

# BMT™ – Exploration Tool Combining Tectonic and Temperature Modelling

a report by

**Willy Fjeldskaar**

Research Director, RF-Rogaland Research

## Introduction

The most important factors behind the generation of hydrocarbons in sedimentary basins are temperature and time. The temperature regime in a basin is affected by various geological processes throughout the history of the basin. This includes processes related to basin geometry, such as basin formation, deposition/erosion of sediments and faulting, and physical processes related to compaction, heat flow and fluid flow.

Hydrocarbon generation potential in many basins is a critical factor in the prospectivity of potential traps. One of the tools used for exploration is a basin modelling program. With increasing geological complexity of relevant sedimentary basins, there is a growing need for basin modelling systems that can handle more of the complex controlling geological processes that lead to the generation and migration of hydrocarbons.

It is particularly important to be able to represent the present geometry of the basin properly and to be able to reconstruct a realistic description of the geometry over geological time. With large errors in the present and palaeo-geometry, simulations of the temperature history and the hydrocarbon generation and migration history will be unreliable.

## BMT™

The BMT™ program (BMT™ – Tectonic Modelling of Basins – a trademark of RF-Rogaland Research) comprises a powerful and broadly applicable set of tools for solving exploration problems in basins around the world. BMT™ is an advanced two-dimensional (2-D) basin modelling system with high resolution and structural reconstruction capabilities. The ability to create area balanced cross-sections in environments with normal or reverse faults, and to analyse the interplay between tectonic processes, heat flow and timing of generation and distribution of hydrocarbons in a basin, makes BMT™ a tool for the expert user. Due to the high resolution capabilities, BMT™ also has the power to analyse complex tectonic processes,

including salt diapirism and igneous intrusions, and to model the related heat flow response.

BMT™, designed for a Unix environment, has been developed at RF-Rogaland Research by a team of geoscientists, mathematicians and software engineers. Basin modelling development has been underway more or less continuously since 1985. BMT™ was the first commercial system for combining tectonic modelling with the temperature history and hydrocarbon generation modelling in a single integrated program. It is still the only system on the market bridging the gap between structural geology and basin modelling. This is a very important point, because better insight into the tectonic processes responsible for the basin evolution has a direct bearing on the predictive power of basin models.

## Processes

BMT™ is used to simulate the geological processes that affect the temperature evolution and hydrocarbon maturation throughout the history of a basin.

This includes the following processes:

- sediment deposition, erosion and compaction;
- structural restoration of normal and reverse fault complexes;
- user-defined restoration of salt geometries;
- isostatic response to sediment loading, erosion and fault movements;
- tectonic response to lithospheric thinning;
- dependence of rock thermal conductivity and heat capacity on mineralogy, porosity and temperature;
- thermal and subsidence effects of magmatic intrusions and underplating;
- heat flow into the basin associated with lithospheric thinning;



- transient (or steady state) heat transport within the basin; and
- thermal maturation of organic matter.

BMT™ can constrain a number of critical parameters in basin, play or prospect assessment. The system is especially well suited for establishing the controls on the subsidence history of the basin and the timing of hydrocarbon generation, but can also provide valuable information on timing of trap formation and possible hydrocarbon migration pathways.

### Applications

BMT™ is particularly well suited for addressing the following:

#### Sequence Stratigraphy

- geohistory analysis that can incorporate a high-resolution sequence stratigraphic framework, structural reconstruction of normal and reverse faults, and subsidence analysis in a single integrated program
- geohistory analysis that can incorporate user-specified movement of salt simulating diapirism, pillowing and salt-induced inversion

#### Subsidence Analysis

- modelling the flexural-isostatic response of the lithosphere to extension by faulting and to erosion
- estimate tectonic subsidence/uplift (displacements that cannot be ascribed to loading)
- model the palaeo-heat flow into the basin (rift basins)

#### Hydrocarbon Maturation

- area, timing, duration and rate of source rock maturation together with timing of fault movement and prospective trap formation
- evaluation of the effect of faulting on maturation timing and distribution
- evaluation of the thermal influence of salt distribution and movement on maturation timing and distribution

#### Hydrocarbon Migration and Entrapment

- reconstructed fault geometries give insight into possible role of faults as conduits or barriers

between mature sources and potential reservoirs through time

- fault restoration algorithm provides insights into the timing of trap formation with respect to source rock maturation

#### Reservoir Quality Prediction

- burial history can give insight into possible diagenetic effects on porosity where diagenetic reactions are temperature-dependent (for example illite formation, quartz cementation, opal to quartz transformation, etc.)

#### Learning Tool

- One of the most important but often overlooked benefits of basin modelling is that it requires that the user to carefully consider the factors controlling the history of the basin under study. With BMT™, you must evaluate the stratigraphy, lithology types and distributions, palaeo-depositional environments, subsidence history and structural deformation, etc.

#### Model Scales of Observation

- BMT™ can be used at scales of observation ranging from an entire basin to that of a producing field. As a result, it can be used for reconnaissance work in largely unexplored basins to help constrain the necessary geological factors for economically viable production or it can be used to evaluate a prospect or outpost well in a mature basin.

#### Basin Types

- BMT™ is designed specifically to model rift basins, but can also be applied to a number of other types such as forearc and cratonic basins.

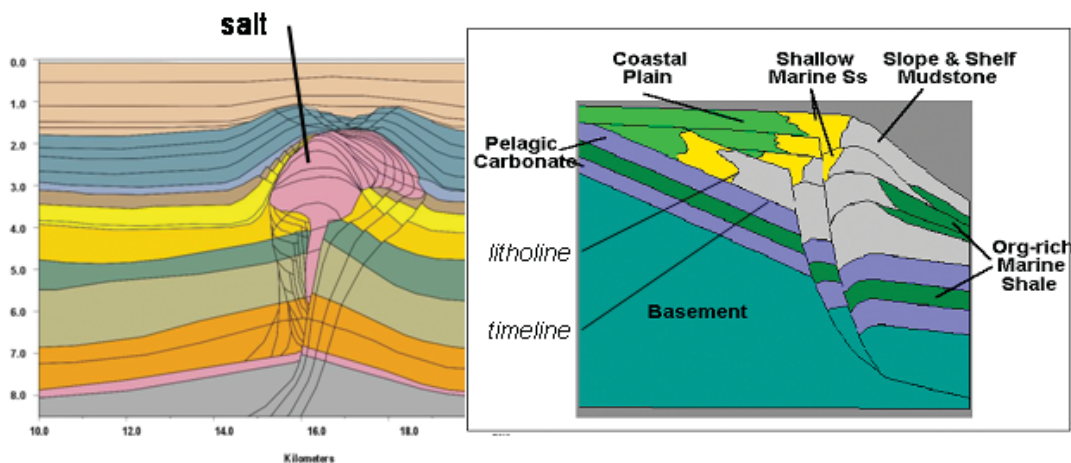
#### Basin Evolution

To reconstruct the geometry of the basin through time, one cross-sectional layer (see *Figure 1*) at a time is removed, the sediments underneath are decompacted and the faults restored. All fault systems that intersect the new top layer will be restored.

#### Fault Restoration

Faulting of a reservoir may create hydrocarbon traps, migration pathways or may ruin a potential reservoir by leakage through faults and fractures. The timing of tectonic episodes, fault movements and development of the structural elements can be crucial for the commercial success of a field. Faults can act as seals due to a number of mechanisms. It is therefore

Figure 1: Examples of Modelled Cross-sections



The right figure shows a section incorporating a high-resolution sequence stratigraphic framework, and the left figure shows a section that has been modelled with user-specified movement of salt.

of utmost importance to incorporate fault movements in the basin modelling.

Fault restoration is included in BMT™ to account for structural effects on maturation timing and to give insights into the geometry of possible hydrocarbon migration pathways and traps through time. It is important to keep in mind, however, that BMT™ is not designed to replace specialised fault restoration programs for rigorous analysis of structurally complex areas.

There are a number of fault restoration methods described in the literature such as vertical shear, inclined shear, bedding plane slip and slip line, etc. In general, it is reported in literature that the inclined shear model with an antithetic shear of 20° gave the best fit with observations, though all models did a reasonably good job of restoration. This includes the vertical shear method.

### Vertical Shear Model

BMT™ utilises the vertical simple shear model. It is called vertical shear because the bars remain vertical throughout the fault restoration process (see Figure 2). The reason for choosing a vertical simple shear model in BMT™ is:

1. it provides a good approximation to observed fault displacements
2. it is able to keep track of rock mass (a requirement for temperature and maturation modelling that some other restoration methods cannot provide);
3. it greatly simplifies and accelerates calculation of compaction effects and tracking of mass; and
4. it needs much less user interaction than the

inclined shear method, which requires that shear angles be defined on a fault-by-fault basis.

BMT™ employs several types of gridding systems to calculate, store and display results. Each gridding system is optimised for its task. The foundation of all the grid systems are the elementary grid lines, or bambinos. Bambinos are grid elements that define the geometry of reconstructions as well as serve as a data storage reference. Bambinos are tied logically to polygons, which are areas of the modelled cross-section that are bounded by lines (timelines, faults, lithological boundaries (litholines) or the model side boundaries) (see Figure 2).

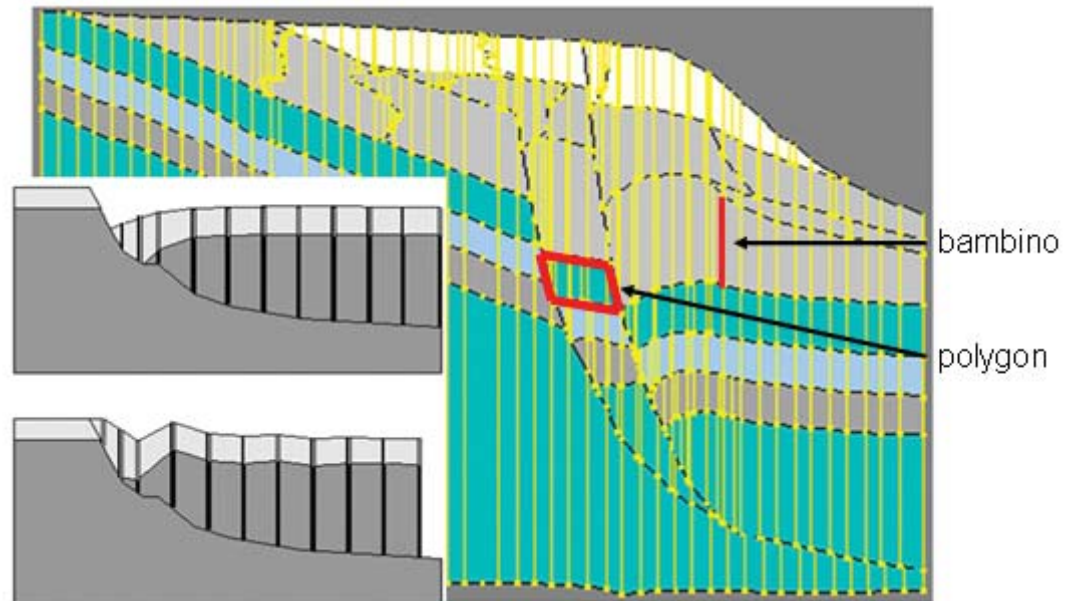
### Temperature History

The temperature history over geologic time is decisive for whether or not hydrocarbons may have been formed in the basin. Among other factors, the temperature regime depends on the sedimentary basin evolution and the geometry of structures that are formed during the deformation of the basin.

The temperature history of the basin is calculated in BMT™ by conduction. One of the most important controls for temperature distribution is the thermal conductivity structure. The parameters that control the thermal conductivity structure are defined for each lithology type in the model, and BMT™ predicts the horizontal and vertical thermal conductivity of the lithology. The resulting present-day temperature, shown in Figure 3, and the temperature history reflects the difference in porosity (partly caused by lateral variations in the burial history) and the thermal conductivity of the sedimentary rocks.

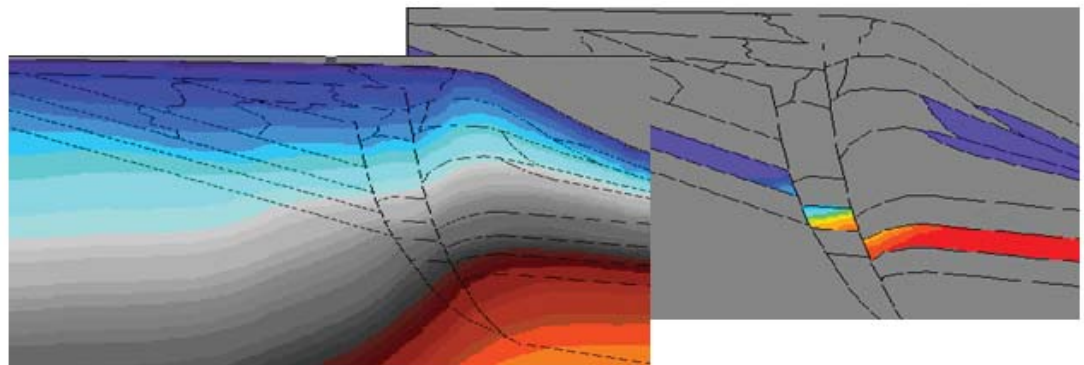
BMT™ uses kinetic maturation models along with the temperature history to predict the timing of hydrocarbon formation from a given source rock (see

Figure 2: BMT™ Gridding



Example of the bambino grid at a reconstructed time step (in colours). Schematic illustration of a vertical simple shear model (in greyscale) showing the situation before restoration (upper figure) and after restoration (lower figure).

Figure 3: Temperature and Maturity Modelling



The left figure shows the calculated present-day temperature distribution for the basin. The right figure shows the predicted transformation ratio for source intervals for present-day conditions: red colour indicates 100% and blue colour 0% transformed hydrocarbons.

Figure 3). The parameters governing the formation of petroleum are, in addition to temperature history, time (or heating rate) and organic matter type. Thus, the reliability of the prediction of oil and gas formation depends on:

1. the reliability of the temperature history; and
2. the reliability of the organic kinetic parameters used in the maturation modelling.

### Conclusion

Fairly simple exploration methods led to the early discoveries of the structural traps of oil and gasfields globally. A lot of interesting fields are, however, characterised by complicated geological structures. More sophisticated exploration methods are needed to make hydrocarbon discoveries in structural traps in these areas. There is therefore a growing need for basin modelling systems that can handle more of the complex controlling geological processes that lead

to generation and migration of hydrocarbons. Better insight into the mechanisms of basin formation has a direct bearing on the predictive power of basin models.

BMT™ has been used in a number of studies of sedimentary basins at the Norwegian continental shelf, in the Gulf of Mexico, South America, Asia and Africa. BMT™ technology, combining tectonic modelling with the temperature history in a single integrated program, gives better insight into the complex structures that we call sedimentary basins. ■

### Contact Information

**BMT is now a trademark of  
Tector AS, Stavanger, Norway.**

**For more information,  
please contact:  
Willy Fjeldskaar  
wf@tector.com**

