Validation of Compositional Kinetic Predictions

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Kinetic models of petroleum generation have become the standard tool for the prediction of hydrocarbon distribution and properties using basin modelling. Such models rely on laboratory analysis of hydrocarbon generation and extrapolation of the reactions characterised to geologic heating rates. Bulk kinetic models describe the primary generation of hydrocarbons using open-system pyrolysis, whereas compositional kinetic models capabale of predicting composition, gas vs. oil proportions etc. require either multiple open or closed system pyrolysis experiments.

The compositional kinetic models developed at GFZ, termed PhaseKinetics [1], are based on a combination of bulk kinetics and closed system pyrolysis experiments to describe the compositional evolution of generated fluids as a function of increasing maturity. Due to the compositional resolution used, which is based on that of PVT data formats, the prediction of petroleum phase properties is possible. Here we demonstrate for a series of new study areas that such compositional predictions are accurate.

Four study areas where geologic models, geochemical data and natural fluid physical properties were available for calibration are presented here: The Williston Basin, USA, focussing on the Bakken Formation; the Jean d´Arc basin offshore eastern Canada; the Mackenzie Basin, northern Canada; and the North Sea Central Graben.

The Devonian-Mississippian Bakken Formation of the Williston Basin in central North America (Canada & USA) contains a productive Siltstone Member which is encased within the source rocks of the upper and lower Bakken Formation. Production data from these units made available by the North Dakota Geologic Survey indicates that fluid GORs span a range from roughly 50 to 500 Sm^3/Sm^3. The most common GOR encountered is around 150 Sm^3/Sm^3, with GORs above 300 Sm^3/Sm^3 being comparatively scarce. The maturity of the Bakken Formation is constrained to the oil window. Analysis of six immature Bakken source rocks indicates kinetic variability; however, predictions with respect to GOR closely reproduce the observed natural variability.

In the Jean d´Arc Basin offshore Canada the Late Jurassic Ranking Formation is the main source rock and is also characterised by significant facies variability. 5 samples with petroleum type organofacies [2] ranging from paraffinic-napthenic-aromatic sulfur-rich to paraffinic high-wax were studied in detail and compositional kinetic predictions compared to production data from over 100 well tests. In this case 3D basin modelling including the simulation of petroleum generation and migration taking hydrocarbon phase behaviour into account was performed. The basin model predictions correctly reproduced observed distribution, phase state and GORs of the known accumulations in the area.

In the Mackenzie Basin, northwest Canada, sediment deposition took place from the Late Cretaceous to present. Over 9 km of sediments contain a variety of potential source rocks, reservoir formation s and cap rocks. A detailed 3D model of the study area was constructed [3] and source rock compositional kinetics assigned from a standard dataset [1] based on petroleum type organofacies. In the Mackenzie Basin a variety of fluid types exist, including single phase gases, gas condensates and oils. Data concerning the phisical properties of reservoired fluids was not available, but descriptions of oil type and phase state were, such that the reconstruction of the basin migration dynamics was aimed at reproducing observed phase state. The results of the modelling matched the occurrence of deep gas condensates, intermediate depth oil accumulations (in part with gas caps) as well as the occurrence of shallow gas.

In the Central graben of the North Sea a 3D basin modelling study focussed on the deep overpressured parts of the Graben [4]. Here compositional kinetic models of the main source rocks (Kimmeridge Clay, Heather Formation and Pentland Coals) were combined with in-source secondary cracking kinetics [5] to succesfully reproduce gas condensate properties and compositions in HPHT reservoirs.

In all cases studied compositional kinetic predictions accurately matched natural fluid properties and phase state, providing thus a significant step forward in enhancing our understanding of hydrocarbon generation and migration dynamics as well as reducing exploration risk.

References

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