Effect of Groundwater Flow on the Subsurface Temperature Within Crystalline Rocks of Southern Norway

Y. P. Maystrenko [1], O. Olesen [1]

[1]Geological Survey of Norway (NGU), Trondheim, Norway

Abstract

The subsurface thermal regime has been investigated in three boreholes, drilled within the crystalline rocks in southern Norway (Maystrenko, 2013; Rønning et al., 2013). The results of thermal measurements demonstrate that the temperatures are unexpectedly low in two boreholes from southwestern Norway compared to the borehole from southeastern Norway (Maystrenko et al., 2014, 2015a, b). Therefore, the low values of the measured temperature have to be scientifically explained.

In order to understand major features of thermal regime within the upper crystalline rocks of the areas under consideration, the data-based 2D structural models have been derived for the areas in the vicinity of the investigated boreholes. During the construction of 2D structural models, all available recently published/released structural data have been used. These lithosphere-scale 2D models were used during the 2D conductive thermal modeling and 2D modeling of coupled groundwater flow and heat transfer. A 2D thermal modeling has been done with the help of COMSOL Multiphysics.

During the purely conductive 2D thermal modeling, the COMSOL physics interface "Heat Transfer in Solids" has been used to simulate the stationary and time-dependent heat transfer by heat conduction, which is assumed to be the dominant mechanism of heat transfer at the regional scale within the study area. Furthermore, two COMSOL physics interfaces "Heat Transfer in Porous Media" and "Porous Media and Subsurface Flow/Darcy's Law" have been used to carry out a fully coupled thermal modeling with taking into account the advection heat transfer due to groundwater flow. We applied Darcy's law to model the flow of water through the subsurface.

According to the results of the 2D conductive thermal modeling, a significant decrease of the Earth's surface temperatures during the two last Weichselian and Saalian glaciations still affects the subsurface thermal field of the study areas in terms of the reduced heat flow densities within the uppermost part of the crystalline crust (Maystrenko et al., 2015b).

Furthermore, results of the modeling of coupled groundwater flow and heat transfer indicate that the advective cooling due to groundwater flow is also one of the important factors for the reduction of temperatures in two boreholes within southwestern Norway where the normal annual

precipitation is one of the highest in Europe, reaching locally more than 4000 mm/year on the western (windward) side of the 1000-2000 m high Scandes mountains (Maystrenko et al., 2015a). On the other hand, the influence of the groundwater flow on subsurface temperatures is most likely relatively low within southeastern Norway which is the rain-shadow area with light precipitation and is characterized by smoothed landforms (Maystrenko et al., 2015a). Thus, the atmospheric precipitation-related groundwater flow through the crystalline rocks of southwestern Norway can affect the regional-scale conductive thermal field in terms of the reduced temperatures.

Reference

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Figures used in the abstract

Figure 1

Figure 2

Figure 3

Figure 4