P-05-220

Forsmark site investigation

Borehole KFM08A

Determination of porosity by water saturation and density by buoyancy technique

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September 2006

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Abstract

The density and porosity was determined on 16 specimens (each divided into two pieces) from borehole KFM08A, Forsmark, Sweden. The specimens were sampled at different levels between 200–820 m borehole length. The investigated rock types are mapped as 101057 (medium-grained granite), 102017 (amphibolite), 101051 (metamorphic, fine- to medium-grained granite, granodiorite and tonalite), 103076 (metamorphic, felsic to intermediate volcanic rock), 101061 (pegmatitic granite), and 101058 (metamorphic, aplitic granite). The results for the dry density varied between 2,620 and 2,990 kg/m^3, and for the wet density between 2,630 and 3,000 kg/m^3. Finally, the porosity results varied between 0.2 and 0.5%.

Sammanfattning

Densiteten och porositeten har bestämts på 16 provkroppar (varje provkropp delad i två delar) från borrhål KFM08A i Forsmark. Proverna togs från två nivåer i borrhålet mellan 200–820 m borrhålslängd. De undersökta bergarterna är karterade som 101057 (medelkornig granit), 102017 (amfibolit), 101051 (metamorf, fin- till medelkornig granit, granodiorit och tonalit), 103076 (metamorf, sur till intermediär vulkanit), 101061 (pegmatitisk granit) and 101058 (metamorf, aplitisk granit). Resultaten för den torra densiteten varierade mellan 2 620 och 2 990 kg/m^3 och för den våta densiteten mellan 2 630 och 3 000 kg/m^3. Porositeten varierade mellan 0,2 och 0,5 %.

Contents

1	**Introduction**	7
2	**Objective**	9
3	**Equipment**	11
4	**Execution**	13
4.1	Description of the specimens	13
4.2	Testing	13
4.3	Nonconformities	14
5	**Results**	15
5.1	Results from respective rock type	15
5.2	Results for the entire test series	17
References		19
Appendix	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 at Forsmark, Sweden /1/. The controlling documents for the activity are listed in Table 1-1. Both Activity Plan and Method Descriptions are SKB's internal controlling documents. The thermal properties conductivity and diffusivity of the specimens were determined within the scope of another activity /2/.

Sampled were collected from the drill core of borehole KFM08A within the Forsmark site investigation area, Sweden, see Figure 1-1, for determination of the water saturated respectively dry density as well as of the porosity. Borehole KFM08A is a telescopic drilled borehole inclined c 60° from the horizontal plane and with a total length of c 1,000 m. The borehole section 0–100.55 m is percussion drilled, whereas the section 100.55–1,000 m is core drilled.

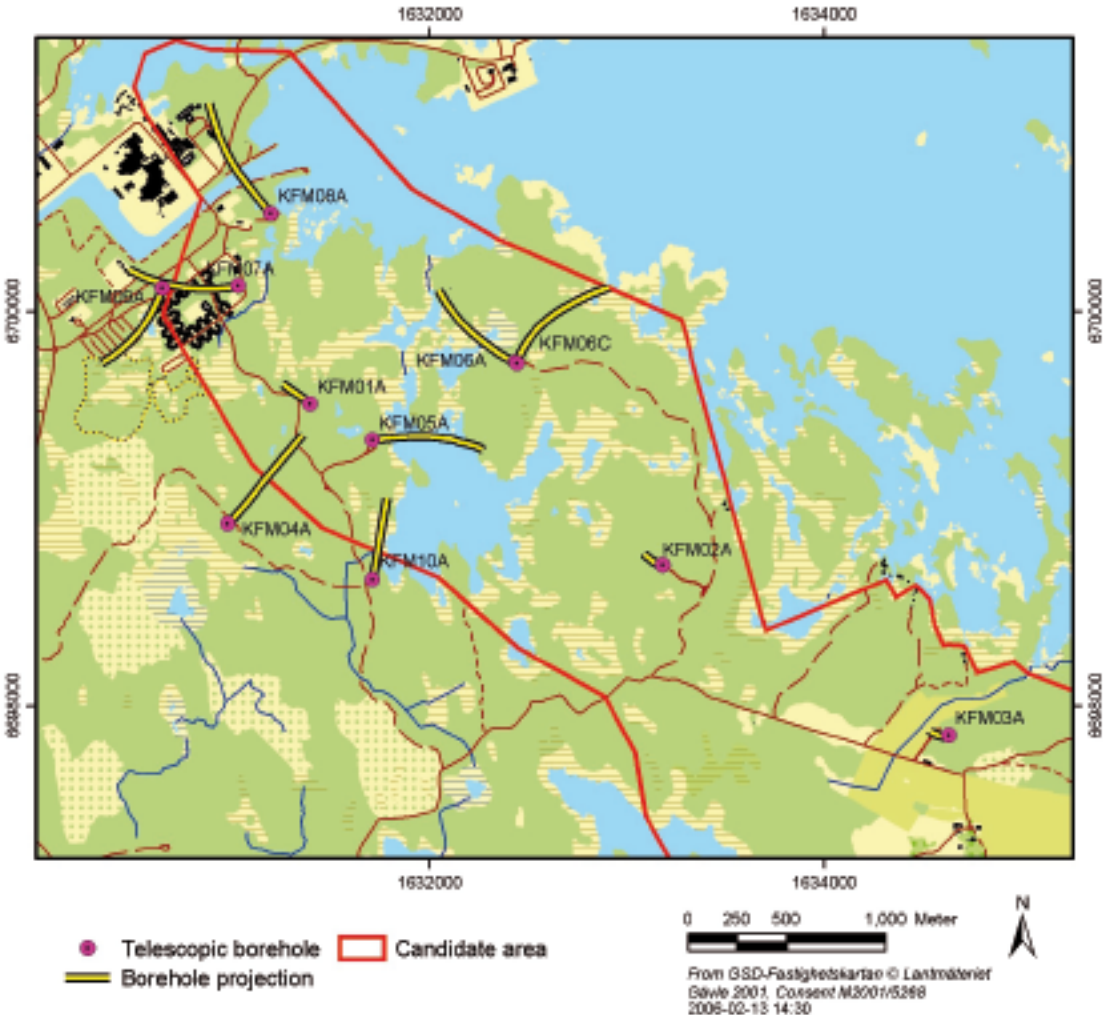

Figure 1-1. *Location of all telescopic boreholes drilled up to now (December 2005) within or close to the Forsmark candidate area. The projection of each borehole on the horizontal plane at top of casing is also shown in the figure.*

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

Activity Plan	Number	Version
KFM08A. Bergmekaniska och termiska laboratoriebestämningar	AP PF 400-05-058	1.0
Method Description	**Number**	**Version**
Determining density and porosity of intact rock	SKB MD 160.002	2.0

The sampling was based on the preliminary core logging with the strategy to investigate the properties of both dominant and minority rock types. The samples, which were collected by Thomas Jansson and Björn Ljunggren, Tyréns AB, in June, 2005, were transported to SP (Swedish National Testing and Research institute), department of Building and Mechanics, where they arrived on August 15, 2005. The testing was started in August 2005 and ended in October 2005.

2 Objective

The results of the density and porosity determinations of the intact rock cores will serve as inpur 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 used for the density and porosity determinations:

- Thermometer (inv no 102185) for measurement of water temperature. Calibrated 2005-02-04. Measurement uncertainty ± 0.4°C.
- Scale (inv no 102291) for weight measurement. Calibrated in 2005-04-10. Measurement uncertainty ± 0.2 g.
- Heating chamber (inv no 102289) for drying the specimens. Calibrated 2004-08-31. Measurement accuracy ± 5°C.
- A covered plastic box filled with water for water saturation of the samples.
- A desiccator for cooling of 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 160.002, (SKB internal controlling document). This includes determination of density in accordance to ISRM 1979 /3/ and water saturation by EN 13755 /4/ and in compliance with Activity Plan AP PF 400-05-058 (internal controlling document of SKB, see Table 1-1). The department of Building Technology and Mechanics (BM) at SP performed the test.

4.1 Description of the specimens

The specimens from borehole KFM08A were sampled at levels ranging between 200 and 820 m borehole length. Table 4-1 shows the identification mark, sampling level and rock type of each specimen.

4.2 Testing

The execution procedure followed the prescription in SKB MD 160.002, (SKB internal controlling document), see Table 4-2. The temperature of the water used for water saturation was 18°C, and the density was 999 kg/m^3. The specimens were dried in 105°C for one week after water saturation.

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 4-1. Identification mark, sampling levels (borehole length) and rock type of the collected specimens from borehole KFM08A at Forsmark. Each identification mark represents two specimens, designated A and B respectively.

Identification	Sampling level (m) (Adj seclow)	Rock type
KFM08A-90V-1	200.896	101057
KFM08A-90V-2	257.312	102017
KFM08A-90V-3	288.798	101057
KFM08A-90V-4	350.193	101057
KFM08A-90V-5	424.299	101057
KFM08A-90V-6	460.258	101051
KFM08A-90V-7	478.476	102017
KFM08A-90V-8	494.625	103076
KFM08A-90V-9	503.615	101057
KFM08A-90V-10	576.502	101057
KFM08A-90V-11	650.050	101057
KFM08A-90V-12	668.600	101061
KFM08A-90V-13	670.376	101061
KFM08A-90V-14	783.895	101058
KFM08A-90V-15	807.613	101058
KFM08A-90V-16	812.795	101058

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

Activity No	Activity
1	The specimens were cut according to the marks on the rock cores. Every specimen was cut into two pieces, marked A and B and about 25 mm thick each. The same specimens were used the thermal properties thermal conductivity and thermal diffusivity by applying the TPS method /3/.
2	The specimens were water saturated in normal air pressure for at least seven days.
3	The specimens were weighed in tapwater.
4	The specimens were surface dried with a towel and weighed.
5	The water saturated density was determined.
6	The samples were sent from SP Building and Mechanics to SP Fire Technology for measurement of thermal properties /3/.
7	The samples were sent back from SP Fire Technology to SP Building and Mechanics
8	The specimens were dried in a heating chamber during one week 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 Description. The Activity Plan was followed without deviations.

5 Results

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

Minutes and photos are presented in Appendix 1.

5.1 Results from respective rock type

Tables 5-1 to 5-6 show the results of the porosity and density determinations of the specimens from KFM08A. The results are grouped according to rock type.

Table 5-1. Summary of the results for porosity, dry density and wet density of the specimens of rock type 101057 (medium-grained granite). The result for each specimen is a mean value of sub-samples A and B.

Specimen	Sampling level (m borehole length), according to the marks on the drill-core boxes (Adj seclow)	Porosity (%)	Dry density (kg/m^3)	Wet density (kg/m^3)
KFM08A-90V-1	200.896	0.5	2,650	2,650
KFM08A-90V-3	288.798	0.4	2,650	2,660
KFM08A-90V-4	350.193	0.3	2,660	2,660
KFM08A-90V-5	424.299	0.3	2,650	2,650
KFM08A-90V-9	503.615	0.3	2,650	2,660
KFM08A-90V-10	576.502	0.3	2,650	2,650
KFM08A-90V-11	650.050	0.3	2,650	2,660
Mean value		0.3	2,650	2,650
Standard deviation		0.09	4	3

Table 5-2. Summary of the results for porosity, dry density and wet density of the specimens of rock type 102017 (amphibolite). The result for each specimen is a mean value of sub-samples A and B.

Specimen	Sampling level (m borehole length), according to the marks on the drill-core boxes (Adj seclow)	Porosity (%)	Dry density (kg/m^3)	Wet density (kg/m^3)
KFM08A-90V-2	257.312	0.4	2,990	3,000
KFM08A-90V-7	478.476	0.5	2,970	2,980
Mean value		0.4	2,980	2,990
Standard deviation		0.03	11	11

Table 5-3. Summary of the results for porosity, dry density and wet density of the specimens of rock type 101051 (granite, granodiorite and tonalite, metamorphic, fine- to medium-grained). The result for each specimen is a mean value of sub- samples A and B.

Specimen	Sampling level (m borehole length), according to the marks on the drill-core boxes (Adj seclow)	Porosity (%)	Dry density (kg/m^3)	Wet density (kg/m^3)
KFM08A-90V-6	460.258	0.3	2,720	2,720
Mean value		–	–	–
Standard deviation		–	–	–

Table 5-4. Summary of the results for porosity, dry density and wet density of the specimens of rock type 103076 (felsic to intermediate volcanic rock, metamorphic). The result for each specimen is a mean value of sub-samples A and B.

Specimen	Sampling level (m borehole length), according to the marks on the drill-core boxes (Adj seclow)	Porosity (%)	Dry density (kg/m^3)	Wet density (kg/m^3)
KFM08A-90V-8	494.625	0.4	2,700	2,700
Mean value		–	–	–
Standard deviation		–	–	–

Table 5-5. Summary of the results for porosity, dry density and wet density of the specimens of rock type 101061 (pegmatitic granite). The result for each specimen is a mean value of sub-samples A and B.

Specimen	Sampling level (m borehole length), according to the marks on the drill-core boxes (Adj seclow)	Porosity (%)	Dry density (kg/m^3)	Wet density (kg/m^3)
KFM08A-90V-12	668.600	0.3	2,620	2,630
KFM08A-90V-13	670.376	0.3	2,640	2,640
Mean value		0.3	2,630	2,630
Standard deviation		0.02	14	14

Table 5-6. Summary of the results for porosity, dry density and wet density of the specimens of rock type 101058 (granite, metamorphic, aplitic). The result for each specimen is a mean value of sub-samples A and B.

Specimen	Sampling level (m borehole length), according to the marks on the drill-core boxes (Adj seclow)	Porosity (%)	Dry density (kg/m³)	Wet density (kg/m³)
KFM08A-90V-14	783.895	0.2	2,630	2,630
KFM08A-90V-15	807.613	0.4	2,620	2,630
KFM08A-90V-16	812.795	0.3	2,630	2,630
Mean value		0.3	2,630	2,630
Standard deviation		0.05	4	4

5.2 Results for the entire test series

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

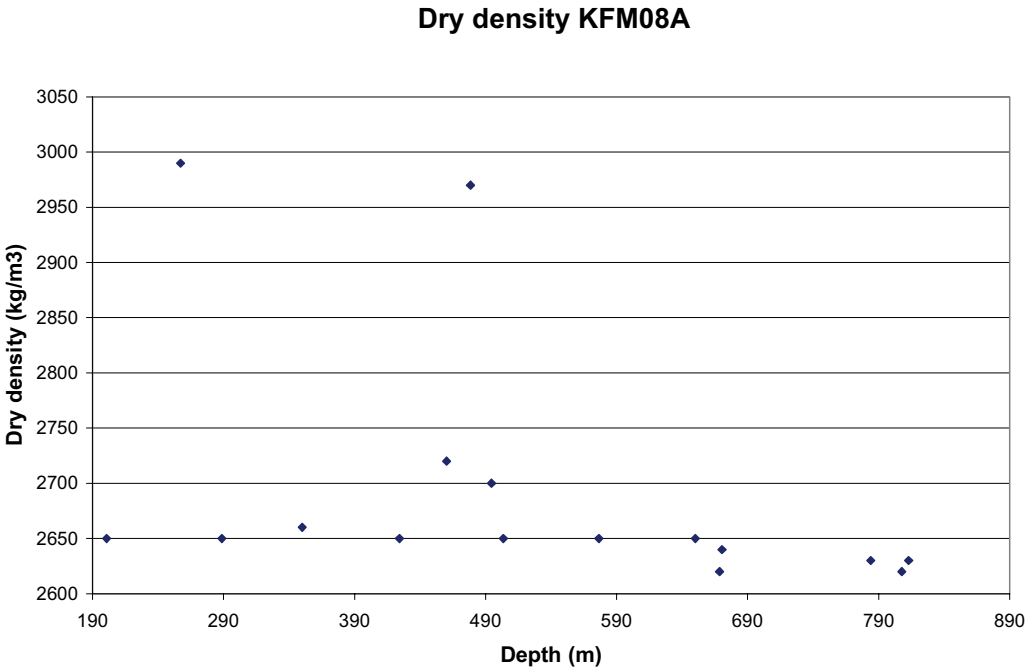

Figure 5-1. *Density (dry) versus sampling level (borehole length).*

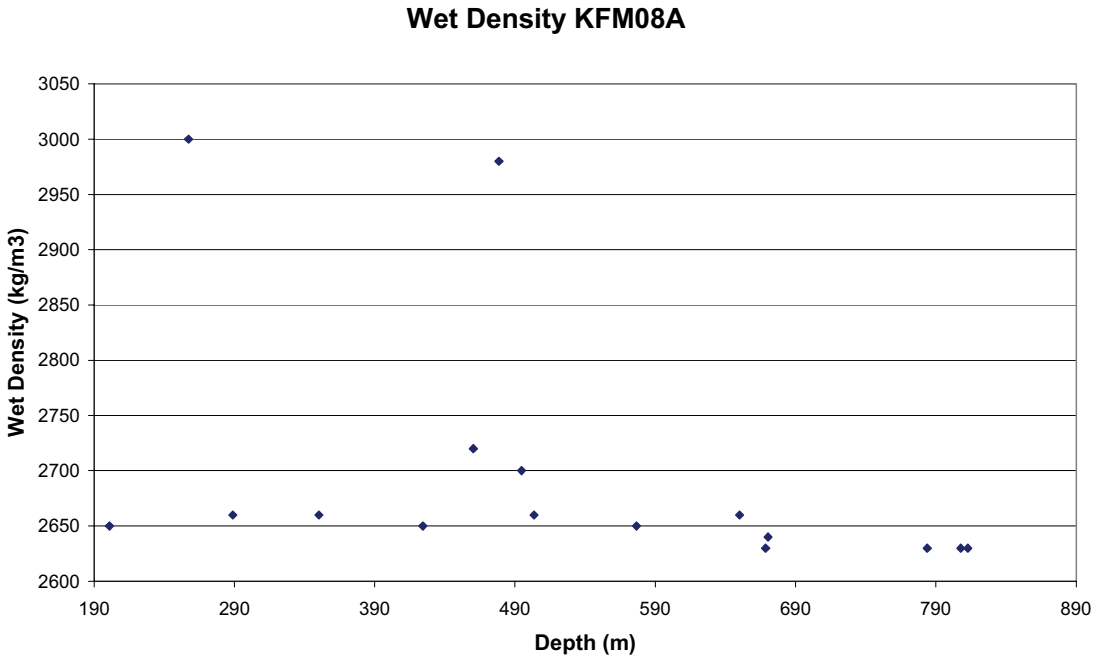

Figure 5-2. *Density (wet) versus sampling level (borehole length).*

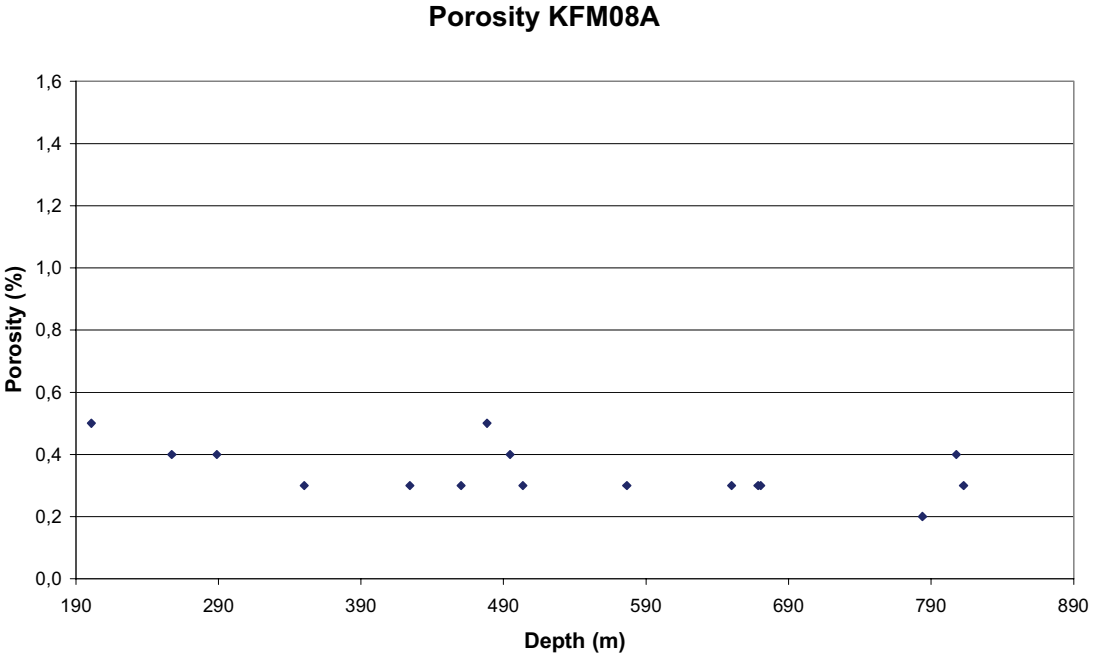

Figure 5-3. *Porosity versus sampling level (borehole length).*

References

/1/ **SKB, 2001.** Site investigation methods and general execution programme. SKB TR-01-29, Svensk Kärnbränslehantering AB.

/2/ **Adl-Zarrabi B, 2005.** Borehole KFM08A.Thermal conductivity and thermal diffusivity determined using the TPS method. SKB P-05-219, Svensk Kärnbränslehantering AB.

/3/ **ISRM, 1979.** Volume 16, Number 2.

/4/ **EN 13755.** Natural stone test methods – Determination of water absorption at atmospheric pressure.

Results and photos

Table A-1. KFM08A, level 200–820 m. Specimens KFM08A-090V-1 to KFM08A-090V-16.

KFM08A-90V-1 (200.896 m) The dry density for specimen KFM08A-90V-1A was measured to be 2,650 kg/m^3 and the porosity 0.6%. The dry density for specimen KFM08A-90V-1B was measured to be 2,650 kg/m^3 and the porosity 0.4%.	 ***Figure A-1.*** *Specimen KFM08A-90V-1.*
KFM08A-90V-2 (257.312 m) The dry density for specimen KFM08A-90V-2A was measured to be 2,990 kg/m^3 and the porosity 0.4%. The dry density for specimen KFM08A-90V-2B was measured to be 2,990 kg/m^3 and the porosity 0.5%.	 ***Figure A-2.*** *Specimen KFM08A-90V-2.*

KFM08A-90V-3 (288.798 m)

The dry density for specimen KFM08A-90V-3A was measured to be 2,660 kg/m^3 and the porosity 0.4%.

The dry density for specimen KFM08A-90V-3B was measured to be 2,650 kg/m^3 and the porosity 0.4%.

Figure A-3. *Specimens KFM08A-90V-3.*

KFM08A-90V-4 (350.193 m)

The dry density for specimen KFM08A-90V-4A was measured to be 2,660 kg/m^3 and the porosity 0.2%.

The dry density for specimen KFM08A-90V-4B was measured to be 2,660 kg/m^3 and the porosity 0.3%.

Figure A-4. *Specimens KFM08A-90V-4.*

KFM08A-90V-5 (424.299 m)

The dry density for specimen KFM08A-90V-5A was measured to be 2,650 kg/m^3 and the porosity 0.4%.

The dry density for specimen KFM08A-90V-5B was measured to be 2,650 kg/m^3 and the porosity 0.3%.

Figure A-5. *Specimens KFM08A-90V-5.*

KFM08A-90V-6 (460.258 m)

The dry density for specimen KFM08A-90V-6A was measured to be 2,720 kg/m^3 and the porosity 0.3%.

The dry density for specimen KFM08A-90V-6B was measured to be 2,720 kg/m^3 and the porosity 0.3%.

Figure A-6. *Specimens KFM08A-90V-6.*

KFM08A-90V-7 (478.476 m)

The dry density for specimen KFM08A-90V-7A was measured to be 2,980 kg/m^3 and the porosity 0.5%.

The dry density for specimen KFM08A-90V-7B was measured to be 2,970 kg/m^3 and the porosity 0.4%.

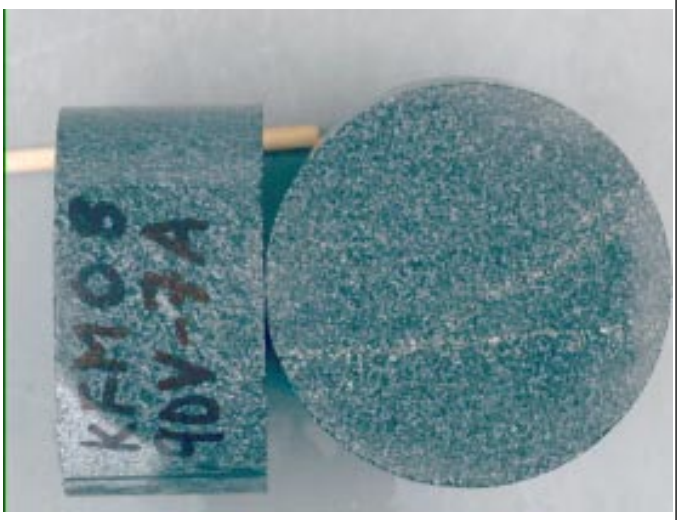

Figure A-7. *Specimens KFM08A-90V-7.*

KFM08A-90V-8 (494.625 m)

The dry density for specimen KFM08A-90V-8A was measured to be 2,700 kg/m^3 and the porosity 0.3%.

The dry density for specimen KFM08A-90V-8B was measured to be 2,700 kg/m^3 and the porosity 0.4%.

Figure A-8. *Specimens KFM08A-90V-8.*

KFM08A-90V-9 (503.615 m)

The dry density for specimen KFM08A-90V-9A was measured to be 2,650 kg/m^3 and the porosity 0.3%.

The dry density for specimen KFM08A-90V-9B was measured to be 2,650 kg/m^3 and the porosity 0.2%.

Figure A-9. *Specimens KFM08A-90V-9.*

KFM08A-90V-10 (576.502 m)

The dry density for specimen KFM08A-90V-10A was measured to be 2,650 kg/m^3 and the porosity 0.3%.

The dry density for specimen KFM08A-90V-10B was measured to be 2,650 kg/m^3 and the porosity 0.3%.

Figure A-10. *Specimens KFM08A-90V-10.*

KFM08A-90V-11 (650.050 m)

The dry density for specimen KFM08A-90V-11A was measured to be 2,650 kg/m^3 and the porosity 0.3%.

The dry density for specimen KFM08A-90V-11B was measured to be 2,660 kg/m^3 and the porosity 0.3%.

Figure A-11. *Specimens KFM08A-90V-11.*

KFM08A-90V-12 (668,600)

The dry density for specimen KFM08A-90V-12A was measured to be 2,610 kg/m^3 and the porosity 0.3%.

The dry density for specimen KFM08A-90V-12B was measured to be 2,640 kg/m^3 and the porosity 0.3%.

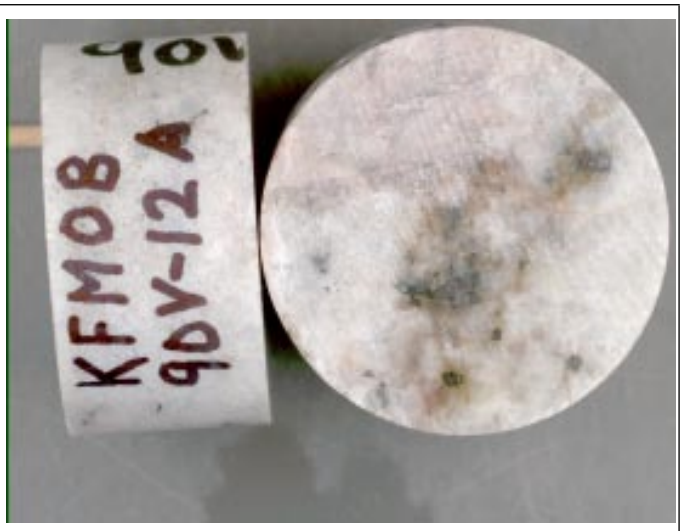

Figure A-12. *Specimens KFM08A-90V-12.*

KFM08A-90V-13 (670.376 m)

The dry density for specimen KFM08A-90V-13A was measured to be 2,630 kg/m^3 and the porosity 0.3%.

The dry density for specimen KFM08A-90V-13B was measured to be 2,640 kg/m^3 and the porosity 0.3%.

Figure A-13. *Specimens KFM08A-90V-13.*

KFM08A-90V-14 (783.895 m)

The dry density for specimen KFM08A-90V-14A was measured to be 2,630 kg/m^3 and the porosity 0.2%.

The dry density for specimen KFM08A-90V-14B was measured to be 2,630 kg/m^3 and the porosity 0.2%.

Figure A-14. *Specimens KFM08A-90V-14.*

KFM08A-90V-15 (807.613 m) The dry density for specimen KFM08A-90V-15A was measured to be 2,620 kg/m^3 and the porosity 0.3%. The dry density for specimen KFM08A-90V-15B was measured to be 2,620 kg/m^3 and the porosity 0.4%.	 ***Figure A-15.*** *Specimens KFM08A-90V-15.*
KFM08A-90V-16 (812.795 m) The dry density for specimen KFM08A-90V-16A was measured to be 2,630 kg/m^3 and the porosity 0.3%. The dry density for specimen KFM08A-90V-16B was measured to be 2,630 kg/m^3 and the porosity 0.3%.	 ***Figure A-16.*** *Specimens KFM08A-90V-16.*