Geophysical Research Abstracts
Vol. 21, EGU2019-7863, 2019
EGU General Assembly 2019

The influence of granite bodies on extensional basins: insights from structural, geodynamic and thermal modelling

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Crustal heterogeneities, in the form of large granitic intrusions, have a pronounced impact on the characteristics of extensional basins. Here, a series of structural, geodynamic and thermal modelling experiments have been used to investigate the influence of granite bodies on the North Pennine Basin of northern England, as well as to provide insights into their influence on hydrocarbon and geothermal prospectivity.

The link between intra-basinal highs and granite bodies has been recognised as far back as the 1950s, whereby the comparative buoyancy of granite-cored blocks with respect to accommodating crust has been proposed to cause a resistance to subsidence. Results from one-dimensional geodynamic modelling are presented that indicate granite bodies do not 'resist' subsidence during lithospheric extension, as was previously thought. Instead, the formation of granitic highs relates to initial isostatic compensation which is limited somewhat by the flexural rigidity of the lithosphere. Additionally, two-dimensional structural and geodynamic modelling further highlights the role of density variations within the crust due to the presence of granite, the flexural properties of the lithosphere and extensional faults in controlling the formation and evolution of granite-cored highs. These findings have significant implications for subsidence, sediment routing and reservoir distribution within hydrocarbon systems.

Heat flow anomalies, lateral variations in coal rank and the distribution of Mississippi Valley-Type ore deposits of the North Pennine orefields have been attributed to the thermal properties of subsurface granite in northern England. It is important to be able to quantify the thermal effects of these granite bodies, particularly given recent investments in geothermal energy projects in the UK and elsewhere. A regional 3D subsurface thermal model for northern England is being developed. It is hoped that such a model will lead to a better understanding of the geothermal potential of the region than current resource maps that, are often constructed using sparsely distributed temperature data points. Structural, lithological and rock property information derived from seismic and borehole data from the area, as well as radiogenic heat production values from concealed granite bodies have been integrated into a 3D model to help predict lateral and vertical temperature variations. A sensitivity analysis has been undertaken to constrain conductivity and radiogenic heat production values of concealed granite bodies. Model results show that subsurface temperature variations are strongly controlled by granitic radiogenic heat production, the measured values of which vary widely even within single boreholes intersecting the North Pennine Batholith.