

Forsmark site investigation

Borehole KFM07A

Determination of porosity by water saturation and density by buoyancy technique

Marjo Savukoski
Swedish National Testing and Research Institute, SP

November 2005

Svensk Kärnbränslehantering AB

Swedish Nuclear Fuel
and Waste Management Co
Box 5864
SE-102 40 Stockholm Sweden
Tel 08-459 84 00
+46 8 459 84 00
Fax 08-661 57 19
+46 8 661 57 19



Forsmark site investigation

Borehole KFM07A

Determination of porosity by water saturation and density by buoyancy technique

Marjo Savukoski

Swedish National Testing and Research Institute, SP

November 2005

Keywords: Rock Mechanics, Petro-physics, Density, Porosity, AP PF 400 05-024.

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.

A pdf version of this document can be downloaded from www.skb.se

Abstract

The density and porosity have been determined on 9 specimens (each divided into two pieces) from borehole KFM07A, Forsmark, Sweden. The specimens were sampled at two levels: level 1, 300–380 m, and level 2, 670–680 m (borehole length). The investigated rock types are mapped as medium-grained granite, pegmatite and amphibolite. The dry density as well as the wet density varied between 2,610 and 3,030 kg/m³, whereas the porosity values ranged within the interval 0.2 to 0.4%.

Sammanfattning

Densiteten och porositeten har bestämts på 9 provkroppar (varje provkropp delad i två delar) från borrhål KFM07A i Forsmark. Proverna togs från två nivåer i borrhålet: nivå 1, 300–380 m, och nivå 2, 670–680 m (borrhåls längd). De undersökta bergarterna är karterade som medelkornig granit, pegmatit och amfibolit. Såväl torrdensiteten som våtdensiteten varierade mellan 2 610 och 3 030 kg/m³, medan porositetsvärdena låg i intervallet 0,2 till 0,4 %.

Contents

1	Introduction	7
2	Objective	9
3	Equipment	11
4	Execution	13
4.1	Description of the samples	13
4.2	Testing	13
4.3	Nonconformities	14
5	Results	15
5.1	Results from respective level	15
5.2	Results for the entire test series	16
	References	19
	Appendix 1 Results and photos	21

1 Introduction

This document reports performance and results of determination of porosity by water saturation and density by buoyancy technique within the site investigation programme at Forsmark, Sweden, /1/. The controlling documents for the activity are listed in Table 1-1. Both Activity Plan and Method Description are SKB's internal controlling documents. The thermal properties conductivity and diffusivity of the specimens were determined within the scope of parallel activity /2/.

Samples were collected from the drill core of borehole KFM07A within the site investigation area at Forsmark, see Figure 1-1. Borehole KFM07A is a telescopic drilled borehole inclined c 60° from the horizontal plane and with a total length of 1,001,55 m. The borehole section 0–100,40 m is percussion drilled, whereas the section 100,40–1,001,55 m is core drilled.

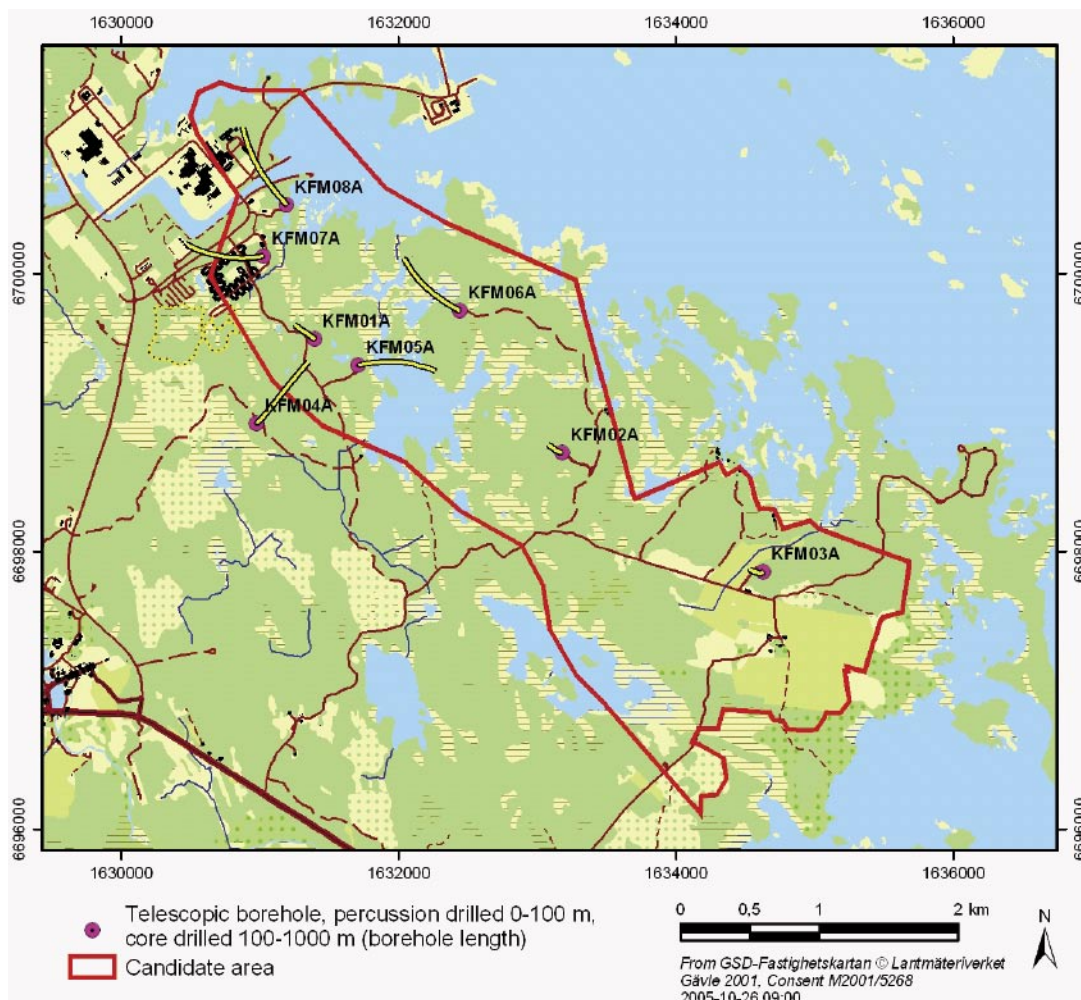


Figure 1-1. Location of all telescopic boreholes drilled up to August 2005 within or close to the Forsmark candidate area. The projection of each borehole on the horizontal plane at top of casing is also shown in the figure.

Thomas Jansson and Björn Ljunggren, Tyréns AB, performed the sampling in March 2005. The samples were collected from two levels of the borehole, level 1 between 300 and 380 m, and level 2 between 670–680 m (borehole length). The samples were selected based on the preliminary core logging, and with the strategy to primarily investigate the properties of the dominating rock types. The rock samples were transported from Forsmark and arrived at the Swedish National Testing and Research Institute (SP) on the 5th of April, 2005. Testing commenced in April 2005 and ended in May the same year.

Table 1-1. Controlling documents for performance of the activity.

Activity Plan	Number	Version
KFM07A. Bergmekaniska och termiska laboratoriebestämningar.	AP PF 400-05-024	1.0
Method Description	Number	Version
Determination of density and porosity of intact rock.	SKB MD 160.002	2.0

2 Objective

The results of the density and porosity determinations of the of intact rock cores will serve as input data for the rock mechanics and thermal site descriptive model, which will be established for the candidate area selected for site investigations at Forsmark.

3 Equipment

The following equipment was employed for the analyses:

- Thermometer (inv no 102185) for measurement of water temperature. Calibrated 2005-02-04. Uncertainty of measurement $\pm 0.4^{\circ}\text{C}$.
- Scale (inv no 102291) for weight measurement. Calibrated in 2005-04-10. Uncertainty of measurement ± 0.2 g.
- Heating chamber (inv no 102289) for drying the specimens. Calibrated 2004-08-31. 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 $\pm 4 \text{ kg/m}^3$

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 160.002, (SKB internal controlling document) including determination of density according to ISRM 1979 /3/ and water saturation by EN 13755 /4/ and in compliance with Activity Plan AP PF 400-05-024 (SKB internal controlling document). The department of Building Technology and Mechanics (BM) at the Swedish National Testing and Research Institute (SP) performed the tests.

4.1 Description of the samples

Table 4-1 shows identification marks, sampling levels and rock type of all specimens included in the tests.

Table 4-1. Identification marks, sampling levels (borehole length) and rock type of the collected specimens from borehole KFM07A at Forsmark (rock-type classification according to Boremap). Each identification mark represents two specimens, designated A and B, respectively.

Identification	Sampling level (seclow = lower end of the sample) (m)	Rock type
KFM07A-90V-1	300.18	Medium-grained granite
KFM07A-90V-2	319.86	Medium-grained granite
KFM07A-90V-3	340.64	Medium-grained granite
KFM07A-90V-4	358.85	Medium-grained granite
KFM07A-90V-5	379.92	Medium-grained granite
KFM07A-90V-6	678.55	Pegmatite
KFM07A-90V-7	678.61	Pegmatite
KFM07A-90V-8	674.05	Amphibolite
KFM07A-90V-9	674.11	Amphibolite

4.2 Testing

The temperature of the water used for water saturation was 19.9°C and the density was 998 kg/m³. The specimens were dried in 105°C for one week after water saturation. The execution procedure followed the prescription in SKB MD 160.002, see Table 4-2.

The present activity was performed parallel to another activity /2/, conducted by the department of Fire Technology at SP, and by which the thermal properties conductivity and diffusivity of the specimens were determined. The following logistic sequence was applied for the two activities:

Table 4-2. The logistic sequence applied for the present activity and activity /2/.

Activity no	Activity
1	The samples from SKB were cut according to the marks on the rock cores. Every sample was cut into two pieces, marked A and B, and about 25 mm thick each. The same specimens were used to determine thermal conductivity and thermal diffusivity by applying the TPS method.
2	The specimens were water saturated in ambient air pressure for at least seven days.
3	The specimens were weighed in tap-water.
4	The specimens were surface dried with a towel and weighed.
5	The water saturated density was determined.
6	The specimens were sent from the department of Building and Mechanics at SP to the department of Fire Technology at SP for measurements of thermal properties (within the scope of the parallel activity /2/).
7	The specimens were sent back from Fire Technology to Building and Mechanics.
8	The specimens were dried in a heating chamber at 105°C.
9	The specimens were transported to a desiccator for cooling.
10	The dry density and porosity were determined.
11	The specimens were photographed in JPEG-format.

4.3 Nonconformities

The tests were performed in accordance with the method descriptions. The Activity Plan was followed without deviations.

5 Results

The results of activity are stored in SKB's database SICADA, where they are traceable by the Activity Plan number.

Result minutes and photos are presented Appendix 1.

5.1 Results from respective level

Table 5-1 shows the results of the porosity and density determinations of the specimens from level 1 in KFM07A, 300–380 m. Table 5-2 displays the corresponding results from level 2, 670–680 m.

Table 5-1. Summary of the results for porosity, dry density and wet density determinations of the specimens from level 1, secrow 300 to 380 m (borehole length). The result for each specimen is a mean value of sub-samples A and B.

Specimen	Sampling level according to the marks on the drill-core boxes (secrow) (m)	Porosity (%)	Dry density (kg/m ³)	Wet density (kg/m ³)
KFM07A-90V-1	300.18	0.4	2,640	2,640
KFM07A-90V-2	319.86	0.4	2,650	2,650
KFM07A-90V-3	340.64	0.4	2,650	2,650
KFM07A-90V-4	358.85	0.3	2,660	2,660
KFM07A-90V-5	379.92	0.3	2,650	2,650
Mean value		0.4	2,650	2,650
Standard deviation		0.07	5	5

Table 5-2. Summary of the results for porosity, dry density and wet density determinations of the specimens from level 2, secrow 670 to 680 m (borehole length). The result for each specimen is a mean value of sub-samples 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)
KFM07A-90V-6	678.55	0.4	2,610	2,610
KFM07A-90V-7	678.61	0.3	2,630	2,630
KFM07A-90V-8	674.05	0.2	3,030	3,030
KFM07A-90V-9	674.11	0.3	3,030	3,030
Mean value		0.3	2,820	2,830
Standard deviation		0.06	218	218

5.2 Results for the entire test series

Results for the entire test series are presented in three diagrams below, representing dry density, wet density and porosity versus borehole length.

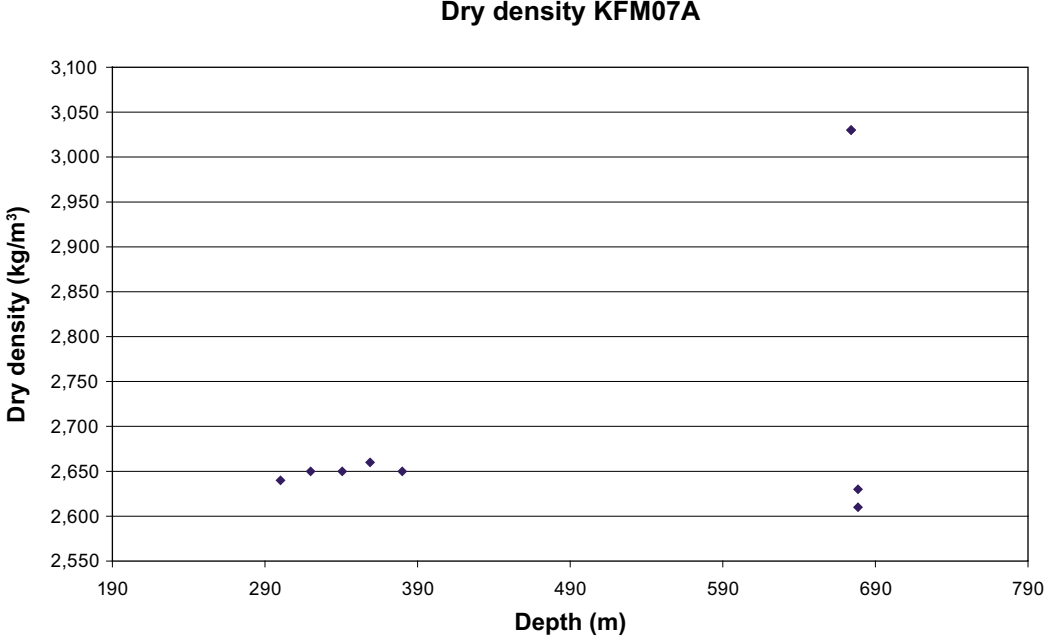


Figure 5-1. Dry density versus sampling level (borehole length). The value 3,030 kg/m³ represents results from two specimens collected close to each other.

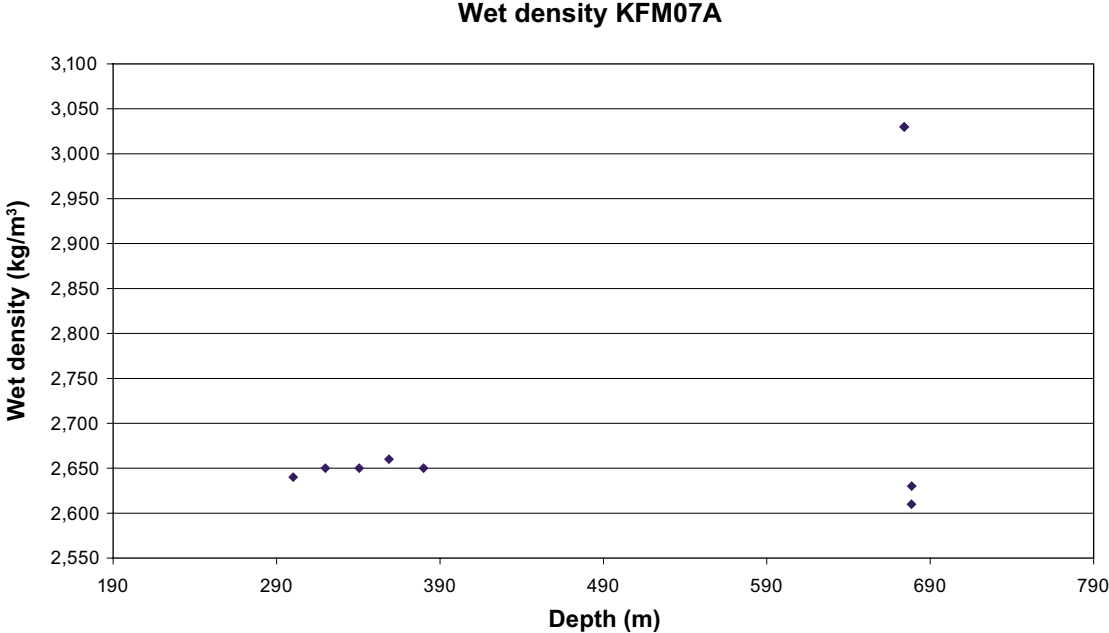


Figure 5-2. Wet density versus sampling level (borehole length). The value 3,030 kg/m³ represents results from two specimens collected close to each other.

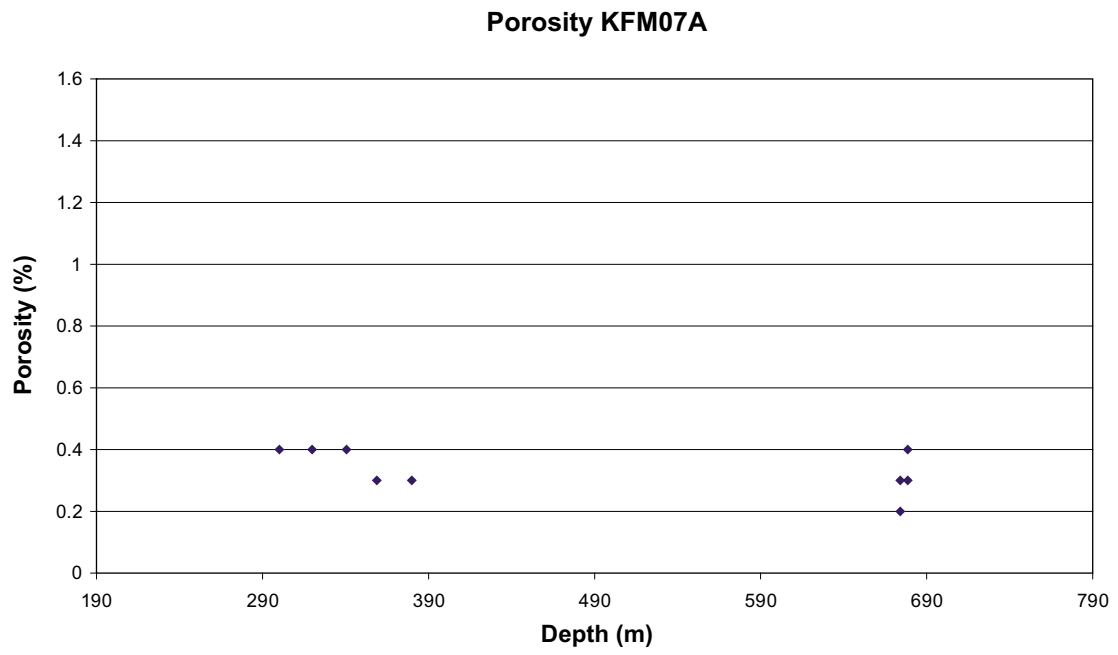


Figure 5-3. Porosity versus sampling level (borehole length).

References

- /1/ **SKB, 2001.** Site investigations. Investigation methods and general execution programme. SKB TR-01-29, Svensk Kärnbränslehantering AB.
- /2/ **Adl-Zarrabi B, 2005.** Forsmark site investigation. Borehole KFM07A. Thermal conductivity and thermal diffusivity determined using the TPS method. SKB P-05-214. Svensk Kärnbränslehantering AB.
- /2/ **ISRM. 1979.** Volume 16, Number 2.
- /3/ EN 13755, Natural stone test methods – Determination of water absorption at atmospheric pressure.

Results and photos

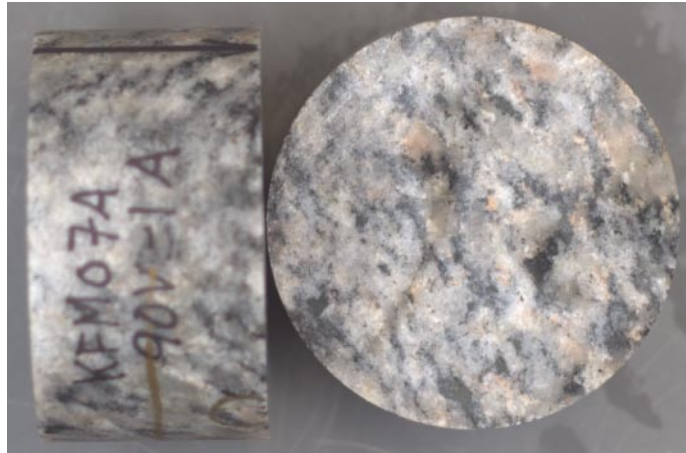
Table A-1. Level 1, 300–380 m, Specimens KFM07A-090V-1 to KFM07A-090V-5.

KFM07A-90V-1 (300.18 m)

Dry density of specimen KFM07A-90V-1A 2,640 kg/m³ and porosity 0.4%.

Dry density of specimen KFM07A-90V-1B 2,640 kg/m³ and porosity 0.4%.

Figure A-1. Specimen KFM07A-90V-1.

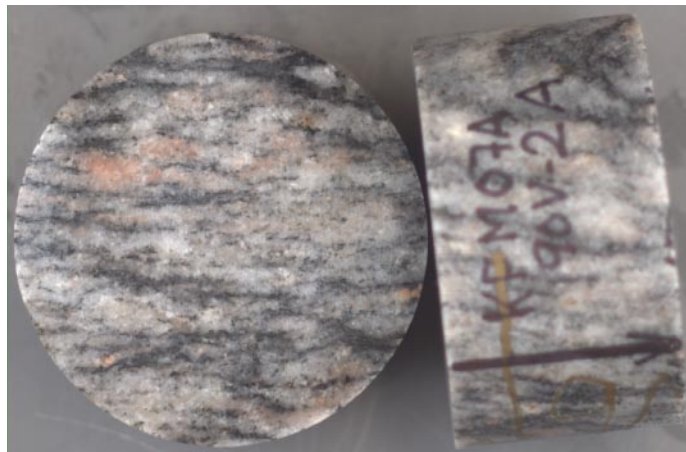


KFM07A-90V-2 (319.86 m)

Dry density of specimen KFM07A-90V-2A 2,650 kg/m³ and porosity 0.3%.

Dry density of specimen KFM07A-90V-2B 2,650 kg/m³ and porosity 0.4%.

Figure A-2. Specimen KFM07A-90V-2.

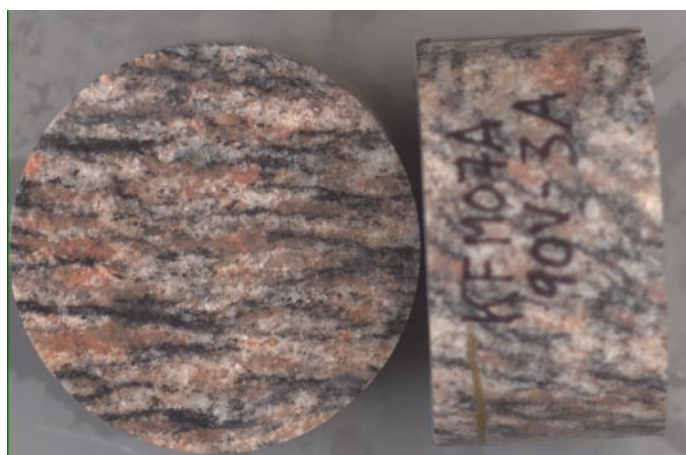


KFM07A-90V-3 (340.64 m)

Dry density of specimen KFM07A-90V-3A 2,650 kg/m³ and porosity 0.4%.

Dry density of specimen KFM07A-90V-3B 2,650 kg/m³ and porosity 0.4%.

Figure A-3. Specimen KFM07A-90V-3.



KFM07A -90V-4 (358.85 m)

Dry density of specimen KFM07A-90V-4A 2,660 kg/m³ and porosity 0.3%.

Dry density of specimen KFM07A-90V-4B 2,660 kg/m³ and porosity 0.3%.

Figure A-4. Specimen KFM07A-90V-4.



KFM07A -90V-5 (379.92 m)

Dry density of specimen KFM07A-90V-5A 2,650 kg/m³ and porosity 0.3%.

Dry density of specimen KFM07A-90V-5B 2,650 kg/m³ and porosity 0.3%.

Figure A-5. Specimen KFM07A-90V-5.



Table A-2. Level 2, 670–680 m, Specimens KFM07A-090V-6 to KFM07A-090V-9.

KFM07A -90V-6 (678.55 m)

Dry density of specimen KFM07A-90V-6A 2,610 kg/m³ and porosity 0.4%.

Dry density of specimen KFM07A-90V-6B 2,610 kg/m³ and porosity 0.3%.

Figure A-6. Specimen KFM07A-90V-6.

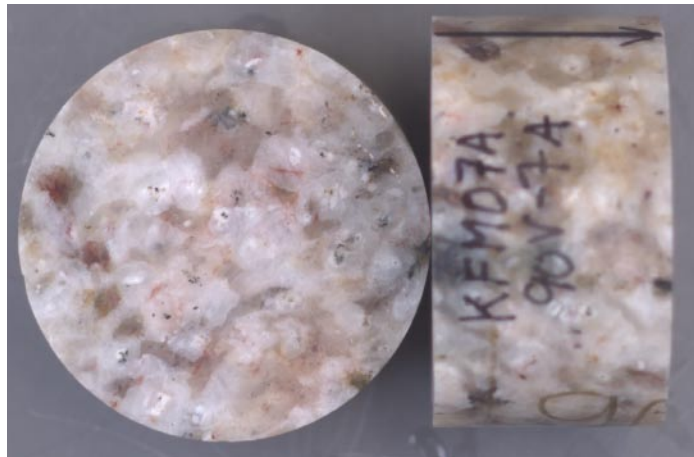


KFM07A -90V-7 (678.61 m)

Dry density of specimen
KFM07A-90V-7A 2,640 kg/m³
and porosity 0.3%.

Dry density of specimen
KFM07A-90V-7B 2,620 kg/m³
and porosity 0.3%.

Figure A-7. Specimen KFM07A-90V-7.



KFM07A -90V-8 (674.05 m)

Dry density of specimen
KFM07A-90V-8A 3,020 kg/m³
and porosity 0.2%.

Dry density of specimen
KFM07A-90V-8B 3,030 kg/m³
and porosity 0.3%.

Figure A-8. Specimen KFM07A-90V-8.



KFM07A-90V-9 (674.11 m)

Dry density of specimen
KFM07A-90V-9A 3,030 kg/m³
and porosity 0.3%.

Dry density of specimen
KFM07A-90V-9B 3,030 kg/m³
and porosity 0.4%.

Figure A-9. Specimen KFM07A-90V-9.

