P-06-268

Oskarshamn site investigation

Borehole KLX11A

Determination of porosity by water saturation and density by buoyancy technique

Marjo Savukoski
SP Swedish National Testing and Research Institute

December 2007

Svensk Kärnbränslehantering AB
Swedish Nuclear Fuel
and Waste Management Co
Box 250, SE-101 24 Stockholm
Tel +46 8 459 84 00

ISSN 1651-4416
SKB P-06-268

Oskarshamn site investigation

Borehole KLX11A

Determination of porosity by water saturation and density by buoyancy technique

Marjo Savukoski
SP Swedish National Testing and Research Institute

December 2007

Keywords: Rock mechanics, Petro-physics, Density, Porosity, AP PS 400-06-062.

Abstract

The density and porosity was determined on 12 specimens (each divided into two pieces) from borehole KLX11A, Oskarshamn, Sweden. The specimens were sampled at bore hole lengths measuring between 320–775 m. The investigated rock type is mapped as quartz monzodiorite. The results for the dry density varied between 2,740 and 2,780 kg/m^3, and for the wet density between 2,740 and 2,790 kg/m^3. Finally, the porosity results varied between 0.2 and 0.4%.

Sammanfattning

Densiteten och porositeten bestämdes på 12 provkroppar (varje provkropp delad i två delar) från borrhål KLX11A i Oskarshamn. Proverna togs mellan borrhålslängden 320–775 m. Den undersökta bergarten är karterad som kvartsmonzodiorit. Resultaten för torrdensiteten varierade mellan 2 740 och 2 780 kg/m^3 och för våtdensiteten mellan 2 740 och 2 790 kg/m^3. För porositeten, slutligen, varierade resultaten mellan 0,2 och 0,4 %.

Contents

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 Oskarshamn, 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 KLX11A within the Oskarshamn site investigation area at Oskarshamn, Sweden, see Figure 1-1.Borehole KLX11A is a telescopic drilled borehole strike 89° and dip 76° from the horizontal plane and with a total length of 1,000 m.

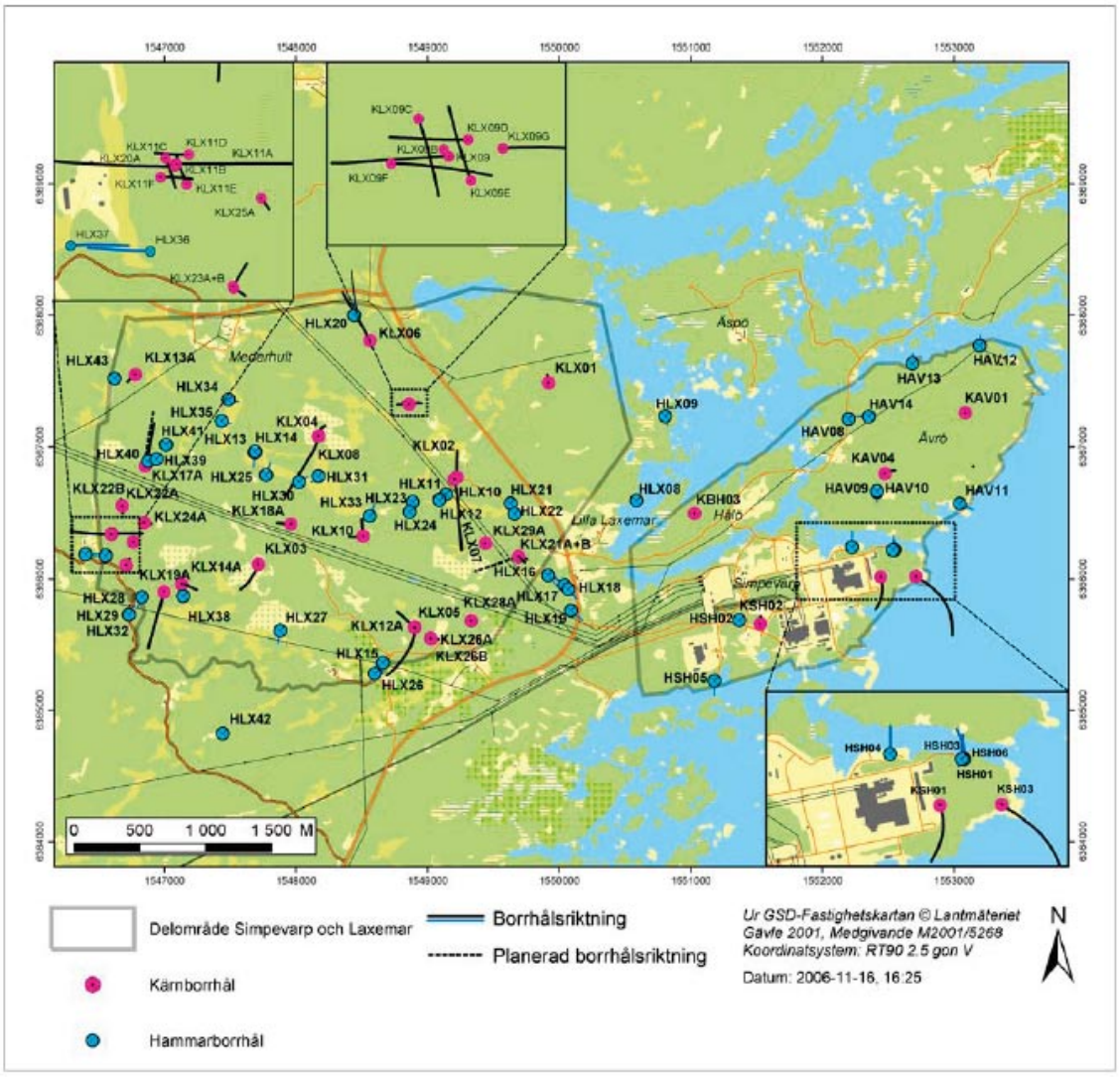

Figure 1-1. *Location of boreholes drilled up to November 2006.*

The samples were selected based on the preliminary core logging, and with the strategy to primarily investigate the properties of the rock type quartz monzodiorite (501036). The samples, which were collected in May 24, 2006, were transported to SP (Swedish National Testing and Research institute), department of Building and Mechanics, where they arrived in May 31, 2006. Testing commenced in July 2006 and was completed in August 2006.

The commission was carried out in compliance with the controlling documents presented in Table 1-1. Activity Plan and Method Descriptions are SKB's (The Swedish Nuclear Fuel and waste Management Company) internal controlling documents, whereas SP-QD 13.1 is an SP internal Quality document.

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

Activity plan	**Number**	**Version**
KLX11A. Bergmekaniska och termiska laboratoriebestämningar	AP PS 400-06-062	1.0
Method description	**Number**	**Version**
Determining density and porosity of intact rock	SKB MD 160.002	2.0
Quality plan		
SP-QD 13.1		

2 Objective and scope

The purpose of determining density and porosity of intact rock cores is to use these parameters in the rock mechanics and thermal site descriptive model, which will be established for the candidate area selected for site investigations at Oskarshamn.

The testing comprised of 12 rock samples from borehole KLX11A collected within the borehole interval 320–775 m.

3 Equipment

The following equipment was used for the density and porosity determinations:

- Thermometer (inv no 102185) for measurement of water temperature. Calibrated 2006-01-17. Measurement accuracy ± 0.4°C.
- Scale (inv no 102291) for weight measurement. Calibrated in 2005-03-10. Measurement accuracy ± 0.2 g.
- Heating chamber (inv no 102284) for drying the specimens. Calibrated 2006-01-17. Measurement accuracy ± 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 160.002, (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 PS 400-06-062 (internal controlling document of SKB). The department of Building Technology and Mechanics (BM) at SP performed the test.

4.1 Description of the specimens

The specimens from borehole KLX11A were sampled at levels ranging between 320 and 775 m borehole length. Table 4-1 shows the identification mark, sampling level and rock type of each specimen.

4.2 Testing

The temperature of the water used for water saturation was 21°C and the density was 998 kg/m^3.The specimens were dried in 105°C for twelve days 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 activities /2/, conducted by the Fire technology at SP and Measurement technology at SP, and by whom the thermal properties were determined. The folloving logistic sequence was applied for the two activities.

Table 4-1. Identification mark, sampling level and rock type/occurance of each specimen (rock-type classification according to Boremap).

Identification	Sampling level (m borehole length, Adj seclow)	Rock type
KLX11A-90V-1	319.140	Quartz Monzodiorite (501036)
KLX11A-90V-2	356.140	Quartz Monzodiorite (501036)
KLX11A-90V-3	400.510	Quartz Monzodiorite (501036)
KLX11A-90V-4	440.260	Quartz Monzodiorite (501036)
KLX11A-90V-5	457.310	Quartz Monzodiorite (501036)
KLX11A-90V-6	482.030	Quartz Monzodiorite (501036)
KLX11A-90V-7	522.231	Quartz Monzodiorite (501036)
KLX11A-90V-8	553.261	Quartz Monzodiorite (501036)
KLX11A-90V-9	613.031	Quartz Monzodiorite (501036)
KLX11A-90V-10	638.551	Quartz Monzodiorite (501036)
KLX11A-90V-11	721.310	Quartz Monzodiorite (501036)
KLX11A-90V-12	774.751	Quartz Monzodiorite (501036)

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 into two pieces, marked A and B and about 25 mm thick each. The same specimens were used in a parallel activity to determine the thermal properties thermal conductivity and thermal diffusivity by applying the TPS method /2/.
2	The specimens were water saturated in normal air pressure for at least seven days.
3	The specimens were photographed in JPEG-format.
4	The specimens were weighed in tapwater. The temperature of the water was 20.7°C and the density 998 kg/m^3.
5	The specimens were surface dried with a towel and weighed.
6	The water saturated density was determined.
7	The samples were sent from SP Building Technology and Mechanics to SP Measurement technology for measurement of thermal properties
8	The samples were sent from SP Measurement technology to SP Fire Technology for measurement of thermal properties /2/.
9	The samples were sent back from SP Fire Technology to SP Building Technology and Mechanics.
10	The specimens were dried in a heating chamber for twelve days at 105°C.
11	The specimens were transported to a desiccator for cooling.
12	The dry density and porosity were determined.

4.3 Nonconformities

The tests were performed in accordance with the Method Description.

An exception from the method was the statement of significant numbers in Appendix 1. The precision in the method for density gives only three significant digits the fourth digit given here is thus not significant. The precision in the method for porosity gives only one significant digit the second digit given here is thus not significant. It is important that this is kept in mind when the results are used for further calculation.

5 Results

The results of the porosity and density determinations of core samples from KLX11A 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 grouped according to rock type of the specimens

Table 5-1 summarizes the results of the porosity and density determinations divided according to rock type of the specimens.

5.2 Results for the entire test series

Results for the entire test series are shown in the diagrams below. They are divided into three diagrams, see Figures 5-1 to 5-3, illustrating dry density, wet density and porosity.

Table 5-1. Summary of the results for porosity, dry density and wet density. The result for each specimen is a mean value of sub samples A and B.

Specimen	Sampling level (m borehole length), (Adj seclow)	Porosity (%)	Dry density (kg/m^3)	Wet density (kg/m^3)
KLX11A-90V-1	319.140	0.3	2,770	2,770
KLX11A-90V-2	356.140	0.4	2,740	2,740
KLX11A-90V-3	400.510	0.3	2,770	2,780
KLX11A-90V-4	440.260	0.4	2,770	2,770
KLX11A-90V-5	457.310	0.3	2,770	2,770
KLX11A-90V-6	482.030	0.4	2,760	2,770
KLX11A-90V-7	522.231	0.3	2,780	2,790
KLX11A-90V-8	553.261	0.2	2,780	2,780
KLX11A-90V-9	613.031	0.3	2,770	2,770
KLX11A-90V-10	638.551	0.3	2,780	2,790
KLX11A-90V-11	721.310	0.4	2,780	2,790
KLX11A-90V-12	774.751	0.4	2,760	2,760
Mean value		0.3	2,770	2,770
Standard deviation		0.07	13	13

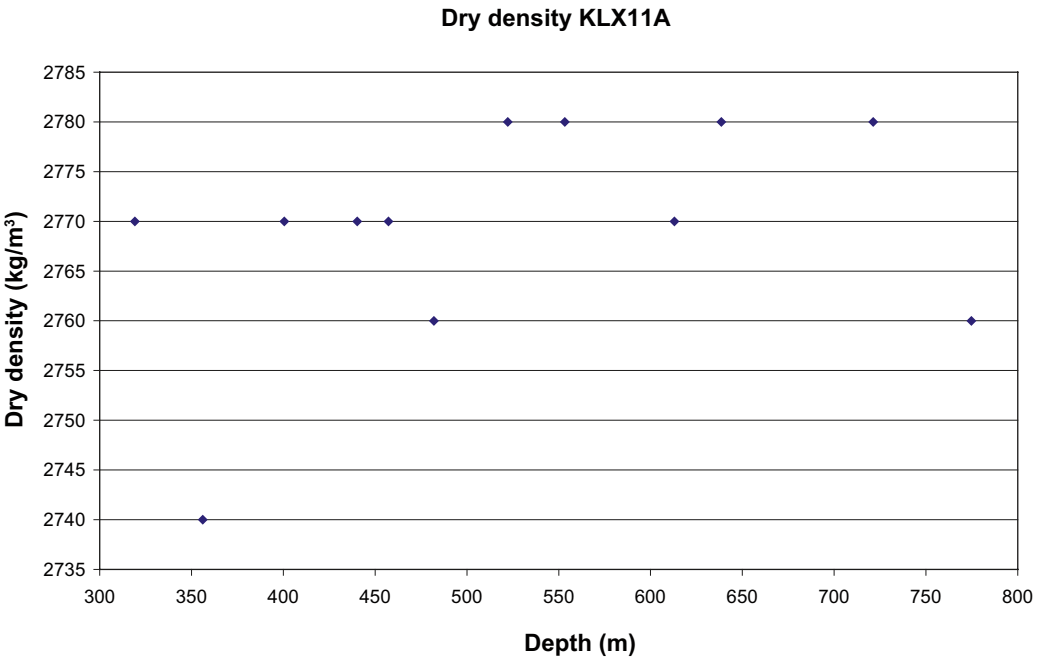

Figure 5-1. *Density (dry) versus sampling level (borehole length).*

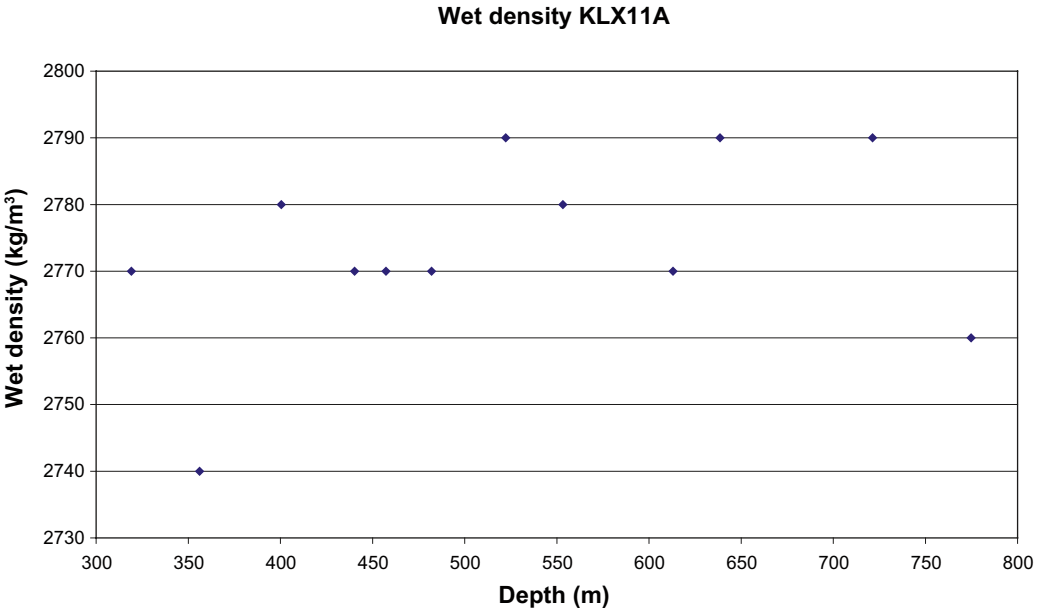

Figure 5-2. *Density (wet) versus sampling level (borehole length).*

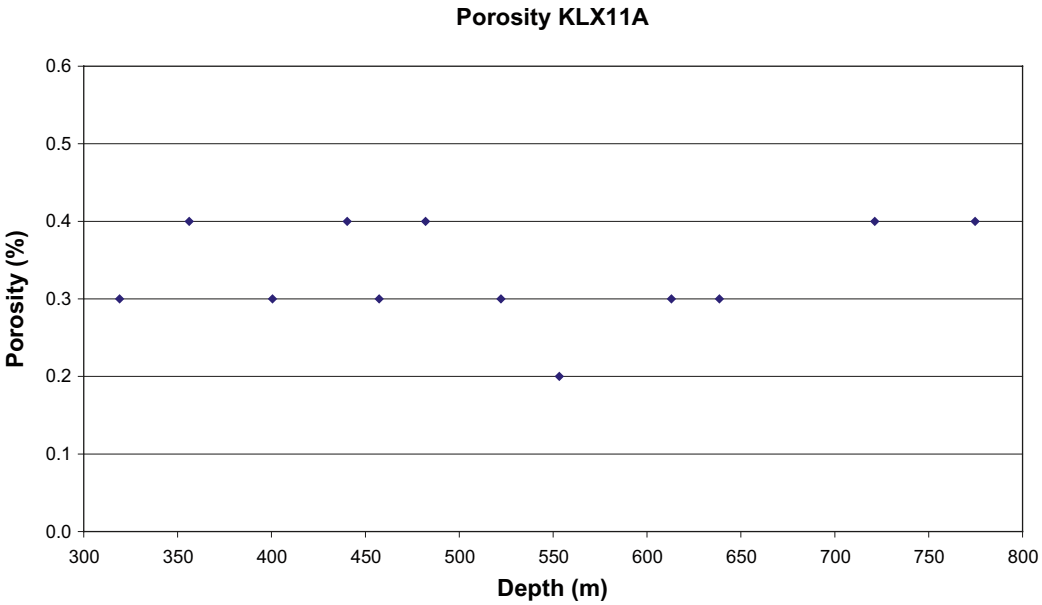

Figure 5-3. *Porosity versus sampling level (borehole length).*

References

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

/2/ **Adl-Zarrabi B, 2006.** Borehole KLX11A. Thermal properties of rocks using calorimeter and TPS method. SKB P-06-269, Svensk Kärnbränslehantering AB.

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

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

Result minutes and photos

Table A-1. KLX11A, level 320–775 m. Specimens KLX11A-090V-1 to KLX11A-090V-12.

KLX11A-90V-1 (319.140 m) Dry density of specimen KLX11A-90V-1A 2,768 kg/m^3 and porosity 0.30% Dry density of specimen KLX11A-90V-1B 2,766 kg/m^3 and porosity 0.34%	 ***Figure A-1.*** *Specimens KLX11A-90V-1 A and B.*
KLX11A-90V-2 (356.140 m) Dry density of specimen KLX11A-90V-2A 2,747 kg/m^3 and porosity 0.38%. Dry density of specimen KLX11A-90V-2B 2,733 kg/m^3 and porosity 0.38%.	 ***Figure A-2.*** *Specimens KLX11A-90V-2 A and B.*
KLX11A-90V-3 (400.510 m) Dry density of specimen KLX11A-90V-3A 2,775 kg/m^3 and porosity 0.30%. Dry density of specimen KLX11A-90V-3B 2,768 kg/m^3 and porosity 0.34%.	 ***Figure A-3.*** *Specimens KLX11A-90V-3 A and B.*

KLX11A-90V-4 (440.260 m)

Dry density of specimen KLX11A-90V-4A 2,774 kg/m^3 and porosity 0.34%.

Dry density of specimen KLX11A-90V-4B 2,765 kg/m^3 and porosity 0.38%.

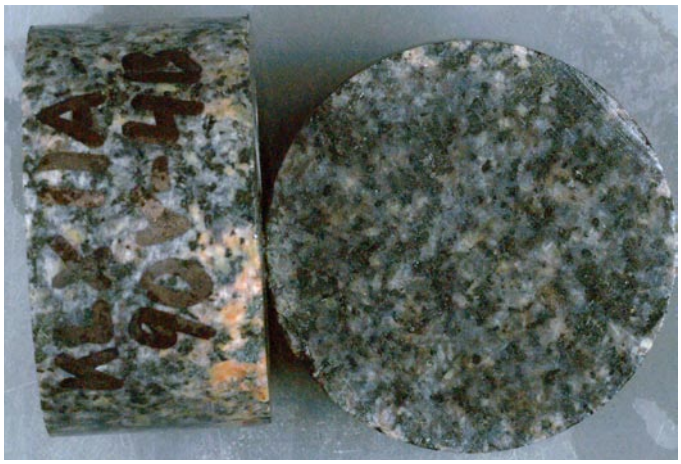

Figure A-4. *Specimens KLX11A-90V-4 A and B.*

KLX11A-90V-5 (457.310 m)

Dry density of specimen KLX11A-90V-5A 2,771 kg/m^3 and porosity 0.32%.

Dry density of specimen KLX11A-90V-5B 2,769 kg/m^3 and porosity 0.32%.

Figure A-5. *Specimens KLX11A-90V-5 A and B.*

KLX11A-90V-6 (482.030 m)

Dry density of specimen KLX11A-90V-6A 2,760 kg/m^3 and porosity 0.43%.

Dry density of specimen KLX11A-90V-6B 2,765 kg/m^3 and porosity 0.38%.

Figure A-6. *Specimens KLX11A-90V-6 A and B.*

KLX11A-90V-7 (522.231 m)

Dry density of specimen KLX11A-90V-7A 2,791 kg/m^3 and porosity 0.30%.

Dry density of specimen KLX11A-90V-7B 2,777 kg/m^3 and porosity 0.32%.

Figure A-7. *Specimens KLX11A-90V-7 A and B.*

KLX11A-90V-8 (553.261 m)

Dry density of specimen KLX11A-90V-8A 2,780 kg/m^3 and porosity 0.21%.

Dry density of specimen KLX11A-90V-8B 2,786 kg/m^3 and porosity 0.19%.

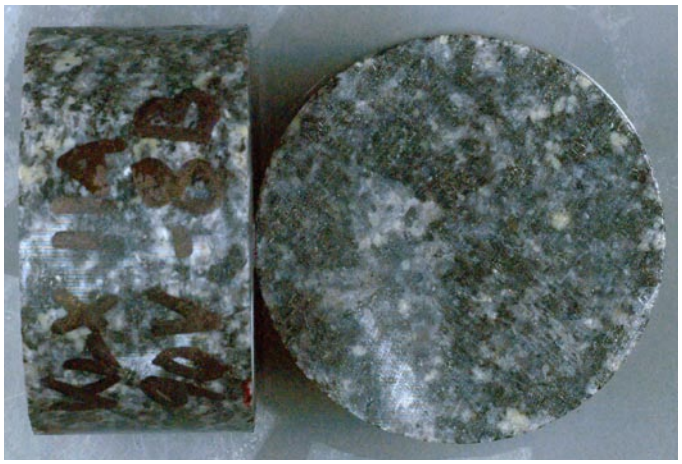

Figure A-8. *Specimens KLX11A-90V-8 A and B.*

KLX11A-90V-9 (613.031 m)

Dry density of specimen KLX11A-90V-9A 2,772 kg/m^3 and porosity 0.26%.

Dry density of specimen KLX11A-90V-9B 2,766 kg/m^3 and porosity 0.29%.

Figure A-9. *Specimens KLX11A-90V-9 A and B.*

KLX11A-90V-10 (638.551 m)

Dry density of specimen KLX11A-90V-10A 2,785 kg/m^3 and porosity 0.26%.

Dry density of specimen KLX11A-90V-10B 2,785 kg/m^3 and porosity 0.26%.

Figure A-10. *Specimens KLX11A-90V-10 A and B.*

KLX11A-90V-11 (721.310 m)

Dry density of specimen KLX11A-90V-11A 2,783 kg/m^3 and porosity 0.38%.

Dry density of specimen KLX11A-90V-11B 2,780 kg/m^3 and porosity 0.40%.

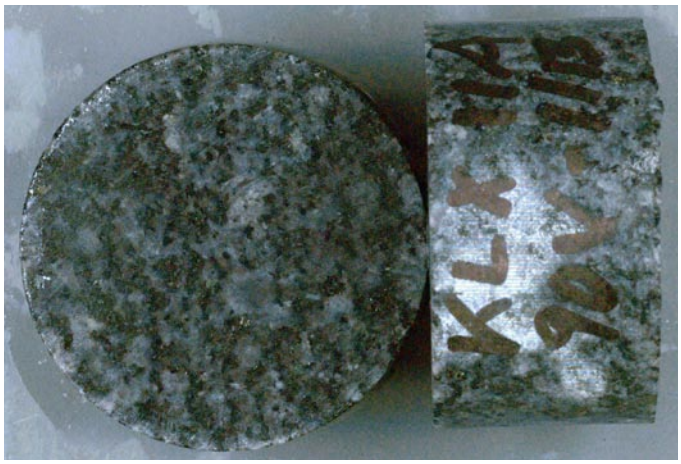

Figure A-11. *Specimens KLX11A-90V-11 A and B.*

KLX11A-90V-12 (774.751 m)

Dry density of specimen KLX11A-90V-12A 2,768 kg/m^3 and porosity 0.43%.

Dry density of specimen KLX11A-90V-12B 2,748 kg/m^3 and porosity 0.45%.

Figure A-12. *Specimens KLX11A-90V-12 A and B.*