Petroleum System Modeling and Risk Analysis, Cambay Basin, India*

Monmayuri Sarma[1]

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[1]Schlumberger Information Solutions, Mumbai, India (msarma@slb.com)

Abstract

Exploration is associated with risks and uncertainties, especially with limited or poor quality data. Understanding the uncertainties of results is the goal of every explorationist, and one of the best ways is to build several equi-probable stochastic models of predictions. The aim of this study is to risk the critical geochemical components and arrive at an unbiased understanding of the petroleum system. The study also defines the effects of these uncertainties and finds which particular component will have the highest sensitivity on the simulation result. The more specific objectives are:

1) Determination of generation potential of the source rock.
2) Timing of hydrocarbon generation.
3) Migration modeling of the hydrocarbon (if generated) in a 2D cross section along the basin.

This case study only has access to public domain data of Cambay Basin. The exploration stage usually has very limited data and this study is aimed at showing how a meager amount of data may also be useful for better understanding of the geological system and thereby leading to a better chance of success. The Petromod Suite of software was used for the analysis. The Cambay Basin is regarded as an important hydrocarbon bearing basin of India. Sedimentary rocks in this petroleum province range from Paleocene to Recent and were deposited on a Tertiary rift basin.

Methodology

1D modeling at various locations in the basins was carried out. The total sedimentary column (lithology) at each location was determined based on well data. The default lithologies were edited using a lithology editor to derive the appropriate lithological mix for a particular layer.

This is an important step as the compaction curve will vary according to the lithology (Figure1). Geochemical parameters such as hydrogen index (HI), total organic carbon (TOC) and kinetics were risked in the study because of the limited availability of data, and a tornado plot was generated to understand the parameter that has the greatest effect (Figure 2). In this case it is seen that the TOC has the largest uncertainty, followed by kinetics and HI.

A 20 km 2D section through Ankleshwar to Dabka fields (Biswas et al., 1994) is used for 2D migration modeling. The stratigraphic column was determined and the boundary conditions of heat flow, sediment water interface and paleo-water depths were obtained from the 1D models. Both the “hybrid method” as well as “invasion percolation” migration modeling was performed. The hybrid method provided the most accurate solution to the fundamental problem of simulating the relationship between hydrocarbon column heights and seal breakthrough, while domain decomposition can be avoided by using the invasion percolation method and thus one migration method can be applied for the whole model (Hantschel and Kauerauf, 2009).

Basin Evolution

The tectono-stratigraphic reconstruction of the basin indicates that prior to achieving its present-day basin configuration, the lithosphere underwent a phase of rifting and drifting as the Indian Plate disintegrated from the Gondwana supercontinent. The first stage of separation of Western Gondwanaland from Eastern Gondwanaland is recorded during Late Triassic/Jurassic (~196-203 Ma). The second stage was the separation of Seychelles-India from Madagascar in Late Cretaceous (~93 Ma). However, the final breakup of Seychelles at KTB (~65 Ma), contiguous with the Deccan volcanism, is associated with a series of rift basins along the western continental margins of which the Cenozoic Cambay Basin (Bhowmick et al., 2004) is the one discussed in the study.

Geochemical Data

The main source rock of the area is the Cambay Shale. Source rock (SR) data reveal six laterally extensive potential sources (PS) with kerogen type II/III in the Middle Eocene-Lower Paleocene. The Cambay Shale average TOC content varies from 2.6% to 3% and the average HI (Hydrogen Index is 121 mg/g TOC; Banerjee et al., 2002; Biswas et al., 1994).

Boundary Conditions

The most important boundary condition is the heat flow in the basin. Since the basin is rift related and the source and the reservoirs are mainly the result of synrift and postrift sedimentation, a Mckenzie Stretching model is applied with a beta factor of 2 and a heat flow of 80 mw/sq m is obtained during the rift phase and around 50 mw/sq m in the subsequent phase of thermal sag (Figure 3 and Figure 4).

Sediment Water Interface Temperature is obtained automatically from the software. A paleo-reconstruction is done in the background to obtain the location of the basin throughout time. A constant paleowater depth was considered due to the lack of data. As mentioned earlier, Kinetics was found to be a uncertain parameter and hence calculated using Pepper and Corvi (1995).

Results

Reconstruction of burial and thermal history indicates that a critical moment of generation in this basin was reached in Late Miocene. A Petroleum Event Chart was constructed (Figure 5). The trap and reservoir rock were in place by that time and a seal rock was deposited on top of the reservoirs, indicating prevention of loss of hydrocarbon leading to a functional and working petroleum system in the area.

Ideally a detailed calibration should be performed, but due to lack of public domain data this step cannot be attempted. However, the results obtained from migration modeling in the 2D section (Figure 6), when matched with the original section used, shows accumulation at known fields indicating that even with bare minimum data it is useful to carry out the generation as well as migration modeling to increase the confidence of exploration.

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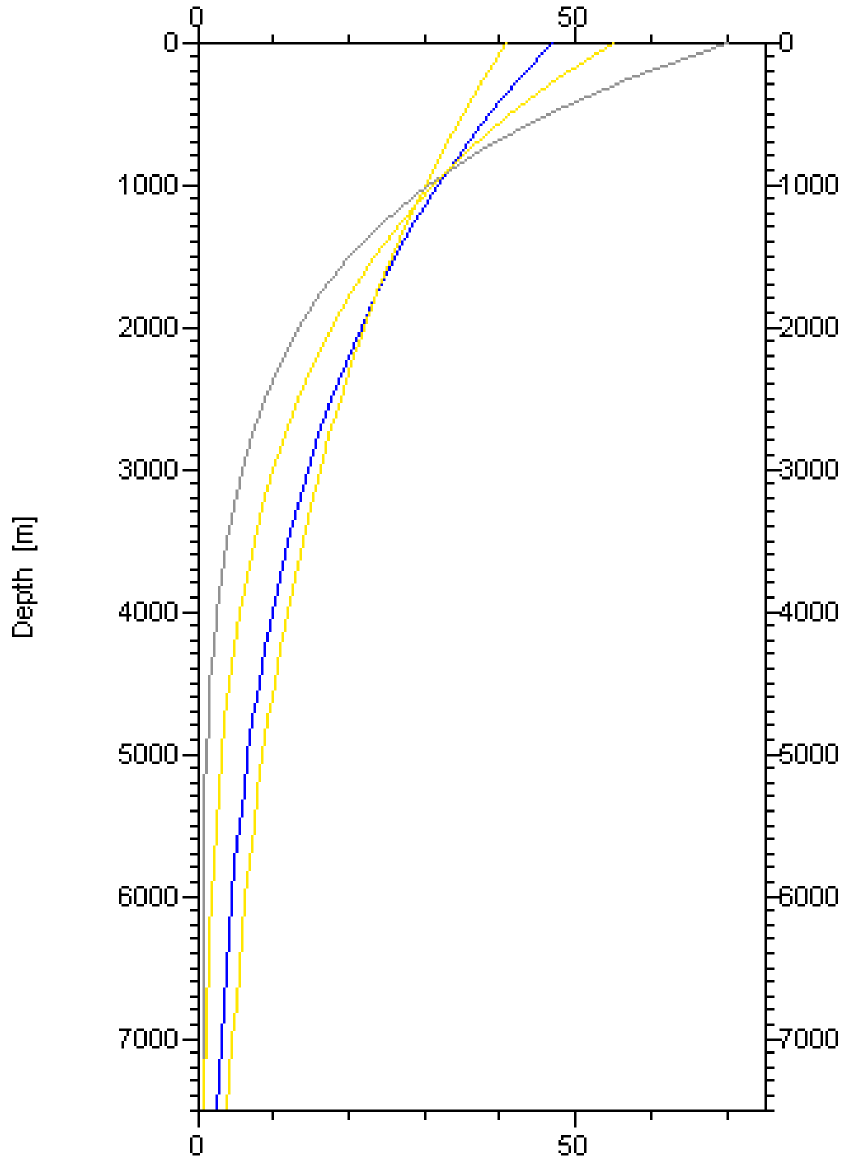

Figure 1. Compaction curves for various lithologies. Grey indicates typical shale, Yellow 1 curve for typical sandstone, and the Blue curve and the Yellow 2 curves represent a mixture of shale and sand.

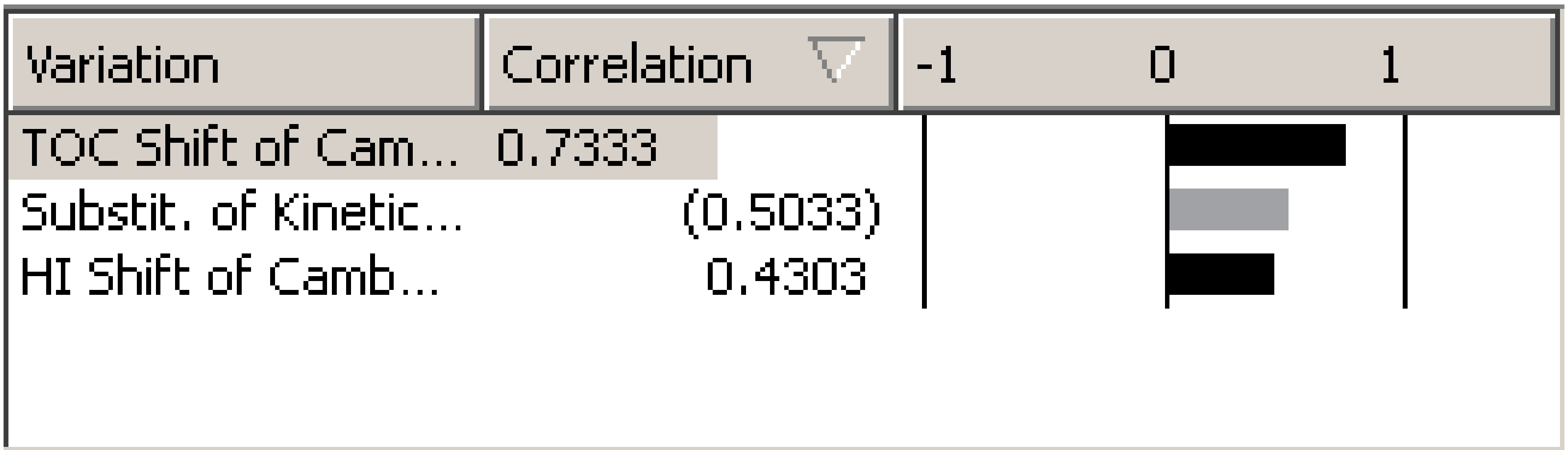

Figure 2. Risking of TOC, Kinetics and HI. It is shown in the tornado plot that TOC shift has a maximum effect.

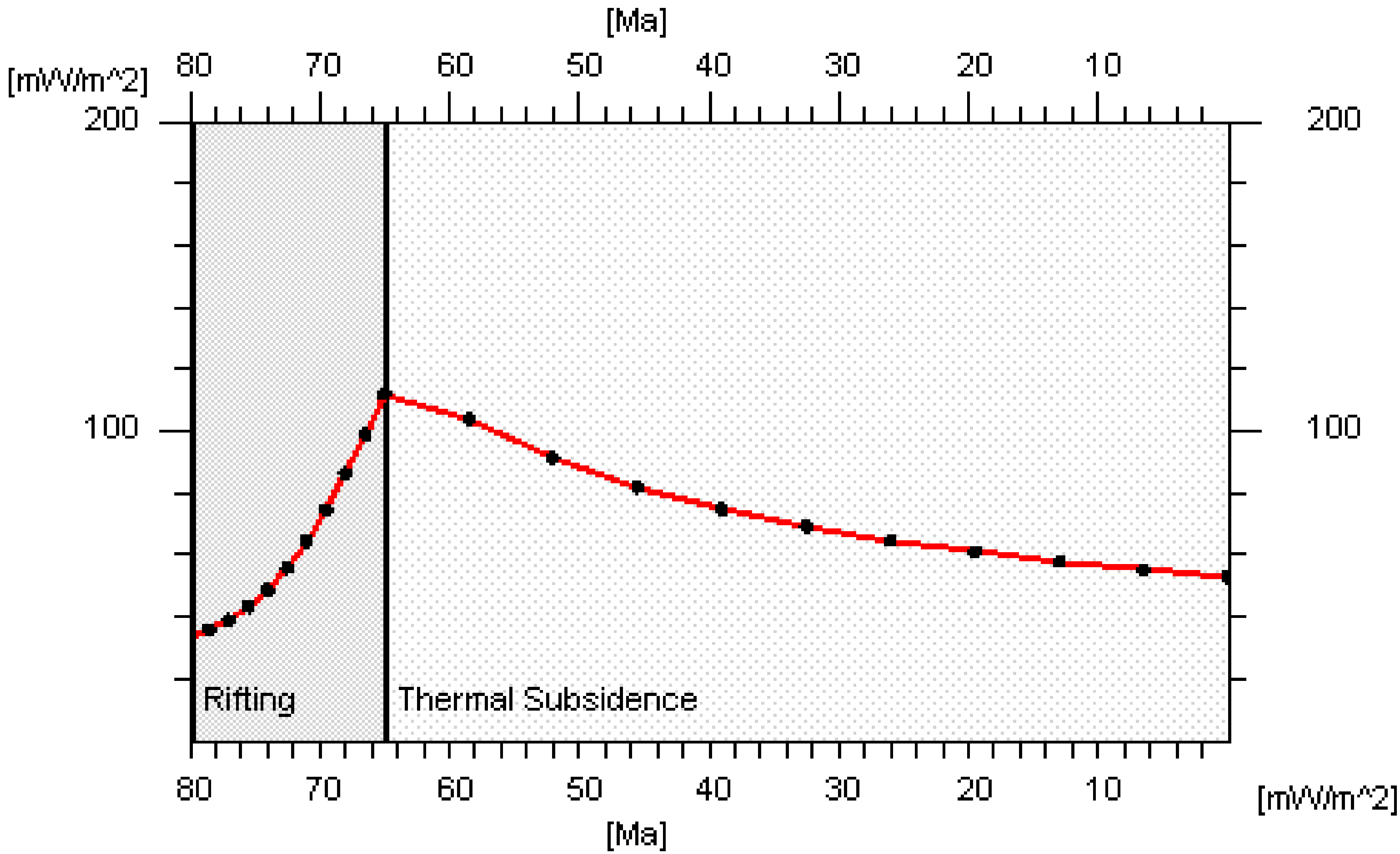

Figure 3. Heat flow distribution curve.

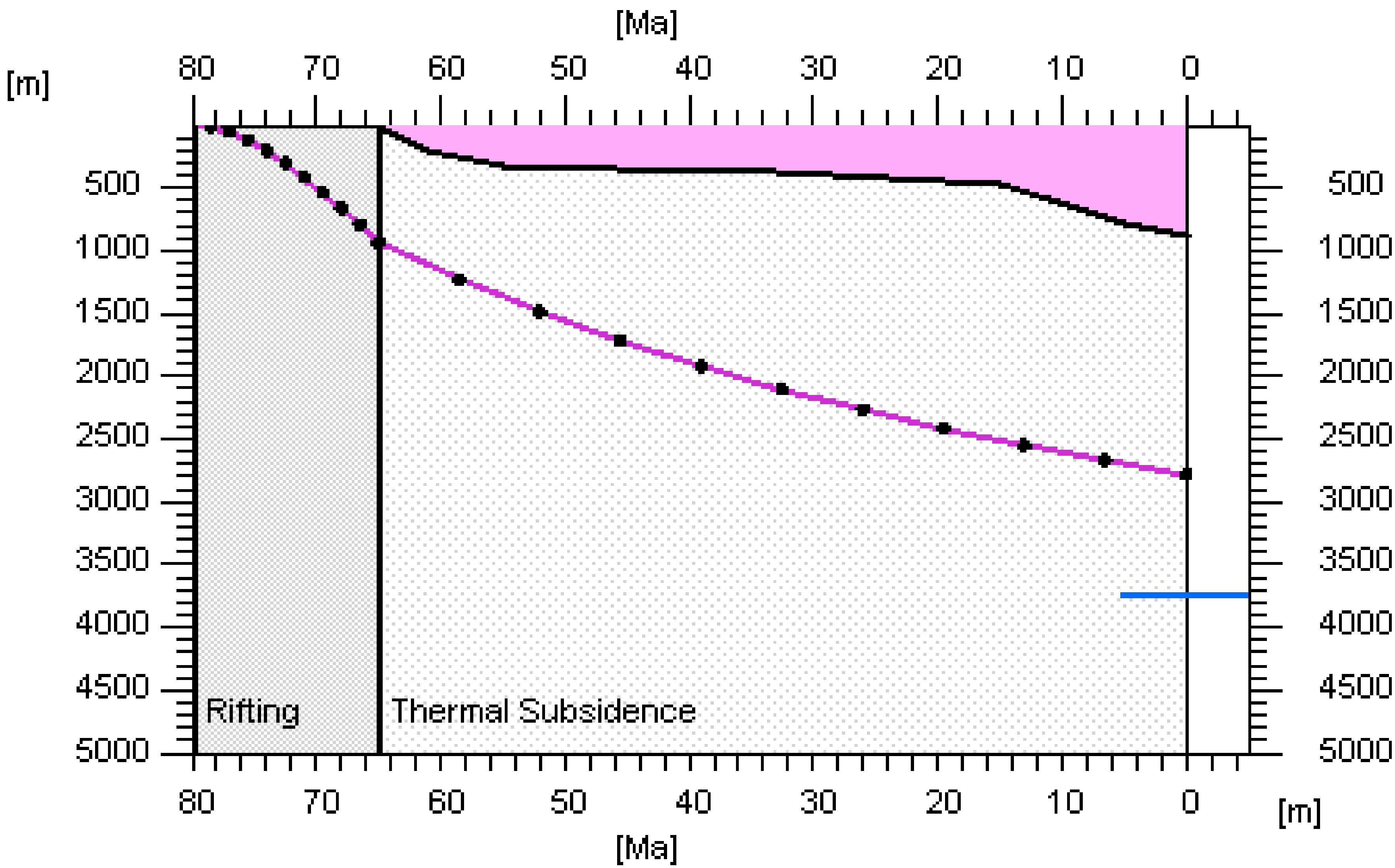

Figure 4. Subsidence curve.

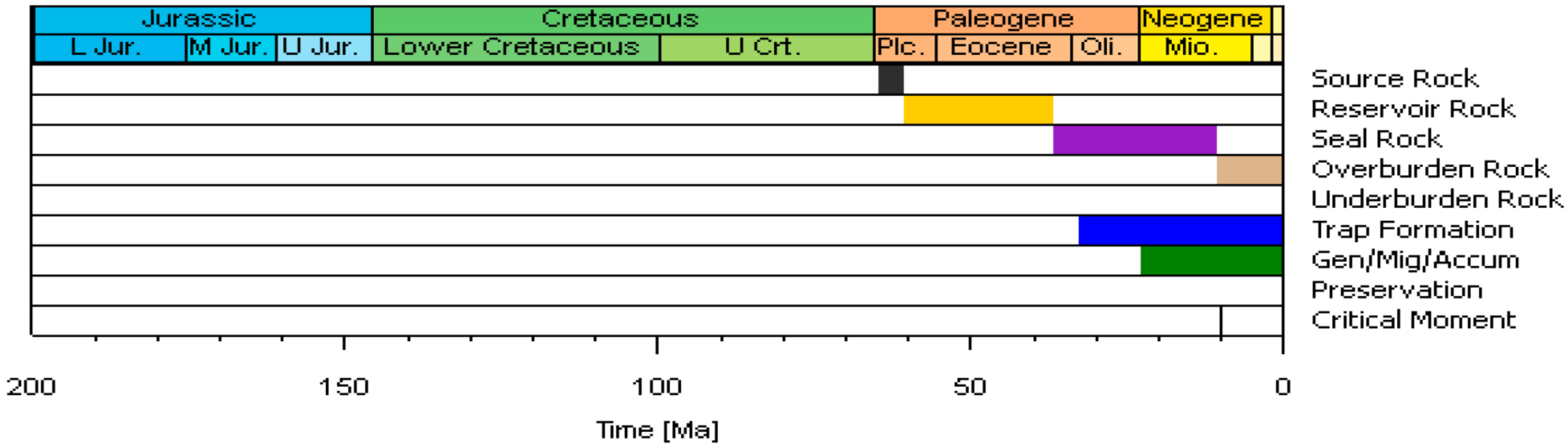

Figure 5. Petroleum system events chart.

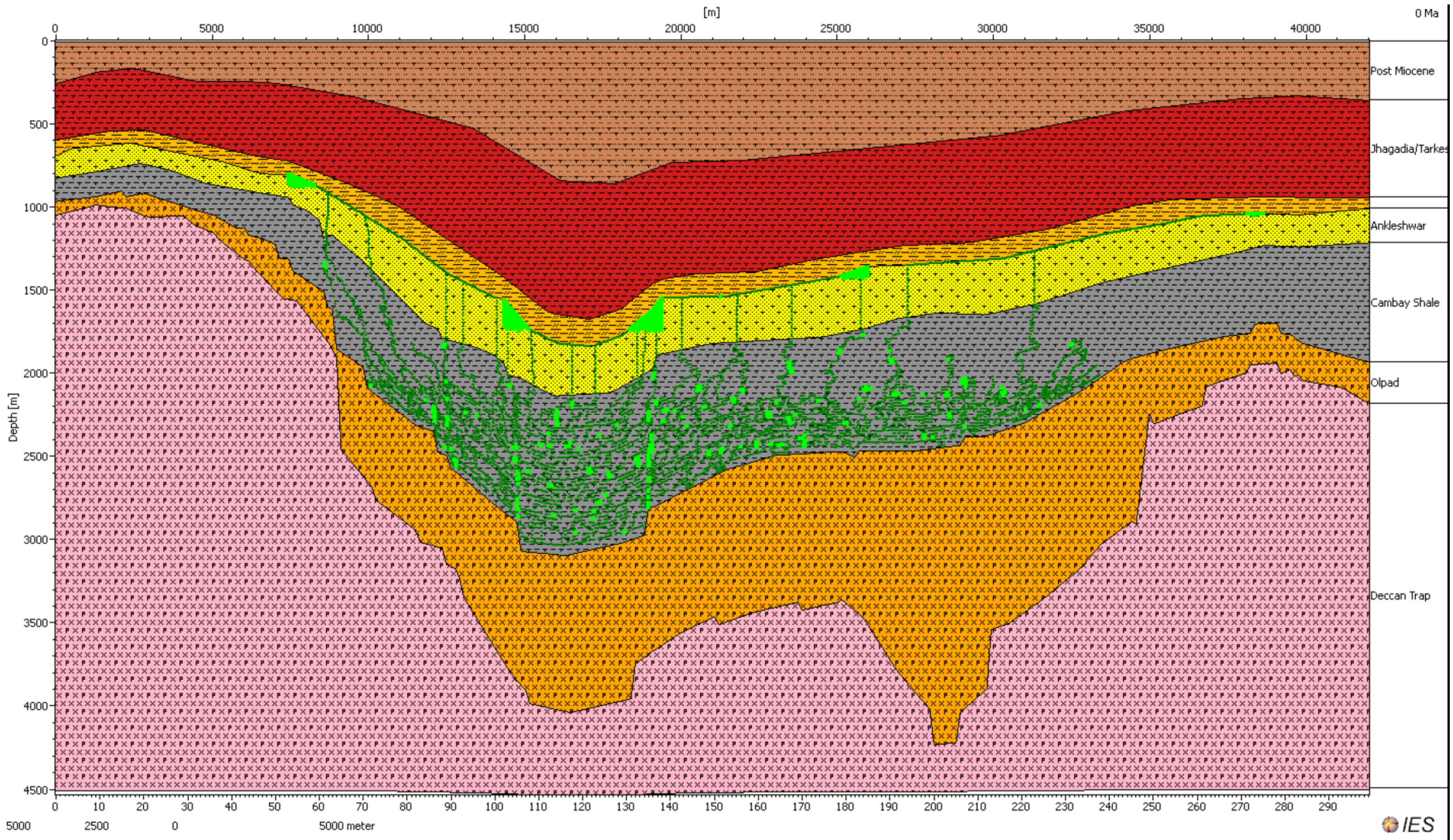

Figure 6: Migration modeling on 2D section (Invasion Percolation) result.