Lithosphere-Scale 3D Thermal Models of the Norwegian Continental Shelf

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Abstract

To reveal key features of the thermal pattern at different structural levels of the Norwegian continental shelf and the adjacent mainland, the lithosphere-scale 3D structural models have been used to represent a structure of the sedimentary cover, underlying crystalline crust, and lithospheric mantle during a 3D thermal modeling. For the construction of these 3D models, all available geological and geophysical data have been combined together. The initially constructed models have been in addition validated by a 3D density and magnetic modeling in order to reasonably fill the data gaps which are not covered by the existing datasets. After that, the final gravity/magnetically-validated 3D models have been taken as a realistic structural background for the 3D thermal modeling. The 3D thermal modeling itself has been made with the help of COMSOL Multiphysics® software.

In general, the heat conduction can be considered as the dominant mechanism of heat transfer at the lithosphere scale within the present-day 'magmatic' quiet areas. Accordingly, the constraint-based 3D thermal modeling has been performed, using the COMSOL Multiphysics® interface "Heat Transfer in Solids" to simulate the stationary and time-dependent heat transfer by heat conduction at the regional scale within the closely located study areas. The 3D conductive thermal field within the structurally complex 3D models of the Norwegian continental shelf and the adjacent mainland has been calculated based on physical principles of the conductive 3D thermal field by solving the heat equation. The lateral boundaries were closed to heat transfer, assuming that the temperature gradient is zero across the thermally insulated lateral boundaries. The time-dependent temperatures at the sea floor and at the Earth's surface have been set as the upper thermal boundary condition with taking into account major changes of the paleoclimate. The lithosphere-asthenosphere boundary has been taken as a lower thermal boundary, corresponding to the 1300 °C isotherm.

Thermal properties represented by specific heat capacity, thermal conductivity, and radiogenic heat production have been set to each layer of the 3D structural models. The thermal conductivities of all layers have been set to be temperature-dependent and the thermal conductivities of the sedimentary cover have been additionally taken to be dependent on increasing compaction with depth.

The obtained results of the 3D thermal calculations have been compared with the measured temperatures in the available boreholes within the uppermost part of the 3D thermal model, indicating that there is a reasonable agreement between the measured and modeled temperatures and implying that deep modeled temperatures are also in a reasonable range. Therefore, the major features of the subsurface 3D conductive thermal

field within the Norwegian continental shelf and the adjacent mainland can be successfully reproduced by the lithosphere-scale 3D thermal modeling with help of the finite-element analysis software package COMSOL Multiphysics®.

Figures used in the abstract

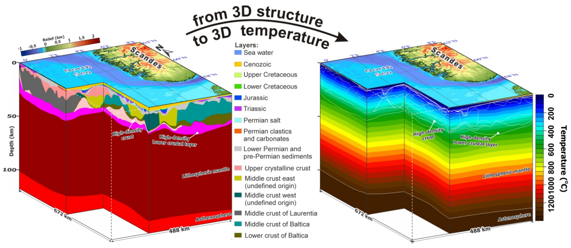

Figure 1: The lithosphere-scale 3D structural and 3D thermal models of the Norwegian continental shelf and the adjacent mainland (an example from the northern North Sea). Models are four times vertically exaggerated.