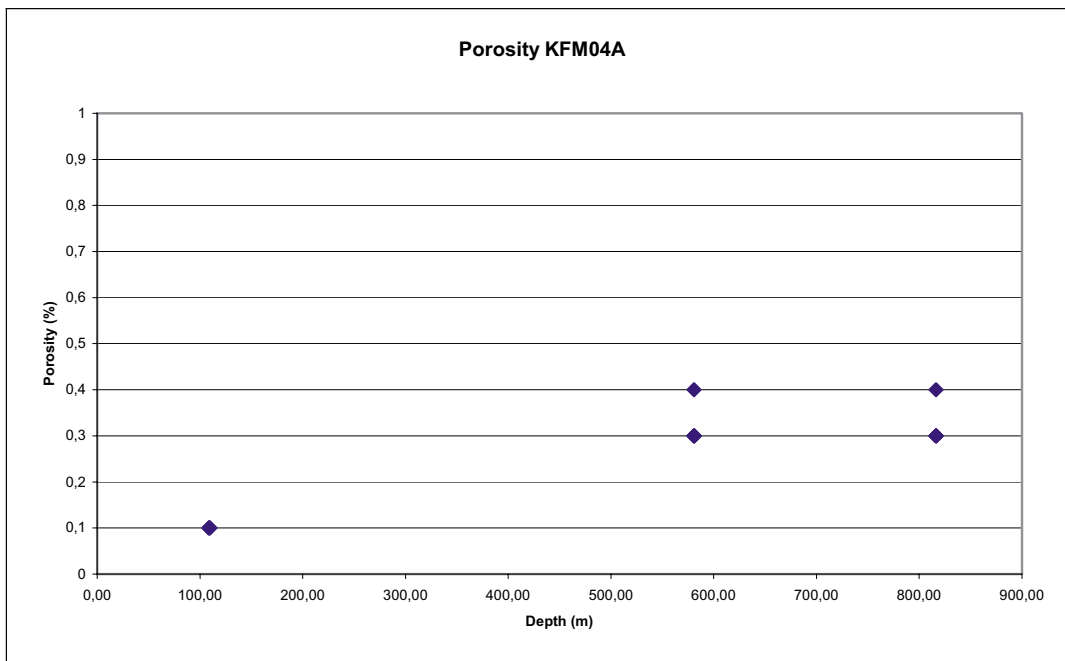


Figure 5-3. Porosity versus sampling depth.

References




ISRM, 1979. Volume 16, Number 2.

EN 13755. Natural stone test methods – Determination of water absorption at atmospheric pressure.

Results and pictures

KFM04A: Density and porosity

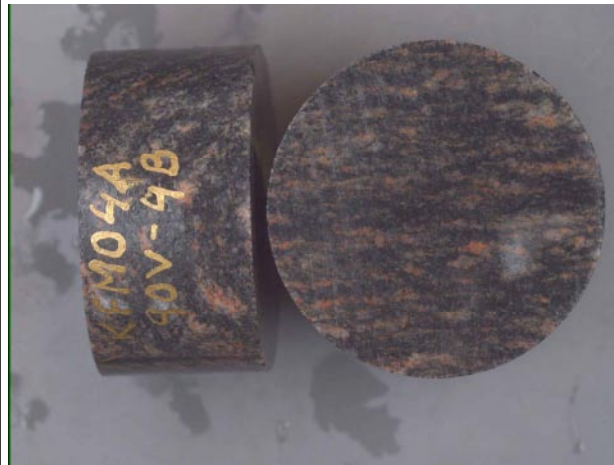
Table 1: Level 1 108–110 m, specimen KFM04A-090V-1 to KFM04A-090V-5

<p>KFM04A-90V-1 (108.87)</p> <p>The dry density for specimen KFM04A-90V-1A was measured to be $2,720 \text{ kg/m}^3$ and the porosity to 0.1% and the dry density for specimen KFM04A-90V-1B was measured to be $2,720 \text{ kg/m}^3$ and the porosity to 0.1%.</p>	<p>Fig. 1. <i>Specimen KFM04A-90V-1</i></p> 
<p>KFM04A-90V-2 (108.93)</p> <p>The dry density for specimen KFM04A-90V-2A was measured to be $2,720 \text{ kg/m}^3$ and the porosity to 0.1% and the dry density for specimen KFM04A-90V-2B was measured to be $2,720 \text{ kg/m}^3$ and the porosity to 0.1%.</p>	<p>Fig. 2. <i>Specimen KFM04A-90V-2</i></p> 
<p>KFM04A-90V-3 (108.99)</p> <p>The dry density for specimen KFM04A-90V-3A was measured to be $2,720 \text{ kg/m}^3$ and the porosity to 0.1% and the dry density for specimen KFM04A-90V-3B was measured to be $2,720 \text{ kg/m}^3$ and the porosity to 0.1%.</p>	<p>Fig. 3. <i>Specimen KFM04A-90V-3</i></p> 

KFM04A-90V-4 (109.05)

The dry density for specimen KFM04A-90V-4A was measured to be $2,720 \text{ kg/m}^3$ and the porosity to 0.1% and the dry density for specimen KFM04A-90V-4B was measured to be $2,720 \text{ kg/m}^3$ and the porosity to 0.1%.

Fig. 4. Specimen KFM04A-90V-4



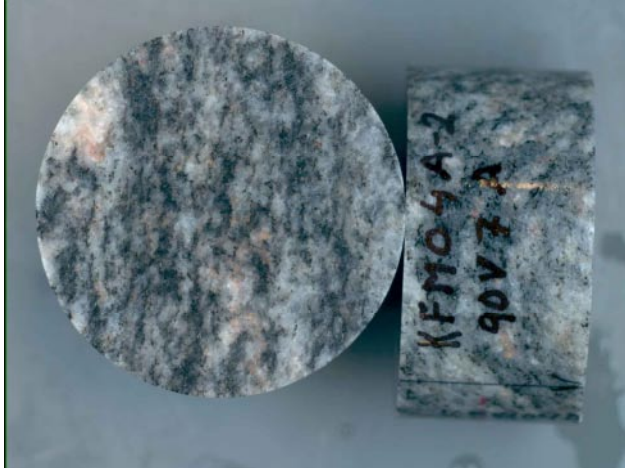
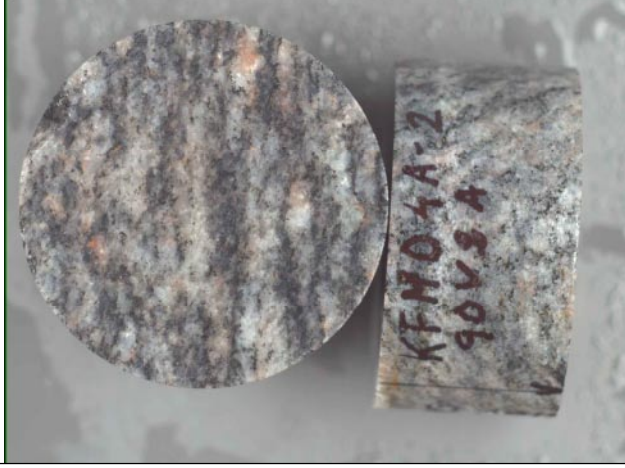
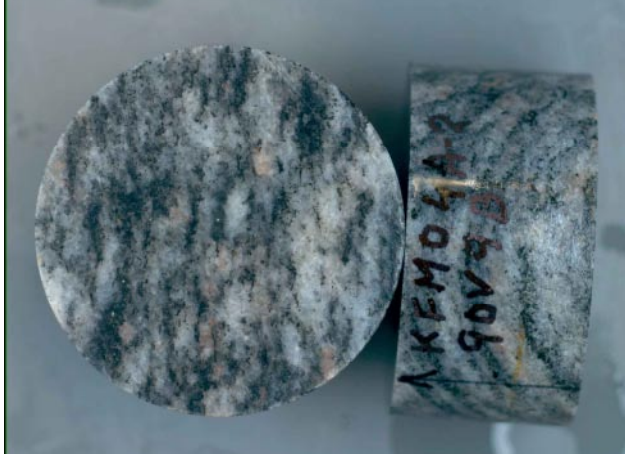
KFM04A-90V-5 (109.76)

The dry density for specimen KFM04A-90V-5A was measured to be $2,710 \text{ kg/m}^3$ and the porosity to 0.1% and the dry density for specimen KFM04A-90V-5B was measured to be $2,710 \text{ kg/m}^3$ and the porosity to 0.1%.

Fig. 5. Specimen KFM04A-90V-5



Table 2: Level 2 580–581 m, specimen KFM04A-090V-7 to KFM04A-090V-11

<p>KFM04A-90V-7 (580.75)</p> <p>The dry density for specimen KFM04A-90V-7A was measured to be $2,650 \text{ kg/m}^3$ and the porosity to 0.4% and the dry density for specimen KFM04A-90V-7B was measured to be $2,640 \text{ kg/m}^3$ and the porosity to 0.4%.</p>	<p>Fig. 6. Specimen KFM04A-90V-7</p> 
<p>KFM04A-90V-8 (580.81)</p> <p>The dry density for specimen KFM04A-90V-8A was measured to be $2,650 \text{ kg/m}^3$ and the porosity to 0.3% and the dry density for specimen KFM04A-90V-8B was measured to be $2,650 \text{ kg/m}^3$ and the porosity to 0.3%.</p>	<p>Fig. 7. Specimen KFM04A-90V-8</p> 
<p>KFM04A-90V-9 (580.87)</p> <p>The dry density for specimen KFM04A-90V-9A was measured to be $2,650 \text{ kg/m}^3$ and the porosity to 0.3% and the dry density for specimen KFM04A-90V-9B was measured to be $2,650 \text{ kg/m}^3$ and the porosity to 0.3%.</p>	<p>Fig. 8. Specimen KFM04A-90V-9</p> 

KFM04A-90V-10 (580.93)

The dry density for specimen KFM04A-90V-10A was measured to be $2,660 \text{ kg/m}^3$ and the porosity to 0.3% and the dry density for specimen KFM04A-90V-10B was measured to be $2,650 \text{ kg/m}^3$ and the porosity to 0.3%.

Fig. 9. Specimen KFM04A-90V-10



KFM04A-90V-11 (581.00)

The dry density for specimen KFM04A-90V-11A was measured to be $2,660 \text{ kg/m}^3$ and the porosity to 0.3% and the dry density for specimen KFM04A-90V-11B was measured to be $2,650 \text{ kg/m}^3$ and the porosity to 0.3%.

Fig. 10. Specimen KFM04A-90V-11

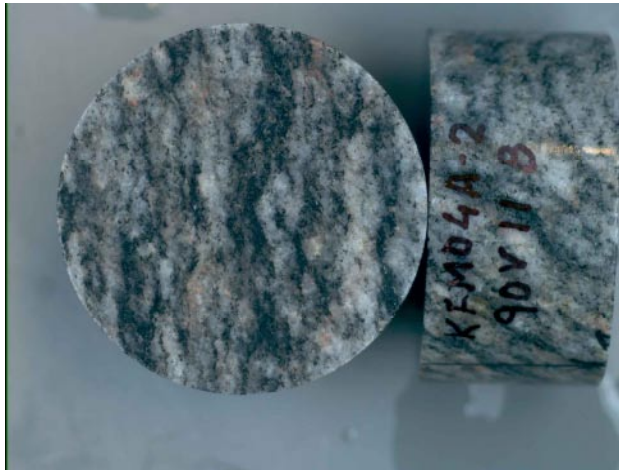


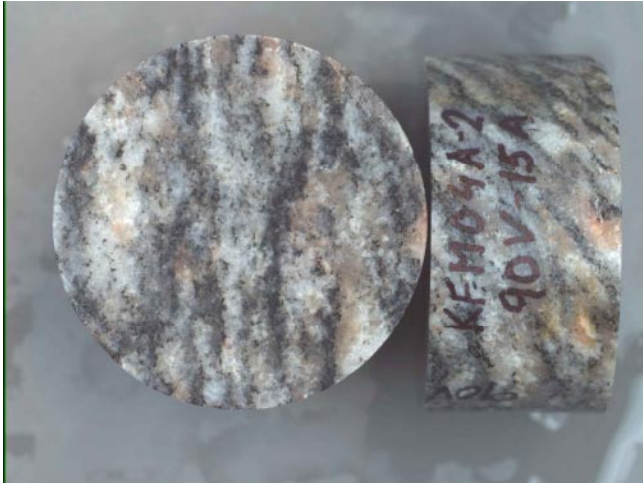


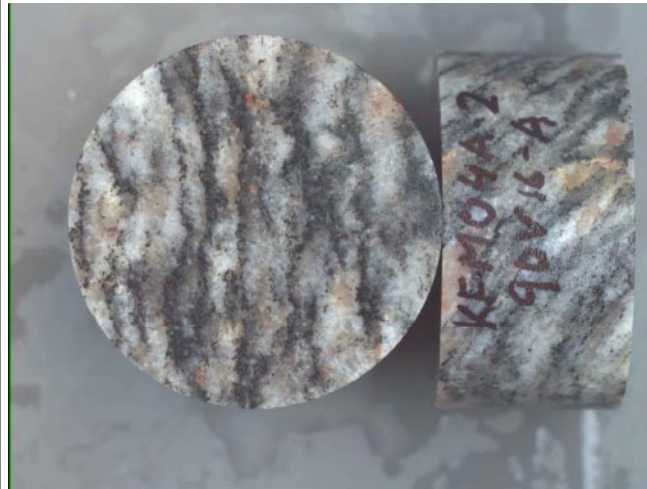
Table 3: Level 3 816–817 m, specimen KFM04A-090V-13 to KFM04A-090V-17

<p>KFM04A-90V-13 (816.29)</p> <p>The dry density for specimen KFM04A-90V-13A was measured to be $2,650 \text{ kg/m}^3$ and the porosity to 0.3% and the dry density for specimen KFM04A-90V-13B was measured to be $2,650 \text{ kg/m}^3$ and the porosity to 0.3%.</p>	<p>Fig. 11. Specimen KFM04A-90V-13</p> 
<p>KFM04A-90V-14 (816.35)</p> <p>The dry density for specimen KFM04A-90V-14A was measured to be $2,660 \text{ kg/m}^3$ and the porosity to 0.3% and the dry density for specimen KFM04A-90V-14B was measured to be $2,650 \text{ kg/m}^3$ and the porosity to 0.4%.</p>	<p>Fig. 12. Specimen KFM04A-90V-14</p> 
<p>KFM04A-90V-15 (816.40)</p> <p>The dry density for specimen KFM04A-90V-15A was measured to be $2,650 \text{ kg/m}^3$ and the porosity to 0.3% and the dry density for specimen KFM04A-90V-15B was measured to be $2,650 \text{ kg/m}^3$ and the porosity to 0.3%.</p>	<p>Fig. 13. Specimen KFM04A-90V-15</p> 

KFM04A-90V-16 (816.46)

The dry density for specimen KFM04A-90V-16A was measured to be $2,660 \text{ kg/m}^3$ and the porosity to 0.3% and the dry density for specimen KFM04A-90V-16B was measured to be $2,650 \text{ kg/m}^3$ and the porosity to 0.3%.

Fig. 14. Specimen KFM04A-90V-16



KFM04A-90V-17 (816.70)

The dry density for specimen KFM04A-90V-17A was measured to be $2,660 \text{ kg/m}^3$ and the porosity to 0.3% and the dry density for specimen KFM04A-90V-17B was measured to be $2,650 \text{ kg/m}^3$ and the porosity to 0.3%.

Fig. 15. Specimen KFM04A-90V-17



Protokoll checklista densitet och porositet (Protocol checklist density and porosity)

Kvalitetsdokument **Blankett**
Bygg och Mekanik
Checklista densitet och vattenabsorption

BMm-QR 53
 Version () (ej publ)
 Utfärdat 2004-01-15
 Författare Lotta Carlsson
 Godkännare Matz Sandström
 Sida 1(1)

Appendix 2

Density porosity

KFM04A

BMm-QR 53 Checklista densitet och vattenabsorption

Fyll i datum och signatur:

Prov id	Prov-beredning/ sågning	Foto	Vattenmätning EN 13755 och SKB MD 160.002	Densitets- mätning	Till värme- kapacitet, BRk BMm/BRk	Åter från BRk	Torkning
1KFM04A- 1	06-04		06-04	06-14			
2							
3							
4							
5							
6							
7							
8							
9							
13							
14							
15							

Våg id: 102291.....

Torkskåp id:102289.....

Termometer id:...100877.....

Appendix 3a

Beräkning densitet och porositet (Calculation density and porosity)

Density and porosity, SKB

Report no: P400242
 Method: EN 13765, ISRM (1973), chapter 3 and SKB MD 160.002 version 1.0
 Scale inv.no: 102291
 Thermometer inv.no: 100877
 Tested by: Lej
 Date: 04-05-13--06-10

Water temperature (°C): 21.1
 Water density (g/cm³): 0.9982

Sample marking:	Weight in water Msub (g)	Surface dry weight Msat (g)	Dry weight Ms (g)	Bulk volume V (cm ³)	Pore volume Vv (cm ³)	Porosity n (%)	Porosity n (%)	Dry Density AB pd (g/cm ³)	Dry density pd (g/cm ³)	Wet density pd (g/cm ³)	Wet density AB pd (g/cm ³)
1	89.73	141.65	141.58	52.01	0.07	0.13	0.14	2.72	2.72	2.72	2.72
2	88.55	139.81	139.74	51.35	0.07	0.14	0.13	2.72	2.72	2.72	2.72
3	89.14	140.80	140.73	51.75	0.07	0.14	0.13	2.72	2.72	2.72	2.72
4	89.54	141.39	141.33	51.94	0.06	0.12	0.12	2.72	2.72	2.72	2.72
5	89.95	142.09	142.03	52.23	0.06	0.12	0.12	2.72	2.72	2.72	2.72
6	89.70	141.76	141.69	52.15	0.07	0.13	0.13	2.72	2.72	2.72	2.72
7	89.77	141.87	141.80	52.19	0.07	0.13	0.13	2.72	2.72	2.72	2.72
8	90.17	142.47	142.40	52.39	0.07	0.13	0.13	2.72	2.72	2.72	2.72
9	90.66	143.46	143.40	52.90	0.06	0.11	0.12	2.71	2.71	2.71	2.71
10	90.91	143.96	143.91	53.17	0.07	0.13	0.13	2.71	2.71	2.71	2.71
11	91.36	144.52	144.44	53.26	0.08	0.15	0.15	2.71	2.71	2.71	2.71
12	91.02	144.15	144.07	53.23	0.08	0.15	0.15	2.71	2.71	2.71	2.71

Beräkning densitet och porositet (Calculation density and porosity)

Density and porosity, SKB

Report no: P400242
 Method: EN 13755, ISRM (1973), chapter 3 and SKB MD 160.002 version 1.0
 Tested by: Lej
 Date: 14/06/2004

Scale inv.no: 102291
 Thermometer inv.no: 100877

Water temperature (°C): 21.1
 Water density (g/cm³): 0.9982

Sample marking:	Weight in water Msub (g)	Surface dry weight Msd (g)	Dry weight Ms (g)	Bulk volume V (cm ³)	Pore volume Vv (cm ³)	Porosity n (%)	Porosity AB n (%)	Dry density pd (g/cm ³)	Dry Density AB pd (g/cm ³)	Wet density pd (g/cm ³)	Wet density AB pd (g/cm ³)
13	87.16	139.85	139.66	52.79	0.19	0.36	0.36	2.65	2.65	2.65	2.65
14	87.20	139.96	139.77	52.86	0.19	0.36	0.36	2.64	2.65	2.65	2.65
15	87.60	140.55	140.38	53.05	0.17	0.32	0.31	2.65	2.65	2.65	2.65
16	88.00	141.07	140.91	53.17	0.16	0.30	0.31	2.65	2.65	2.65	2.65
17	87.58	140.33	140.17	52.85	0.16	0.30	0.31	2.65	2.65	2.66	2.66
18	87.52	140.25	140.08	52.83	0.17	0.32		2.65		2.65	
19	88.13	141.04	140.90	53.01	0.14	0.26	0.27	2.66	2.65	2.66	2.66
20	87.45	140.19	140.04	52.84	0.15	0.28		2.65		2.65	
21	87.78	140.54	140.38	52.86	0.16	0.30	0.30	2.66	2.66	2.66	2.66
22	87.50	140.15	139.99	52.74	0.16	0.30		2.65		2.66	
23	87.35	140.04	139.88	52.79	0.16	0.30	0.29	2.65	2.65	2.65	2.65
24	87.27	139.95	139.80	52.77	0.15	0.28		2.65		2.65	
25	88.29	141.41	141.24	53.22	0.17	0.32	0.32	2.65	2.65	2.66	2.66
26	88.35	141.55	141.38	53.30	0.17	0.32		2.65		2.66	
27	88.30	141.31	141.13	53.11	0.18	0.34	0.37	2.66	2.66	2.66	2.66
28	87.59	140.28	140.07	52.79	0.21	0.40		2.65		2.66	
29	86.99	139.43	139.26	52.53	0.17	0.32	0.32	2.65	2.65	2.65	2.66
30	87.58	140.29	140.12	52.81	0.17	0.32		2.65		2.66	
31	88.16	141.18	141.02	53.12	0.16	0.30	0.29	2.65	2.65	2.66	2.66
32	87.42	140.07	139.92	52.74	0.15	0.28		2.65		2.66	
33	87.74	140.47	140.31	52.83	0.16	0.30	0.28	2.66	2.66	2.66	2.66
34	87.28	139.81	139.67	52.62	0.14	0.27		2.65		2.66	
35	87.14	139.52	139.37	52.47	0.15	0.29	0.28	2.66	2.65	2.66	2.66
36	87.01	139.45	139.31	52.53	0.14	0.27		2.65		2.65	