P-04-167

Forsmark site investigation

Drill hole KFM02A

Determination of porosity by water saturation and density by buoyancy technique

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May 2004

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Keywords: AP PF 400-04-19, Field note no Forsmark 142, Rock mechanics, Petro physics, Density, Porosity.

Abstract

The density and porosity has been determined on 15 specimens (each divided in two pieces) from drill hole KFM02A, Forsmark, Sweden. The specimens were collected from three levels of the drill hole: at c 335, 530 and 710 m. The investigated rock types are mapped as medium-grained metagranite (-granodiorite). The results for dry density varied between 2,640 and 2,660 kg/m^3, for wet density between 2,640 and 2,660 kg/m^3, and for porosity between 0.2 and 0.4%.

Contents

1 Introduction

The laboratory test program presented in this report for determination of porosity and density of drill core samples from Forsmark, Sweden, was preformed in compliance with the activity plan AP PF 400-04-19 (SKB internal controlling document) and is part of the on-going site investigations for a deep repository.

The specimens were sampled from the drill core of borehole KFM02A in the Forsmark area, Figure 1-1, by Thomas Janson, Tyréns, and Urban Åkesson, Swedish National Testing and Research Institute (SP) on June 17th 2003. Specimens were collected from three levels of the rock core: level 1 between 330 and 340 m, level 2 between 520 and 540 m and level 3 between 700 and 720 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 June 18th 2003. The testing was started in March 2004 and ended in May 2004.

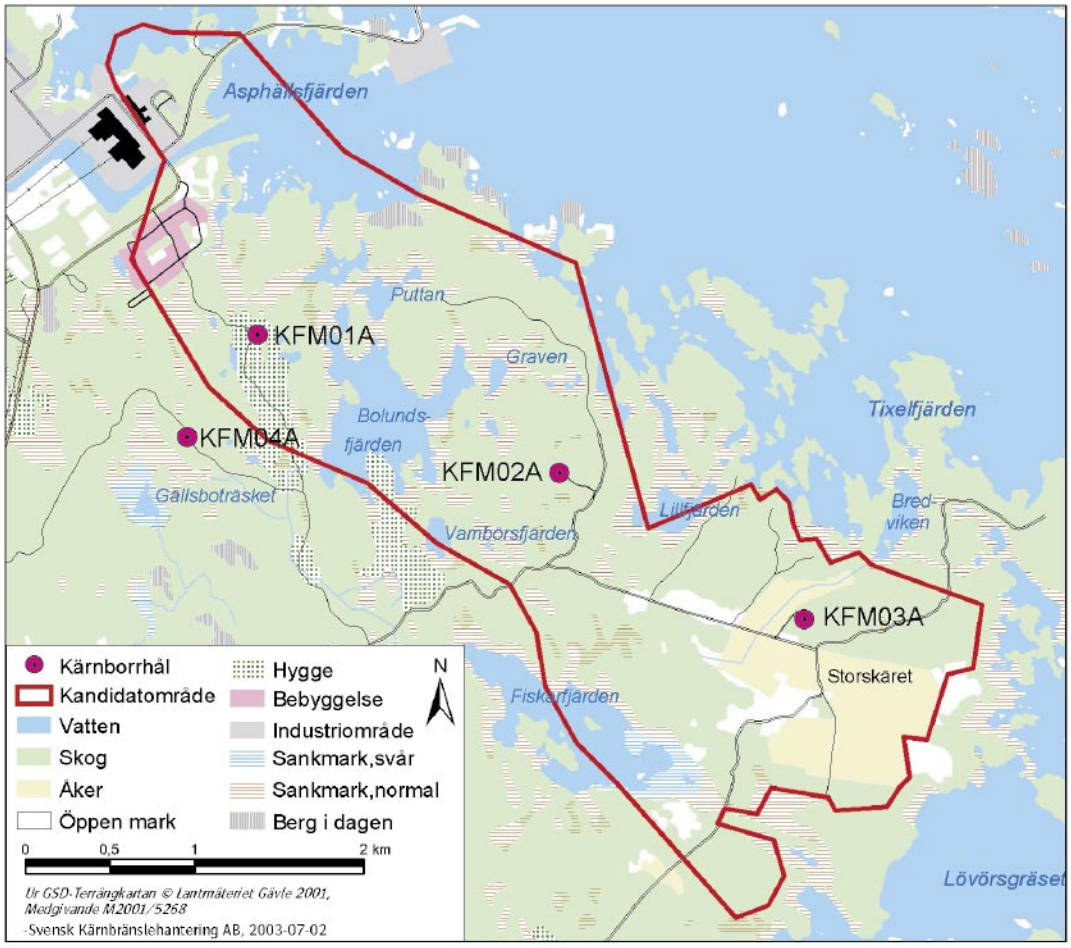


Figure 1-1. *Location of drill hole KFM02A at the Forsmark site.*

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 derive from borehole KFM02A at Forsmark, which is a near-vertical telescopic borehole of SKB-chemistry type with a borehole length of c 1,000 m. The samples in this report are collected from 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 ± 0.4°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 ± 5°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/m^3
Porosity	± 0.09%
Water absorption	± 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 400-04-19 (internal controlling document of SKB). The department of Building Technology and Mechanics (BM) at SP performed the tests.

4.1 Description of the samples

Specimens were sampled from three levels in drill hole KFM02A. Core drilling of the borehole started at a depth of c 100 m. Sampling level 1 ranges between 330 and 337 m, level 2 between 528 and 537 m and level 3 between 704 and 720 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
KFM02A-90V-1	330.60	Meta granite
KFM02A-90V-2	336.11	Meta granite
KFM02A-90V-3	336.68	Meta granite
KFM02A-90V-4	336.87	Meta granite
KFM02A-90V-5	336.99	Meta granite
KFM02A-90V-7	528.27	Meta granite
KFM02A-90V-8	530.88	Meta granite
KFM02A-90V-9	531.01	Meta granite
KFM02A-90V-10	532.21	Meta granite
KFM02A-90V-11	536.69	Meta granite
KFM02A-90V-13	704.56	Meta granite
KFM02A-90V-14	706.38	Meta granite
KFM02A-90V-15	706.70	Meta granite
KFM02A-90V-16	718.34	Meta granite
KFM02A-90V-17	719.41	Meta 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 of 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 19.4°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).

4.3 Nonconformities

None.

5 Results

Data resulting from this activity are stored in the SKB database SICADA under field note no Forsmark 142.

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

A summary of the results of porosity and density determinations is displayed in Tables 5-1, 5-2 and 5-3 as well as in the diagrams in Figures 5-1, 5-2 and 5-3. The tables represent dry density, wet density respectively porosity.

Table 5-1. Summary of the results of porosity, dry density and wet density determinations of the specimens from level 1, seclow 330 to 337 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)
KFM02A-90V-1	330.60	0.3	2,650	2,660
KFM02A-90V-2	336.11	0.3	2,650	2,660
KFM02A-90V-3	336.68	0.2	2,650	2,650
KFM02A-90V-4	336.87	0.3	2,660	2,660
KFM02A-90V-5	336.99	0.4	2,660	2,660
Mean value		0.3	2,650	2,660
Standard deviation		0.07	5	5

Table 5-2. Summary of the results of porosity, dry density and wet density determinations of the specimens from level 2, seclow 528 to 537 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)
KFM02A-90V-7	528.27	0.4	2,640	2,640
KFM02A-90V-8	530.88	0.3	2,660	2,660
KFM02A-90V-9	531.01	0.4	2,650	2,660
KFM02A-90V-10	532.21	0.4	2,650	2,650
KFM02A-90V-11	536.69	0.3	2,650	2,650
Mean value		0.4	2,650	2,650
Standard deviation		0.05	6	6

Table 5-3. Summary of the results of porosity, dry density and wet density determinations of the specimens from level 3, seclow 704 to 720 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/m³)	Wet density (kg/m³)
KFM02A-90V-13	704.56	0.2	2,650	2,660
KFM02A-90V-14	706.38	0.3	2,650	2,660
KFM02A-90V-15	706.70	0.3	2,660	2,660
KFM02A-90V-16	718.34	0.3	2,650	2,650
KFM02A-90V-17	719.41	0.3	2,650	2,650
Mean value		0.3	2,650	2,660
Standard deviation		0.04	3	3

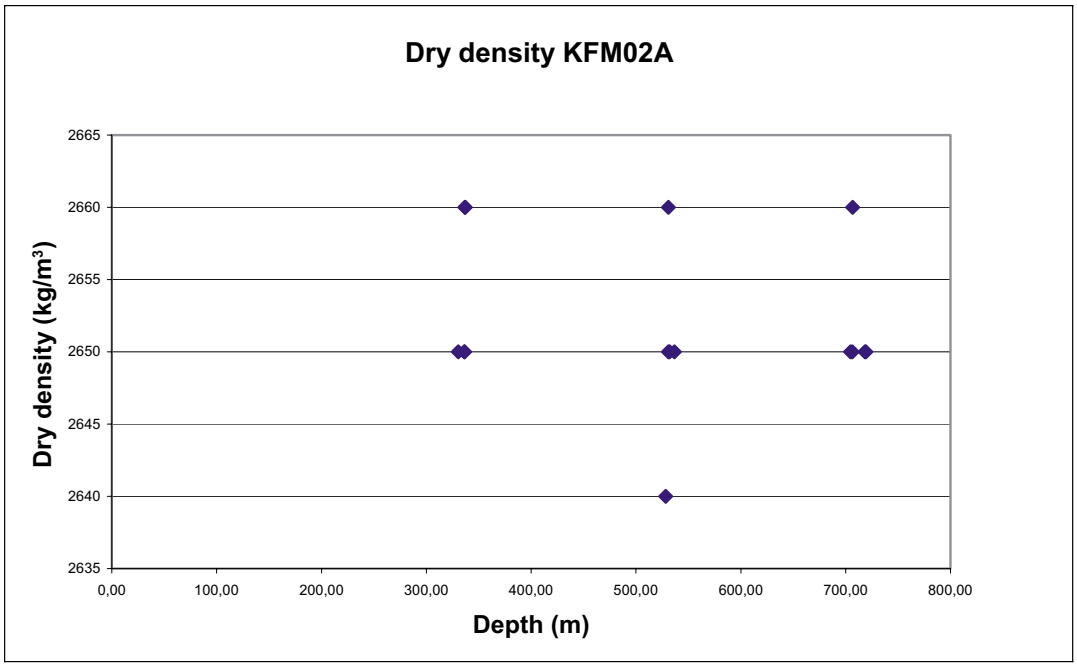


Figure 5-1. *Density (dry) versus sampling depth.*

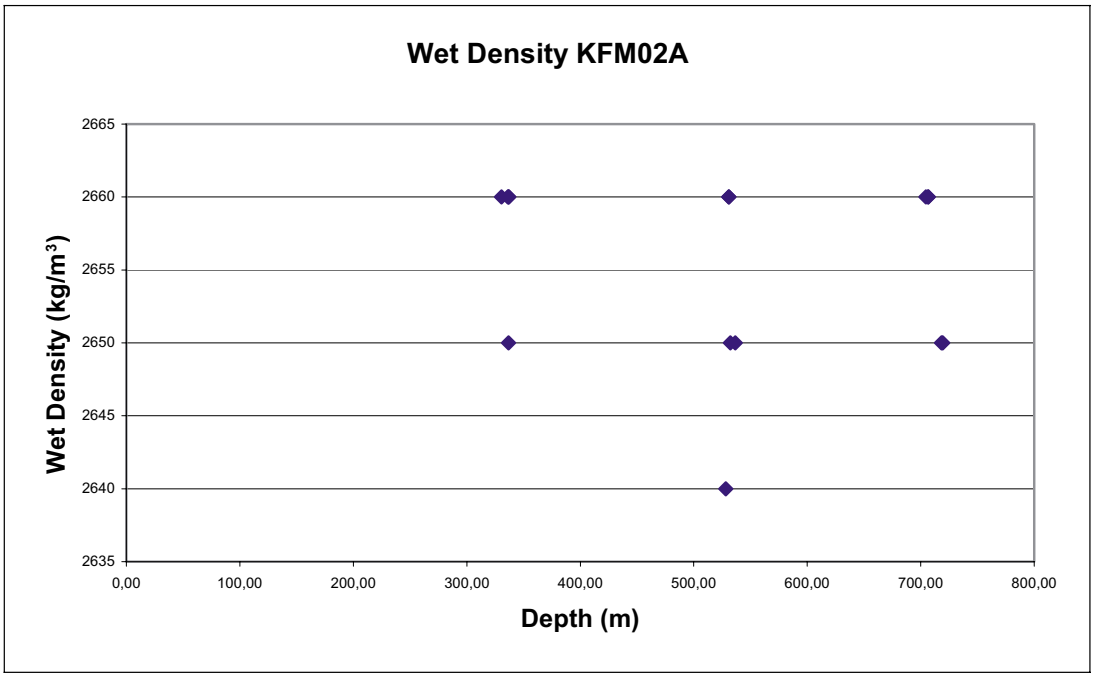


Figure 5-2. *Density (wet) versus sampling depth.*

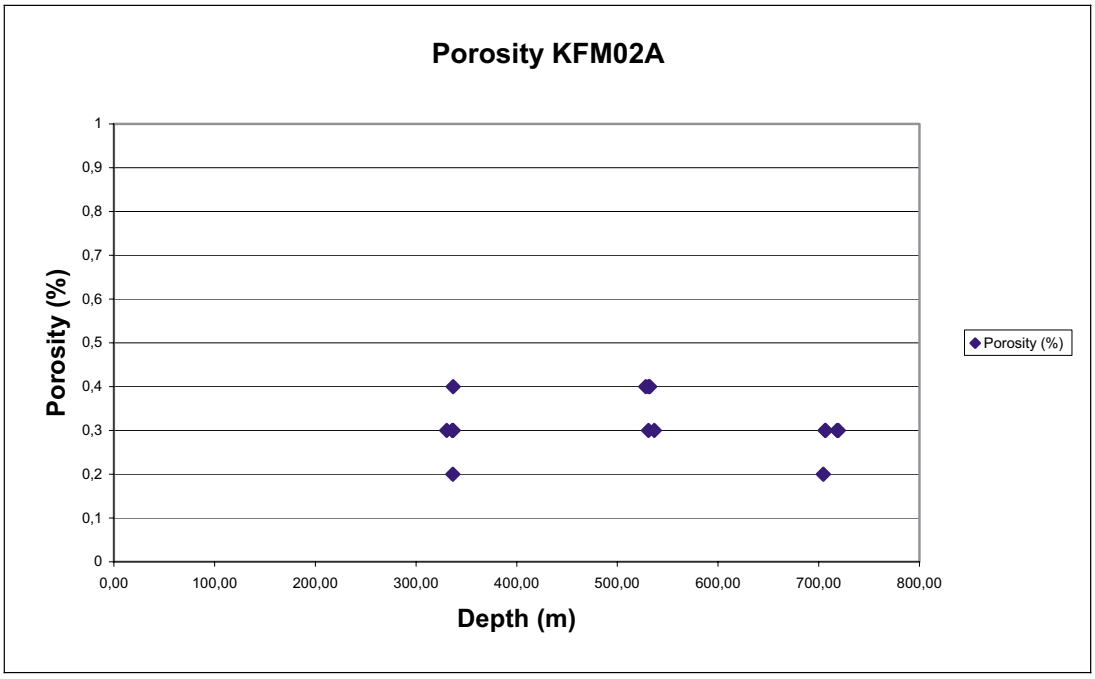


Figure 5-3. *Porosity versus sampling depth.*

References

ISRM, 1979. Volume 16, Number 2.

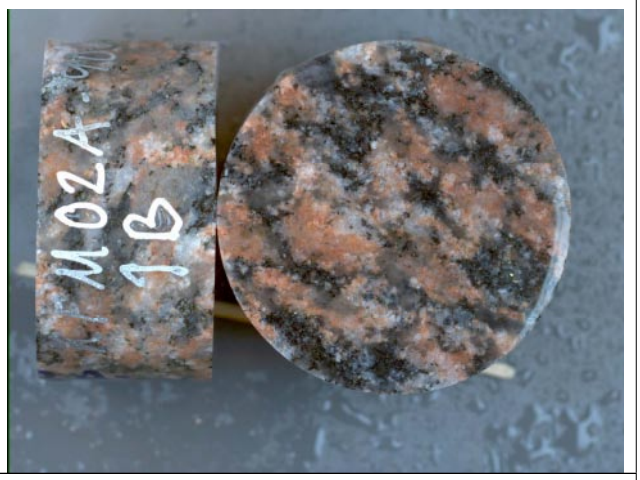
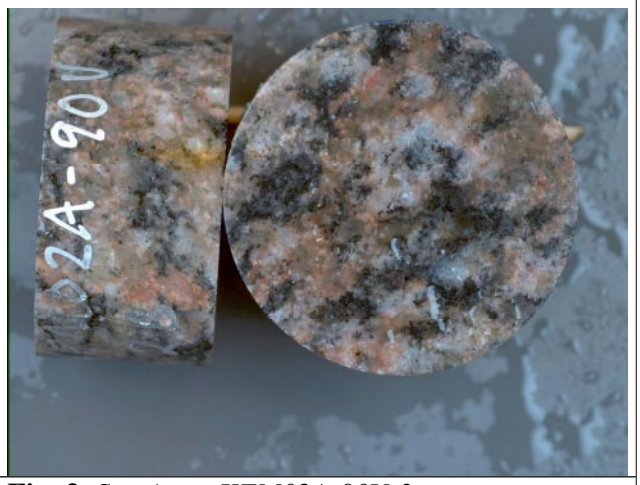
EN 13755. Natural stone test methods – Determination of water absorption at atmospheric pressure.

Appendix 1

Results and pictures

KFM02A: Density and porosity

Table 1: Level 1 330–337 m, specimens KFM02A-090V-1 to KFM02A-090V-5

KFM02A-90V-1 (330.60) The dry density for specimen KFM02A-90V-1A was measured to be 2,660 kg/m^3 and the porosity to 0.3% and the dry density for specimen KFM02A-90V-1B was measured to be 2,650 kg/m^3 and the porosity to 0.3%.	**Fig. 1**. *Specimen KFM02A-90V-1.* 
KFM02A-90V-2 (336.11) The dry density for specimen KFM02A-90V-2A was measured to be 2,650 kg/m^3 and the porosity to 0.2% and the dry density for specimen KFM02A-90V-2B was measured to be 2,660 kg/m^3 and the porosity to 0.3%.	**Fig. 2.** *Specimen KFM02A-90V-2* 
KFM02A-90V-3 (336.68) The dry density for specimen KFM02A-90V-3A was measured to be 2,650 kg/m^3 and the porosity to 0.2% and the dry density for specimen KFM02A-90V-3B was measured to be 2,640 kg/m^3 and the porosity to 0.2%.	**Fig. 3**. *Specimen KFM02A-90V-3.* 

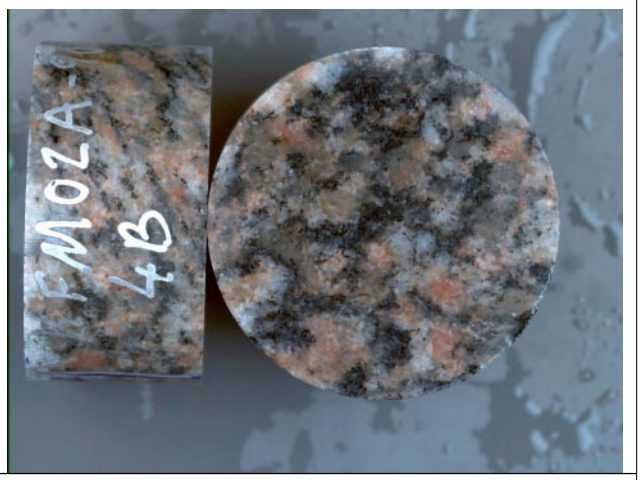
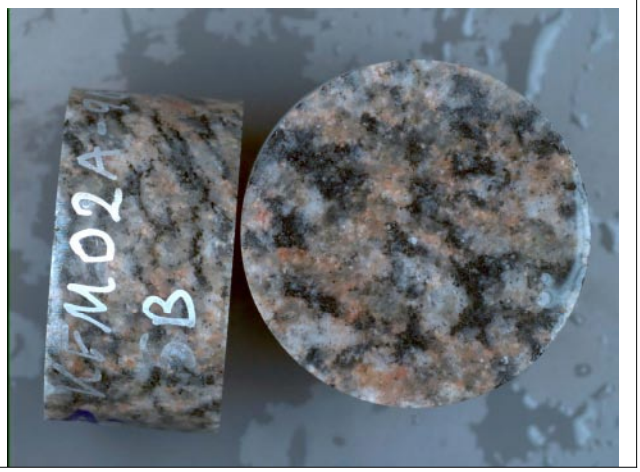
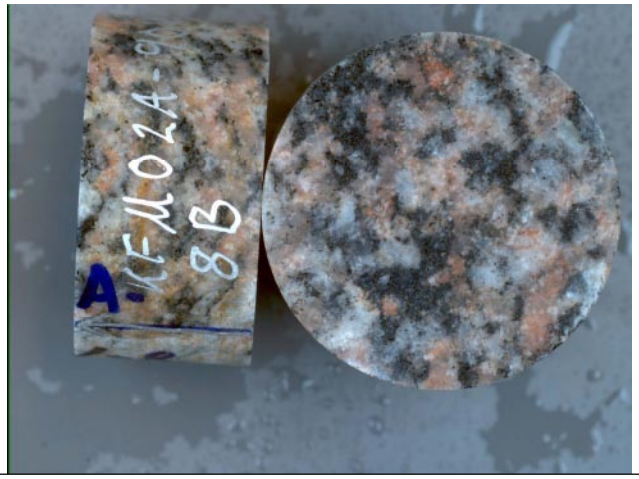
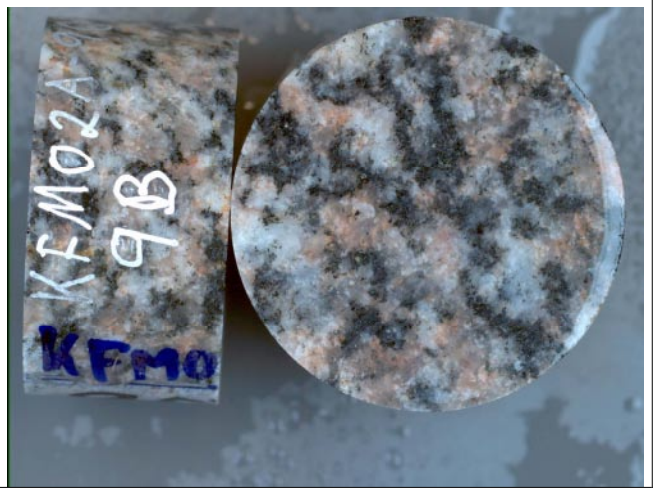
KFM02A-90V-4 (336.87) The dry density for specimen KFM02A-90V-4A was measured to be 2,660 kg/m^3 and the porosity to 0.3% and the dry density for specimen KFM02A-90V-4B was measured to be 2,660 kg/m^3 and the porosity to 0.3%.	**Fig. 4**. *Specimen KFM02A-90V-4.* 
KFM02A-90V-5 (336.99) The dry density for specimen KFM02A-90V-5A was measured to be 2,660 kg/m^3 and the porosity to 0.4% and the dry density for specimen KFM02A-90V-5B was measured to be 2,660 kg/m^3 and the porosity to 0.4%.	**Fig. 5**. *Specimen KFM02A-90V-5.* 

Table 2: Level 2 528–537 m, specimens KFM02A-090V-7 to KFM02A-090V-11

KFM02A-90V-7 (528.27) The dry density for specimen KFM02A-90V-7A was measured to be 2,640 kg/m^3 and the porosity to 0.4% and the dry density for specimen KFM02A-90V-7B was measured to be 2,640 kg/m^3 and the porosity to 0.4%.	**Fig. 6**. *Specimen KFM02A-90V-7.* 
KFM02A-90V-8 (530.88) The dry density for specimen KFM02A-90V-8A was measured to be 2,660 kg/m^3 and the porosity to 0.3% and the dry density for specimen KFM02A-90V-8B was measured to be 2,660 kg/m^3 and the porosity to 0.4%.	**Fig. 7**. *Specimen KFM02A-90V-8.* 
KFM02A-90V-9 (531.01) The dry density for specimen KFM02A-90V-9A was measured to be 2,660 kg/m^3 and the porosity to 0.4% and the dry density for specimen KFM02A-90V-9B was measured to be 2,650 kg/m^3 and the porosity to 0.4%.	**Fig. 8**. *Specimen KFM02A-90V-9.* 

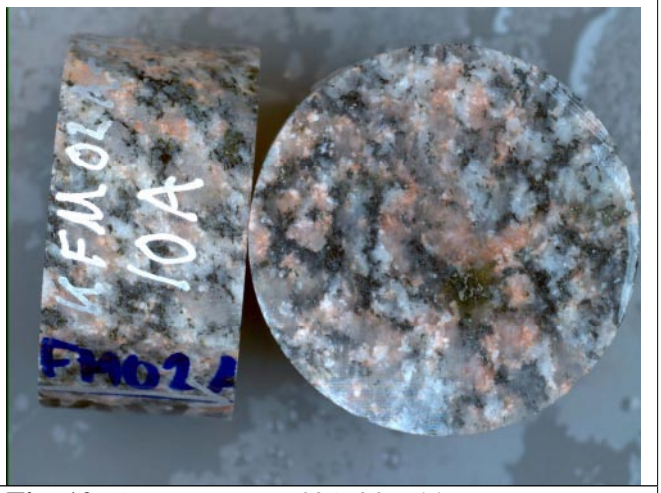
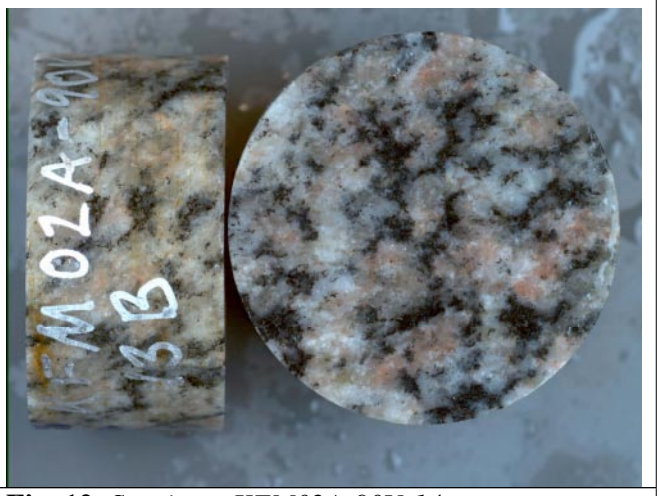
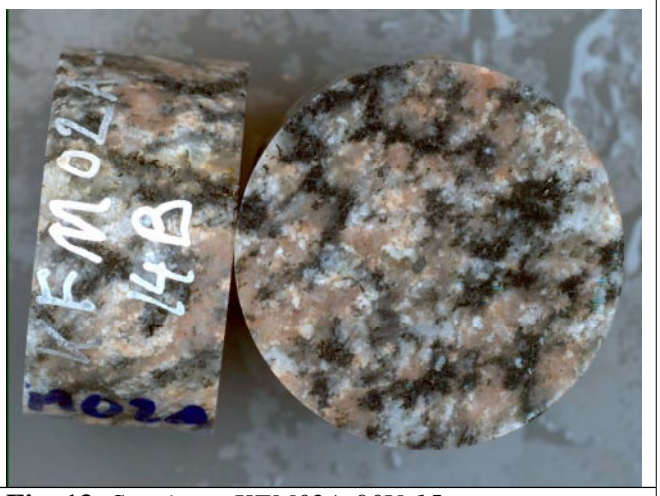
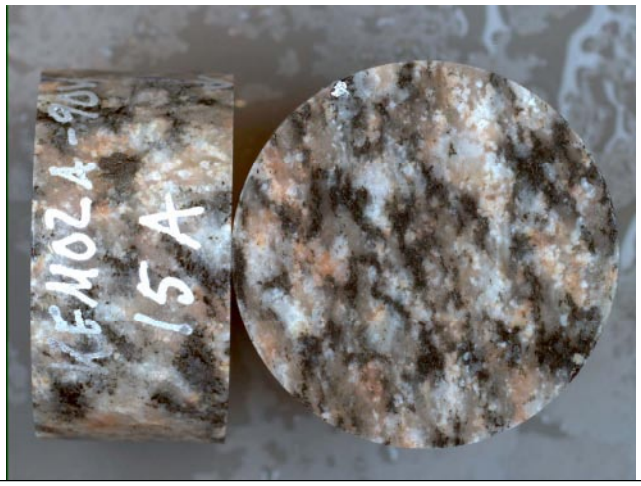
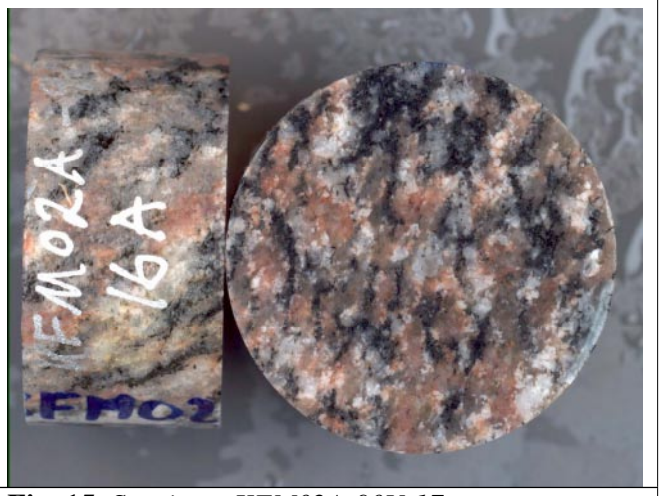
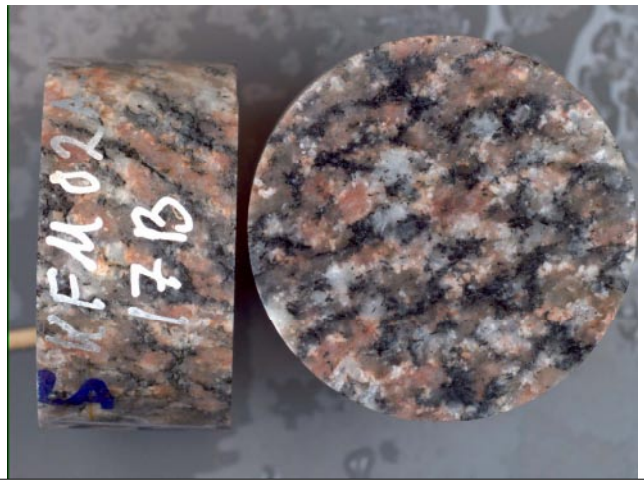
KFM02A-90V-10 (532.21) The dry density for specimen KFM02A-90V-10A was measured to be 2,650 kg/m^3 and the porosity to 0.4% and the dry density for specimen KFM02A-90V-10B was measured to be 2,650 kg/m^3 and the porosity to 0.3%.	**Fig. 9**. *Specimen KFM02A-90V-10.* 
KFM02A-90V-11 (536.69) The dry density for specimen KFM02A-90V-10A was measured to be 2,650 kg/m^3 and the porosity to 0.3% and the dry density for specimen KFM02A-90V-10B was measured to be 2,650 kg/m^3 and the porosity to 0.3%.	**Fig. 10**. *Specimen KFM02A-90V-11.* 

Table 3: Level 3 704–720 m, specimens KFM02A-090V-13 to KFM02A-090V-17

KFM02A-90V-13 (704.56) The dry density for specimen KFM02A-90V-13A was measured to be 2,650 kg/m^3 and the porosity to 0.3% and the dry density for specimen KFM02A-90V-13B was measured to be 2,650 kg/m^3 and the porosity to 0.2%.	**Fig. 11**. *Specimen KFM02A-90V-13.* 
KFM02A-90V-14 (706.38) The dry density for specimen KFM02A-90V-14A was measured to be 2,650 kg/m^3 and the porosity to 0.3% and the dry density for specimen KFM02A-90V-14B was measured to be 2,660 kg/m^3 and the porosity to 0.3%.	**Fig. 12**. *Specimen KFM02A-90V-14.* 
KFM02A-90V-15 (706.70) The dry density for specimen KFM02A-90V-15A was measured to be 2,660 kg/m^3 and the porosity to 0.3% and the dry density for specimen KFM02A-90V-15B was measured to be 2,650 kg/m^3 and the porosity to 0.3%.	**Fig. 13**. *Specimen KFM02A-90V-15.* 

KFM02A-90V-16 (718.34) The dry density for specimen KFM02A-90V-16A was measured to be 2,650 kg/m^3 and the porosity to 0.3% and the dry density for specimen KFM02A-90V-16B was measured to be 2,650 kg/m^3 and the porosity to 0.3%.	**Fig. 14**. *Specimen KFM02A-90V-16* 
KFM02A-90V-17 (719.41) The dry density for specimen KFM02A-90V-18A was measured to be 2,650 kg/m^3 and the porosity to 0.3% and the dry density for specimen KFM02A-90V-18B was measured to be 2,650 kg/m^3 and the porosity to 0.3%.	**Fig. 15**. *Specimen KFM02A-90V-17.* 

Appendix 2

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 KFM02A: Density and porosity Sida 1 (1)

BMm-QR 53 Checklista densitet och vattenabsorption

Fyll i datum och signatur:

Prov id	Prov-beredning/ sågning	Foto	Vattenmättning EN 13755 och SKB MD 160.002	Densitets-mätning	Till värme-kapacitet, BRk BMm/BRk		Åter från BRk	Torkning
KFMO2A-1	04-03-17	04-03-08	04-03-10	04-03-17	04-03-18		04-05-10	04-05-12
2								
3								
4								
5								
7								
8								
9								
10								
11								
13								
14								
15								
16								

17

Våg id: 102291…….

Torkskåp id:102289……..

Termometer id: 100877……

Appendix 3

Beräkning densitet och porositet (Calculation density and porosity)

Density and porosity, SKB

Report no: P302604 KFMO2A
Method: EN 13755, ISRM (1973), chapter 3 and SKB MD 160.002 version 1.0
Water temperature (ºC): 19.4 Scale inv.no: 102291 Tested by: Lej
Water density (g/cm3): 0.9983 Thermometer inv.no: 100877 Date: 04-03-17--05-12

	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 AB n (%)	Dry density ρd (g/cm^3)	Dry Density AB ρd (g/cm^3)	Wet density ρd (g/cm^3)	Wet density AB ρd (g/cm^3)
1	1A	86.47	138.40	138.24	52.02	0.16	0.31	0.31	2.66	2.65	2.66	2.66
2	1B	86.30	138.37	138.21	52.16	0.16	0.31		2.65		2.65	
3	2A	87.23	139.85	139.72	52.71	0.13	0.25	0.26	2.65	2.65	2.65	2.66
4	2B	87.47	140.10	139.96	52.72	0.14	0.27		2.65		2.66	
5	3A	86.61	138.82	138.70	52.30	0.12	0.23	0.24	2.65	2.65	2.65	2.65
6	3B	86.55	138.98	138.85	52.52	0.13	0.25		2.64		2.65	
7	4A	87.62	140.33	140.19	52.80	0.14	0.27	0.28	2.66	2.66	2.66	2.66
8	4B	87.76	140.49	140.34	52.82	0.15	0.28		2.66		2.66	
9	5A	87.85	140.58	140.36	52.82	0.22	0.42	0.42	2.66	2.66	2.66	2.66
10	5B	87.97	140.75	140.53	52.87	0.22	0.42		2.66		2.66	
13	7A	87.30	140.20	139.99	52.99	0.21	0.40	0.40	2.64	2.64	2.65	2.64
14	7B	85.54	137.49	137.28	52.04	0.21	0.40		2.64		2.64	
15	8A	88.10	141.00	140.83	52.99	0.17	0.32	0.34	2.66	2.66	2.66	2.66
16	8B	87.92	140.78	140.59	52.95	0.19	0.36		2.66		2.66	
17	9A	88.05	140.96	140.73	53.00	0.23	0.43	0.40	2.66	2.65	2.66	2.66
18	9B	87.82	140.71	140.52	52.98	0.19	0.36		2.65		2.66	
19	10A	87.03	139.60	139.41	52.66	0.19	0.36	0.35	2.65	2.65	2.65	2.65
20	10B	87.29	139.93	139.75	52.73	0.18	0.34		2.65		2.65	
21	11A	87.63	140.62	140.45	53.08	0.17	0.32	0.29	2.65	2.65	2.65	2.65
22	11B	87.50	140.34	140.20	52.93	0.14	0.26		2.65		2.65	
25	13A	86.75	138.97	138.83	52.31	0.14	0.27	0.25	2.65	2.65	2.66	2.66
26	13B	86.53	138.68	138.56	52.24	0.12	0.23		2.65		2.65	
27	14A	84.79	135.87	135.72	51.17	0.15	0.29	0.30	2.65	2.65	2.66	2.66
28	14B	85.49	136.89	136.73	51.49	0.16	0.31		2.66		2.66	
29	15A	86.99	139.16	138.99	52.26	0.17	0.33	0.34	2.66	2.66	2.66	2.66
30	15B	86.55	138.62	138.44	52.16	0.18	0.35		2.65		2.66	
31	16A	87.13	139.69	139.52	52.65	0.17	0.32	0.29	2.65	2.65	2.65	2.65
32	16B	87.21	139.75	139.61	52.63	0.14	0.27		2.65		2.66	
33	17A	86.04	137.87	137.72	51.92	0.15	0.29	0.31	2.65	2.65	2.66	2.65
34	17B	86.15	138.13	137.96	52.07	0.17	0.33		2.65		2.65	