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Laboratory measurements of rock thermal properties by a transient divided bar method

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Key elements in understanding and modelling the subsurface thermal regime, is the thermal properties of the subsurface. These properties include thermal conductivity, thermal diffusivity and heat capacity. Thermal conductivity governs the steady-state undisturbed thermal regime, whereas thermal diffusivity is important for the transient behaviour including “disturbances” to the thermal regime, from e.g. borehole drillings and production-injection schemes.

The divided bar method is a classical method that uses steady state situations and analytical solutions to measure thermal conductivity. The setup consists of a stack of cylindrical discs with equal radius. At the centre of the stack is the sample to be measured. On both sides of the sample are two copper discs, then two discs of a ceramic standard material, then again two copper discs and finally, at the top and bottom is attached either a heating or cooling source. In our setup the source consists of circulating water. In each copper disc a small hole is drilled and a thermistor is inserted to measure the temperature at the centre. The thermistors then provide a temperature profile in the stack, and by fixing the upper and lower temperatures, a steady state temperature gradient will be established and using Fourier’s law of heat conduction, the thermal conductivity of the sample is measured.

In this study we present an improvement to the classical method, taking it from steady state to the transient regime thus enabling a simultaneous measurement of thermal diffusivity. The physical setup of the stack is unchanged, but instead of fixing the temperatures at the boundaries, we impose a time varying temperature-field by circulating water of variable temperature. The time-varying temperatures in the stack are measured and modelled numerically by a finite element procedure. To estimate the thermal properties of the sample we utilise a Markov Chain Monte Carlo inversion scheme that also provides estimates of uncertainty of parameters.
The main improvement with this method is that not only are we able to measure thermal conductivity, robust and accurate measurements of thermal diffusivity and heat capacity are also provided.