Structural and Geodynamic Modeling of the Influence of Granite Bodies During Lithospheric Extension: Application to the Carboniferous Basins of Northern England

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Abstract

After the discovery of the Breagh gas field, in Quadrant 42 of the UK Continental Shelf (UKCS), the previously considered barren Lower Carboniferous play of the Central and Southern North Sea has attracted increased interest. Decades of studying the onshore succession has led to the broad agreement of a Lower Carboniferous 'block and basin' style megatectonic framework within which fault-bounded highs are separated by contemporaneous rift basins. This framework affects facies development, depocentre positioning and sediment transport pathways throughout the Lower Carboniferous and beyond.

In areas such as northern England, structural highs are underpinned by large granite bodies. This is widely believed to relate to the comparative rigidity and buoyancy of granite in relation to accommodating basement. It has been suggested that during periods of tectonic extension, normal faulting around the peripheral regions of granite batholiths permits granite-cored blocks to resist subsidence, thus forming stable areas during periods of widespread faulting-induced subsidence. In this study, we have used an integrated two-dimensional numerical modelling approach to demonstrate that relatively less dense crust is incapable of resisting subsidence in this way. Instead, the occurrence of granite-cored highs relates to initial isostatic compensation following granite emplacement, which is somewhat limited by the flexural rigidity of the lithosphere. It is suggested that such a response leaves residual, second-order stresses associated with the under-compensated buoyancy of the granite body and flexural tension.

The regional flexural profile in response to underlying granite bodies and large extensional faults observed in the Carboniferous North Pennine Basin of northern England are replicated by incorporating a density deficiency within the crust, flexural rigidity, shallow lithospheric simple shear deformation and deeper pure shear deformation. It is proposed that the interaction of three factors

dictate the tectonic framework within a partially granitic lithosphere and the occurrence of inter-basinal highs: 1) non-tectonic, second-order stresses; 2) extensional tectonic stress and importantly; 3) inherited basement fabric.

We endeavour to use our findings to better constrain the tectonostratigraphic evolution of the Lower Carboniferous basins of northern England, which provide an important analogue for similar block and basin style rift basins.