P-04-53

Oskarshamn site investigation

Drill hole KSH01A

Thermal properties: heat conductivity and heat capacity determined using the TPS method and Mineralogical composition by modal analysis

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March 2004

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Keywords: Thermal properties, Rock mechanics, Thermal conductivity, Thermal diffusivity, Heat capacity, Transient Plane Source method, Modal analysis.

Abstract

Thermal properties on twenty-one specimens of drill hole KSH01A, Oskarshamn, were measured at ambient and elevated temperature. The rock types of the samples are Quartz monzodiorite and Fine–grained dioritoid. The mineralogical content was determined by using modal analysis.

The determination of the thermal properties are based on a direct measurement method, the so called "Transient Plane Source Method" (TPS), Gustafsson, 1991 /1/.

Generally, the influence of temperature on the thermal diffusivity was greater than on the conductivity. Thermal conductivity and thermal diffusivity of specimens at different depth at 20°C were in the range of 2.58–3.02 W/(m, K) and 1.17–1.36 mm^2/s respectively. At 80°C, thermal conductivity and thermal diffusivity of specimens were in the range of 2.66–2.96 W/(m, K) and 1.01–1.11 mm^2/s respectively.

Contents

1 Introduction

The objective of this investigation was to measure thermal properties of borehole KSH01A, Oskarshamn, see Figure 1-1, at different temperature levels by using the TPS-method /1/. The thermal properties were determined for water-saturated specimens. The specimens, in form of circular discs, were cut from rock cores. The samples were selected based on the preliminary core logging, and with the strategy to primarily investigate the properties of the dominant rock properties. The principle of the TPS method is to place a sensor between two rock samples. The sensor consists of a thin metal double spiral, embedded in an insulation material. During the measurement the sensor works both as a heat emitter and a heat receptor. The input data and results of the direct measurement are registered and analysed by the same software and electronics that govern the measurement. The method gives information on the heat conductivity and diffusivity of a material and from this the volumetric heat capacity can be determined, if the density is known.

The test programme follows the activity plan AP PS 400-03-066 (SKB internal controlling document) and is controlled by SP-QD 13.1 (SP quality document).

The samples were water saturated and stored in this condition for 7 days. This yields complete water saturation whereupon the density and the thermal properties were determined. The specimens were photographed when measuring was completed.

Modal analyses, based on point counting using a polarising microscope were performed on 7 specimens that were sampled on the same level as the specimens for thermal properties.

The rock cores arrived to SP in September 2003. The testing was performed during January, February 2004.

Determination of thermal properties was made in accordance to SKB's method description SKB MD 191.001, version 1.9 (SKB internal controlling document) at the department of Fire Technology at SP. Density was determined in accordance to SKB MD 160.002, version 1.9 (SKB internal controlling document) at the department of Building Technology at SP.

Modal analyses are performed according to SKB MD 160.001, version 1.9 (SKB internal controlling document) and BMm-P54 (SP quality document).

Figure 1-1. *Map of Oskarshamn site.*

2 Objective and scope

The purpose of the testing is to determine the thermal properties of rock specimens. The properties are used in the rock thermal model, which will be established for the candidate area selected for site investigations at Oskarshamn.

The samples are from the borehole KSH01A in Oskarshamn. The specimens were sampled on four levels in the drill hole: 300, 400, 480 and 700 m. The investigated rock types are mapped as quartz monzodiorite (300 and 700 m) and fine–grained dioritoid (400 and 480 m).

3 Equipment

Technical devices used for determination of thermal properties were:

- Kapton sensor 5501, radius of the sensor was 6.403 mm, and output of power was 0.7 W. The sensor 5501 fulfils the recommended relation between the radius of sensor and geometry of the samples in /2/.
- TPS-apparatus, Source meter Keithley 2400, Multi-meter Keithley 2000 and bridge, see Figure 3-1.
- PC + Microsoft Office and Hot Disk version 5.4.
- Stainless Sample holder.
- Water bath with immersion heater.
- Immersion heater, Grant, type TD, The accuracy of the thermostat is 0.004°C.
- Hand instrument for control measuring of the water bath temperature.

More information about the design of the water bath is given in /3/. Specimen mounting is shown in Figure 3-2.

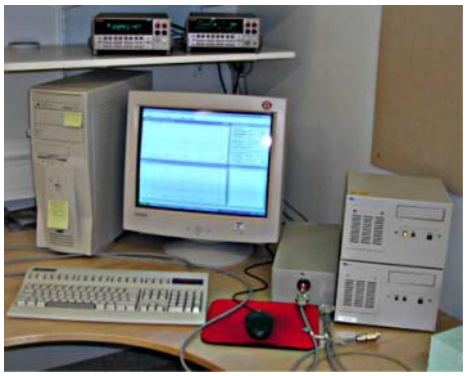

Figure 3-1. *TPS-apparatus with source meter, multi-meter, bridge, and computer.*

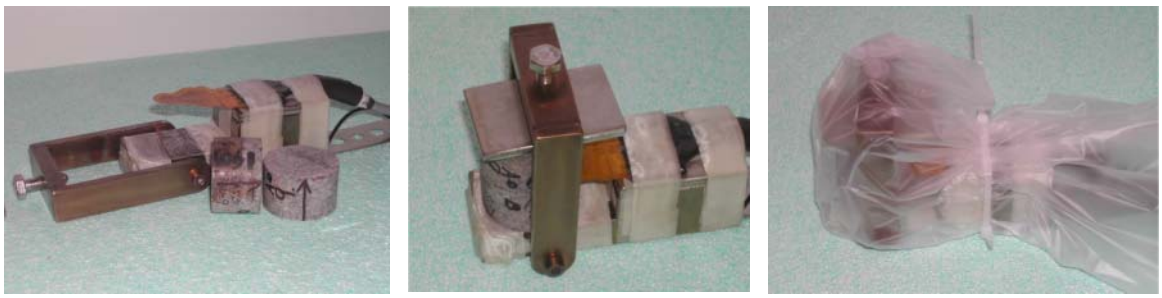

Figure 3-2. *Specimens prior to mounting (left), mounted in stainless sample holder (middle), and sample holder with mounted specimens wrapped in plastic (right).*

Technical devices used for modal analyses (point counting) were:

- Leitz Orthoplan optical microscope (inv nr 100276).

4 Execution

Determination of thermal properties was made in accordance to SKB's method description SKB MD 191.001, version 1.9 (SKB internal controlling document) and Hot Disc Instruction Manual /2/ at the department of Fire Technology at SP.

Density was determined in accordance to SKB MD 160.002, version 1.9 (SKB internal controlling document) and ISRM /4/. Modal analysis was determined in according to SKB MD 160.001, version 1.9 (SKB internal controlling document) and Chayes /5/, Streckeisen /6,7,8,9/, Le Maitre /10/, Le Bas and Streckeisen /11/ and Sigmond and Gjelle /12/ at the department of Building Technology at SP.

4.1 Description of the samples

Twenty-one cores were sampled from four levels of drill hole KSH01A, Oskarshamn, Sweden. The first level was between 299 m and 306 m, the second level was between 399 m and 415, the third level between 480 m and 497 m, and the fourth level was between 703 m and 713 m. The forty-two specimens, with a thickness of 25 mm each, were prepared from the samples at SP, see Figure 3-2. The diameter of the specimens was 50 mm. The rock type, identification marks and depth of the specimens are presented in Table 4-1. Detailed geological description of the rock is given in SKB's BOREMAP of KSH01A and in the SICADA database (FN 96) at SKB.

Shortened sample identification S01A-90V has been used through out the report.

Table 4-1. Rock type and identification marks (Rock-type classification according to bore map).

Identification	Rock type	Sampling depth (Sec low)
KSH01A-090V-01	Quartz monzodiorite	299.27
KSH01A-090V-02	Quartz monzodiorite	300.33
KSH01A-090V-03	Quartz monzodiorite	300.45
KSH01A-090V-04	Quartz monzodiorite	302.06
KSH01A-090V-05	Quartz monzodiorite	306.01
KSH01A-090V-07	Fine–grained dioritoid	399.39
KSH01A-090V-08	Fine–grained dioritoid	401.21
KSH01A-090V-09	Fine–grained dioritoid	401.75
KSH01A-090V-10	Fine–grained dioritoid	404.12
KSH01A-090V-11	Fine–grained dioritoid	404.24
KSH01A-090V-12	Fine–grained dioritoid	414.80
KSH01A-090V-13	Fine–grained dioritoid	479.71
KSH01A-090V-14	Fine–grained dioritoid	483.02
KSH01A-090V-15	Fine–grained dioritoid	483.54
KSH01A-090V-16	Fine–grained dioritoid	495.09
KSH01A-090V-17	Fine–grained dioritoid	495.84
KSH01A-090V-19	Quartz monzodiorite	703.49
KSH01A-090V-20	Quartz monzodiorite	703.61
KSH01A-090V-21	Quartz monzodiorite	707.12
KSH01A-090V-22	Quartz monzodiorite	708.04
KSH01A-090V-23	Quartz monzodiorite	709.24
KSH01A-090V-24	Quartz monzodiorite	712.85

4.2 Test Procedure

4.2.1 Thermal properties

The following steps were performed:

1. Samples were cut and polished by SP Building Technology.
2. Samples were water saturated and wet density was determined by SP Building Technology.
3. Samples were sent from SP Building Technology to SP Fire Technology.
4. Thermal properties were determined.
5. Samples were sent from SP Fire Technology to SP Building Technology.
6. Dry density of samples determined at SP Building Technology.
7. Samples were sprayed with water and photographed by SP Building Technology.

Thermal properties of water-saturated specimens were measured in ambient air (20°C) as well as at 50°C and 80°C. In order to remain water saturation and obtain desired temperature, the samples and the sensor were kept in a plastic bag during the measurement, see Figure 3-2.

Each core pair was measured five times. The time lag between two repeated measurements was at least 20 minutes. The result of each measurement was evaluated separately. The average value of these five measurements was calculated.

Function control of TPS instrumentation was performed according to BRk-QB-M26-02 (SP quality document), see Appendix A.

Measured raw data were saved as text files. Analysed data were saved as Excel files. These files were stored on the hard disc of the measurement computer. These stored files were sent to SKB catalogue at SP network. Further calculations of mean values and standard deviations were performed in the same catalogue.

Thermal properties, density and porosity measurements were performed during January–February, 2004.

Dry weight was measured after the specimens had been dried to constant mass according to ISRM /4/ at 105°C. The drying procedure took seven days.

4.2.2 Modal analysis

Modal analysis, based on point counting with at least 500 points counted in each sample, was performed by SP Building Technology.

The analysis was performed on 8 specimens that were sampled on the same level as the specimens for thermal properties (see Sec low in Table 4-1). The modal analysis was done in order to calculate the thermal properties based on the specimen's mineralogical composition.

5 Results

5.1 Thermal properties

Mean values of measured data, five repeated measurements, are reported in 5.1.1 and 5.1.2 and in the SICADA database (FN 96) at SKB. Values of each separate measurement as described in 4.2 are reported in Appendix B. Furthermore, the total measuring time, the ratio between total measuring time and characteristic time, and the number of analysed points are presented in Appendix C. In a correct measurement the ratio between the total measuring time and the characteristic time should be between 0.4 and 1.

5.1.1 Test results, sample by sample

Sample S01A-90V-01

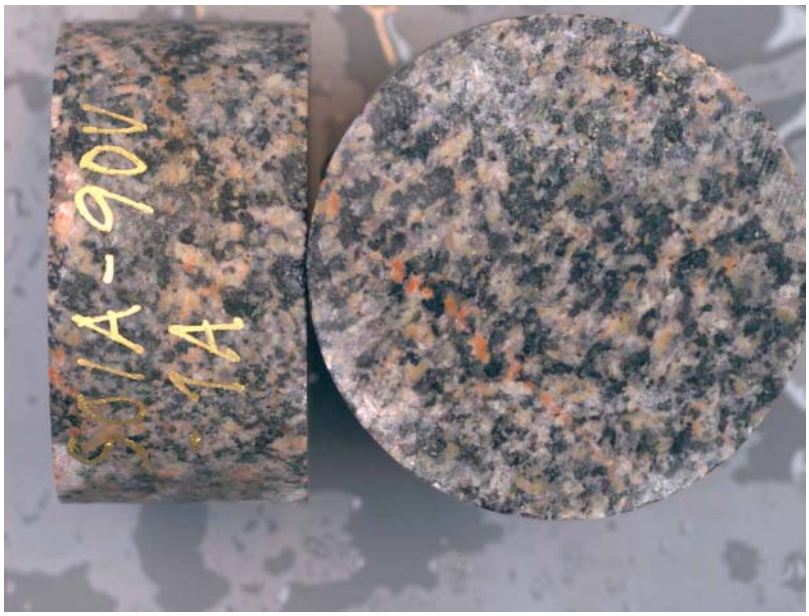

Figure 5-1. *Specimens S01A-90V-01.*

Table 5-1. Porosity, wet and dry density of specimens S01A-90V-01, average values.

Sample	Density, wet 0kg/m^3]	Density, dry [kg/m^3]	Porosity [%]
S01A-90V-01			
Sec low: 299.27	2782	2779	0,35

Table 5-2. Thermal properties of sample S01A-90V-01 at different temperatures.

S01A-90V-01 Sec low: 299.27	Conductivity [W/(m, K)]	Diffusivity [mm^2/s]	Heat capacity [MJ/(m^3, K)]
20°C			
Mean value	2.74	1.22	2.24
Standard deviation	0.005	0.003	0.010
50°C			
Mean value	2.76	1.13	2.45
Standard deviation	0.007	0.013	0.033
80°C			
Mean value	2.73	1.06	2.58
Standard deviation	0.001	0.005	0.014

Sample S01A-90V-02

Figure 5-2. *Specimens S01A-90V-02.*

Table 5-3. Porosity, wet and dry density of specimens S01A-90V-02, average values.

Sample	Density, wet [kg/m^3]	Density, dry [kg/m^3]	Porosity [%]
S01A-90V-02			
Sec low: 300.33	2783	2780	0,23

Table 5-4. Thermal properties of sample S01A-90V-02 at different temperatures

S01A-90V-02 Sec low: 300.33	Conductivity [W/(m, K)]	Diffusivity [mm^2/s]	Heat capacity [MJ/(m^3, K)]
20°C			
Mean value	2.80	1.21	2.31
Standard deviation	0.003	0.003	0.008
50°C			
Mean value	2.81	1.11	2.53
Standard deviation	0.015	0.006	0.012
80°C			
Mean value	2.79	1.04	2.70
Standard deviation	0.008	0.006	0.021

Sample S01A-90V-03

Figure 5-3. *Specimens S01A-90V-03.*

Table 5-5. Porosity, wet and dry density of specimens S01A-90V-03, average values.

Sample	Density, wet [kg/m^3]	Density, dry [kg/m^3]	Porosity [%]
S01A-90V-03			
Sec low: 300.45	2778	2776	0,22

Table 5-6. Thermal properties of sample S01A-90V-03 at different temperatures.

S01A-90V-03 Sec low: 300.45	Conductivity [W/(m, K)]	Diffusivity [mm^2/s]	Heat capacity [MJ/(m^3, K)]
20°C			
Mean value	2.80	1.23	2.28
Standard deviation	0.005	0.003	0.008
50°C			
Mean value	2.77	1.14	2.43
Standard deviation	0.002	0.003	0.006
80°C			
Mean value	2.75	1.06	2.61
Standard deviation	0.002	0.002	0.007

Sample S01A-90V-04

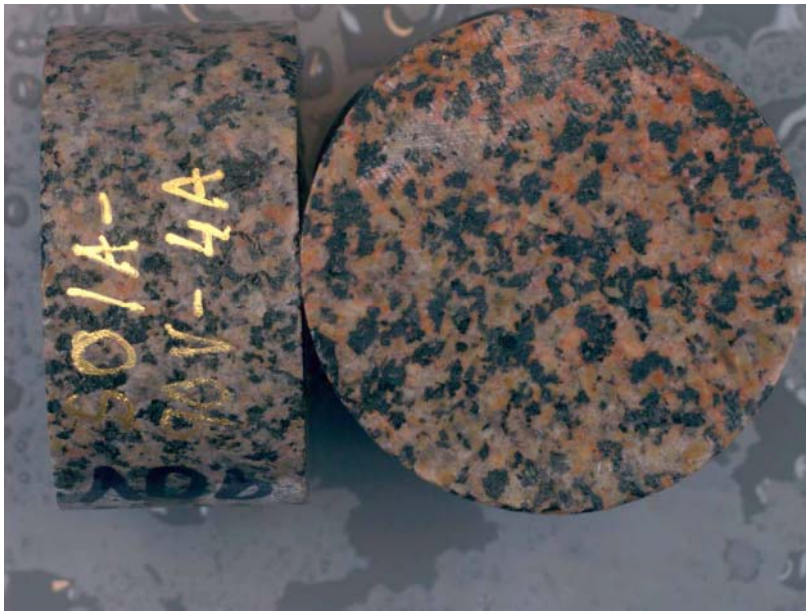

Figure 5-4. *Specimens S01A-90V-04.*

Table 5-7. Porosity, wet and dry density of specimens S01A-90V-04, average values.

Sample	Density, wet [kg/m^3]	Density, dry [kg/m^3]	Porosity [%]
S01A-90V-04			
Sec low: 302.06	2765	2761	0,45

Table 5-8. Thermal properties of sample S01A-90V-04 at different temperatures.

S01A-90V-04 Sec low: 302.06	Conductivity [W/(m, K)]	Diffusivity [mm^2/s]	Heat capacity [MJ/(m^3, K)]
20°C			
Mean value	2.79	1.25	2.23
Standard deviation	0.005	0.001	0.006
50°C			
Mean value	2.80	1.16	2.41
Standard deviation	0.005	0.003	0.008
80°C			
Mean value	2.79	1.07	2.61
Standard deviation	0.004	0.012	0.030

Sample S01A-90V-05

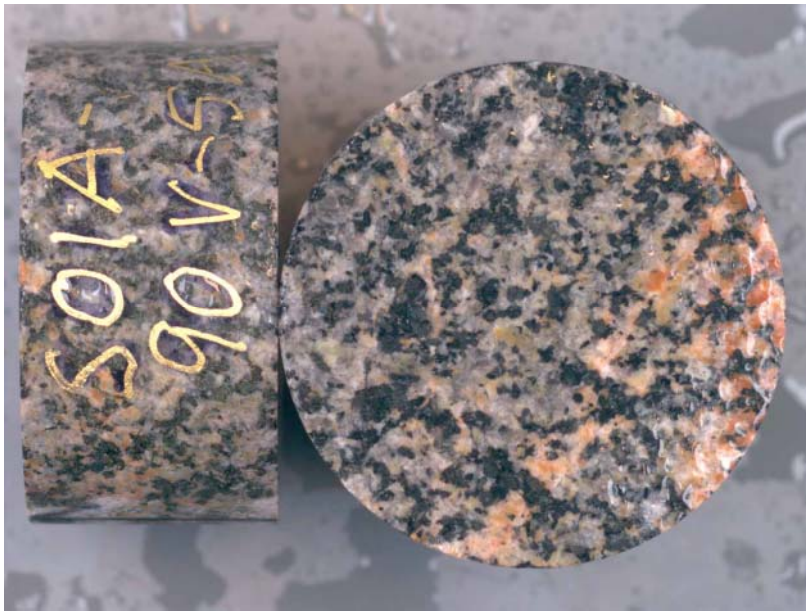

Figure 5-5. *Specimens S01A-90V-05.*

Table 5-9. Porosity, wet and dry density of specimens S01A-90V-05, average values.

Sample	Density, wet [kg/m^3]	Density, dry [kg/m^3]	Porosity [%]
S01A-90V-05			
Sec low: 306.01	2786	2784	0,17

Table 5-10. Thermal properties of sample S01A-90V-05 at different temperatures.

S01A-90V-05 Sec low: 306.01	Conductivity [W/(m, K)]	Diffusivity [mm^2/s]	Heat capacity [MJ/(m^3, K)]
20°C			
Mean value	2.78	1.31	2.13
Standard deviation	0.001	0.003	0.005
50°C			
Mean value	2.78	1.22	2.27
Standard deviation	0.007	0.021	0.041
80°C			
Mean value	2.76	1.15	2.39
Standard deviation	0.007	0.021	0.047

Sample S01A-90V-07

Figure 5-6. *Specimens S01A-90V-07.*

Table 5-11. Porosity, wet and dry density of specimens S01A-90V-07, average values.

Sample	Density, wet [kg/m^3]	Density, dry [kg/m^3]	Porosity [%]
S01A-90V-07	2791	2789	0,19
Sec low: 399.39			

Table 5-12. Thermal properties of sample S01A-90V-07 at different temperatures.

S01A-90V-07 Sec low: 399.39	Conductivity [W/(m, K)]	Diffusivity [mm^2/s]	Heat capacity [MJ/(m^3, K)]
20°C			
Mean value	2.75	1.20	2.29
Standard deviation	0.009	0.007	0.012
50°C			
Mean value	2.73	1.12	2.44
Standard deviation	0.004	0.011	0.028
80°C			
Mean value	2.71	1.04	2.60
Standard deviation	0.008	0.012	0.028

Sample S01A-90V-08

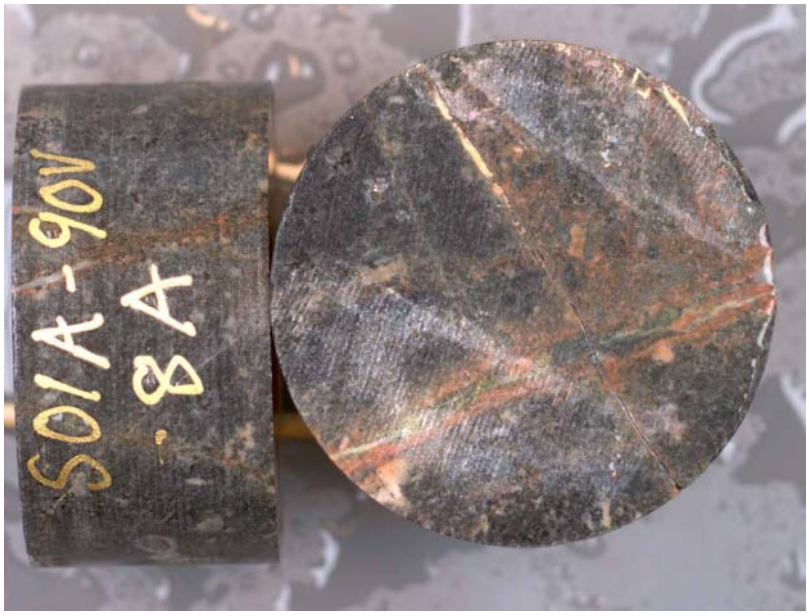

Figure 5-7. *Specimens S01A-90V-08.*

Table 5-13. Porosity, wet and dry density of specimens S01A-90V-08, average values.

Sample	Density, wet [kg/m^3]	Density, dry [kg/m^3]	Porosity [%]
S01A-90V-08	2771	-*	-*
Sec low: 401.21			

*The specimens broke during test. Dry density not determined.

Table 5-14. Thermal properties of sample S01A-90V-08 at different temperatures.

S01A-90V-08 Sec low: 401.21	Conductivity [W/(m, K)]	Diffusivity [mm^2/s]	Heat capacity [MJ/(m^3, K)]
20°C			
Mean value	2.83	1.23	2.29
Standard deviation	0.004	0.005	0.008
50°C			
Mean value	2.81	1.12	2.50
Standard deviation	0.004	0.008	0.020
80°C			
Mean value	2.73	1.01	2.71
Standard deviation	0.009	0.008	0.015

Sample S01A-90V-09

Figure 5-8. *Specimens S01A-90V-09.*

Table 5-15. Porosity, wet and dry density of specimens S01A-90V-09, average values.

Sample	Density, wet [kg/m^3]	Density, dry [kg/m^3]	Porosity [%]
S01A-90V-09	2772	2770	0,23
Sec low: 401.75			

Table 5-16. Thermal properties of sample S01A-90V-09 at different temperatures.

S01A-90V-09 Sec low: 401.75	Conductivity [W/(m, K)]	Diffusivity [mm^2/s]	Heat capacity [MJ/(m^3, K)]
20°C			
Mean value	3.02	1.29	2.35
Standard deviation	0.003	0.002	0.004
50°C			
Mean value	2.99	1.19	2.51
Standard deviation	0.003	0.002	0.007
80°C			
Mean value	2.96	1.11	2.66
Standard deviation	0.007	0.013	0.035

Sample S01A-90V-10

Figure 5-9. *Specimens S01A-90V-10.*

Table 5-17. Porosity, wet and dry density of specimens S01A-90V-10, average values.

Sample	Density, wet [kg/m^3]	Density, dry [kg/m^3]	Porosity [%]
S01A-90V-10	2776	2775	0,13
Sec low: 404.12			

Table 5-18. Thermal properties of sample S01A-90V-10 at different temperatures.

S01A-90V-10 Sec low: 404.12	Conductivity [W/(m, K)]	Diffusivity [mm^2/s]	Heat capacity [MJ/(m^3, K)]
20°C			
Mean value	2.87	1.36	2.11
Standard deviation	0.001	0.001	0.003
50°C			
Mean value	2.82	1.22	2.31
Standard deviation	0.008	0.009	0.022
80°C			
Mean value	2.77	1.11	2.50
Standard deviation	0.012	0.014	0.031

Sample S01A-90V-11

Figure 5-10. *Specimens S01A-90V-11.*

Table 5-19. Porosity, wet and dry density of specimens S01A-90V-11, average values.

Sample	Density, wet [kg/m^3]	Density, dry [kg/m^3]	Porosity [%]
S01A-90V-11	2782	2780	0,18
Sec low: 404.24			

Table 5-20, Thermal properties of sample S01A-90V-11 at different temperatures.

S01A-90V-11 Sec low: 404.24	Conductivity [W/(m, K)]	Diffusivity [mm^2/s]	Heat capacity [MJ/(m^3, K)]
20°C			
Mean value	2.80	1.17	2.39
Standard deviation	0.008	0.005	0.017
50°C			
Mean value	2.77	1.09	2.55
Standard deviation	0.003	0.005	0.012
80°C			
Mean value	2.72	1.01	2.69
Standard deviation	0.006	0.010	0.031

Sample S01A-90V-12

Figure 5-11. *Specimens S01A-90V-12.*

Table 5-21. Porosity, wet and dry density of specimens S01A-90V-12, average values.

Sample	Density, wet [kg/m^3]	Density, dry [kg/m^3]	Porosity [%]
S01A-90V-12	2790	2787	0,26
Sec low: 414.80			

Table 5-22. Thermal properties of sample S01A-90V-12 at different temperatures.

S01A-90V-12 Sec low: 414.80	Conductivity [W/(m, K)]	Diffusivity [mm^2/s]	Heat capacity [MJ/(m^3, K)]
20°C			
Mean value	2.67	1.30	2.06
Standard deviation	0.002	0.003	0.005
50°C			
Mean value	2.68	1.20	2.23
Standard deviation	0.003	0.006	0.009
80°C			
Mean value	2.66	1.12	2.38
Standard deviation	0.006	0.004	0.014

Sample S01A-90V-13

Figure 5-12. *Specimens S01A-90V-13.*

Table 5-23. Porosity, wet and dry density of specimens S01A-90V-13, average values.

Sample	Density, wet [kg/m^3]	Density, dry [kg/m^3]	Porosity [%]
S01A-90V-13	2821	2819	0,14
Sec low: 479.71			

Table 5-24. Thermal properties of sample S01A-90V-13.

S01A-90V-13 Sec low: 479.71	Conductivity [W/(m, K)]	Diffusivity [mm^2/s]	Heat capacity [MJ/(m^3, K)]
20°C			
Mean value	2.58	1.22	2.12
Standard deviation	0.006	0.005	0.008

Sample S01A-90V-14

Figure 5-13. *Specimens S01A-90V-14.*

Table 5-25. Porosity, wet and dry density of specimens S01A-90V-14, average values.

Sample	Density, wet [kg/m^3]	Density, dry [kg/m^3]	Porosity [%]
S01A-90V-14	2801	2800	0,11
Sec low: 483.02			

Table 5-26. Thermal properties of sample S01A-90V-14.

S01A-90V-14 Sec low: 483.02	Conductivity [W/(m, K)]	Diffusivity [mm^2/s]	Heat capacity [MJ/(m^3, K)]
20°C			
Mean value	2.84	1.24	2.30
Standard deviation	0.005	0.007	0.012

Sample S01A-90V-15

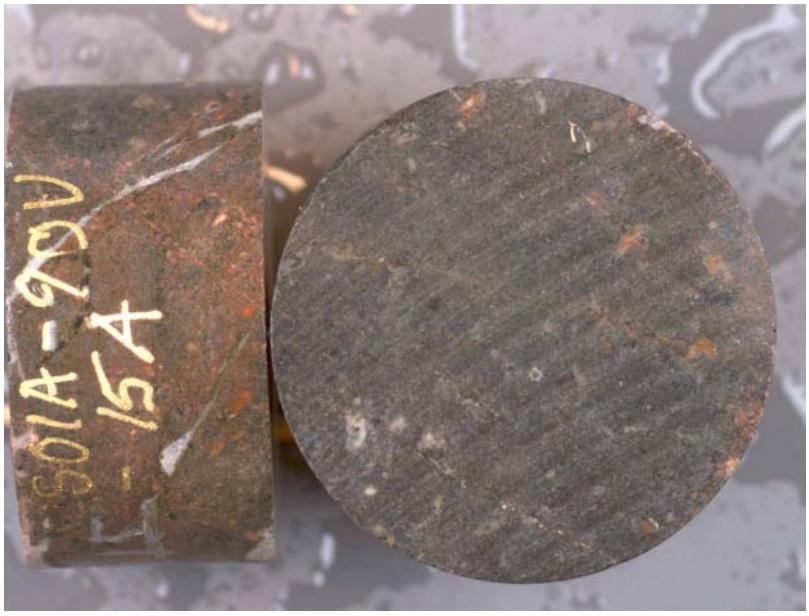

Figure 5-14. *Specimens S01A-90V-15.*

Table 5-27. Porosity, wet and dry density of specimens S01A-90V-15, average values.

Sample	Density, wet [kg/m^3]	Density, dry [kg/m^3]	Porosity [%]
S01A-90V-15	2773	2769	0,38
Sec low: 483.54			

Table 5-28. Thermal properties of sample S01A-90V-15.

S01A-90V-15 Sec low: 483.54	Conductivity [W/(m, K)]	Diffusivity [mm^2/s]	Heat capacity [MJ/(m^3, K)]
20°C			
Mean value	2.75	1.30	2.11
Standard deviation	0.003	0.013	0.022

Sample S01A-90V-16

Figure 5-15. *Specimens S01A-90V-16.*

Table 5-29. Porosity, wet and dry density of specimens S01A-90V-16, average values.

Sample	Density, wet [kg/m^3]	Density, dry [kg/m^3]	Porosity [%]
S01A-90V-16	2790	2788	0,20
Sec low: 495.09			

Table 5-30. Thermal properties of sample S01A-90V-16.

S01A-90V-16 Sec low: 495.09	Conductivity [W/(m, K)]	Diffusivity [mm^2/s]	Heat capacity [MJ/(m^3, K)]
20°C			
Mean value	2.73	1.21	2.26
Standard deviation	0.003	0.004	0.010

Sample S01A-90V-17

Figure 5-16. *Specimens S01A-90V-17.*

Table 5-31. Porosity, wet and dry density of specimens S01A-90V-17, average values.

Sample	Density, wet [kg/m^3]	Density, dry [kg/m^3]	Porosity [%]
S01A-90V-17	2796	2794	0,21
Sec low: 495.84			

Table 5-32. Thermal properties of sample S01A-90V-17.

S01A-90V-17 Sec low: 495.84	Conductivity [W/(m, K)]	Diffusivity [mm^2/s]	Heat capacity [MJ/(m^3, K)]
20°C			
Mean value	2.92	1.22	2.40
Standard deviation	0.005	0.007	0.011

Sample S01A-90V-19

Figure 5-17. *Specimens S01A-90V-19.*

Table 5-33. Porosity, wet and dry density of specimens S01A-90V-19, average values.

Sample	Density, wet [kg/m^3]	Density, dry [kg/m^3]	Porosity [%]
S01A-90V-19	2835	2834	0,14
Sec low: 703.49			

Table 5-34. Thermal properties of sample S01A-90V-19.

S01A-90V-19 Sec low: 703.49	Conductivity [W/(m, K)]	Diffusivity [mm^2/s]	Heat capacity [MJ/(m^3, K)]
20°C			
Mean value	2.89	1.26	2.30
Standard deviation	0.004	0.005	0.010

Sample S01A-90V-20

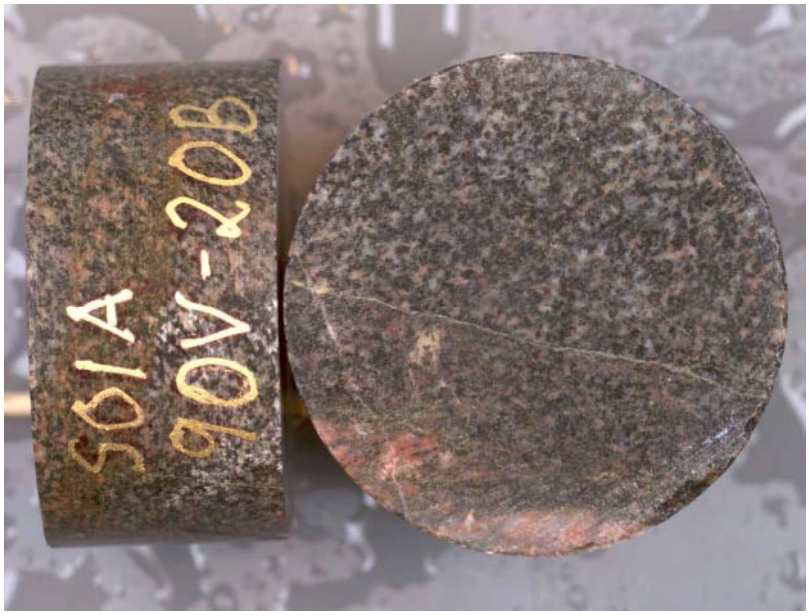

Figure 5-18. *Specimens S01A-90V-20.*

Table 5-35. Porosity, wet and dry density of specimens S01A-90V-20, average values.

Sample	Density, wet [kg/m^3]	Density, dry [kg/m^3]	Porosity [%]
S01A-90V-20	2802	2800	0,16
Sec low: 703.61			

Table 5-36. Thermal properties of sample S01A-90V-20.

S01A-90V-20 Sec low: 703.61	Conductivity [W/(m, K)]	Diffusivity [mm^2/s]	Heat capacity [MJ/(m^3, K)]
20°C			
Mean value	2.78	1.23	2.26
Standard deviation	0.014	0.009	0.027

Sample S01A-90V-22

Figure 5-19. *Specimens S01A-90V-22.*

Table 5-37. Porosity, wet and dry density of specimens S01A-90V-22, average values.

Sample	Density, wet [kg/m^3]	Density, dry [kg/m^3]	Porosity [%]
S01A-90V-22	2854	2853	0,19
Sec low: 708.04			

Table 5-38. Thermal properties of sample S01A-90V-22.

S01A-90V-22 Sec low: 708.04	Conductivity [W/(m, K)]	Diffusivity [mm^2/s]	Heat capacity [MJ/(m^3, K)]
20°C			
Mean value	2.85	1.25	2.29
Standard deviation	0.006	0.009	0.021

Sample S01A-90V-23

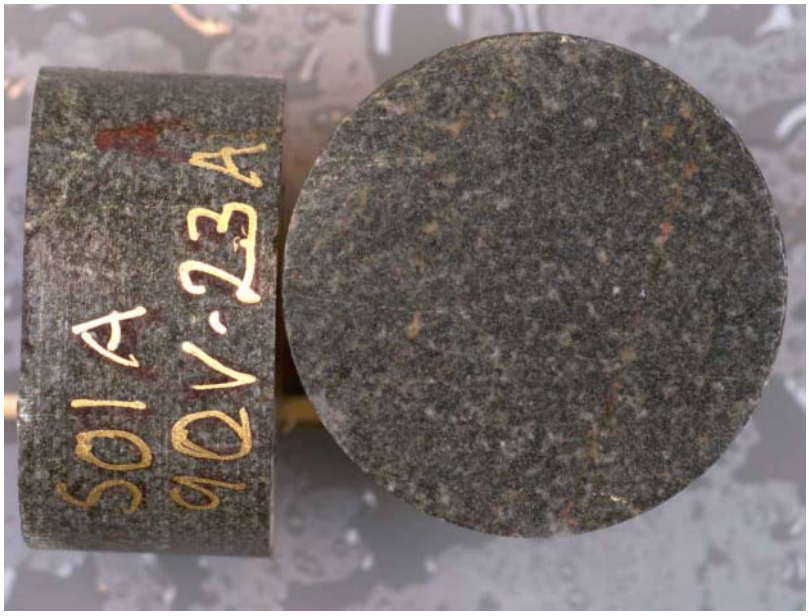

Figure 5-20. *Specimens S01A-90V-23.*

Table 5-39. Porosity, wet and dry density of specimens S01A-90V-23, average values.

Sample	Density, wet [kg/m^3]	Density, dry [kg/m^3]	Porosity [%]
S01A-90V-23	2878	2876	0,18
Sec low: 709.24			

Table 5-40. Thermal properties of sample S01A-90V-23.

S01A-90V-23 Sec low: 709.24	Conductivity [W/(m, K)]	Diffusivity [mm^2/s]	Heat capacity [MJ/(m^3, K)]
20°C			
Mean value	2.93	1.36	2.16
Standard deviation	0.010	0.011	0.025

Sample S01A-90V-24

Figure 5-21. *Specimens S01A-90V-24.*

Table 5-41. Porosity, wet and dry density of specimens S01A-90V-24, average values.

Sample	Density, wet [kg/m^3]	Density, dry [kg/m^3]	Porosity [%]
S01A-90V-24	2861	2858	0,23
Sec low: 712.85			

Table 5-42. Thermal properties of sample S01A-90V-24.

S01A-90V-24 Sec low: 712.85	Conductivity [W/(m, K)]	Diffusivity [mm^2/s]	Heat capacity [MJ/(m^3, K)]
20°C			
Mean value	2.95	1.30	2.28
Standard deviation	0.003	0.003	0.008

5.1.2 Results for the entire test series

Table 5-43–Table 5-45 show the mean value of five repeated measurements of the thermal properties. Standard deviation at different temperature levels is shown in Table 5-46–Table 5-48.

Thermal conductivity and thermal diffusivity of specimens at different depth at 20°C were in the range of 2.58–3.02 W/(m, K) and 1.17–1.36 mm^2/s respectively. At 50°C, thermal conductivity and thermal diffusivity of specimens at different depth were in the range of 2.68–2.99 W/(m, K) and 1.09–1.22 mm^2/s respectively and finally at 80°C, thermal conductivity and thermal diffusivity of specimens were in the range of 2.66–2.96 W/(m, K) and 1.01–1.11 mm^2/s respectively.

Table 5-43. Mean value of thermal properties of samples at 20°C.

Sample identification	Conductivity [W/(m, K)]	Diffusivity [mm^2/s]	Heat capacity [$MJ/(m^3, K)$]
S01A-90V-01	2.74	1.22	2.24
S01A-90V-02	2.80	1.21	2.31
S01A-90V-03	2.80	1.23	2.28
S01A-90V-04	2.79	1.25	2.23
S01A-90V-05	2.78	1.31	2.13
Mean value, level 300	**2.78**	**1.24**	**2.24**
S01A-90V-07	2.75	1.20	2.29
S01A-90V-08	2.83	1.23	2.29
S01A-90V-09	3.02	1.29	2.35
S01A-90V-10	2.87	1.36	2.11
S01A-90V-11	2.80	1.17	2.39
S01A-90V-12	2.67	1.30	2.06
Mean value, level 400	**2.82**	**1.26**	**2.25**
S01A-90V-13	2.58	1.22	2.12
S01A-90V-14	2.84	1.24	2.30
S01A-90V-15	2.75	1.30	2.11
S01A-90V-16	2.73	1.21	2.26
S01A-90V-17	2.92	1.22	2.40
Mean value, level 480	**2.76**	**1.24**	**2.24**
S01A-90V-19	2.89	1.26	2.30
S01A-90V-20	2.78	1.23	2.26
S01A-90V-22	2.85	1.25	2.29
S01A-90V-23	2.93	1.36	2.16
S01A-90V-24	2.95	1.30	2.28
Mean value, level 700	**2.88**	**1.28**	**2.26**

Table 5-44. Mean value of thermal properties of samples at 50°C.

Sample identification	Conductivity [W/(m, K)]	Diffusivity [mm^2/s]	Heat capacity [$MJ/(m^3, K)$]
S01A-90V-01	2.76	1.13	2.45
S01A-90V-02	2.81	1.11	2.53
S01A-90V-03	2.77	1.14	2.43
S01A-90V-04	2.80	1.16	2.41
S01A-90V-05	2.78	1.22	2.27
Mean value, level 300	**2.78**	**1.15**	**2.42**
S01A-90V-07	2.73	1.12	2.44
S01A-90V-08	2.81	1.12	2.50
S01A-90V-09	2.99	1.19	2.51
S01A-90V-10	2.82	1.22	2.31
S01A-90V-11	2.77	1.09	2.55
S01A-90V-12	2.68	1.20	2.23
Mean value, level 400	**2.80**	**1.16**	**2.42**

Table 5-45. Mean value of thermal properties of samples at 80°C.

Sample identification	Conductivity [W/(m, K)]	Diffusivity [mm^2/s]	Heat capacity [$MJ/(m^3, K)$]
S01A-90V-01	2.73	1.06	2.58
S01A-90V-02	2.79	1.04	2.70
S01A-90V-03	2.75	1.06	2.61
S01A-90V-04	2.79	1.07	2.61
S01A-90V-05	2.76	1.15	2.39
Mean value, level 300	**2.77**	**1.07**	**2.58**
S01A-90V-07	2.71	1.04	2.60
S01A-90V-08	2.73	1.01	2.71
S01A-90V-09	2.96	1.11	2.66
S01A-90V-10	2.77	1.11	2.50
S01A-90V-11	2.72	1.01	2.69
S01A-90V-12	2.66	1.12	2.38
Mean value, level 400	**2.76**	**1.07**	**2.59**

Table 5-46. Standard deviation of measured values at 20°C.

Sample identification	Conductivity [W/(m, K)]	Diffusivity [mm^2/s]	Heat capacity [$MJ/(m^3, K)$]
S01A-90V-01	0.005	0.003	0.010
S01A-90V-02	0.003	0.003	0.008
S01A-90V-03	0.005	0.003	0.008
S01A-90V-04	0.005	0.001	0.006
S01A-90V-05	0.001	0.003	0.005
S01A-90V-07	0.009	0.007	0.012
S01A-90V-08	0.004	0.005	0.008
S01A-90V-09	0.003	0.002	0.004
S01A-90V-10	0.001	0.001	0.003
S01A-90V-11	0.008	0.005	0.017
S01A-90V-12	0.002	0.003	0.005
S01A-90V-13	0.006	0.005	0.008
S01A-90V-14	0.005	0.007	0.012
S01A-90V-15	0.003	0.013	0.022
S01A-90V-16	0.003	0.004	0.010
S01A-90V-17	0.005	0.007	0.011
S01A-90V-19	0.004	0.005	0.010
S01A-90V-20	0.014	0.009	0.027
S01A-90V-22	0.006	0.009	0.021
S01A-90V-23	0.010	0.011	0.025
S01A-90V-24	0.003	0.003	0.008

Table 5-47. Standard deviation of measured values at 50°C.

Sample identification	Conductivity [W/(m, K)]	Diffusivity [mm^2/s]	Heat capacity [$MJ/(m^3, K)$]
S01A-90V-01	0.007	0.013	0.033
S01A-90V-02	0.015	0.006	0.012
S01A-90V-03	0.002	0.003	0.006
S01A-90V-04	0.005	0.003	0.008
S01A-90V-05	0.007	0.021	0.041
S01A-90V-07	0.004	0.011	0.028
S01A-90V-08	0.004	0.008	0.020
S01A-90V-09	0.003	0.002	0.007
S01A-90V-10	0.008	0.009	0.022
S01A-90V-11	0.003	0.005	0.012
S01A-90V-12	0.003	0.006	0.009

Table 5-48. Standard deviation of measured values at 80°C.

Sample identification	Conductivity [W/(m, K)]	Diffusivity [mm^2/s]	Heat capacity [MJ/(m^3, K)]
S01A-90V-01	0.001	0.005	0.014
S01A-90V-02	0.008	0.006	0.021
S01A-90V-03	0.002	0.002	0.007
S01A-90V-04	0.004	0.012	0.030
S01A-90V-05	0.007	0.021	0.047
S01A-90V-07	0.008	0.012	0.028
S01A-90V-08	0.009	0.008	0.015
S01A-90V-09	0.007	0.013	0.035
S01A-90V-10	0.012	0.014	0.031
S01A-90V-11	0.006	0.010	0.031
S01A-90V-12	0.006	0.004	0.014

5.1.2.1 Graphical presentation of results

Variation of the thermal conductivity and heat capacity in relation to depth of the sampling at different temperatures are shown in Figure 5-22–Figure 5-26.

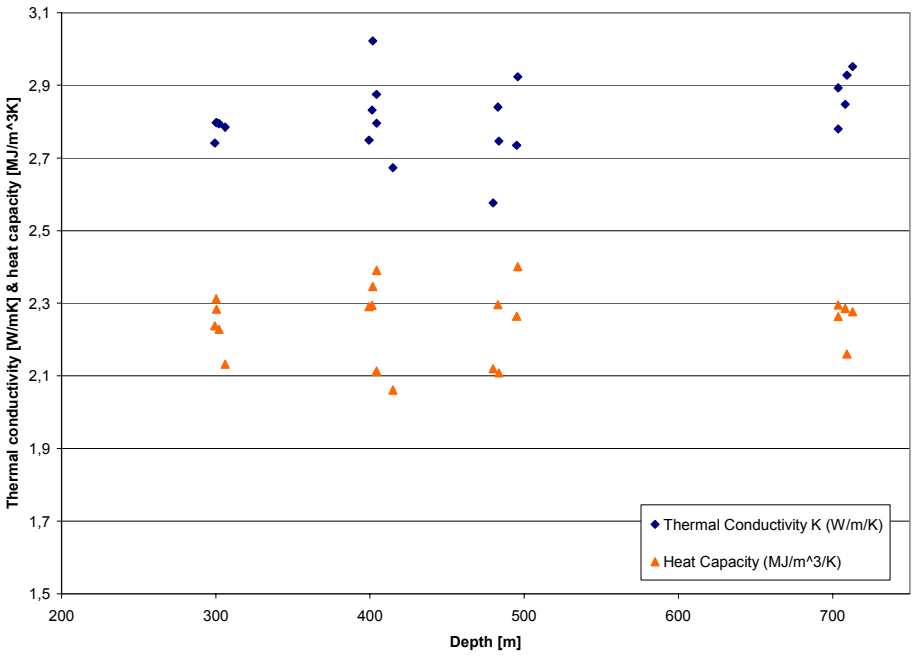

Figure 5-22. *Thermal conductivity and heat capacity at different depth at 20°C.*

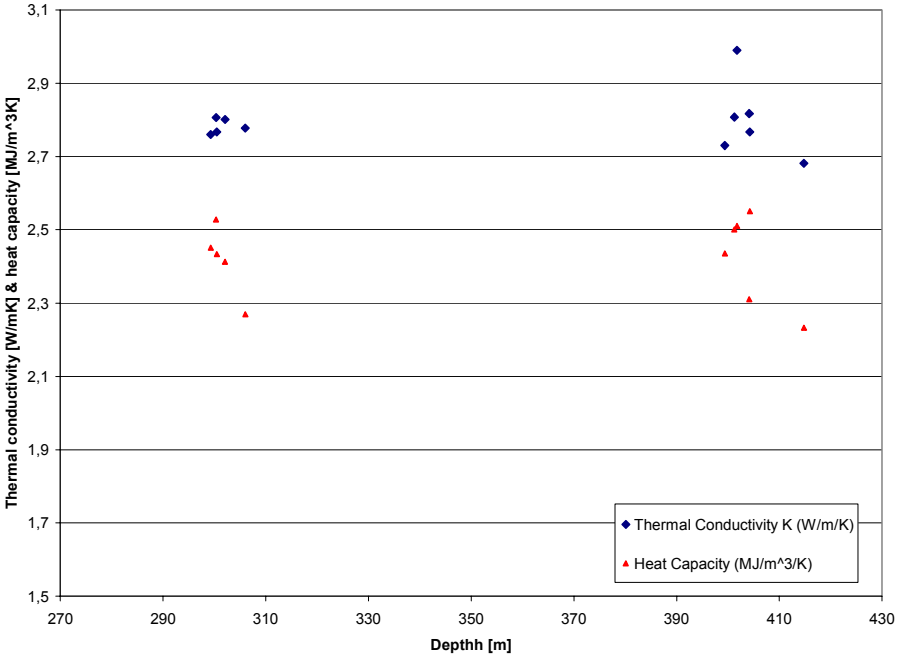

Figure 5-23. *Thermal conductivity and heat capacity at different depth at 50°C.*

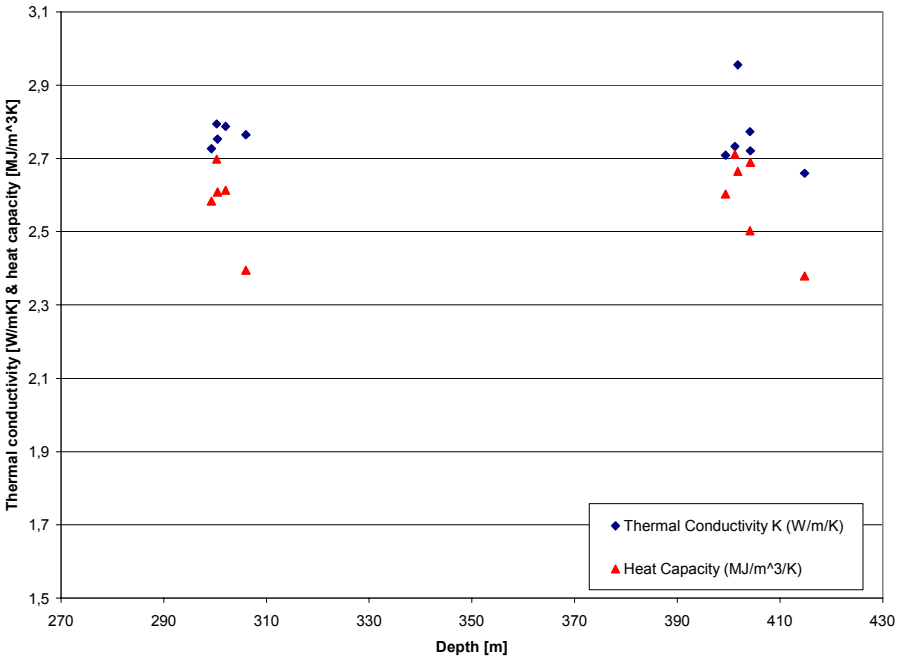

Figure 5-24. *Thermal conductivity and heat capacity at different depth at 80°C.*

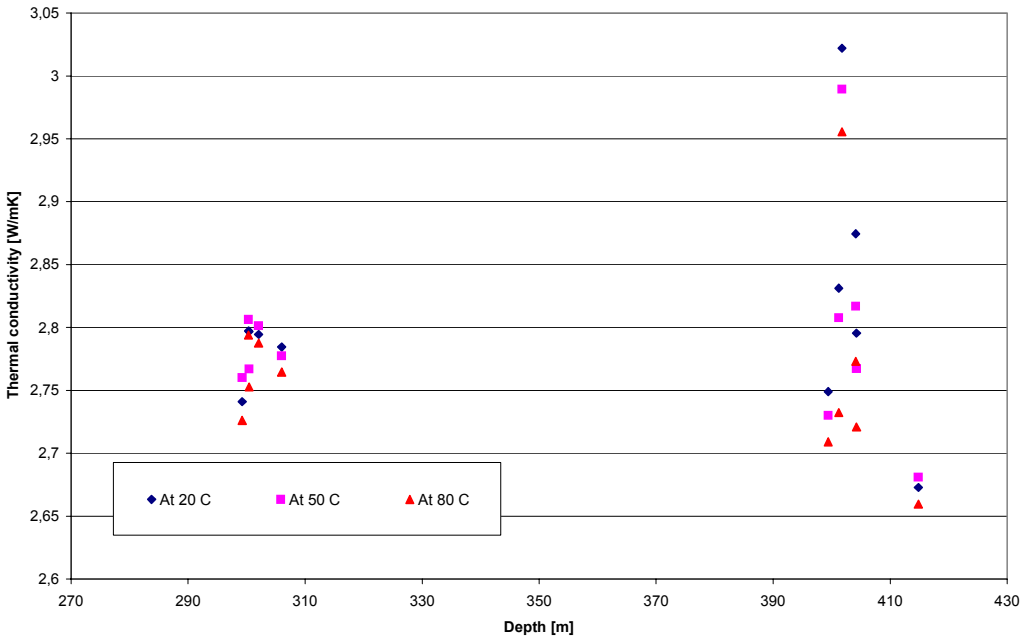

Figure 5-25. *Thermal conductivity at different depth and at different temperatures.*

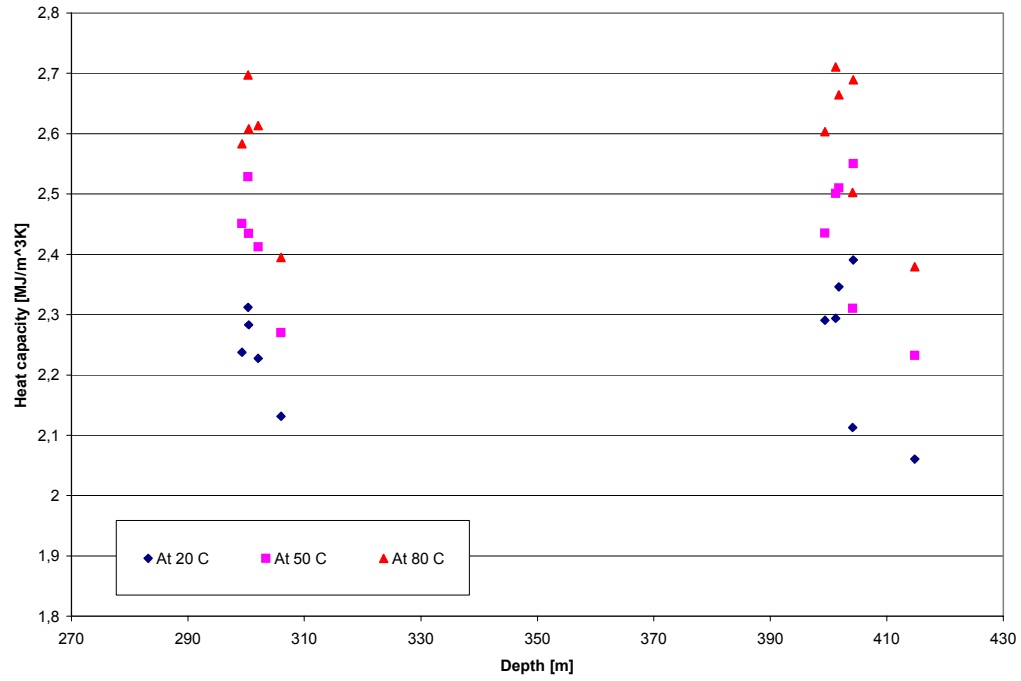

Figure 5-26. *Thermal capacity at different depth and at different temperatures.*

Maximum variation of thermal conductivity in the temperature range 20°C to 80°C was 3.5% for sample S01A-90V-10 and maximum variation of heat capacity in the same temperature range was about 18% for sample S01A-90V-10.

5.2 Modal analysis

The primary mineralogy is to a large extent altered and the feldspars are to a large extent altered to zoisite and sericite. The latter are mainly composed of muscovite.

Table 5-49. Mineralogical composition (in vol. %) of the investigated specimens from KSH01A, 500 points are counted on each specimen.

Identification	Sampling depth (Sec up)	Qtz	Kfs	Pl	Bt	Ch	Amp	Zoi	Ser	Cc	Op
KSH01A-200-1	299.15	18	38	18	7	1	14	2	0	0	2
KSH01A-200-4	301.94	14	35	23	0	13	7	2	5	0	2
KSH01A-200-7	399.27	12	18	34	10	0	1	19	3	0	2
KSH01A-200-9	401.63	17	22	31	4	11	3	10	2	0.4	0.4
KSH01A-200-13	479.59	11	21	27	7	5	16	7	16	0.2	0.4
KSH01A-200-14	482.90	46	14	5	28	0	0	5	0	0.4	3
KSH01A-200-19	703.37	24	4	32	32	0	0	11	0.4	3	0
KSH01A-200-21	707.00	29	11	15	32	0	0	9	0	2.1	0

The mineral mode is based on point counting using a polarising microscope.

Qtz= Quartz, Kfs= K-feldspar, Pl= Plagioclase, Bt= Biotite, Ch=chlorite, Amp=amphibole, Zoi=zoisite, Ser=sericite, Cc=calcite, Op=opaque minerals.

5.3 Discussion

The following deviations to the plans occurred:

- Sample 8 broke during test. Dry density was therefore not determined. Sample 12 replaced this sample.
- Sample 21 broke during determination of wet density. Thus, only single value for wet density reported. No thermal properties were tested. Sample 24 replaced this sample.
- The specimens were photographed when measuring was completed.

6 References

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Appendix A

Calibration protocol for Hot Disk Bridge System

Electronics:	Keithley 2400	Serial No. 0925167
	Keithley 2000	Serial No. 0921454
Hot Disk Bridge:		Serial No. 2003-0004
Computation Device:		Serial No. 2003-0003, ver 1.4.2
Computer:	Hot Disk computer	Serial No. 2003-0003
Test sample:	SIS2343, mild steel	Serial No. 3.52
Sensor for testing:	C5501	

Test measurement: 10 repeated measurements on the test sample at room temperature.

Conditions: Power 1 W, Measurement time 10 s

Results

Thermal Conductivity:	13.48 W/(m, K)	±0.04%
Thermal Diffusivity:	3.528 mm^2/s	±0.16%
Heat Capacity:	3.955 $MJ/(m^3, K)$	±0.15%

This instrument has proved to behave according to specifications described in BRk-QB-M26-02.

Borås 07/01 2004

Bijan Adl-Zarrabi

Appendix B

Table B-1. Thermal properties of samples at 20°C.

Measurement number	Conductivity [W/(m, K)]	Diffusivity [mm^2/s]	Heat capacity [$MJ/(m^3, K)$]
S01A-90V-01			
1	2.73	1.23	2.22
2	2.74	1.23	2.24
3	2.74	1.22	2.24
4	2.74	1.22	2.24
5	2.75	1.22	2.25
S01A-90V-02			
1	2.79	1.21	2.30
2	2.80	1.21	2.32
3	2.79	1.21	2.31
4	2.80	1.21	2.32
5	2.80	1.21	2.31
S01A-90V-03			
1	2.79	1.23	2.27
2	2.79	1.22	2.28
3	2.80	1.22	2.29
4	2.80	1.23	2.28
5	2.80	1.22	2.29
S01A-90V-04			
1	2.79	1.26	2.22
2	2.79	1.26	2.22
3	2.79	1.26	2.23
4	2.80	1.25	2.23
5	2.80	1.25	2.24
S01A-90V-05			
1	2.78	1.31	2.13
2	2.78	1.31	2.13
3	2.78	1.31	2.12
4	2.79	1.30	2.14
5	2.79	1.31	2.13
S01A-90V-07			
1	2.73	1.19	2.30
2	2.75	1.20	2.29
3	2.75	1.21	2.27
4	2.76	1.20	2.29
5	2.76	1.20	2.30
S01A-90V-08			
1	2.83	1.23	2.30
2	2.83	1.23	2.30
3	2.83	1.24	2.29
4	2.83	1.23	2.30
5	2.84	1.24	2.28

Table B-1 (continues). Thermal properties of samples at 20°C.

Measurement number	Conductivity [W/(m, K)]	Diffusivity [mm^2/s]	Heat capacity [$MJ/(m^3, K)$]
S01A-90V-09			
1	3.02	1.29	2.35
2	3.02	1.29	2.34
3	3.02	1.29	2.34
4	3.02	1.29	2.35
5	3.03	1.29	2.35
S01A-90V-10			
1	2.87	1.36	2.11
2	2.88	1.36	2.12
3	2.87	1.36	2.11
4	2.87	1.36	2.11
5	2.88	1.36	2.12
S01A-90V-11			
1	2.78	1.18	2.36
2	2.80	1.16	2.40
3	2.80	1.16	2.40
4	2.80	1.17	2.40
5	2.80	1.17	2.38
S01A-90V-12			
1	2.67	1.29	2.07
2	2.67	1.30	2.06
3	2.67	1.30	2.06
4	2.67	1.30	2.05
5	2.68	1.30	2.06
S01A-90V-13			
1	2.57	1.21	2.13
2	2.57	1.21	2.12
3	2.58	1.22	2.11
4	2.59	1.21	2.13
5	2.58	1.22	2.11
S01A-90V-14			
1	2.84	1.24	2.28
2	2.85	1.24	2.30
3	2.83	1.23	2.30
4	2.84	1.23	2.31
5	2.84	1.24	2.29
S01A-90V-15			
1	2.74	1.31	2.09
2	2.74	1.30	2.12
3	2.75	1.30	2.11
4	2.75	1.32	2.08
5	2.75	1.29	2.14

Table B-1 (continues). Thermal properties of samples at 20°C.

Measurement number	Conductivity [W/(m, K)]	Diffusivity [mm^2/s]	Heat capacity [$MJ/(m^3, K)$]
S01A-90V-16			
1	2.73	1.21	2.25
2	2.73	1.21	2.27
3	2.74	1.20	2.27
4	2.73	1.21	2.26
5	2.74	1.21	2.27
S01A-90V-17			
1	2.92	1.21	2.41
2	2.92	1.22	2.39
3	2.92	1.21	2.41
4	2.93	1.22	2.40
5	2.93	1.23	2.39
S01A-90V-19			
1	2.89	1.26	2.29
2	2.89	1.26	2.30
3	2.89	1.26	2.29
4	2.90	1.25	2.31
5	2.89	1.27	2.29
S01A-90V-20			
1	2.77	1.23	2.24
2	2.77	1.23	2.25
3	2.78	1.24	2.24
4	2.78	1.22	2.27
5	2.80	1.22	2.31
S01A-90V-22			
1	2.84	1.26	2.26
2	2.85	1.24	2.30
3	2.85	1.24	2.30
4	2.86	1.24	2.31
5	2.84	1.25	2.27
S01A-90V-23			
1	2.92	1.36	2.14
2	2.92	1.36	2.15
3	2.95	1.34	2.20
4	2.92	1.36	2.16
5	2.92	1.36	2.15
S01A-90V-24			
1	2.95	1.30	2.27
2	2.95	1.29	2.29
3	2.95	1.29	2.28
4	2.95	1.30	2.27
5	2.95	1.30	2.28

Table B-2. Thermal properties of samples at 50°C.

Measurement number	Conductivity [W/(m, K)]	Diffusivity [mm^2/s]	Heat capacity [$MJ/(m^3, K)$]
S01A-90V-01			
1	2.77	1.11	2.50
2	2.75	1.13	2.44
3	2.75	1.14	2.42
4	2.77	1.12	2.47
5	2.76	1.14	2.43
S01A-90V-02			
1	2.78	1.10	2.52
2	2.81	1.11	2.54
3	2.81	1.12	2.51
4	2.82	1.11	2.53
5	2.82	1.11	2.54
S01A-90V-03			
1	2.76	1.13	2.44
2	2.77	1.13	2.44
3	2.77	1.14	2.43
4	2.77	1.14	2.42
5	2.77	1.14	2.43
S01A-90V-04			
1	2.79	1.16	2.41
2	2.80	1.16	2.42
3	2.80	1.16	2.42
4	2.80	1.17	2.40
5	2.81	1.16	2.42
S01A-90V-05			
1	2.77	1.20	2.32
2	2.79	1.21	2.31
3	2.78	1.23	2.25
4	2.77	1.24	2.24
5	2.77	1.24	2.24
S01A-90V-07			
1	2.73	1.10	2.48
2	2.73	1.11	2.45
3	2.73	1.13	2.41
4	2.73	1.13	2.42
5	2.73	1.13	2.42
S01A-90V-08			
1	2.81	1.11	2.53
2	2.81	1.12	2.50
3	2.82	1.12	2.52
4	2.81	1.13	2.48
5	2.80	1.13	2.48

Table B-2 (continues). Thermal properties of samples at 50°C.

Measurement number	Conductivity [W/(m, K)]	Diffusivity [mm^2/s]	Heat capacity [$MJ/(m^3, K)$]
S01A-90V-09			
1	2.99	1.19	2.50
2	2.99	1.19	2.51
3	2.99	1.19	2.52
4	2.99	1.19	2.50
5	2.99	1.19	2.52
S01A-90V-10			
1	2.82	1.23	2.30
2	2.81	1.23	2.29
3	2.82	1.22	2.31
4	2.83	1.21	2.35
5	2.81	1.22	2.31
S01A-90V-11			
1	2.76	1.08	2.56
2	2.77	1.08	2.56
3	2.77	1.09	2.55
4	2.77	1.09	2.55
5	2.76	1.09	2.53
S01A-90V-12			
1	2.68	1.19	2.25
2	2.68	1.20	2.24
3	2.68	1.20	2.23
4	2.68	1.21	2.23
5	2.68	1.21	2.23

Table B-3. Thermal properties of samples at 80°C.

Measurement number	Conductivity [W/(m, K)]	Diffusivity [mm^2/s]	Heat capacity [$MJ/(m^3, K)$]
S01A-90V-01			
1	2.73	1.05	2.60
2	2.73	1.06	2.58
3	2.73	1.06	2.56
4	2.73	1.06	2.59
5	2.72	1.06	2.58
S01A-90V-02			
1	2.80	1.03	2.71
2	2.80	1.03	2.72
3	2.79	1.04	2.68
4	2.79	1.04	2.67
5	2.80	1.04	2.70
S01A-90V-03			
1	2.75	1.05	2.61
2	2.75	1.05	2.61
3	2.76	1.05	2.62
4	2.75	1.06	2.60
5	2.75	1.06	2.60
S01A-90V-04			
1	2.78	1.05	2.65
2	2.78	1.08	2.59
3	2.79	1.07	2.61
4	2.79	1.06	2.63
5	2.79	1.08	2.58
S01A-90V-05			
1	2.77	1.14	2.43
2	2.78	1.14	2.44
3	2.75	1.16	2.37
4	2.76	1.15	2.40
5	2.76	1.19	2.33
S01A-90V-07			
1	2.70	1.03	2.63
2	2.71	1.03	2.62
3	2.72	1.04	2.62
4	2.71	1.05	2.57
5	2.71	1.05	2.58
S01A-90V-08			
1	2.75	1.02	2.70
2	2.73	1.02	2.69
3	2.73	1.00	2.73
4	2.72	1.00	2.72
5	2.73	1.00	2.71

Table B-3 (continues). Thermal properties of samples at 80°C.

Measurement number	Conductivity [W/(m, K)]	Diffusivity [mm^2/s]	Heat capacity [$MJ/(m^3, K)$]
S01A-90V-09			
1	2.95	1.09	2.70
2	2.96	1.11	2.67
3	2.96	1.12	2.63
4	2.94	1.12	2.63
5	2.96	1.10	2.69
S01A-90V-10			
1	2.75	1.10	2.51
2	2.78	1.11	2.50
3	2.79	1.09	2.55
4	2.77	1.13	2.46
5	2.77	1.11	2.49
S01A-90V-11			
1	2.73	1.00	2.74
2	2.72	1.02	2.67
3	2.72	1.02	2.68
4	2.73	1.01	2.70
5	2.71	1.02	2.66
S01A-90V-12			
1	2.66	1.12	2.39
2	2.65	1.13	2.35
3	2.67	1.12	2.38
4	2.66	1.12	2.38
5	2.66	1.11	2.39

Appendix C

Table C-1. Total time of measurement, ratio of total time and characteristic time, and number of analysed points at 20°C.

Measurement number	Total time(s)	Total/Char. Time	Points
S01A-90V-01			
1	20	0.60	56– 200
2	20	0.59	56– 200
3	20	0.59	56– 200
4	20	0.59	59– 200
5	20	0.59	62– 200
S01A-90V-02			
1	20	0.59	58– 200
2	20	0.59	65– 200
3	20	0.59	49– 200
4	20	0.58	60– 197
5	20	0.59	57– 200
S01A-90V-03			
1	20	0.60	47– 200
2	20	0.59	52– 200
3	20	0.59	24– 200
4	20	0.59	34– 198
5	20	0.59	32– 200
S01A-90V-04			
1	20	0.60	22– 196
2	20	0.61	20– 200
3	20	0.58	21– 191
4	20	0.61	20– 200
5	20	0.61	19– 200
S01A-90V-05			
1	20	0.61	60– 194
2	20	0.61	48– 193
3	20	0.59	41– 186
4	20	0.62	41– 196
5	20	0.63	46– 200
S01A-90V-07			
1	20	0.58	97– 200
2	20	0.55	51– 190
3	20	0.58	23– 196
4	20	0.58	40– 200
5	20	0.56	53– 194
S01A-90V-08			
1	20	0.59	21– 198
2	20	0.58	15– 194
3	20	0.60	28– 200
4	20	0.60	16– 200
5	20	0.60	16– 200

Table C-1 (continues). Total time of measurement, ratio of total time and characteristic time, and number of analysed points at 20°C.

Measurement number	Total time(s)	Total/Char. Time	Points
S01A-90V-09			
1	20	0.62	55– 200
2	20	0.62	60– 198
3	20	0.63	65– 200
4	20	0.62	33– 199
5	20	0.62	32– 200
S01A-90V-10			
1	20	0.66	27– 200
2	20	0.66	28– 200
3	20	0.66	28– 200
4	20	0.66	15– 200
5	20	0.66	24– 200
S01A-90V-11			
1	20	0.57	89– 200
2	20	0.57	60– 200
3	20	0.57	70– 200
4	20	0.57	35– 200
5	20	0.57	33– 200
S01A-90V-12			
1	20	0.63	69– 200
2	20	0.63	51– 200
3	20	0.63	48– 200
4	20	0.63	58– 200
5	20	0.63	66– 200
S01A-90V-13			
1	20	0.59	46– 200
2	20	0.59	60– 200
3	20	0.59	71– 200
4	20	0.59	65– 200
5	20	0.59	61– 200
S01A-90V-14			
1	20	0.60	87– 200
2	20	0.57	81– 191
3	20	0.60	60– 200
4	20	0.60	75– 200
5	20	0.60	63– 200
S01A-90V-15			
1	20	0.64	97– 200
2	20	0.63	69– 200
3	20	0.63	64– 200
4	20	0.64	94– 200
5	20	0.48	41– 153

Table C-1 (continues). Total time of measurement, ratio of total time and characteristic time, and number of analysed points at 20°C.

Measurement number	Total time(s)	Total/Char. Time	Points
S01A-90V-16			
1	20	0.56	26– 189
2	20	0.59	28– 200
3	20	0.58	24– 200
4	20	0.59	25– 200
5	20	0.58	23– 200
S01A-90V-17			
1	20	0.59	75– 200
2	20	0.59	60– 200
3	20	0.59	54– 200
4	20	0.59	52– 200
5	20	0.60	75– 200
S01A-90V-19			
1	20	0.61	26– 200
2	20	0.60	22– 196
3	20	0.61	36– 200
4	20	0.61	36– 200
5	20	0.61	38– 200
S01A-90V-20			
1	20	0.60	64– 200
2	20	0.60	61– 200
3	20	0.60	69– 200
4	20	0.59	66– 200
5	20	0.59	79– 200
S01A-90V-22			
1	20	0.61	34– 200
2	20	0.60	36– 200
3	20	0.60	40– 200
4	20	0.60	36– 200
5	20	0.61	36– 200
S01A-90V-23			
1	20	0.66	74– 199
2	20	0.66	75– 200
3	20	0.65	82– 200
4	20	0.66	74– 200
5	20	0.66	67– 200
S01A-90V-24			
1	20	0.63	15– 199
2	20	0.63	32– 200
3	20	0.63	22– 200
4	20	0.63	19– 200
5	20	0.61	30– 193

Table C-2. Total time of measurement, ratio of total time and characteristic time, and number of analysed points at 50°C.

Measurement number	Total time(s)	Total/Char. Time	Points
S01A-90V-01			
1	20	0.54	77– 200
2	20	0.55	66– 200
3	20	0.55	72– 200
4	20	0.54	69– 200
5	20	0.55	65– 200
S01A-90V-02			
1	20	0.53	70– 200
2	20	0.54	68– 200
3	20	0.54	68– 200
4	20	0.54	79– 200
5	20	0.54	73– 200
S01A-90V-03			
1	20	0.55	30– 200
2	20	0.55	49– 200
3	20	0.54	24– 197
4	20	0.52	21– 188
5	20	0.55	25– 200
S01A-90V-04			
1	20	0.56	37– 200
2	20	0.42	16– 149
3	20	0.56	49– 200
4	20	0.57	37– 200
5	20	0.55	34– 197
S01A-90V-05			
1	20	0.54	37– 185
2	20	0.58	66– 198
3	20	0.58	35– 192
4	20	0.60	24– 200
5	20	0.54	24– 181
S01A-90V-07			
1	20	0.54	50– 200
2	20	0.54	49– 200
3	20	0.55	30– 200
4	20	0.55	32– 200
5	20	0.55	30– 200
S01A-90V-08			
1	20	0.54	37– 200
2	20	0.55	41– 200
3	20	0.54	44– 200
4	20	0.55	35– 200
5	20	0.55	49– 200

Table C-2 (continues). Total time of measurement, ratio of total time and characteristic time, and number of analysed points at 50°C.

Measurement number	Total time(s)	Total/Char. Time	Points
S01A-90V-09			
1	20	0.58	55– 200
2	20	0.58	61– 200
3	20	0.58	29– 200
4	20	0.58	58– 200
5	20	0.58	27– 200
S01A-90V-10			
1	20	0.59	77– 200
2	20	0.60	72– 200
3	20	0.59	78– 200
4	20	0.58	78– 200
5	20	0.59	72– 200
S01A-90V-11			
1	20	0.52	46– 200
2	20	0.53	35– 200
3	20	0.53	47– 200
4	20	0.53	33– 200
5	20	0.53	21– 200
S01A-90V-12			
1	20	0.58	43– 200
2	20	0.58	60– 200
3	20	0.58	60– 200
4	20	0.59	64– 200
5	20	0.59	58– 200

Table C-3. Total time of measurement, ratio of total time and characteristic time, and number of analysed points at 80°C.

Measurement number	Total time(s)	Total/Char. Time	Points
S01A-90V-01			
1	20	0.51	67– 200
2	20	0.51	67– 200
3	20	0.52	70– 200
4	20	0.51	70– 200
5	20	0.51	67– 200
S01A-90V-02			
1	20	0.50	78– 200
2	20	0.50	80– 200
3	20	0.50	59– 200
4	20	0.51	79– 200
5	20	0.50	78– 200
S01A-90V-03			
1	20	0.51	44– 200
2	20	0.51	49– 200
3	20	0.51	48– 200
4	20	0.51	30– 200
5	20	0.51	27– 200
S01A-90V-04			
1	20	0.51	37– 200
2	20	0.52	36– 200
3	20	0.52	56– 200
4	20	0.51	45– 200
5	20	0.52	28– 200
S01A-90V-05			
1	20	0.55	48– 200
2	20	0.55	60– 200
3	20	0.56	38– 200
4	20	0.56	43– 200
5	20	0.58	59– 200
S01A-90V-07			
1	20	0.50	65– 199
2	20	0.49	55– 197
3	20	0.50	47– 200
4	20	0.51	25– 200
5	20	0.51	53– 200
S01A-90V-08			
1	20	0.49	47– 200
2	20	0.49	27– 200
3	20	0.49	70– 200
4	20	0.49	24– 200
5	20	0.49	75– 200

Table C-3 (continues). Total time of measurement, ratio of total time and characteristic time, and number of analysed points at 80°C.

Measurement number	Total time(s)	Total/Char. Time	Points
S01A-90V-09			
1	20	0.53	58– 200
2	20	0.54	45– 200
3	20	0.49	33– 179
4	20	0.54	71– 200
5	20	0.53	27– 200
S01A-90V-10			
1	20	0.53	33– 200
2	20	0.54	77– 200
3	20	0.53	67– 200
4	20	0.55	83– 200
5	20	0.54	75– 200
S01A-90V-11			
1	20	0.48	59– 200
2	20	0.49	53– 200
3	20	0.49	52– 200
4	20	0.49	71– 200
5	20	0.50	65– 200
S01A-90V-12			
1	20	0.58	43– 200
2	20	0.58	60– 200
3	20	0.58	60– 200
4	20	0.59	64– 200
5	20	0.59	58– 200

More details are available in attached excel files.