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A General Kinematic Representation of the Lithosphere to Constrain Thermal Modeling of Sedimentary Basins

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Abstract

Amongst the physical processes represented in petroleum systems modelling (PSM), one of the most critical processes is the thermal evolution of a basin throughout geological ages as it will drive HC generation from source rocks, the physical and chemical evolution of the migrating fluids, and fluid and rocks alterations. In PSM, heat transfer is mostly conductive, where the heat diffuses from the lithosphere, considered as the lower boundary of the sedimentary model, to the topographic surface. But heat flow also depends on the intrinsic properties of sediments, such as thermal conductivity, porosity, and heat capacity. Surface conditions through time are constrained by paleo-latitude and -climate, and rock properties are bounded by endmember lithofacies, even if they present uncertainties. In such a system, the most essential element that drives all the heat entering the sedimentary pile, is the lower thermal boundary.

In modern PSM, bottom boundary conditions are not anymore given by an imposed heat flow but rely on a full lithospheric geometrical reconstruction and its physical changes through time. With this major change in assessing the temperature evolution, we have the possibility to better integrate geological concepts that are necessary to reproduce the behavior of passive or active margins. With the input and insights from our geodynamics studies, we now routinely apply a workflow that fully controls the lithosphere kinematics and physical evolution through time. Starting with genetic domains reflecting the present-day structural configuration of the lithosphere, we apply deformation rules derived from thermomechanical models to constrain the lithosphere kinematics through time. This allows us to model a wide variety of margins and their evolutions. We can integrate multiple scenarios from simple ridge propagation to transform faults, underplating, hot spots, cooling delay, delaminated mantle, multiple rifting events, subductions… or a mix of all of them. We developed tools to produce the necessary map-sets which let us test different concepts and parameter sensitivities. Once done and to ensure a global coherency, the resulting restoration constrains the bathymetric evolution and/or initial configuration of ductile layers. In addition, the resulting crustal and upper mantle properties can be used to estimate mantle fusion which may serve as a proxy for the generation of mantle- derived carbon dioxide.

In this presentation, we show our innovative workflow that we have been routinely applying for several years, with several synthetic and case studies from passive margins and foreland settings.