Guarded hot plate, optical scanning, transient divided bar: comparison of steady-state and transient methods to assess rock thermal conductivity

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Abstract

Thermal conductivity of rocks is a key parameter to model and design both deep and shallow geothermal systems relying on heat transfer simulations. However, in most cases, these models are based on literature data or laboratory measurements with high or unknown uncertainty. Three different laboratory techniques were compared in this work, trying to better understand analysis discrepancy related to the guarded hot plate, the optical scanning and the transient divided bar methods. The first method allows to assess thermal conductivity in steady-state when temperature equilibrium is reached in a small core sample placed between two parallel thermoelectric Peltier elements. The optical scanning technology adopts a moving infrared heat source and temperature sensors to scan diamond cut rock surfaces and thermal conductivity is measured in transient conditions at room temperature. The transient divided bar is a recent modification of the conventional steady-state apparatus and consists of two copper blocks of known conductivity, between which the specimen is interposed. By cooling the lower block with a thermostatic bath, the conductivity is derived from the rate at which the heat leaves the upper block. Rock specimens from two sites in Kuujjuaq (Québec) and Bergen (Norway) were collected to characterize the underground and to evaluate the efficiency of both deep and shallow geothermal systems. The Kuujjuaq samples belong to the Southeastern Churchill Province (1.8 Ga) and the Bergen ones to the Minor Bergen Arc (0.45 Ga). First results show the variability among the three devices ranging from 1 to 15%, with 7% average. The most representative value can be picked depending on the quality of the specimen and knowing advantages and limitations of each method.

Introduction & Geological setting

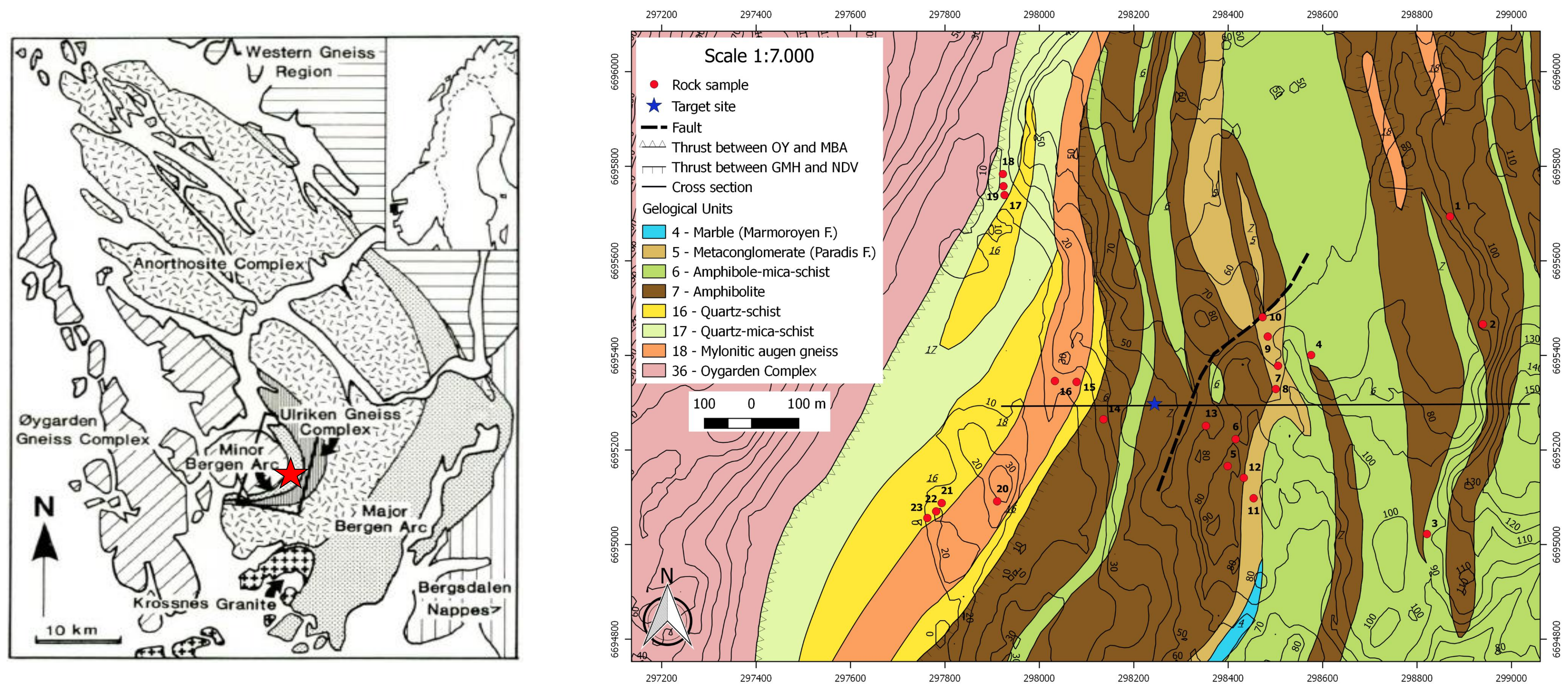

Fig. 1. Geological units of the Bergen area (Norway) from Fossen (1989). The red square comprises the study area and detailed geology of the site studied within Bergen, Norway, area.

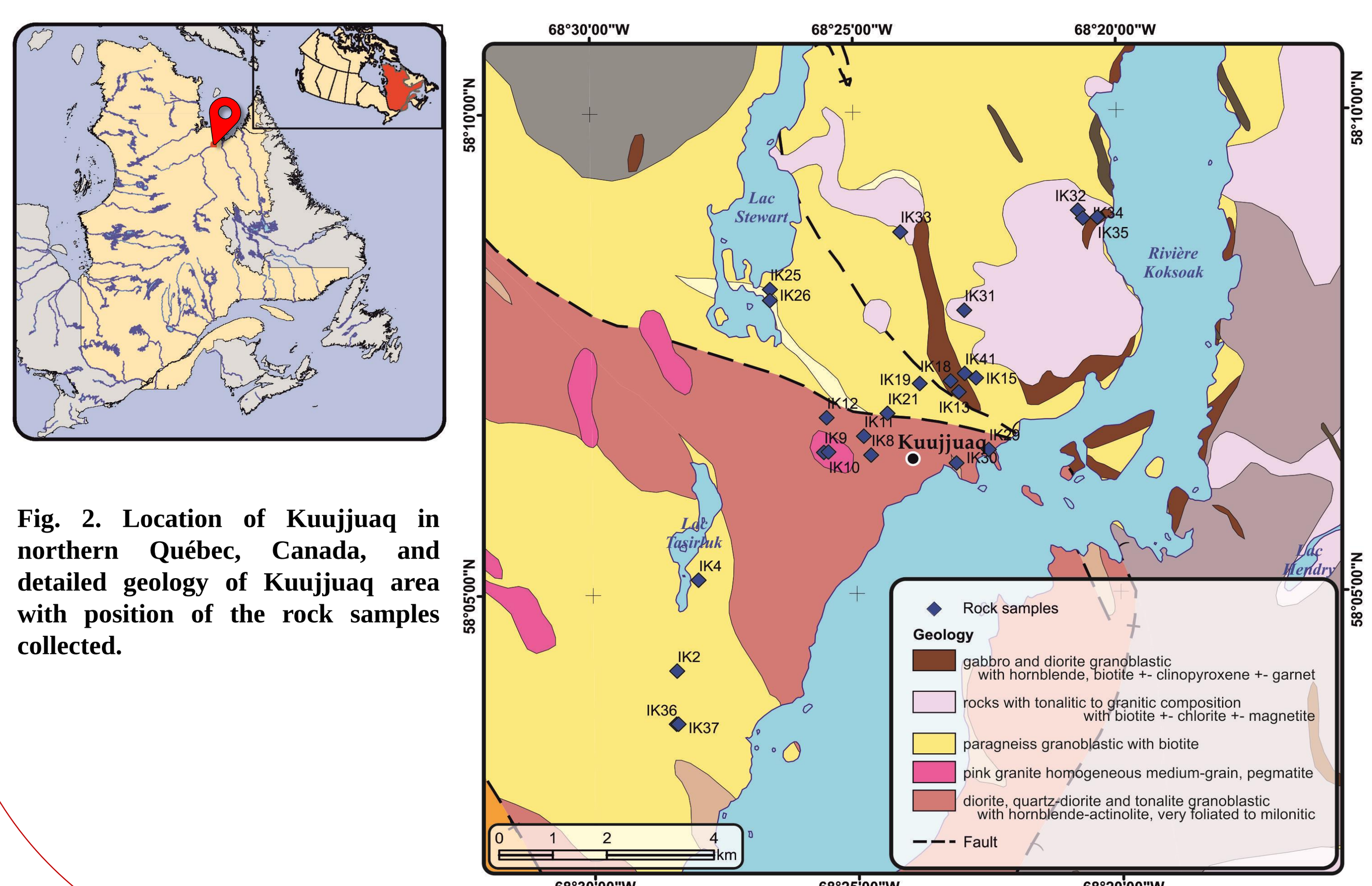

Fig. 2. Location of Kuujjuaq in northern Québec, Canada, and detailed geology of Kuujjuaq area with position of the rock samples collected.

Analyses of the thermal conductivity of rock samples collected in two different geographic and geological locations are described in this work. The first set of samples belongs to an area in Bergen, Norway (Fig. 1), whereas the second corresponds to samples collect in Kuujjuaq, Canada (Fig. 2).

Both sites are under investigation to assess their geothermal potential.

The aim of this work is to compare the thermal conductivity obtained by different equipments and to assess discrepancy among measurement methods.

Results & Conclusions

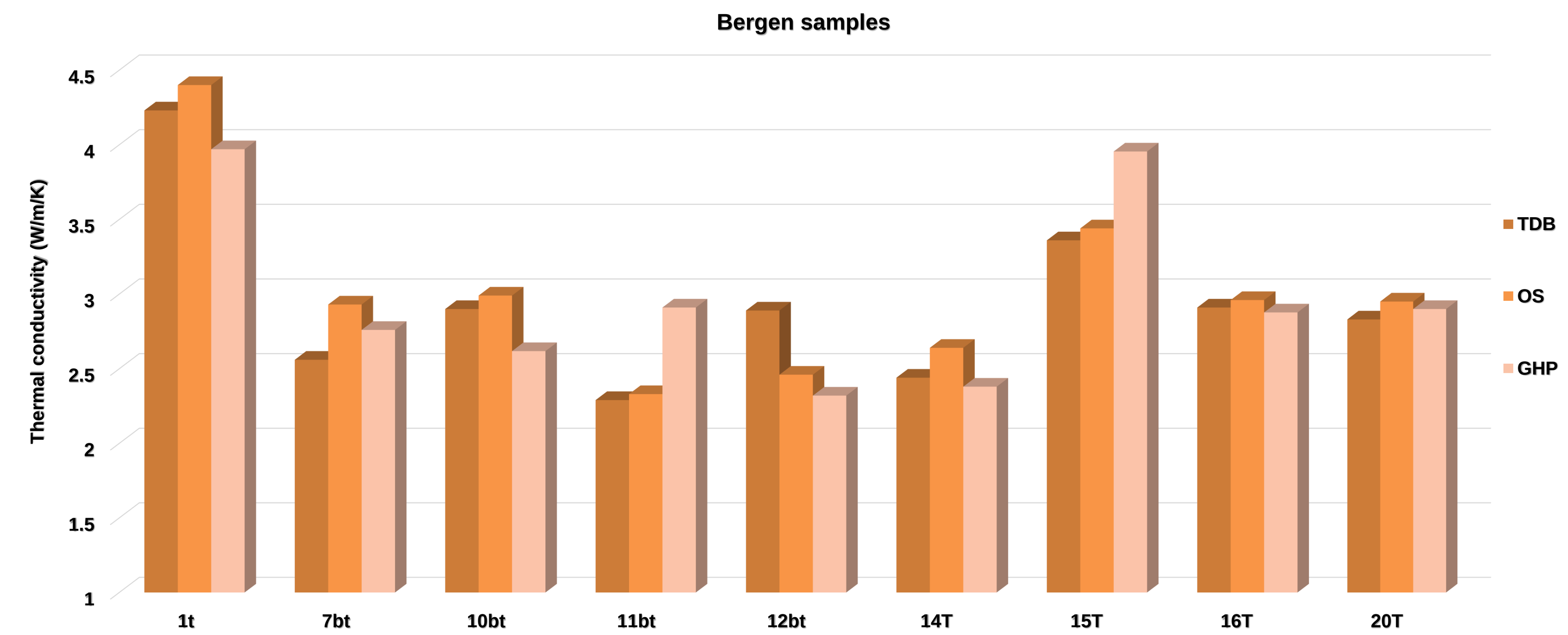

Fig. 6. Comparison of thermal conductivity evaluated with different methods – Bergen dataset (Fig. 1). TDB – Transient divided bar; OS – Optical scanning; GHP – Guarded hot plate

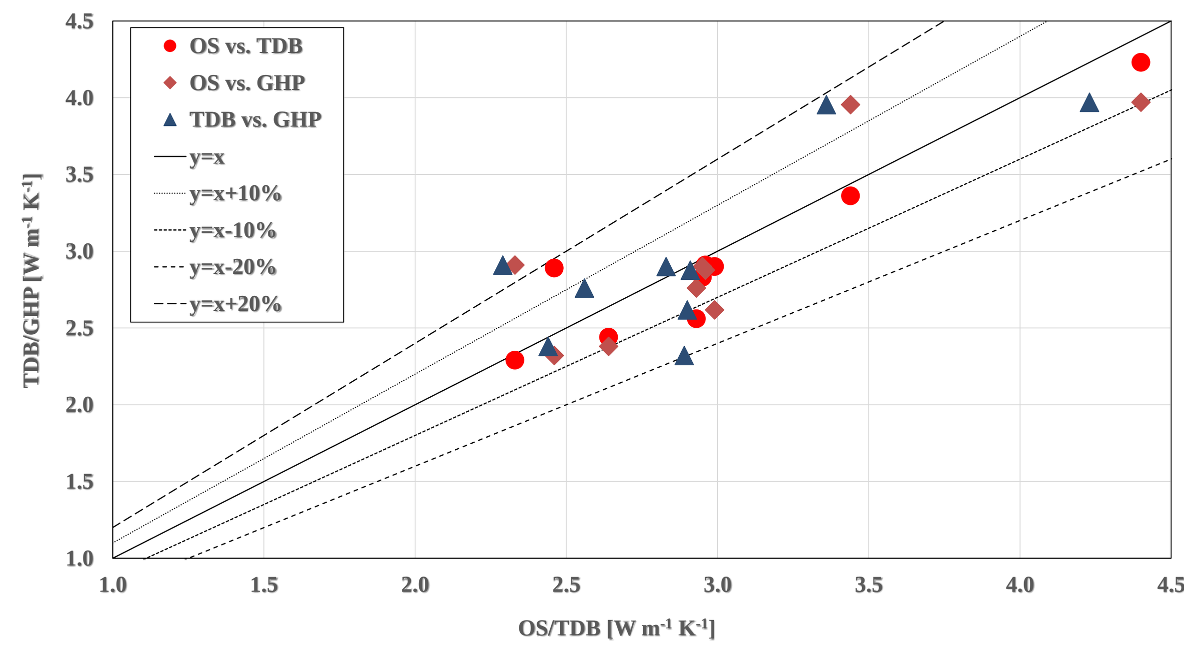

Fig. 7. Comparison between the different methods used on the Bergen samples. TDB – Transient divided bar; OS – Optical scanning; GHP – Guarded hot plate

First results show the variability among the three devices ranging from 1 to 15%, with 7% average (Figs. 6 and 7). The most representative value can be picked depending on the quality of the specimen and knowing advantages and limitations of each method. Due to heterogeneity and anisotropy of the rocks, the use of at least two different techniques seems recommendable in the investigation of rock thermal properties.

Kuujjuaq samples have been only analyzed with GHP so far (Fig. 8). TDB and OS analyses are in progress.

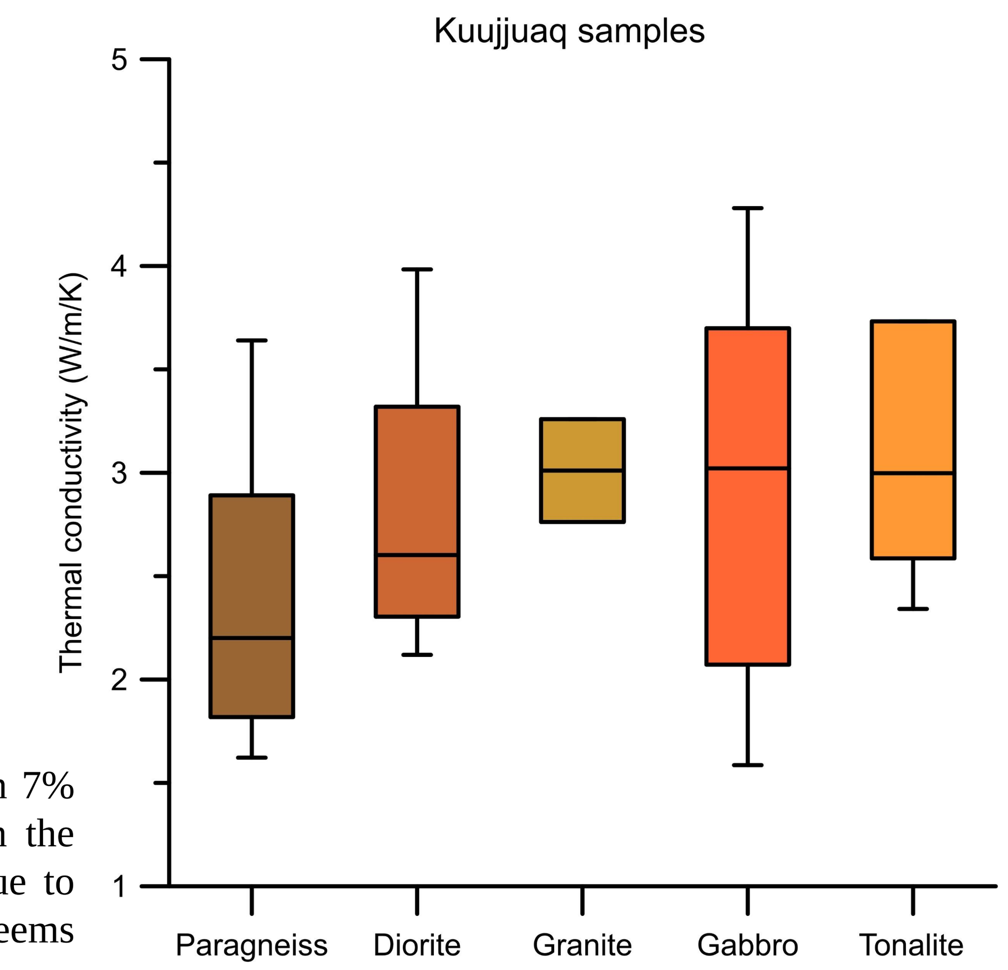

Fig. 8. Thermal conductivity of samples from Kuujjuaq analysed with the guarded hot plate method.

Methods & Techniques

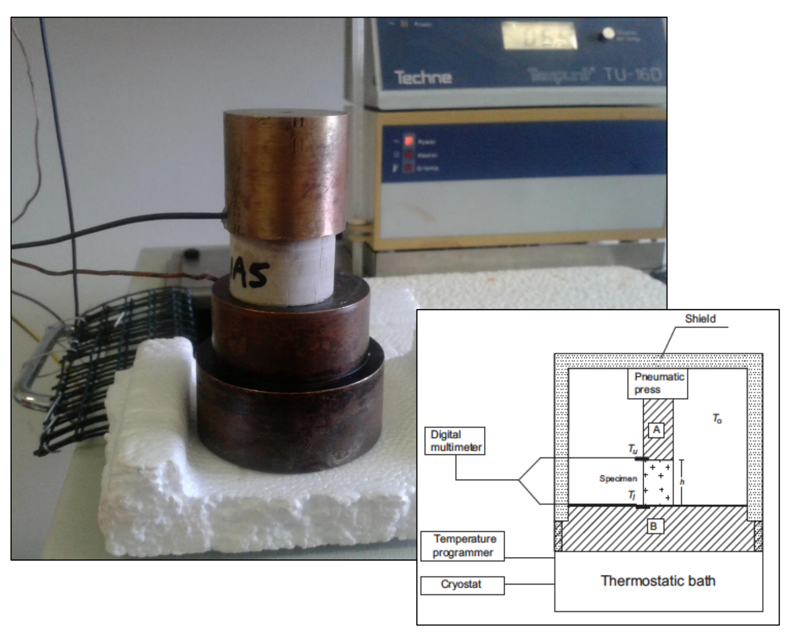

Fig. 3. Transient divided bar (Pasquale et al., 2015)

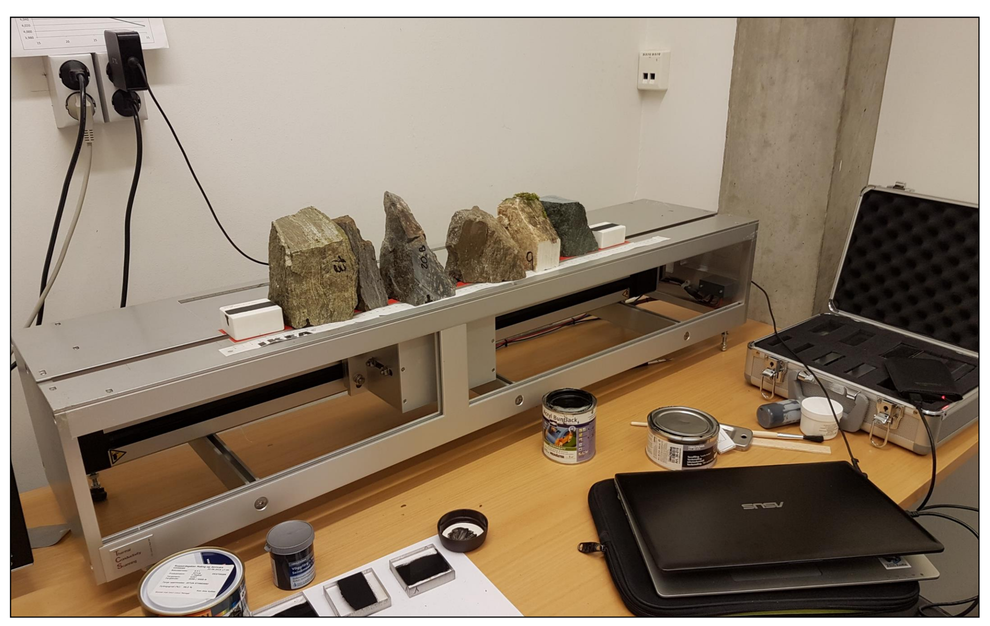

Fig. 4. TCS – optical scanning method (Popov et al., 2016). Measurements of thermal conductivity and diffusivity at room temperature.

Fig. 5. FOX50 Heat Flow Meter – steady state guarded hot plate method. Measurements of thermal conductivity and heat capacity in the range -10 to 190 °C (Raymond et al., 2017).

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