Routes to Thermal Energy: A New Heat Flow Model for Eastern Arabia

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Abstract

Understanding the distribution of heat sources in the earth's crust is essential for energy resource exploration, in particular for hydrocarbons and geothermal energy. The thermal field of the Arabian Plate is poorly constrained so far and heat flow has only been derived from regional geophysical models using gravity or seismic velocity field distributions on a plate scale. The study area is 166,000 km2 in size and spans from the Arabian Gulf to the Eastern Arabian Shield. The basement, covered by a more than 9000m thick Phanerozoic sedimentary cover, is composed of amalgamated crustal terranes of Late Proterozoic age. The tectonic framework of the basement and overlying basins follow the underlying tectonic signature, in some cases interpreted as terrane boundaries, like the En Nala suture limiting the Arabian Platform from the Faydah-Jafurah Basin.

We use gravimetric, magnetic and seismic data to build a 3-D lithosphere scale thermal model, defining the depth structure, vertical density distribution, and thermal properties of sediments, upper crust, lower crust and upper mantle. The gravity-derived variation of the Moho depth across the study area is showing a notable topography between 38 km and 48 km, decreasing in west-east direction. The resulting crustal thickness gives a spread between 29 km and 43 km, decreasing from west to east.

A set of 660 temperature measurements from 230 exploration wells has been available for reconstructing heat flow density maps and lithosphere geotherms as a function of the tectonic setting and presumed crustal compositional variations. Modeled surface heat flow increases from the eastern rim of the Arabian Shield and the Arabian Platform towards the easternmost Arabian Plate boundary, exhibiting values from 44-72 mW/m2. Geothermal gradients, accordingly exhibit an increase from 22 degC/km on the Arabian Platform, to 35 degC/km in the Faydah-Jafurah Basin. Heat flux shows a strong dependency on both lithosphere thickness evolution since accretion and the lithologic composition, i.e., the distribution of crustal thickness and heat sources. Heat flow analysis reveals that the radiogenic heat contribution to the total surface heat flux accounts for up to 58%, and the Moho heat flux for 42%, accordingly. From thermal modeling constraints, i.e., matching borehole temperature data and resulting heat flow distribution, it can be inferred that the crust underneath the easternmost Arabian Platform (east of En Nala terrane suture) is significantly more felsic (~ 2.5 μW/m3) than the central Arabian Platform and Arabian Shield (~ 0.9 μW/m3). This is supported by deep wells intersecting rocks of granitoid composition east of the Arabian Shield. Reconstructions of lithosphere geotherms has revealed Moho temperatures around 850-900 degC. Moho heat flow is in the order of 26 mW/m2.

Thermal modeling revealed a spatial relationship between regional surface heat flow distribution, crustal structure and the extension and composition of basement terranes. We can demonstrate that even on a smaller regional scale basement structure and composition leave a signal in the thermal data allowing to establish more solid heat flow models for future geothermal exploration purposes. The study demonstrates that the Proterozoic crustal configuration has an impact on the Phanerozoic thermal evolution and enables to better predict present day basin heat flow.

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