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Thermodynamic, geophysical and rheological modeling of the lithosphere underneath the North Atlantic Porcupine Basin (Ireland)

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The Porcupine is a North-South oriented basin located southwest of Ireland, along the North Atlantic continental margin, formed by several rifting episodes during Late Carboniferous to Early Cretaceous. The sedimentary cover is underlined by a very thin continental crust in the center of the basin (<5 km) that has been generally associated with hyperextension and mantle serpentinization. From North to South lithospheric stretching factors increase drastically from ∼2 in the North to >10 in the centre of the basin. In spite of the abundant literature, most of the oil and gas exploration in the Porcupine Basin has been targeting its northern part and is mostly restricted to relatively shallow depths, giving a restrained overview of the basin structure. Therefore, studying the thermodynamic and composition of the deep and boarder structures is needed to understand the processes linked to the formation and the symmetry signature of the basin.

Here, we model the present-day thermal and compositional structure of the continental crust and lithospheric mantle underneath the Porcupine basin using gravity, seismic and elevation data. We use an integrated geophysical-petrological framework where most relevant rock properties (density, seismic velocities) are determined as a function of temperature, pressure and composition. Our modelling approach solves simultaneously the heat transfer, thermodynamic, geopotential, seismic and isostasy equations, and fit the results to all available geophysical and petrological observables (LitMod software). In this work we have implemented a module to compute self-consistently a laterally variable lithospheric elastic thickness based on mineral physics rheological laws (yield strength envelopes over the 3D volume). An appropriate understanding of local and flexural isostatic behavior of the basin is essential to unravel its tectonic history (i.e. stretching factors, subsidence etc.). Our Porcupine basin 3D model is first defined by four lithological layers, representing properties from post- and syn-rift sequences to the lithospheric mantle. Several structural and rheological 3D models of the basin are defined and compared to define the most possible scenario and timing of formation. Using low density sediments is not sufficient to obtain an appropriate match of the geophysical data, especially in the south. The introduction and properties representative of hyperextended lithosphere or of serpentinized mantle help to reduce structure uncertainty, and to understand the underlying processes of formation of the Porcupine basin.