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Understanding the subsurface thermal structure of deep sedimentary basins in Denmark - measurements and modelling results

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Most of the Danish area is characterized by deep sedimentary basins with a great potential for exploitation of geothermal energy. Geothermal reservoirs are present at various depths and temperatures. Currently, three geothermal plants are operating producing warm water for district heating purposes. Information of subsurface temperature distribution originates from direct measurements in boreholes and from indirect theoretical modelling. “Point observations” of varying quality are available as industrially measured “Bottom Hole Temperatures” from deep exploration boreholes and accurate continuous equilibrium temperature logging has been carried out in a number of accessible deep boreholes. A regional distribution of subsurface temperatures is obtained by combining measurements and 3D numerical modelling in which the heat equation is solved. Modelling results are constrained by observations in terms of available measured temperatures and observed surface heat flow. Information on subsurface thermal conductivity, which is a critical parameter, is obtained from core measurements and well-log analyses. Interval temperature gradients are found to vary by a factor of three to four across lithologies of different conductivity. Mean geothermal gradients from surface to depths of 1000 to 3000 m are generally between 20 and 35 °C/km. The subsurface thermal structure is clearly dominated by conduction. Advection by groundwater migration is generally insignificant. Heat flow increases significantly with depth due to perturbation from long-term palaeoclimatic surface temperature variations. Examples of modelled temperature distribution for selected geothermal reservoir are shown. In the Gassum Formation, which is present in most of the Danish area, temperatures are largely between 35 and 90 °C for depths of interest.