

Predicting hydrocarbon migration and accumulation in Block 09-3/12, Cuu Long basin by 3D petroleum system modelling

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Summary

Block 09-3/12 is located to the southeastern margin of the Cuu Long basin. Up until now five wells have been drilled in the block, resulting in discoveries at two fields, Soi Main and Central A. In this study, 3D petroleum system modelling has been used for determining the kitchen areas as well as evaluating hydrocarbon migration and accumulation for the remaining prospects in Block 09-3/12. The petroleum system modelling indicates that the Oligocene source rock is the major source for the prospects in Block 09-3/12. The kitchen area for the Central and Western A structures is the East Bach Ho trough, while the kitchen in the Southeast Soi area is the main source for the Southeast A structure. The simulation results predict the presence of oil accumulations in Lower Miocene and Oligocene reservoirs for the A structure.

Key words: Petroleum system modelling, A prospect, drainage area, hydrocarbon migration and accumulation, Block 09-3/12.

1. Introduction

Block 09-3/12 covers an area of 5,559km² and lies in the southeast portion of the Cuu Long basin (Figure 1). The water depth is about 10 - 50m. The study area has several oil discoveries in Lower Miocene and Oligocene sandstones. The success of Soi-1X in the Soi Main prospect and especially the A-2X, 3X and 4X wells in the Central A prospect proves that there is an active petroleum system in the area.

Detailed 3D basin modelling of Block 09-3/12 focuses on the A structure and covers all of the potential fetch area of the source kitchen. The aim of 3D basin modelling is to investigate the migration and charge history of the recent discoveries and help predict where other accumulations in Lower Miocene and Oligocene plays lie on the remaining prospects in the Western A and Southeast A area (Figure 1).

2. Geological setting

The tectono-structural characteristics of Block 09-3/12 and adjacent areas are influenced by the tectonics of the Cuu Long basin. The Cuu

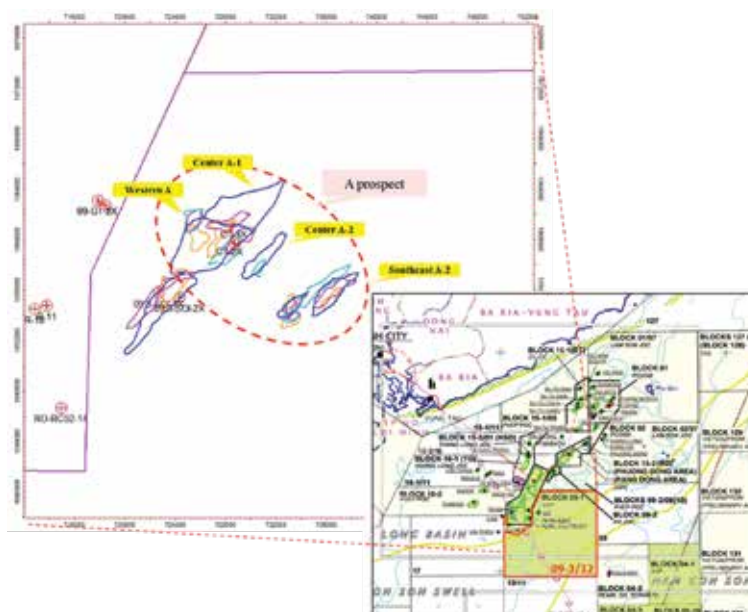


Figure 1. Location of Block 09-3/12.

Long basin is an oval-shaped, early Tertiary rift basin, located on the southern continental shelf of Vietnam. It is separated from the Gulf of Thailand basins to the west by the Khorat High and from the Nam Con Son basin to the southeast by the Con Son swell. Block 09-3/12 encompasses the East Bach Ho trough and the Southeast slope (Figure 2).

The geological evolution of the Cuu Long basin can be divided into 3 episodes: pre-rift (Pre-Tertiary), syn-rift (Eocene to Oligocene), and post-rift (Miocene - Present) (Figure 3). The pre-rift period saw

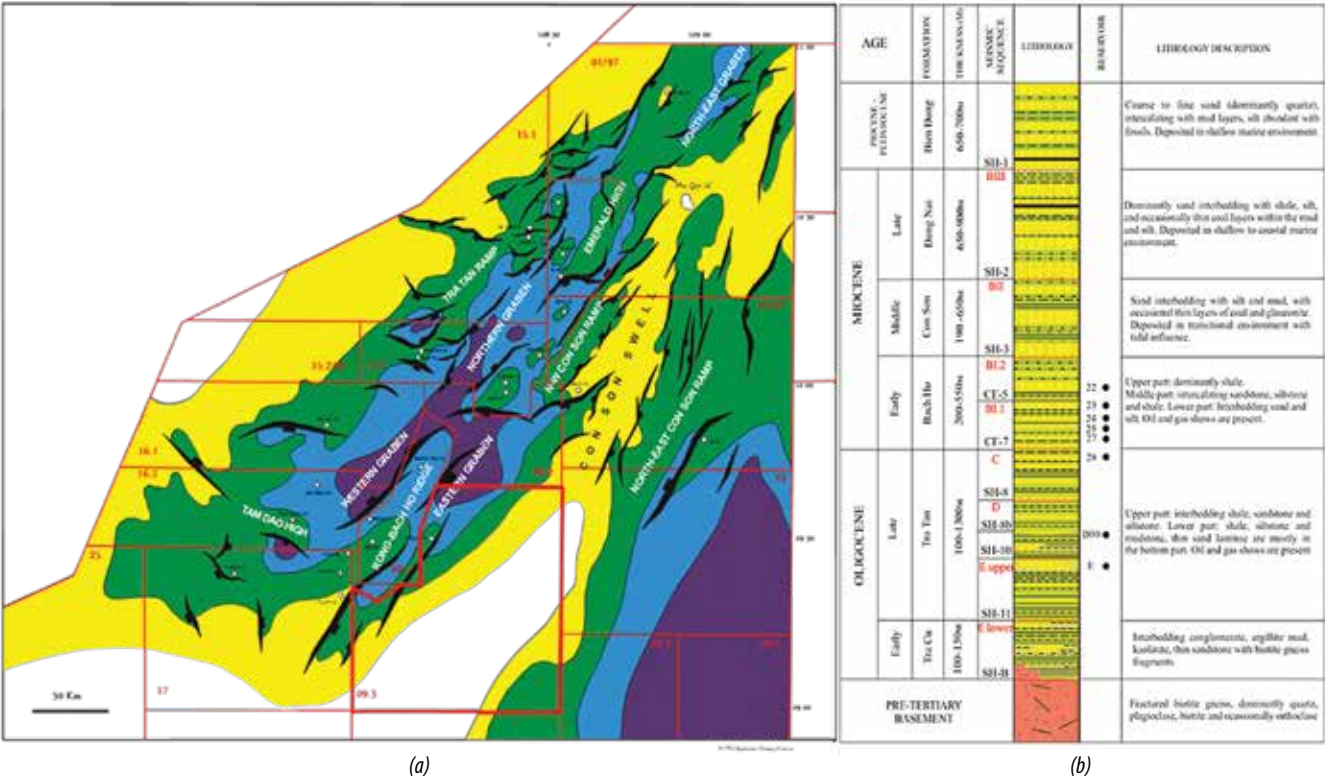


Figure 2. The structural map with major structural components (a) and the general stratigraphic column (b) of Block 09-3/12 [1]. The study area is highlighted.

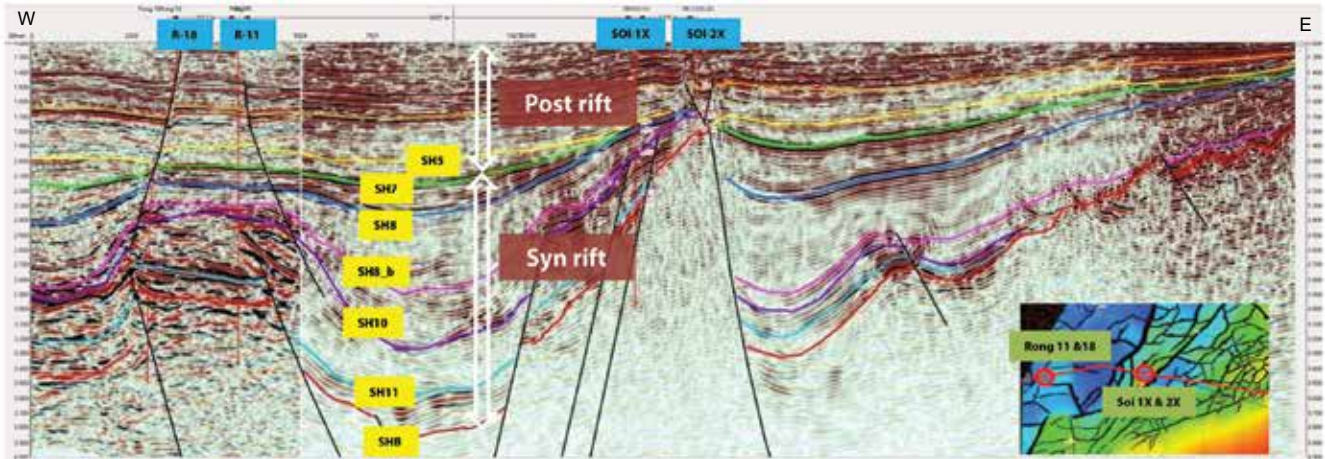


Figure 3. A seismic cross-section through the study area [1].

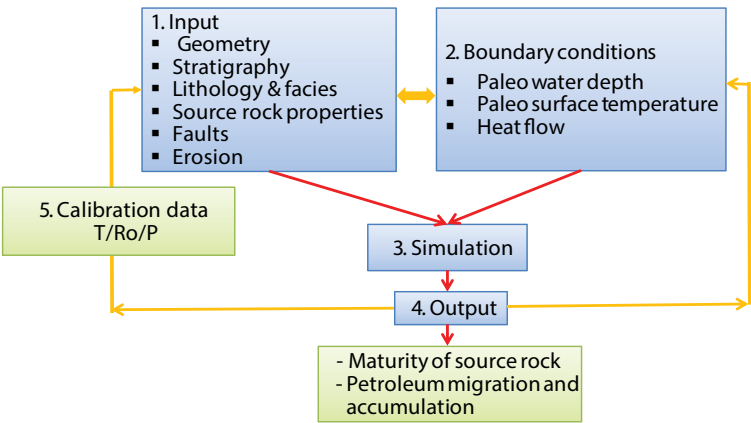


Figure 4. Workflow for 3D basin modelling.

widespread magmatic activities in both the present day onshore and offshore, which formed the crystalline basement for the basin. During the Oligocene, syn-rift basins were initially filled with coarse-grained alluvial to fluvial sand-dominant sediments, represented by the F and lower E sequences. During the Late Oligocene, lacustrine environment dominated, resulting in forming the E and D shale sequences, which are the main source rocks in the basin, as well as in Block 09-3/12. A compressional phase in the Late Oligocene

took place which fractured the basement and created folding and reverse faulting, which is observed in much of the basin. The post rift starts from the Early Miocene, from which point the whole basin enters the thermal sag phase, dominated by fluvio-marine to shallow marine environments [1].

3. Methodology and model input

- Methodology

The method of modelling used combines geological, geophysical, geochemical and petroleum system data [2]. The modelling process using the PetroMod software aims to determine the maturity of source rocks, and model migration and accumulation processes of hydrocarbon through geological time based on the 3D petroleum systems modelling workflow (Figure 4).

- Construction of 3D structural model

The 3D structural model includes the main horizons and fault surfaces. There are 08 horizons interpreted from seismic data: Top Basement (SH-B), Top Lower Oligocene (SH-11), Top Intra Upper

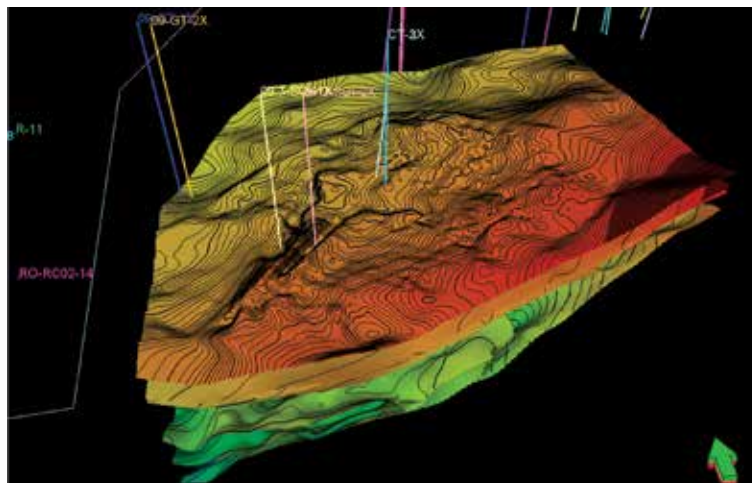


Figure 5. The 3D view of grids of 8 main horizons derived from seismic interpretations.

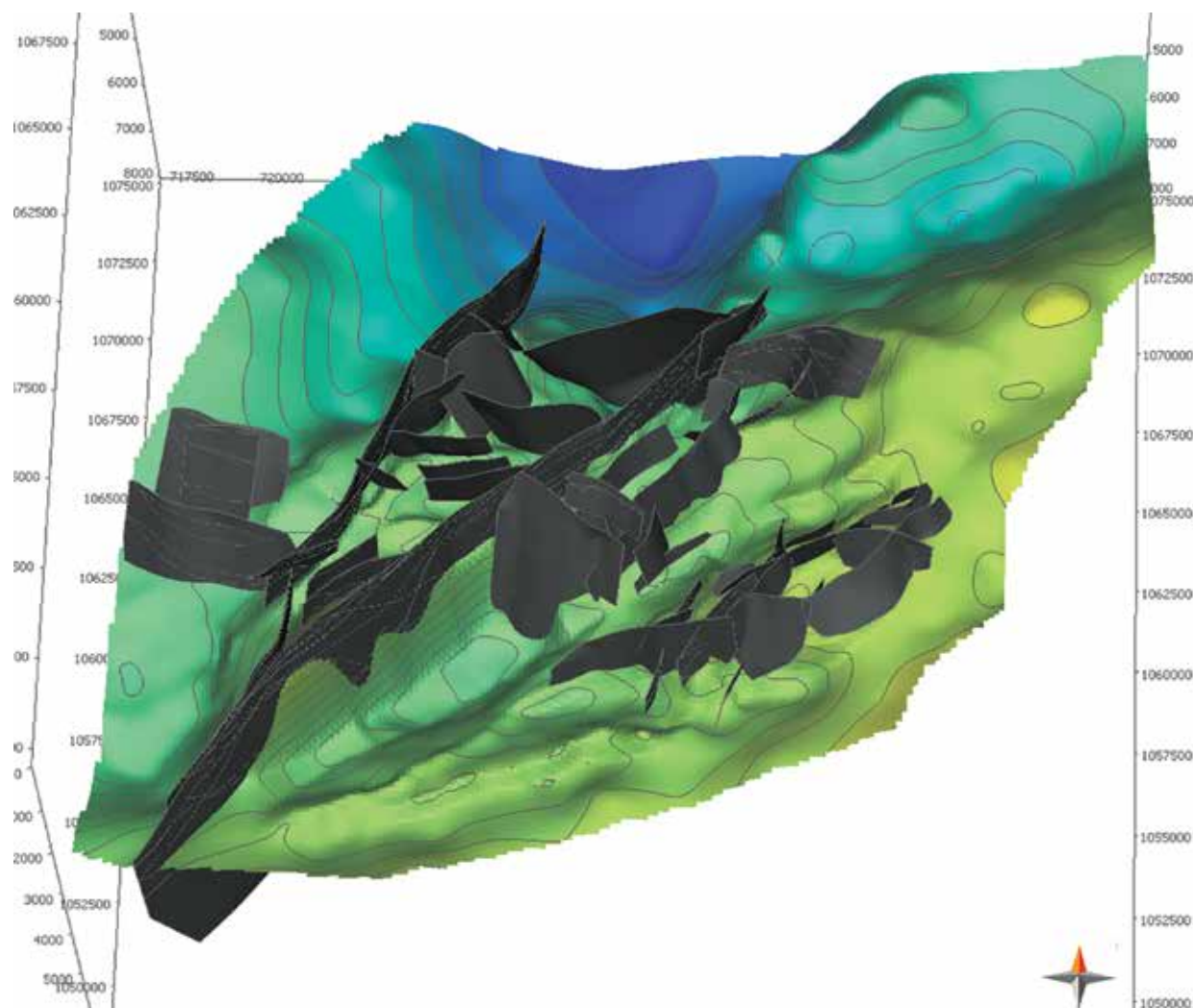


Figure 6. The 3D view of fault plane used for modelling.

Oligocene (SH-10), SH-8b, SH-8, Top Upper Oligocene (SH-7), Top Intra Lower Miocene (SH-5), and Top Lower Miocene (SH-3) (Figure 5). The fault systems in the study area are mostly normal faults trending NE-SW, and a number of small faults trending NW-SE or E-W. In total, there are about 50 main faults chosen to be included in the 3D petroleum system model to simulate the entrapment and migration of hydrocarbon along fault surfaces (Figure 6). The structural model is constructed by PetroMod 3D in the depth domain.

- Source rock properties

The geochemistry analysis results of samples from wells in Block 09-3/12 and the surrounding area show that mature Oligocene sediment is the main source rock with good to very good generation potential [3]. The average TOC values of Oligocene source rock vary from 3 - 5%wt, and HI values higher than 400mgHC/gTOC. Oligocene source rock, which is shale deposited in fluvial-deltatic and lacustrine environments, contains mainly kerogen type I and mixture of type I and III. In contrast, Lower Miocene sediment is not good enough to become source rock because it is immature and has low organic matter richness (Figures 7 and 8) [4].

- 1D well modelling and Heat Flow

The 1D petroleum system model and heat flow are the controlling factor of the maturation modelling in the 3D petroleum system model. The 1D petroleum system model is built for wells A-2X and A-3X, in which the vitrinite reflectance (%Ro) and well temperature (°C) are used to calibrate the heat flow as well as model output.

In this study, the heat flow profile depends on the onset of rifting phase and subsidence phase. Because Cuu Long basin is a Cenozoic rift basin, the heat flow profile is based on the McKenzie model. Heat flow was low during the Pre-rift phase (about 40Ma) and then increased in rifting phase and peaked at 28Ma. In Lower Miocene (subsidence phase), heat flow has decreased until the present time at 40 - 50mW/m² (Figure 9).

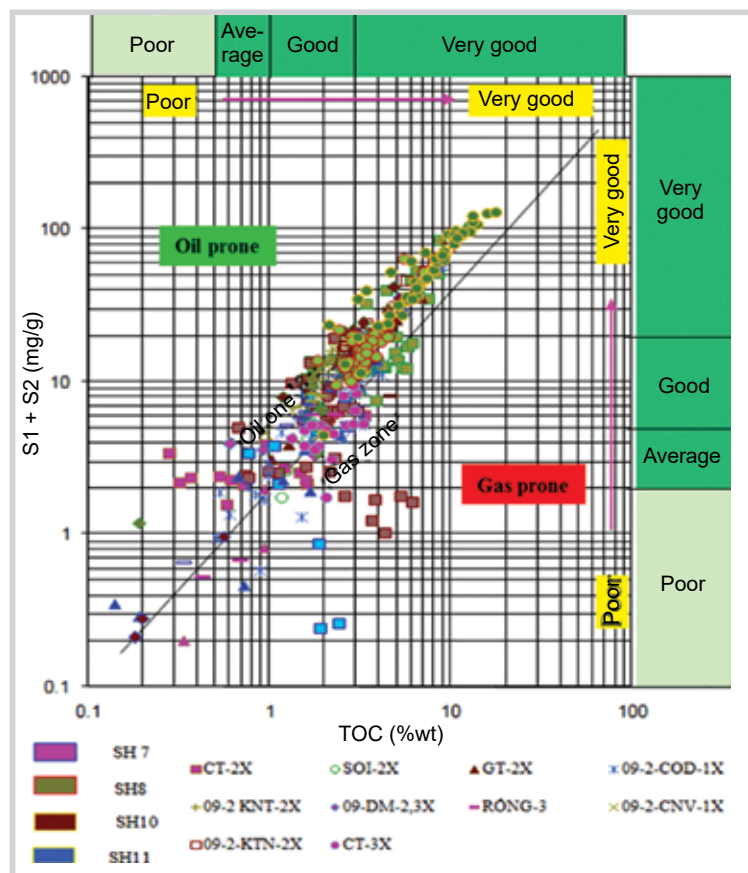


Figure 7. TOC vs (S1+S2) diagram of T2O in Block 09-3/12 and adjacent area, Cuu Long basin.

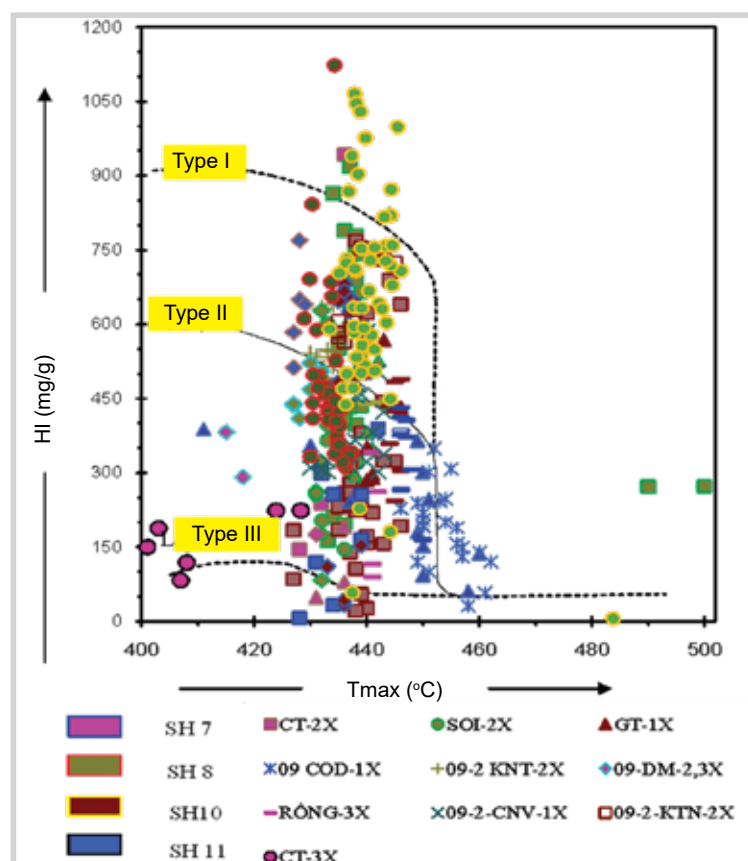


Figure 8. HI vs Tmax diagram of T2O in Block 09-3/12 and adjacent area, Cuu Long basin.

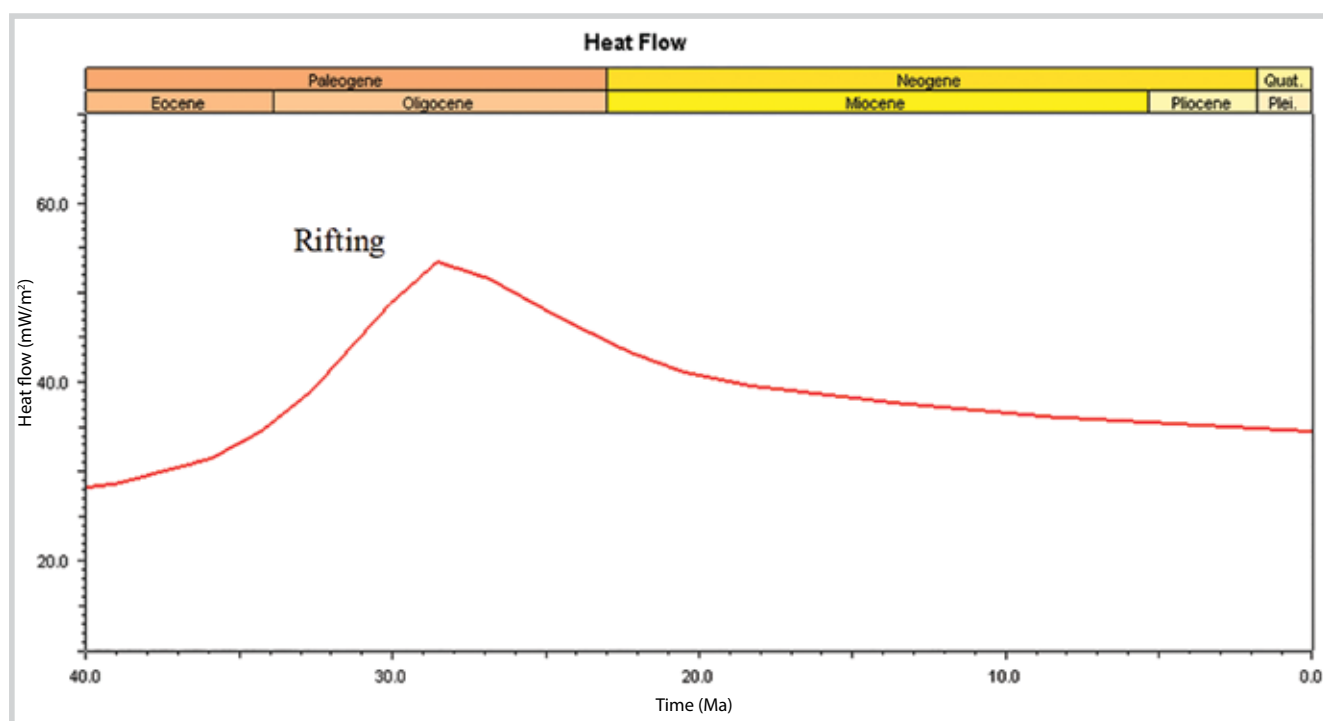


Figure 9. Heat flow curve of study area based on the McKenzie model.

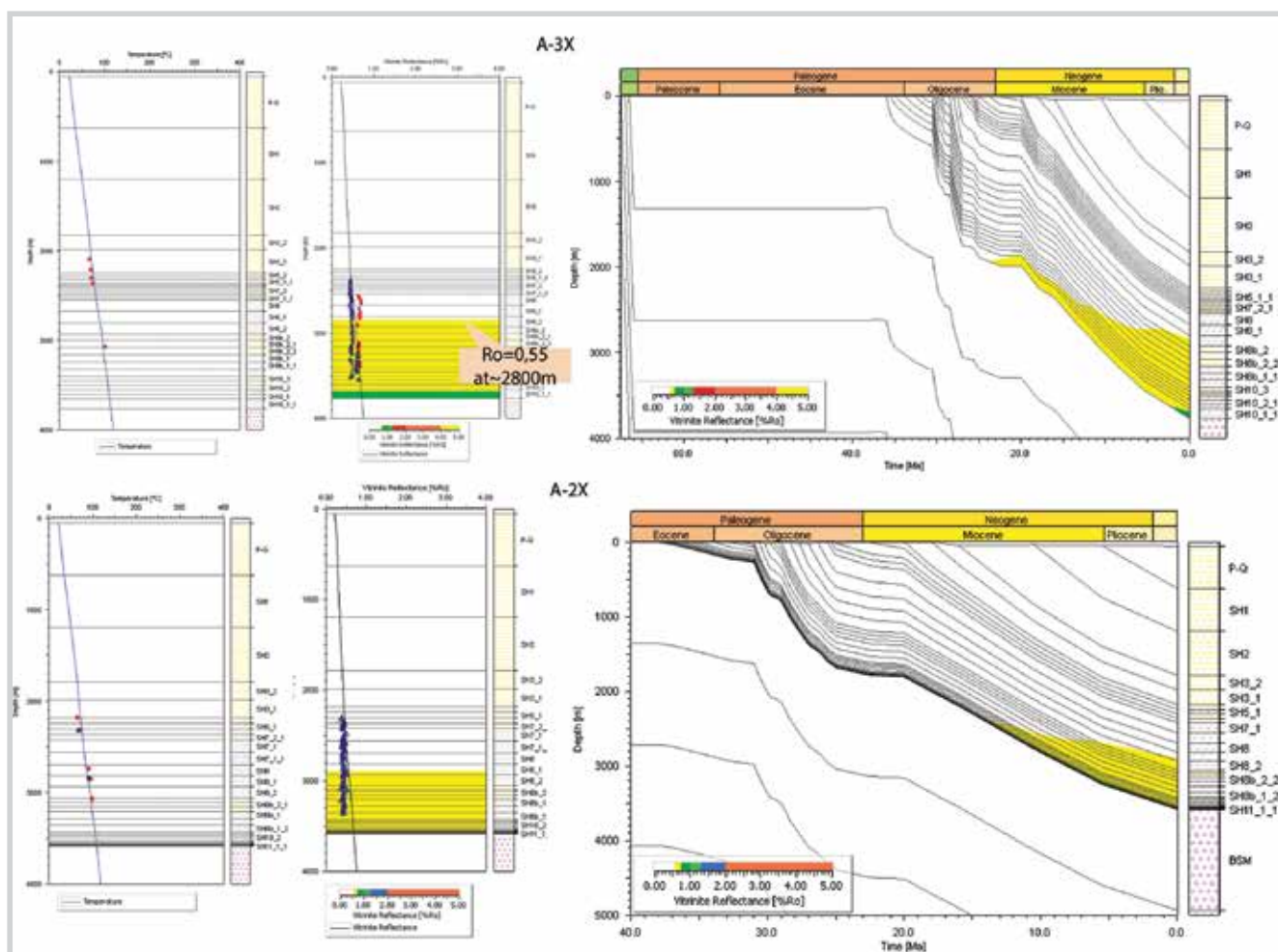


Figure 10. 1D basin modelling at A-3X and A-2X.

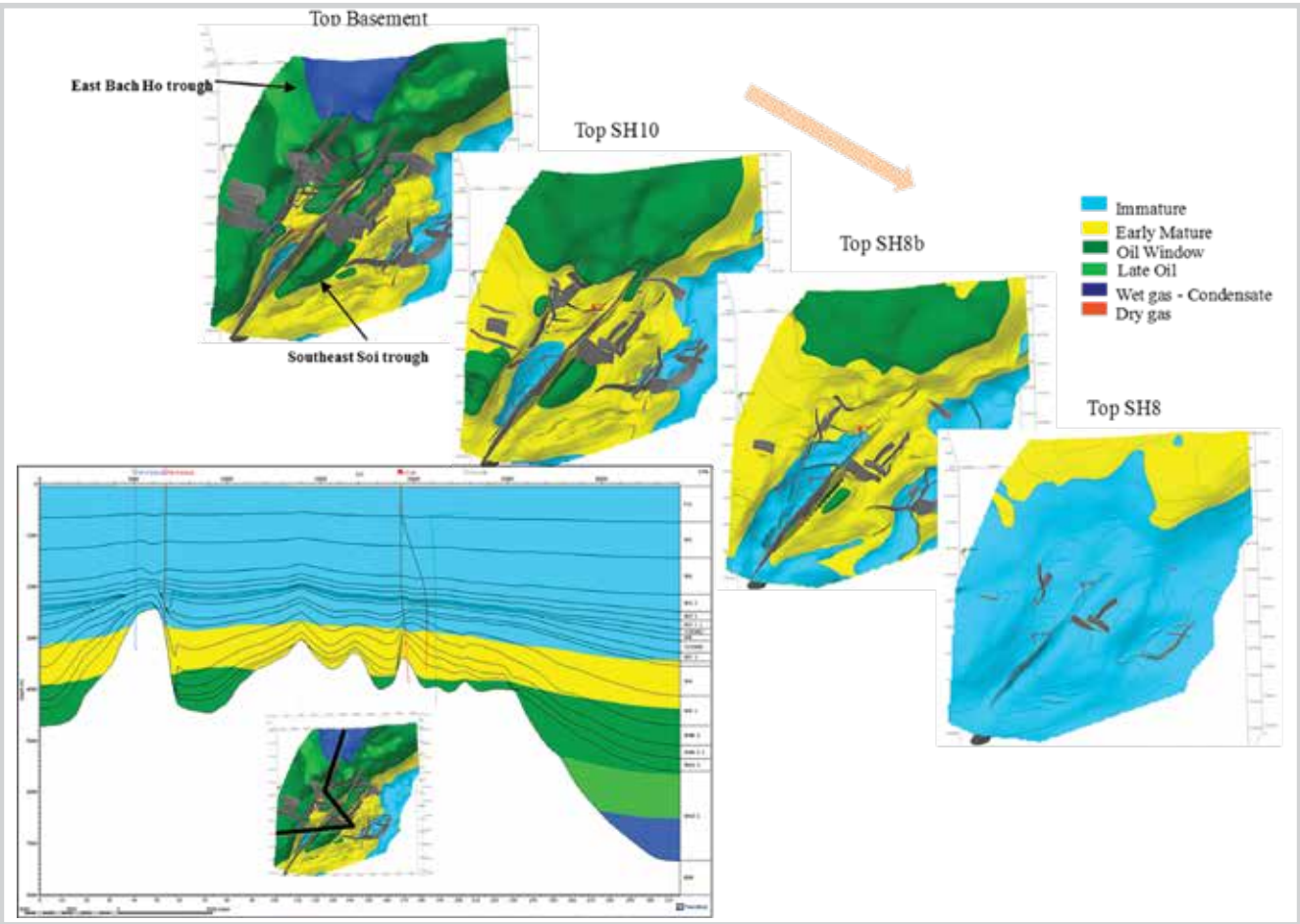


Figure 11. Maturity maps of top basement, SH10, SH8b and SH8.

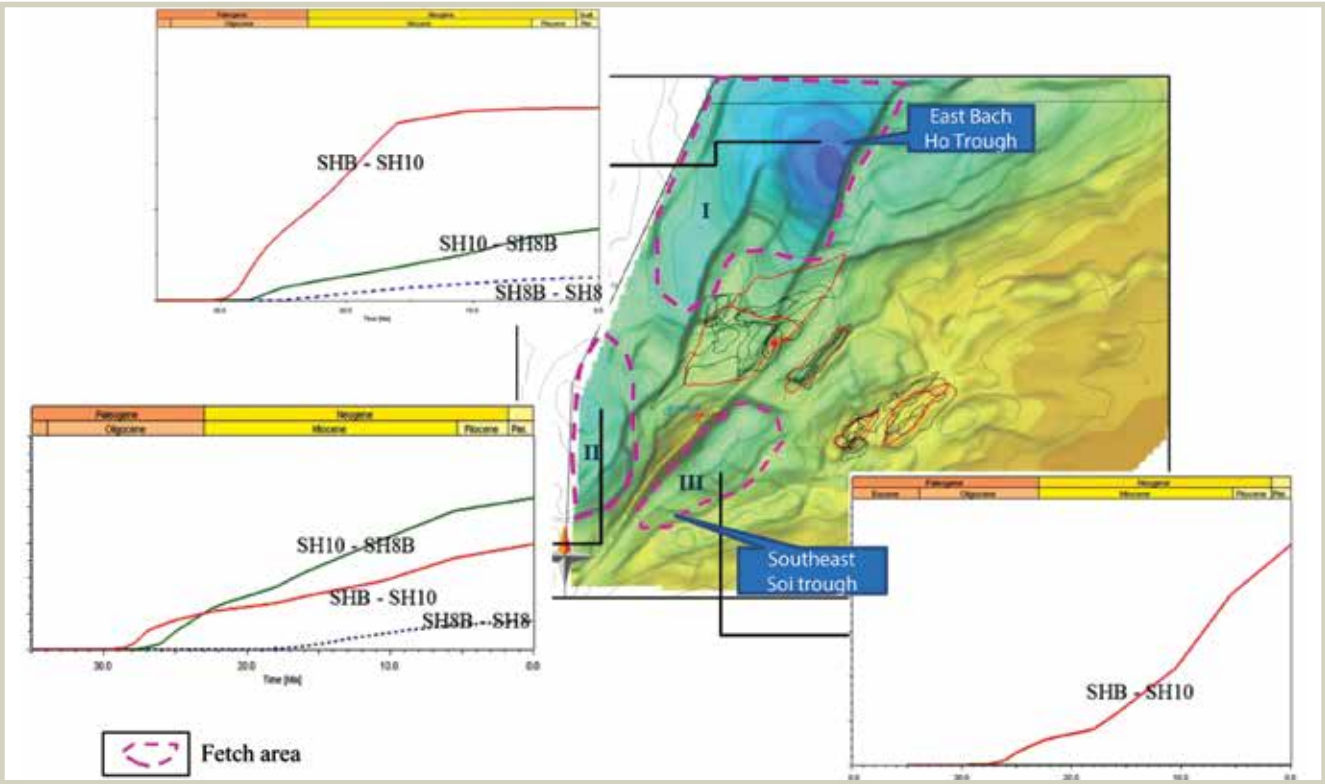


Figure 12. Generation timing of hydrocarbon.

In general, the 1D model results show good agreement between the output and the measured R_o and temperature in the wells (Figure 10). Evaluation of the source rock at the well shows most of the Oligocene source rocks are in the early maturation window.

4. Model results

4.1. Source rock maturity

The start of the maturation depth (0.55 - 0.72% R_o) is about 2,700 - 3,900m; the oil window depth (0.72 - 1.3% R_o) is about 3,520 - 6,500m; and the condensate/wet

gas window depth is from 6,500m. In the study area, there exist 2 main kitchens for the A prospect group, which are the Southeast Soi and East Bach Ho troughs.

The East Bach Ho trough is the main kitchen area, which is currently in the condensate/wet gas stage (1.3 - 2.0% R_o) in the deepest part, while the Southeast Soi trough is just in the oil window with Oligocene source rock (Figure 11).

In general, most of the hydrocarbon accumulations are from the products of the Oligocene source rock. Meanwhile,

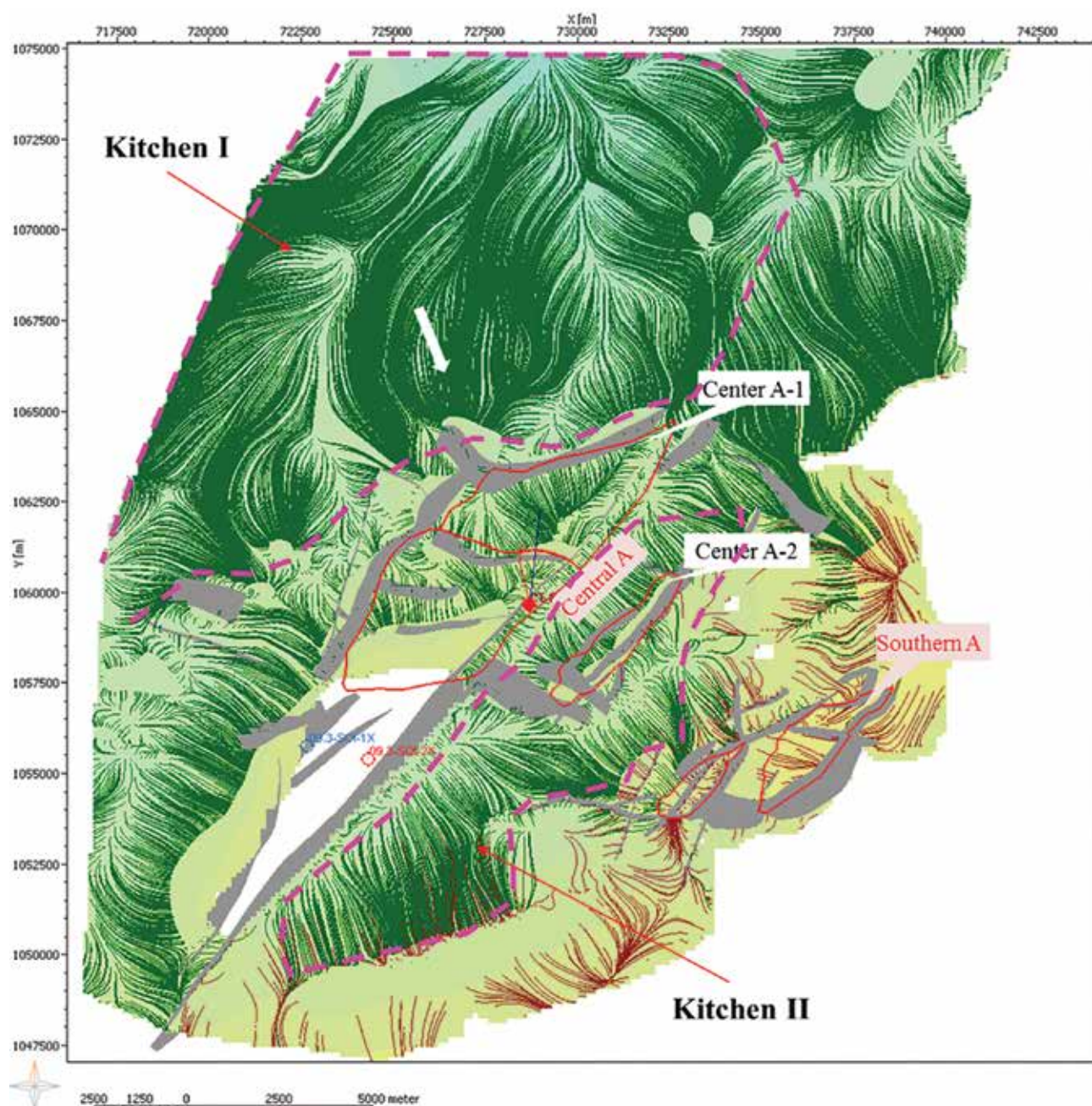


Figure 13. Hydrocarbon migration pathway for Upper Oligocene reservoirs (upper) and 2D cross-section through the A Centre structure (lower).

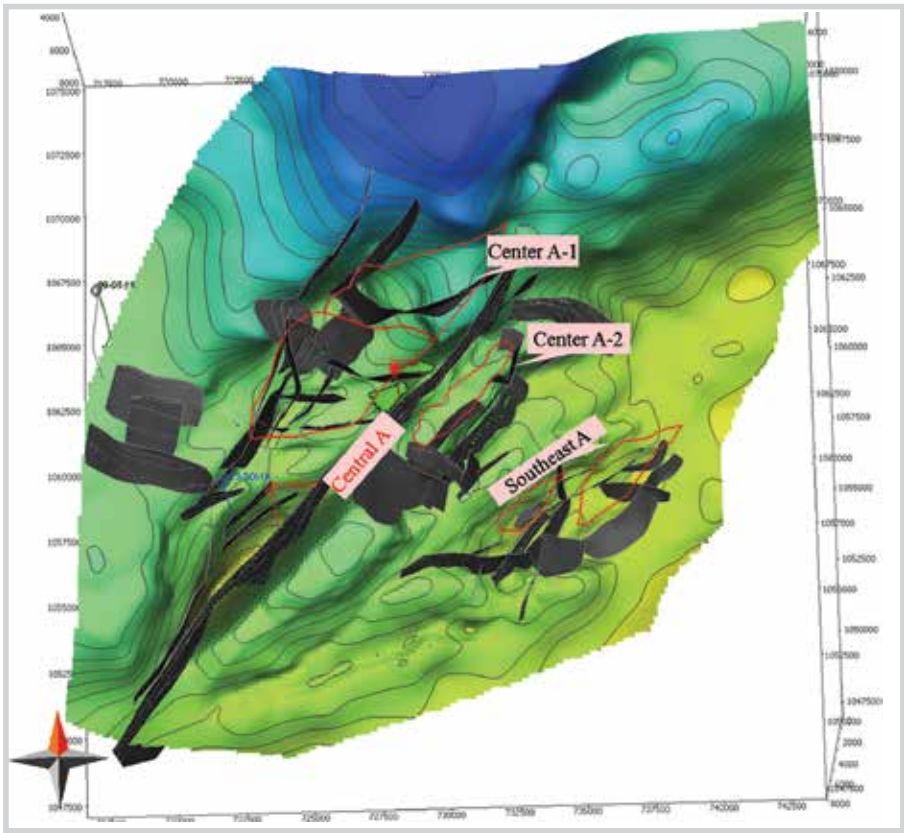


Figure 14. Hydrocarbon accumulation for Upper Oligocene reservoirs.

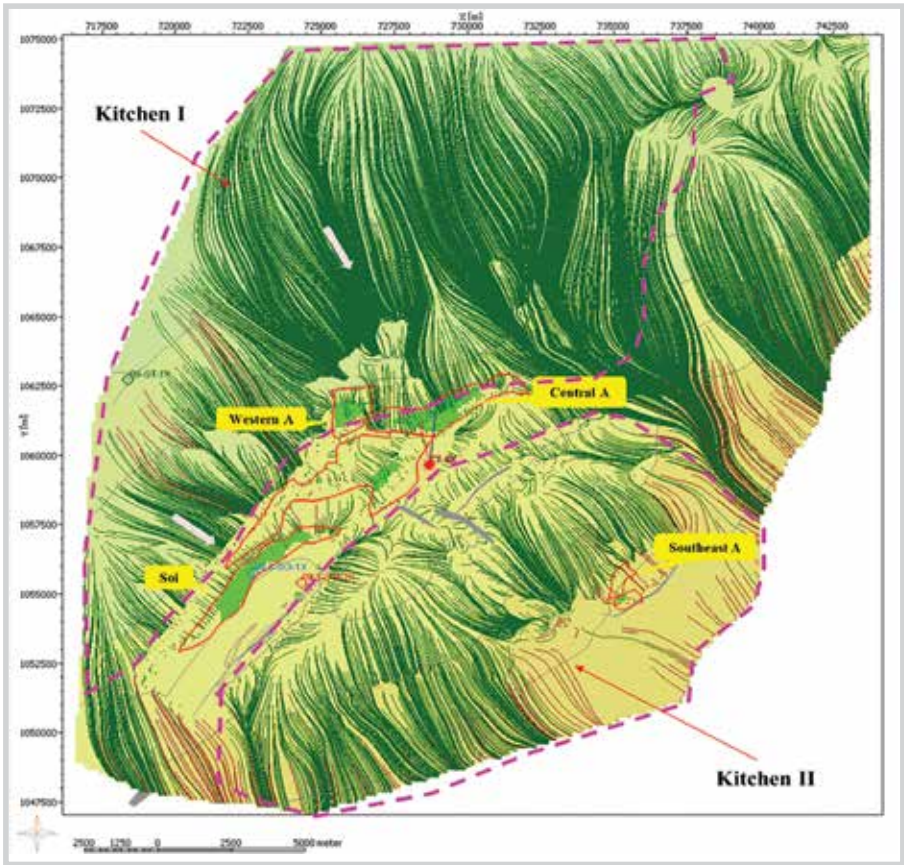


Figure 15. Hydrocarbon migration pathway for Lower Miocene reservoirs (upper) and 2D cross-section through the Soi structure (lower).

the Lower Miocene shale does not meet the requirements for an effective source rock in the study area due to low organic matter concentration and low maturity level. Through the source rock maturity and transformation ratio results from the 3D petroleum system modelling, it can be predicted that the source rock in the East Bach Ho trough (area I and II) has gone through different maturity levels and is the main source rock for the study area. The oil and gas generation history from the Upper Oligocene source rock (SHB-SH10) in area I and II (Figure 12) started from about 28Ma; hydrocarbon migration was strong at about 20Ma, until Middle Miocene. For the SH10-SH8 layer, the hydrocarbon generation took place later and peak oil generation varies from Upper Miocene to Pliocene. While in the Southeast Soi trough (area III), only the SHB-SH10 sequence source rock is in the hydrocarbon generation stage.

4.2. Hydrocarbon migration and accumulation

The most important output for the 3D petroleum system model is the restoration of the migration and accumulation process of hydrocarbon from the past to the present [5]. Based on the newest geological interpretation, 3 prospects in the A prospect group are identified, including: Western area, Central area (Blocks Ia, Ib, and II) and Southeast area (Blocks I and II). In the Central area (Blocks Ia and Ib), there are two exploration wells: A-2X and A-3X.

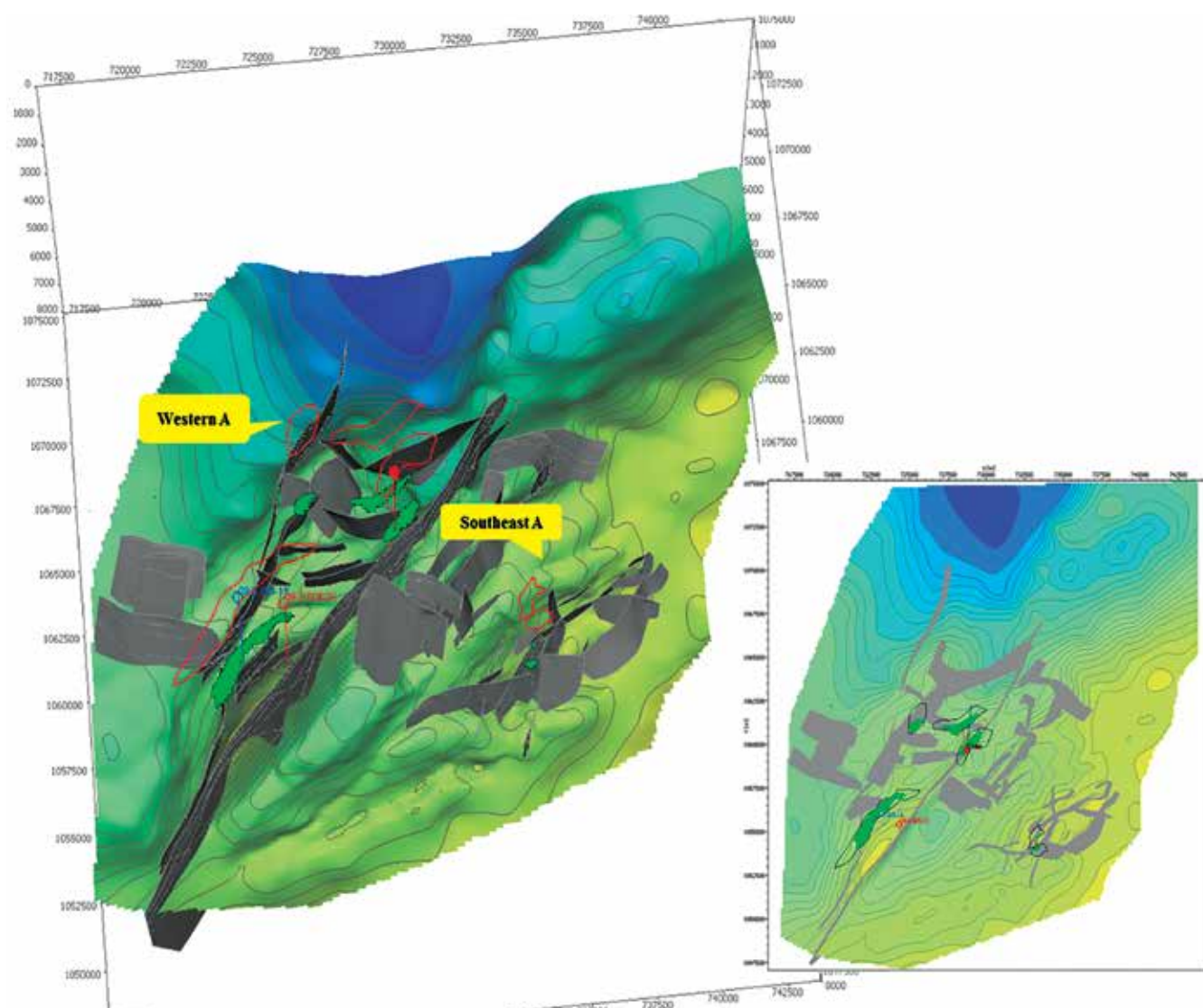


Figure 16. Hydrocarbon accumulation for Lower Miocene reservoirs.

4.2.1. Upper Oligocene reservoir (SH10-SH8b layer)

The results from two wells A-2X and A-3X show that this is an important reservoir in the study area, especially the Central A area. The result of the migration simulation in this region indicates that for the Upper Oligocene reservoir, there are two main kitchen areas: the East Bach Ho trough (Kitchen I) and the Southeast Soi trough (Kitchen II). Kitchen I charges Blocks Ia and Ib, while Kitchen II charges Block II of the Central A cluster as well as the Southeast A cluster (Figures 13 and 14).

Because Kitchen I has a larger extent compared to Kitchen II, and has gone through most of the maturation stages, it has better charge potential than Kitchen II. As a result, Blocks Ia and Ib have better conditions for receiving oil (migration direction denoted by the green

arrows) than Block II of the Central A cluster and also the Southeast structure.

The predictions indicate that the migration and accumulation of hydrocarbon for the Central A-I and II are very favourable and consistent with the results of the A-2X and A-3X. Meanwhile, the Southeast A prospect is predicted by the petroleum system model to contain no hydrocarbon, due to source rock quality risks (Figure 13).

4.2.2. Lower Miocene reservoir

The results of drilling and well tests from A-2X/3X wells have proven the existence of oil bodies in the Upper Oligocene and Lower Miocene interval. The main kitchen area for the prospects in the Lower Miocene section is the Oligocene source rock in the East Bach Ho trough

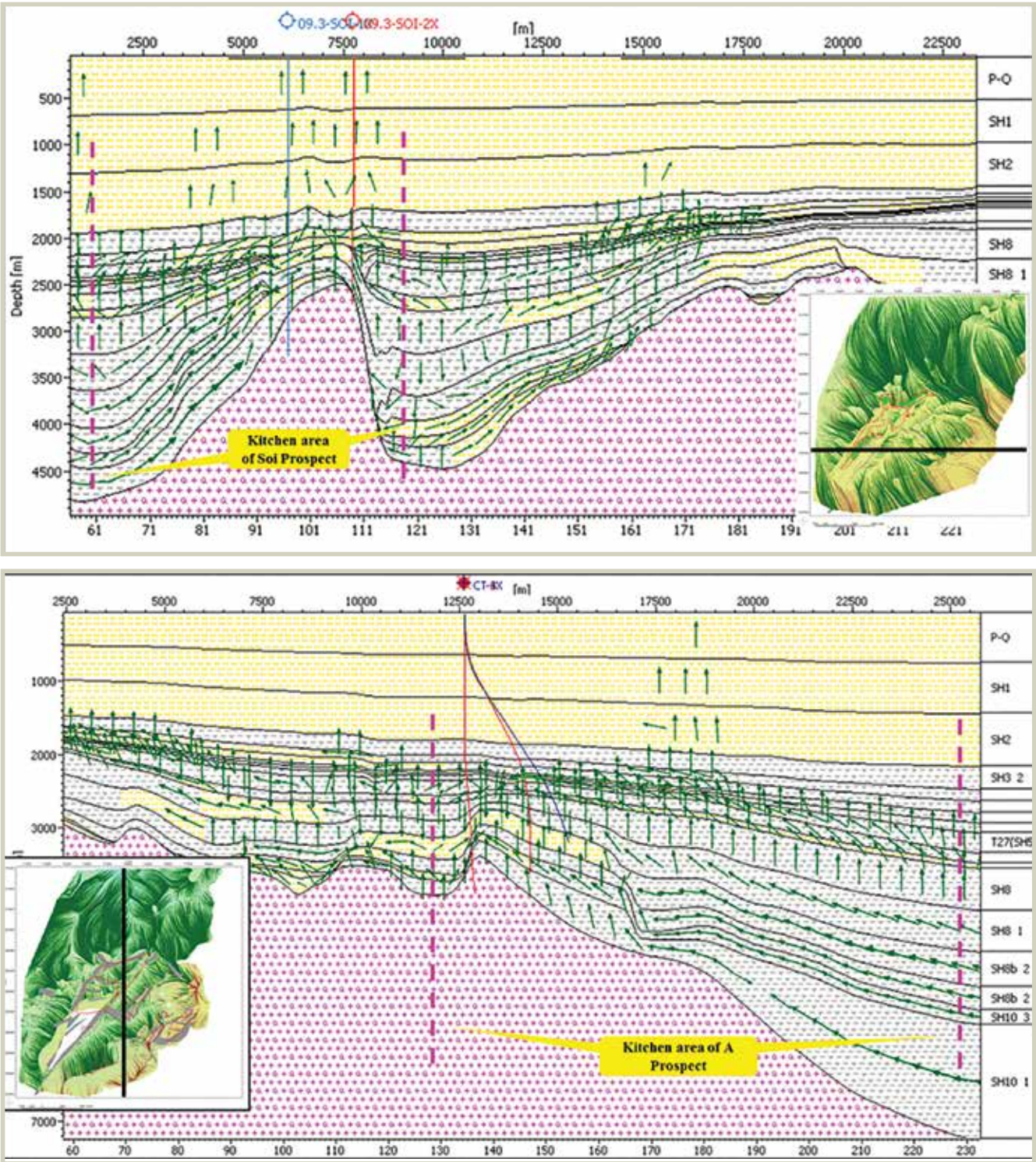


Figure 17. 2D hydrocarbon migration cross-section through the Soi structure (upper) and A Centre structure (lower).

(Kitchen I) (Figure 15). The migration and accumulation model at the Lower Miocene reservoir shows the presence of hydrocarbon in Central & Western A prospect and Soi structure which are mainly provided by the Oligocene source rock from Kitchen I (Figures 16 and 17) while for the accumulation in Southeast A prospect charged by Kitchen II.

In general, based on the results of the 3D Petroleum System Model, for the undrilled structures the Western A and Block II of the Central A prospects are the most favourable for receiving hydrocarbon, with the main kitchen being the East Bach Ho trough. The Southeastern prospect group has lower potential due to limited hydrocarbon pathways and charge volume. This study

was carried out before the drilling of well A-3X and its conclusions contributed to the decision of the well location. A-3X was a discovery, which is consistent with the study's results.

5. Conclusions and recommendations

In particular, the Oligocene source rock in the East Bach Ho trough is the main hydrocarbon source for the Central and Western A prospect group. Meanwhile the source rock in the Southeast Soi trough provides hydrocarbon for the Southeastern prospect group.

The early maturation threshold of the source rock is at about 2,700 - 3,900m, the oil window is at about 3,500 - 6,500m, and the condensate/wet gas window is below 6,500m. The oil and gas generation history from the Upper Oligocene source rock in the East Bach Ho trough started from about 28Ma. Hydrocarbon migration was strong at about 25Ma, until Middle Miocene. For the SH10-SH8 layer, the hydrocarbon generation took place later, from Lower Miocene to the present. In the Southeast Soi trough, only the SHB-SH10 sequence source rock is in the hydrocarbon generation stage.

The simulation result shows the presence of hydrocarbon (oil) accumulations in Lower Miocene

and Oligocene reservoirs for the Central and Western A structure, and in Lower Miocene for the Southeastern structure. Among those, Western A and Block II of the Central A structure have the most favourable conditions for hydrocarbon migration and charge.

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