Risking the Timing of Petroleum Formation from Heterogeneous Source Rocks

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Tools to risk the occurrence and accumulation of petroleum in sedimentary basins have significantly improved during the last years. 3-D basin modelling packages and their capability to trace petroleum system evolution in time and space here provide an excellent opportunity to predict petroleum formation, migration and accumulation relative to source, carrier and reservoir formation. One of the major advances however is the progress in these models to predict volumetrics, since drainage areas can be considered as a whole and not only on a 1-D or 2-D level. This however implies that the definition of the source rock characteristics, distribution and potential in such models is among the major controls on total volumes available for migration and finally charging of a prospect under study.

Petroleum formation kinetics are those parameters which mathematically describe the petroleum generation characteristics of a source rock These parameters, namely the activation energies and the frequency factors, are directly controlled by the petroleum precursor material preserved in a source rock. The depositional environment and the type of organic matter (lacustrine, marine, terrestrial or mixtures) preserved during the deposition of a source rock therefore dictate the petroleum generation kinetics of an entire source rock sequence. In the case of homogeneous source rocks, this can be defined with one set of kinetics while vertically heterogeneous source rock in theory require the definition of its petroleum formation behaviour through a representative set of kinetics models. Latter, however, is often far away from reality. Kinetic studies, and as a consequence basin models, are often limited to the most attractive source rock samples and do not represent the full range of source rock precursor material preserved in a source rock interval. This becomes most dramatic if different source rock types can be found in the source rock of interest which then would also result not only in timing variations but also in compositional (gas-prone vs. oil-prone) uncertainties.

The Draupne Formation, among many others, is an excellent case to demonstrate such a problem. Well logging data, geochemistry, petrography and sedimentology have often reported that the organofacies, the depositional environments, source rock properties and last but not least kinetic parameters show strong variations ranging from a type II (less stable) oil-prone to a type III (stable) gas-prone source rock (Fig. 1and Fig. 2). Although practically always ignored in basin analysis studies, the latter represents around 40% of the overall Draupne Formation in areas such as the Tampen Spur Petroleum System. Kinetic parameters reported in literature as well as the definition of the Draupne Formation in published basin modelling studies are limited in considering the full sequence representing an oil-prone typical type II source rock associated with kinetic parameters typical of those reported for marine organic matter.

The reason for such simplification may be the focus on most attractive source rock samples when planning a conventional kinetic study as well as the limits of basin modelling to handle heterogeneous source rocks. While the splitting of source rock events into different subevents is relatively unproblematic, the handling of such source rock subevents through sensitivity studies as well as the resulting running times can be a strong pain.

In the present article we illustrate the major risks of a simplified definition of source rock petroleum kinetics for the Tampen Spur Area in the North Sea. We will show how far information of organic geochemistry, petrography and well logging can be used to define kinetics which represent the entire source rock characteristics and introduce a procedure to calculate one single kinetic model from 10 kinetic models used to define the Draupne Formation characteristics (Fig. 3). The consequences for the duration of basin modelling runs as well as the enhancement of the petroleum system understanding will be shown and discussed. Hereby improved volumetric estimates and especially an enhanced petroleum formation prospectivity for the highly mature Draupne Formation are the major benefits. Examples from other petroleum systems will be introduced to illustrate the worldwide significance of the presented procedure.

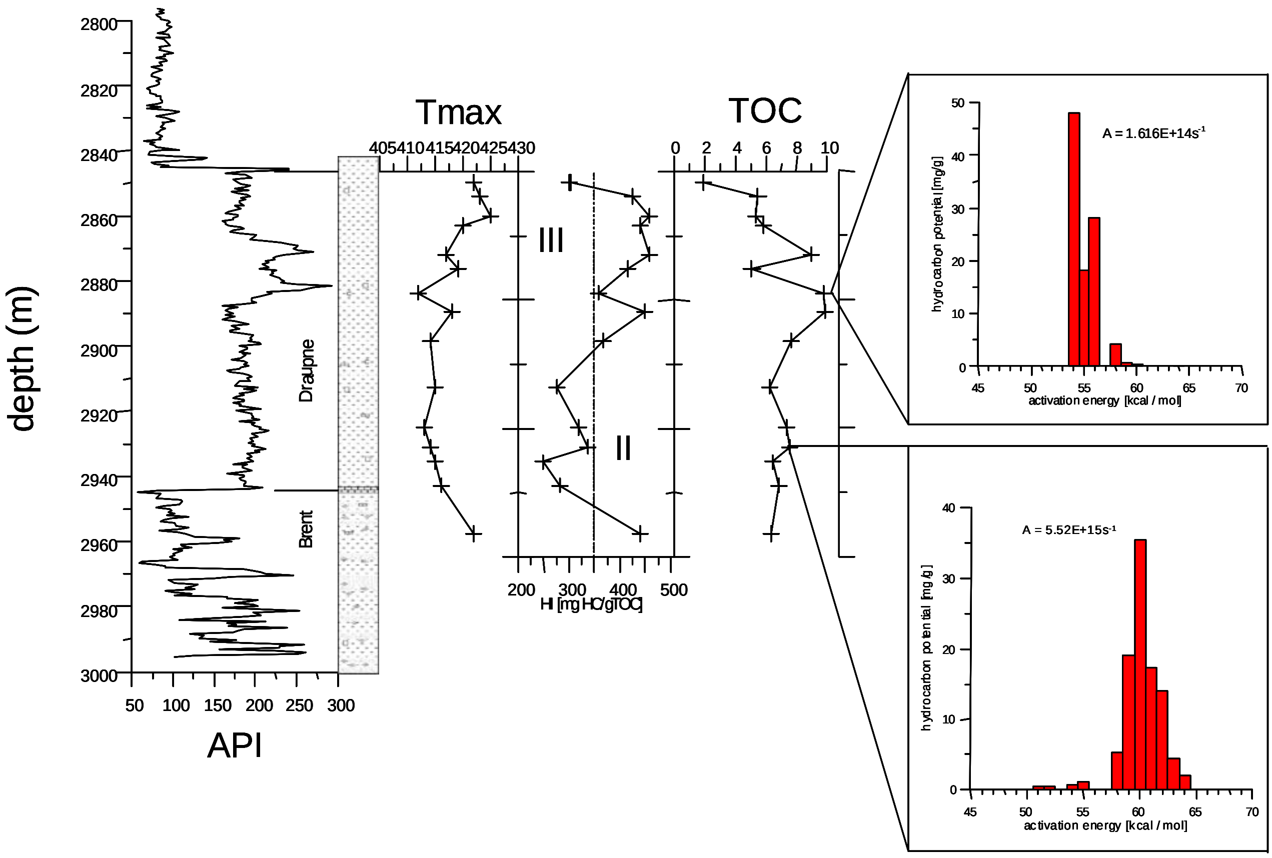


Fig. 1: Organofacies variations and kinetic parameter differences in the Draupne Formation

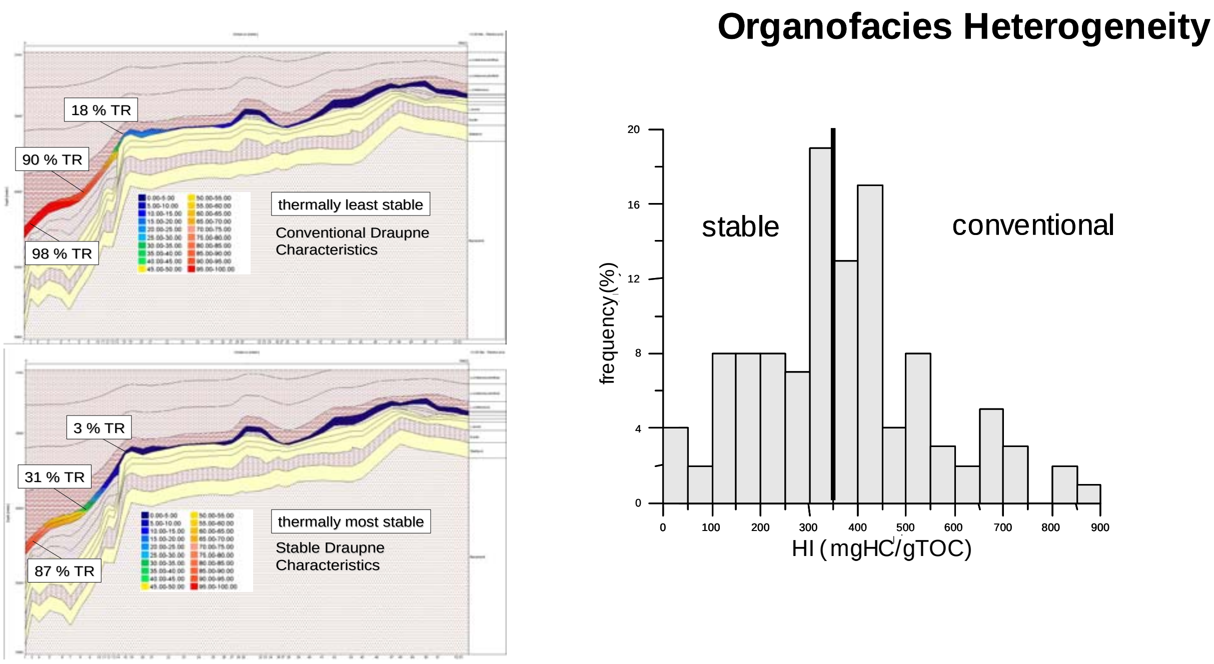
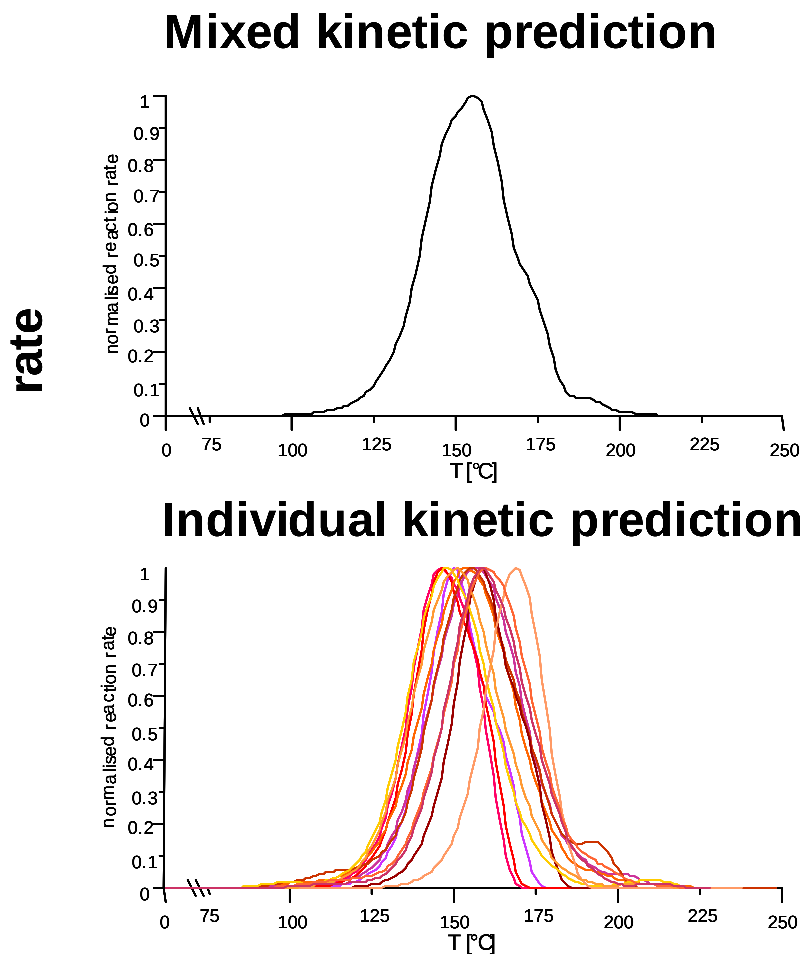


Fig. 2: Differences between conventional type II and often ignored type III kinetics on organic matter transformation. Example from the Tampen Spur Area

	Ea	A (1/s)
0.10	49.03	2.61E+13
0.15	47.66	5.93E+12
0.20	52.39	1.54E+14
0.25	55.25	1.02E+15
0.30	55.81	1.16E+15
0.35	55.57	7.67E+14
0.40	57.02	1.92E+15
0.45	56.62	1.12E+15
0.50	56.34	7.50E+14
0.55	56.40	6.36E+14
0.60	58.05	1.81E+15
0.65	57.78	1.17E+15
0.70	56.33	3.29E+14
0.75	59.18	2.02E+15
0.80	58.78	1.21E+15
0.85	59.07	1.06E+15
0.90	65.40	5.84E+16
0.95	67.38	1.21E+17
1.00	72.74	1.77E+17

a)



b)

Fig. 3 Overall Kinetic Parameters (a) and resulting petroleum formation window at geological heating conditions for the Draupne Formation compared to predictions resulting from individual samples (b).