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Research Article

Study of mechanism for petroleum generation, migration and accumulation, block 04-3, Nam Con Son basin

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ABSTRACT

Exploration drilling and production results in block 04-3 confirmed oil and gas potential on the Thien Ung-Mang Cau prospect. The remaining potential prospects that are not drilled should continue to be studied and evaluated for petroleum potential. The purpose of this paper is to integrate and digitize the data from results of facies and environment studies, petrographic characteristics, and geochemical data to simulate the petroleum system model to determine the processes of generation, migration, the mechanism for hydrocarbon trap charging, and distribution of petroleum accumulations.

Based on the reality of successful oil and gas discovery and exploration in block 04-3, the process of building a 3D petroleum system model is settled and consists of four main steps: input data combined with boundary conditions, running simulations, assess model results and adjusting data. Utilizing studying the role and contribution of hydrocarbon composition in the source rock, the migration direction, the paper clarifying the generation process, the trend of distribution, and the assessment of the hydrocarbon migration and charging mechanism in block 04-3 area. The results of digitalization of data on the geochemical analysis of effective source rock, building facies modeling and the sedimentary environment, boundary conditions models, and 1D models, the 3D petroleum system model has successfully simulated.

The results allow to draw following findings: there are two formations of source rock Oligocene (H-150) and lower Miocene (H-80), in which the source rock belongs to the Oligocene sediment section at 16.5 Ma in the oil generation phase and 10.5 Ma - 5 Ma mostly in the late oil to wet gas and condensate production phases, this source rock plays a crucial role in hydrocarbon generation; hydrocarbon accumulations formed in the suitable trap mechanisms within Oligocene and Miocene periods in the with channel deposits, deltaic (fluvio-deltaic) environments, preserved in stable conditions until hydrocarbon accumulation established in which contribution mainly from Oligocene-aged claystone source rocks; Two potential accumulation groups existence in block 04-3 also revealed: the Hai Au structure and the Hoang Hac structure with the Oligocene, lower Miocene, and middle Miocene reservoirs.

The results of the model will be used to propose the allocation of exploration wells for evaluating the remaining oil and gas potential accumulations in block 04-3. Furthermore, the study not only focuses on evaluating the effective source rocks, determination of the main hydrocarbon charging area, the migration process and mechanism for the petroleum-filled trap but also clarify the role of effective source rock sequences for providing hydrocarbon of potential petroleum accumulation in the study area.

Key words: generation mechanism, hydrocarbon accumulation, potential, modeling, simulation

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INTRODUCTION

Block 04-3 is located in the Southeast of Nam Con Son basin, with an area of 3,120 km^2. There are three potential structures confirmed by exploration wells (Bo Cau, Thien Ung-Mang Cau, Dai Bang-Ung Trang) and two potential structures not yet drilled (Hai Au, Hoang Hac). The study area is adjacent to the Dai Hung oilfield (Block 05-1A) and other potential structures such as Sao Vang, Dai Nguyet, Thanh Long (Blocks 05-1B and 05-1C) (Figure 1a, b).

G EOLOGICAL CHARACTERISTICS

Tectonic characteristics of block 04-3 area are influenced by tectonic framework of Nam Con Son basin. If the Nam Con Son basin is considered as a primary structure, then block 04-3 is limited by the North trough in the North, the Con Son swell in the West, the South trough in the South and in the East is the Northern of South trough. Therefore, block 04-3 has typical tectonic characteristics of Nam Con Son basin and satifies all favorable conditions for oil and gas accumulation. The division of tectonic zones is based on the structure of the basement surface, block 04-3

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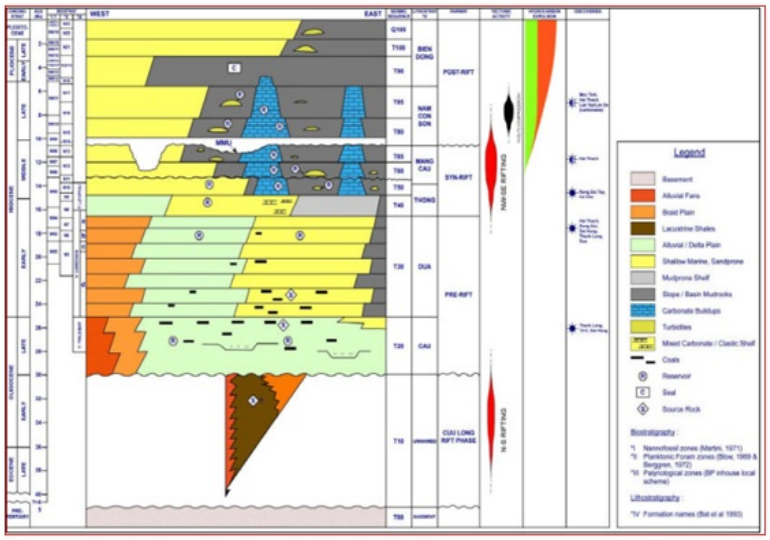

(a)

(b)

Figure 1: a. Stratigraphic column (above), b. Location of the study areas (below).

is divided into smaller structural units, which are uplift blocks and structures such as: uplift blocks of Bo Cau, Dai Hung, Thien Ung - Mang Cau, Dai Bang - Ung Trang, in which the uplift block of Mang Cau - Thien Ung is the highest one. The uplift blocks are divided into invidual structures such as Bo Cau, Đai Bang, Hoang Hac, Hai Au, based on position, size, structural features, in each structure continues to be divided into smaller structural units (Figure 2).

The history of geological development of Nam Con Son basin in general and block 04-3 in particular can be divided into two main phases of rifting and expansion with different mechanisms: the first phase of rifting and expansion occurs in Eocene? - Oligocene early; the second rifting and expansion phase is more clearly shown on the current structure that occurs mainly on the middle Miocene and obscures the signs of the first rifting and expansion phase. Next to Late Miocene, the process of thermal subsidence lasted until the present time. The formation and development history of Nam Con Son basin is demonstrated through three phases: pre-rift and expansion; syn-rift and expansion; and post-rift and expansion.

DATA BASE AND RESEARCH METHOD

In recent studies, block 04-3 has been drilled with 15 exploration wells, in which Thien Ung field has five wells TU-1X, TU-2X, TU-3X, TU-4X, TU-5XP, the remaining ten wells are drilled on other potential structures. Selected data is used to simulate petroleum systems modeling includes: well logging, high-resolution approaches in stratigraphic paleontology, thin section, geochemistry, geophysical well logging research, facies analysis, and depositional environment. In addition to well log data, the project also uses 2D seismic data (6.446 km), was exploded from 1974 to 1995, and 3D seismic data (1,859 km^2) was demolished from 2015 to 2017 and updated the latest interpreting results (2016).

To serve the research on the formation of hydrocarbon migration and accumulation mechanism, some authors apply sedimentary basin analysis based on establishing structural modeling, faults, facies- sedimentology, heat flow (HF), paleo-water depth (PWD), sediment water interface temperature (SWIT), proceed to build 3D oil and gas system model, simulation of migration and accumulation formation. The results of simulation of 3D petroleum system modeling, evaluation of the mechanism of formation, migration, accumulation of oil and gas in the research area contribute to the orientation for allocating th exploration wells in remain potential areas block 04-3.

The process of building a 3D oil and gas system model consists of 4 main steps: input data combined with boundary conditions, running simulations, assess model results and adjusting data; details as follows:

Input parameters include geological parameters such as relative rock age for stratum, history of basin development, denudation followed by the results of the seismic interpretation, conducting structural model of the building, faults based on depositional environment interpretation, building a facies model, and isometric mapping of source-rock geochemistry such as hydrogen indicator (HI Map), total organic carbon (TOC Map) for the primary source rock in block 04-3 area.

Boundary conditions include paleo-water depth (PWD), depending on the depositional environment from the past to the present, sediment water interface temperature (SWIT) depends on PWD; the geographical location of the study area and most importantly, heat flow (HF) varies with the process of separation and heat transfer from the bottom to the top. The three boundary condition parameters combined with the 1D maturity models and are calibrated with the 3D model essential input data contribute to restoring the thermal history of sedimentary basins in each specific stage.

Simulation process: After all the input parameters have been prepared, building 3D models and run simulations with many different scenarios. The point is that the simulation process depends on the number of grid cells and the simulation method (according to Hybrid, Flow path, Darcy, or Invasion percolation). The simulation method for migration applied in this study is hybrid (combining between Darcy and Flow Path based on the shifting model) with a grid cell of 250m x 250m, shown in Figure 3.

Simulation results: including the degree of organic matter maturity, the rate of conversion of kerogen into hydrocarbons of the source rocks, density and direction of HC to expulse from parent rock and migrating into the reservoir by the time from early to late as well as determining the location and the total of hydrocarbons accumulation in trap , block 04-3 area.

Parameter Calibration: 3D models will be extracted in the 1D form to check the level of conformity to the results of the previous 1D model starting to proceed with the construction of the 3D model; in case the results run inappropriately, the input geological information will be adjusted, then continue to simulate the process of hydrocarbon migration and accumulation.

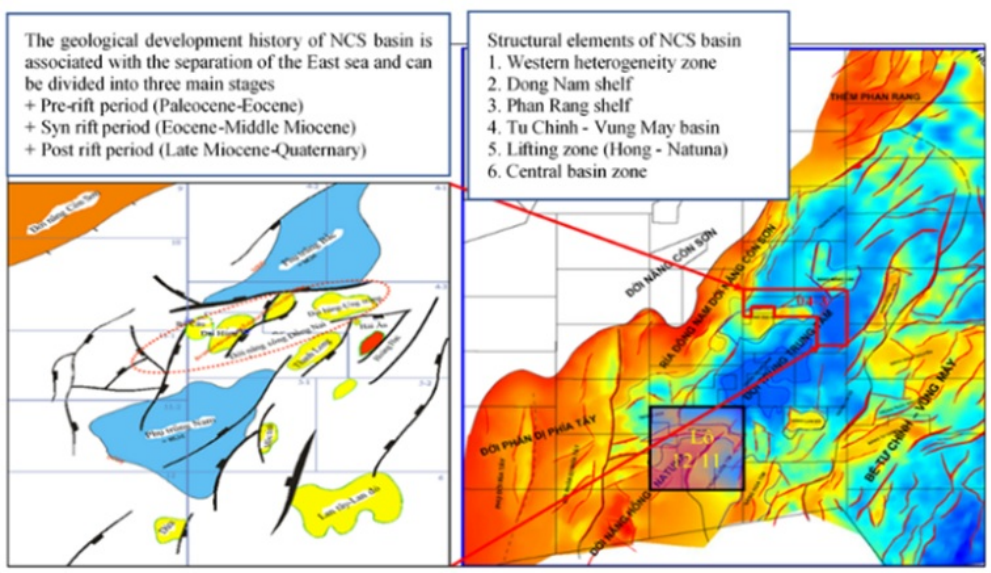

Figure 2: The structural map of Nam Con Son basin

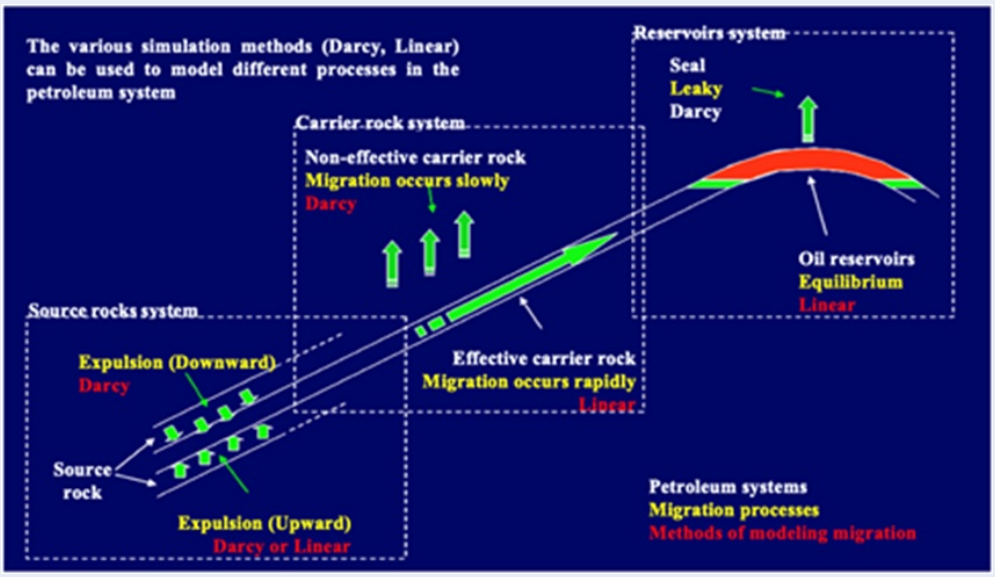

Figure 3: Hybrid Migration Modeling

The simulation process will be run several scenarios until the model results match the well data on isotopic maps in vitrinite, temperature, the distribution of accumulations, until now has accepted the input data. The overall process of building a model of 3D oil and gas system is shown inFigure 4.

Structural modeling

The structural model is the first parameter in the construction of a 3D petroleum system model that allows accurate assessment of the maturation degree of the source rock and simulating the migration direction of HC. The 3D structural model, block 04-3, is built, including the main reflective layers' top and the fault surfaces system. There are 11 reflective layers, including the crest of the basement (H200),

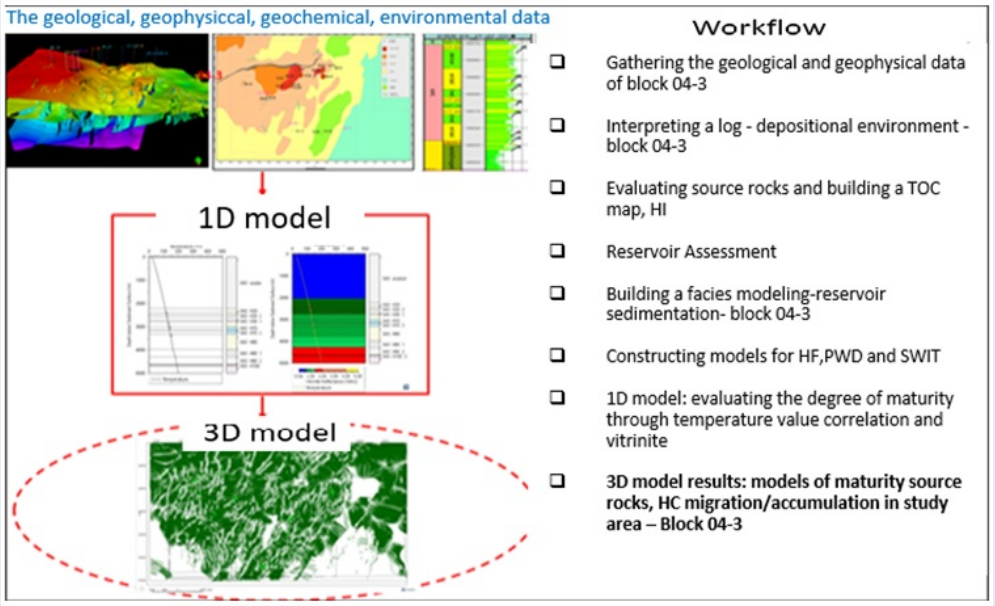

Figure 4: A typical workflow of 3D petroleum system modeling

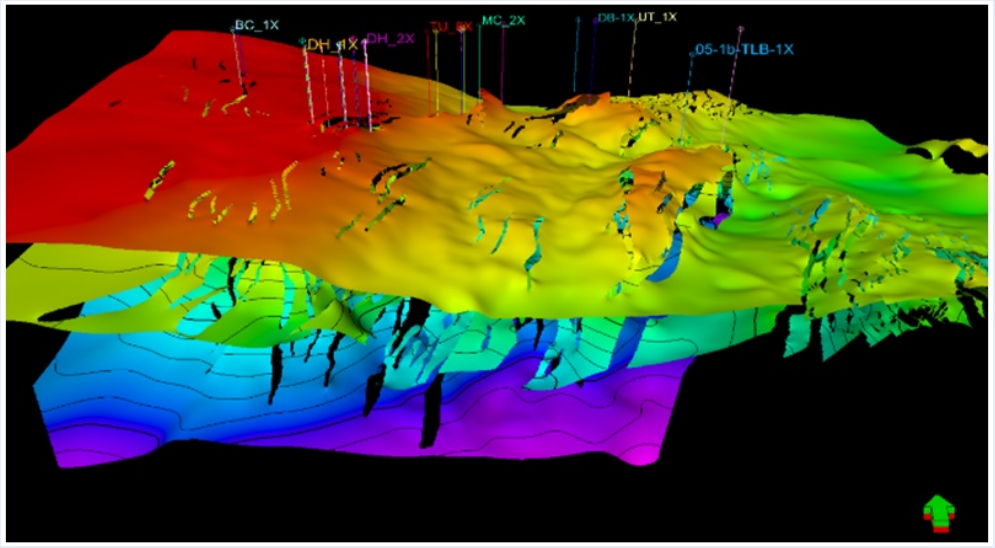

Figure 5: Layers and faults system of the corresponding top

H150 (Oligocene), H120 (Intra Oligocene), H100 (Intra Oligocene), H80 (lower Miocene), H76 (lower Intra Miocene), H70 (lower Intra Miocene), H30 (middle Miocene), H20 (upper Miocene), seabed (SB). Fault surfaces are illustrated based on 3D seismic data, reflective layers and faults system, surface and fault polygon of the corresponding tops (Figure 5). To ensure the migration factors and structural closure, a total of 101 main faults were selected to be used for 3D petroleum system modeling (Figure 6).

F ault modeling

Fault surfaces are interpreted based on the data provided, including 2D/3D seismic cubes, reflective layers, and the corresponding strata tops' polygon fault systems. The study area's fault system includes major normal faults with the Northeast - Southwest, some faults with a sub-latitude, and a sub-longitude. To en-

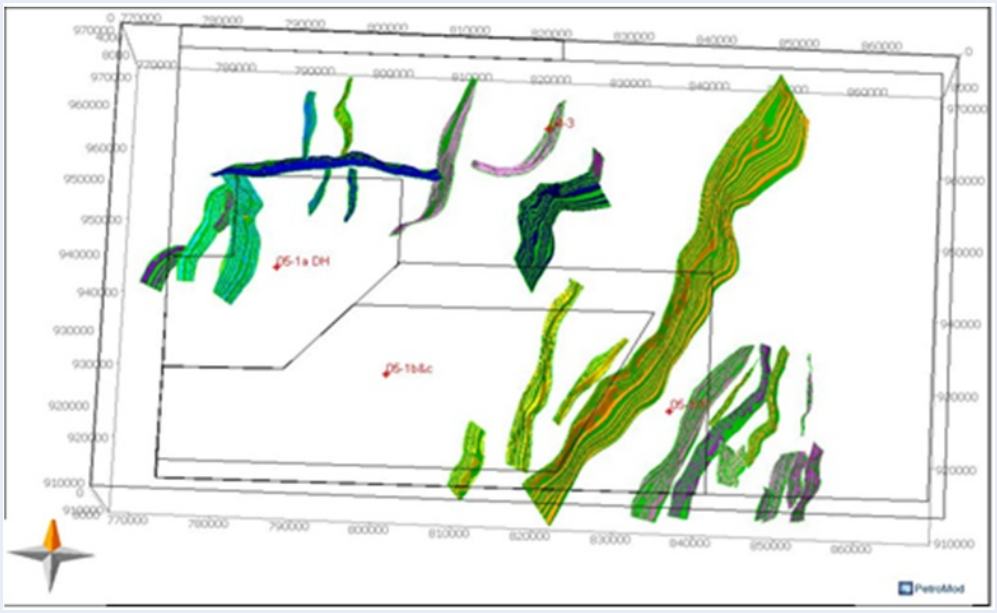

Figure 6: Faults system in block 04-3 area

sure the migration factors and structural closure, a total of 29 main faults are selected in the 3D petroleum system model (figure 6). All faults are converted to depth domains; based on the results of the study of tectonic activity in combination with the seismic cross- sections of the formation time and characteristic of faults (Fault Property) has been identified.

Age assigment

The results of the interpretation of seismic data and geological development history of the Nam Con Son sedimentary basin, the main geological events in block 04-3 (sedimentary stages and deposition or denudation, phases of tectonic activity) have also been identified. The geologic age of sediments is determined based on well log data, lithology, geophysical, seismic, and stratigraphic paleontology analysis (Nanofossils index and microfossils). There are 12 small sedimentary sequences divided from 6 large sequences based on the sequences' primary strata and characteristics in the well. The age of small sedimentary sequences is determined by their thickness and shown in Table 1.

Erosion thickness

The results of previous research on the geological development of the NCS basin showed that in Block 04-3, there exist two heterogeneity, the area at the crest of the Oligocene (H-150) and the middle Miocene crest (H-30), and has also been acknowledged in previous research reports. However, on seismic data and surveying, the change of vitrinite reflectance in-depth at the wells showed no signs of erosion at the crest of the Oligocene sedimentary sequences, and this sign is only evident in the middle Miocene sediment section (H30). Therefore, the middle Miocene sediments (H30) erosion thickness is restored to input data for the 3D model of the basin. The map of erosion thickness is built on the principle relative comparison with the surrounding area where there is no sign of erosion observed through the stability of parallel reflective surfaces of sedimentary sequences (Figures 7 and 8).

Lithofacies/facies definitions

Based on the analysis of facies and depositional environment of the reservoirs in block 04-3 area and the vicinity have been established simultaneously in combination with the well log data, facies are defined and used as the input data for modeling 3D petroleum system.

The percentage of lithology varies with each type of depositional environment as well as by the ratio of sand/clay from well log data; for example, lacustrine is characterized by a high percentage of clay and also source rock as well as a seal for the model or channel deposits with a high ratio of sand more extensive than 80% becoming a potential reservoir[1]. The basis lithologic composition consists of sandstone, siltstone, argillite, used in the model taken from the pet-

Table 1: Major geological events of the sediments

Sedimentary sequences	Sediment deposition time (Ma)	Erosion time/sediment stop time (Ma)
Pliocene-Quaternary (N_2+Q)	5.5 - 0	
Upper Miocene (H-20)	10 - 5.5	10.5 - 10
Middle Miocene (H-30)	12 - 10.5	
Middle Miocene (H70)	14 - 12	
Lower Miocene (H-80)	24 - 16.5	
Oligocene (H-150)	35.5 - 24	
Basement (H-200)	Pre 35.5	

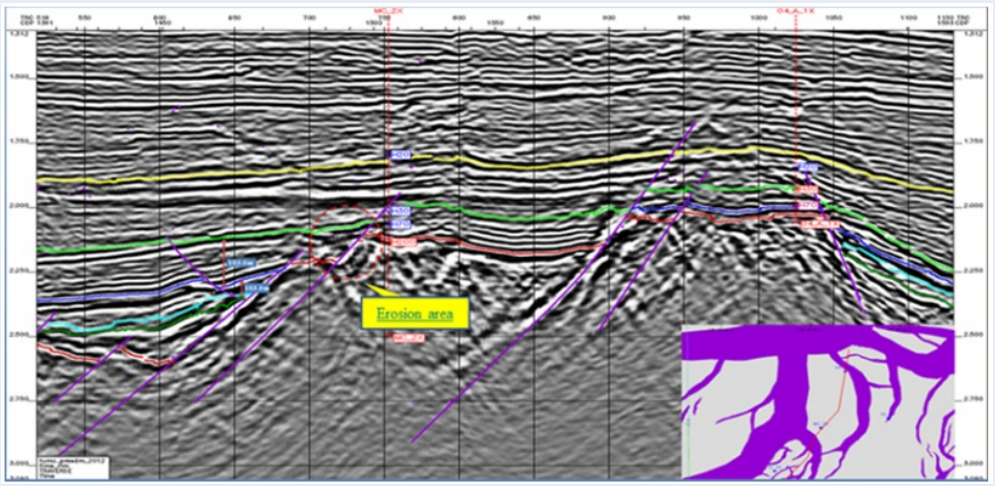

Figure 7: Identify of erosion thickness according to seismic cross section, block 04-3

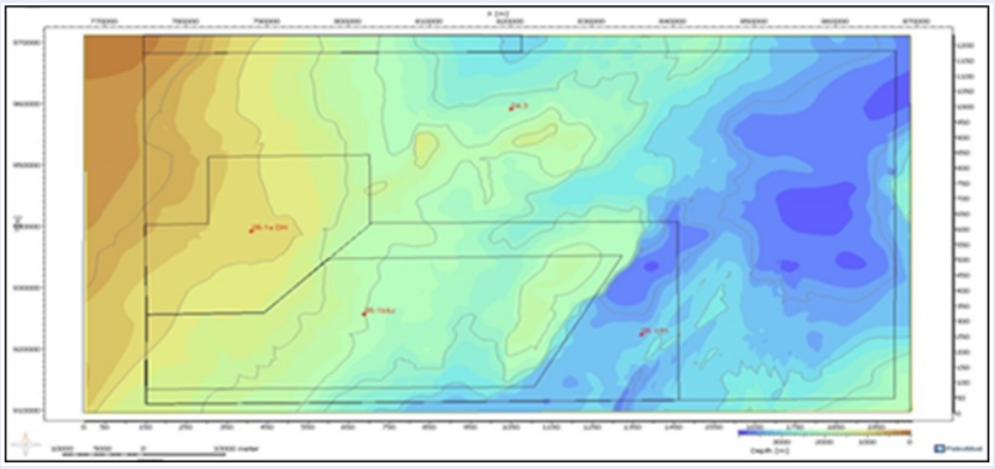

Figure 8: The map of erosion thickness, middle Miocene sequences (H30)

Table 2: Facies and sand/shale ratio in block 04-3

Environment	Facies	Sand/Shale ratio
Upper delta plain	Braided channel	High ratio of Sand
	Flood plain	Shale/Silt dominance
Delta plain/Coastal plain	Stacked channel	High ratio of Sand
	Lacustrine	Shale dominance
Tidal influence/Lower	Tidal flat	Thin Sand interbeds Silt/Shale
	Tidal channel	High ratio of Sand (#80%)
Coastal plain	Mangrove/Swamp	Shale dominance, minor Coal
Subaqueous delta/Shoreface	Delta front	Mostly Shale/Silt
	Shoreface	High ratio of Sand
Shallow marine	Inner Shelf	Shale dominance

rographic library of Petromod software. Each sedimentary sequence has a mixture of rock. Therefore, it is necessary to create a separate petrographic library for the block 04-3 area. In addition to environmental maps for the primary sedimentary sequences (Oligocene, lower Miocene, middle Miocene, upper Miocene), the sequences were also established based on detailed interpretation of the well log, correlated with extrapolation to areas where there are no wells according to the sedimentary environment map, structural map and isotopic map, seismic facies classification. Hence, the facies have been defined and applied in the 3D model block 04-3. The facies and the sand/shale ratio vary according to the depositional environment shown in Table 2.

Geochemical parameters , kinetics

Early Miocene and Oligocene source rocks in Nam Con Son sedimentary basin in general and block 04-3, in particular, are sediments rich in organic matter. Since the source rocks' quality and origin are the above factors that determine the mass and type of hydrocarbons that accumulate in the traps from the results of the model, these are two sets of data that take essential role in the modeling of the 3D petroleum system.

Due to limitation of fundamental geochemical data analysis from the wells in block 04-3, most of study is focused only on the early Miocene source rock, and due to there is no thermal analysis of rock samples for the Oligocene source rock, so the geochemical parameters of this formation are taken according to adjacent wells such as 05-1b-TL-2X , 05-1b-TL-1X and 05-1a-DH-1X, leading to building an isotopic map of TOC and HI for the two main source rocks Oligocene and lower Miocene with low reliability and ineffective in the simulation process of hydrocarbon migration and accumulation. Therefore, the authors propose using value instead of the map in the model's input data after identifying a map of the primary source rock in the study area to increase the efficiency of running simulations of hydrocarbon accumulations.

The results of the thermal analysis of rock samples showed that the average value of the total organic carbon content (TOC) of the Oligocene source rock layer varied from 0.22-4.2%, the average value is 3%, and hydrogen index (HI) ranges from 62-581 mg / g, with mean value is 550 mg / g, with the predominantly lacustrine and lower Miocene source rock, the mean TOC varies from 0.39-5.3%, mean value is 1-2% and (HI) ranges from 10-444 mg / g, with mean value is 250 mg / g (Table 3), with channel deposits, deltaic (fluvio-deltaic), high average values are concentrated in the Thanh Long, Dai Hung and close to the southern sub-basin of the NCS basin, this is considered the main source rock of the study area.

Within the boundary between H80 and near the crest, H150 encountered sediment containing abundant coal samples with high TOC and S2 values also contributed to the generation potential of source rock in this area, with the average value of TOC, HI very high, respectively 45% and 295mgHC/gTOC.

The origin and generation environment of the source rock is essential in selecting kinetics in the model of 3D petroleum system block 04-3. The results of the analysis and evaluation of the geochemical parameters of the source rock show that the existence of source rock sets in the study area has two main origins: the source rock formed in the fluvial-deltaic environment (Figure 9), containing a rich source of

higher plant organic matter (Kerogen type III occupies mainly); the source rock of lacustrine origin is forecasted to develop in the Graben, half-graben formed during the rift period in combination with the results of assessing the origin and types of oil of Nam Con Son sedimentary basin.

The study results showed a parallel distribution trend of two petroleum systems in the NCS basin in general and block 04-3 in particular, the petroleum system with the source rock of lacustrine origin and the source rock of fluvio-deltaic sediment origin. The majority of wells drilled on high-structural zones have not even reached high-quality lacustrine petroleum source rocks. The source rock kinetics used in the model are referenced and utilized source rock in the Tertiary in Southeast Asia and surrounding with climatic conditions and geological features, similar sedimentary strata[3]. The research area's source rock contains mainly kerogen type III deposited in the fluvial-swamp and kerogen type I formed in lacustrine environments. Kerogen type II rich in marine clay is not used in this model because the activation energy is lower, and the sulfur content is high, which is not characteristic of the source rock in the research area. Thus, the selection of kinetics model for source rock in block 04-3, NCS sedimentary basin with the index shown in Table 3 is the most optimal and will be used in running simulations of hydrocarbon migration and accumulation.

Boundary condition

To reliably restore the historical regime of a thermal development of the block in each specific geological stage, the crucial parameters of boundary conditions such as paleo-water depth (PWD), heat flow (HF), sediment water interface temperature (SWIT) are used in the modeling of the 3D petroleum system have been established.

The paleo-water depth

The paleo-water depth of the study area according to the sedimentary environment map and sediment deposition model[4] show that the deltaic coastal environment has a depth of less than 5m water, shallow water marine with depths ranging from 5 -20m of water, shallow marine ranges from 20 - 100m of water, shallow marine on continental shelf varies between 100 - 200m of water (Figure 10). Besides, based on the planktonic and benthic foraminifera fossil from paleontology analysis, it also allows determining the paleo-water depth in each sediment deposition period.

The depositional environment analysis results in block 04-3 show that the environment mainly developed from the river delta from the Oligocene-period to the shallow marine environment in the shelf to the middle of the shelf, offshore the present time. Therefore, the paleo-water depth (PWD) according to the 1D model in the study area ranges from 0 to 130 m. The building of the PWD map needs to calibrate at the well shown in Figure 11.

The paleo-heat flow

Heat flow is one of the crucial factors affecting the results of the basin modeling. In this study, the history of heat current was adjusted according to two parameters temperature (T) and vitrinite reflectance (Ro) with well data. In some cases, the temperature value and vitrinite reflectance cannot be calibrated to match each other; the temperature will be used for the correction procedure.

According to Allen, P.A. Allen, J.R 2005 (Basin analysis Principles & applications), usually, the current heat flow on earth ranges between 50-63mW/m2 (1.2-1.5HFU); in the shelf area of 38mW/m2 (0.9HFU); in the Cenozoic volcanic zone up to 84mW/m2 (2HFU); the mid-ocean ridge is valued at 335mW/m2 (8HFU). Paleo heat currents can be calculated based on reference to the geological history of the research area, such as the tectonic activity, especially magmatic activities, at which time the heat flow may increase accordingly.

The research area belongs to the NCS sedimentary basin, so the heat flow history also varies accordingly with the history of geological development of the sedimentary basin from the Eocene - Oligocene period to Pliocene - Quarternary period[5]. The first phase of separation occurs in Oligocene, the heat flow increases rapidly and reaches a peak of about 25 million years ago with a heat flow value of about 100-120 mWm2, followed by the process of thermal subsidence in the early Miocene, the heat flow decreases before rising again in the second rifting phase occurring in the middle Miocene at 10 million years ago with a heat flow value of about 55-60 mWm2. From 10 million years ago to the present, the heat flow decreases due to thermal subsidence, and the tectonic activity is relatively stable. The heat flow value in each well is used as a basis for building heat flow maps for the whole region through each stage of tectonic activity (Figure 12).

Sediment water interface temperature

Sediment water interface temperature (SWIT) is the seabed surface temperature based on sea level and

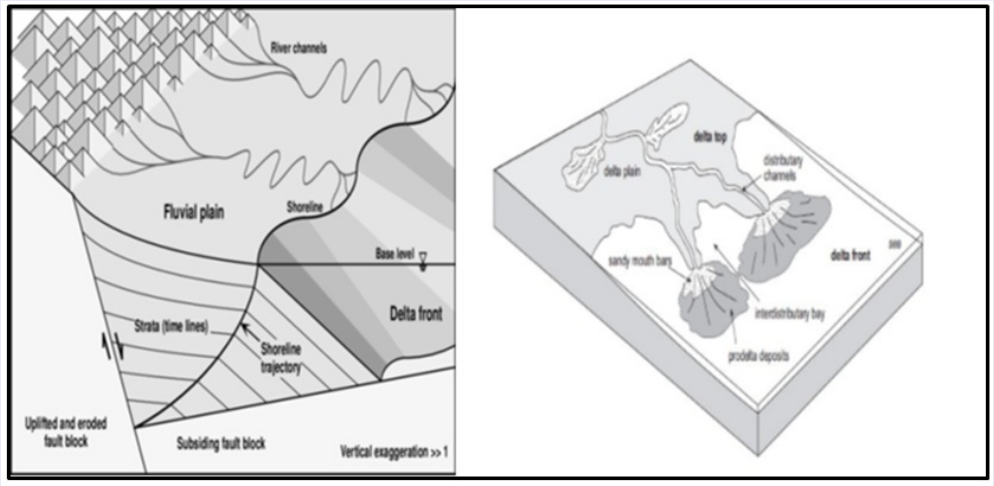

Figure 9: Examples the source rock depositional environment of fluvio-deltaic sediment origin [2]

Table 3: Characteristics of the source rock

Source rock	TOC (%)	HI (mgHC/gTOC)
Lacustrine	3	550
Coal	45	295
Swamp/Bay	1	300
Clay (Delta)	1	200

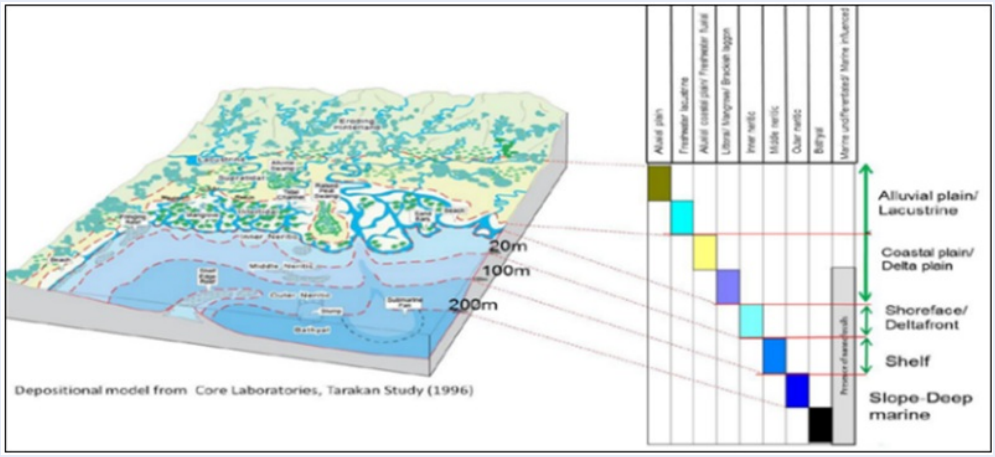

Figure 10: Sediment modeling and water depths

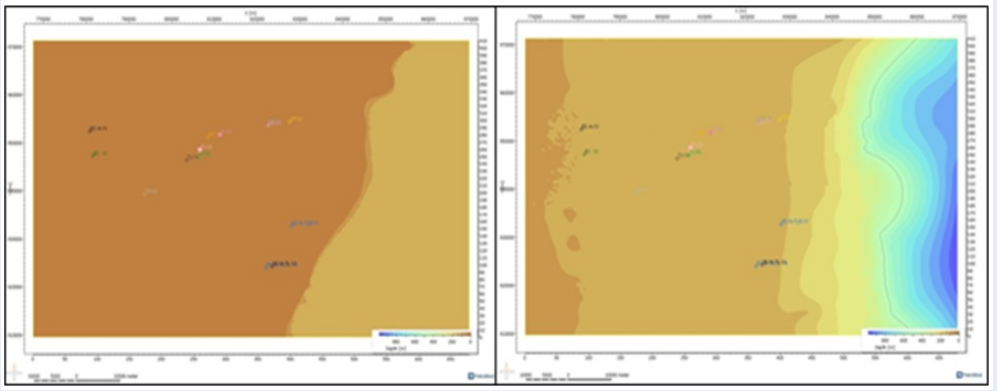

Figure 11: The paleo-water depth map 25 MMa and present

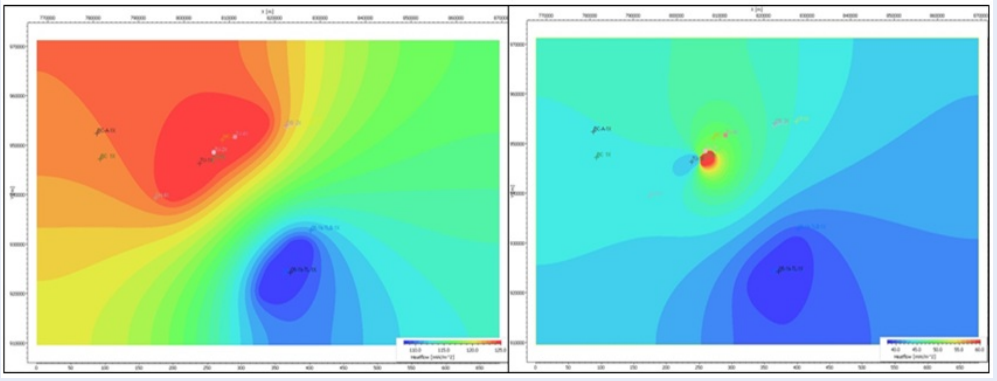

Figure 12: Heat flow map of 25 MMa and present

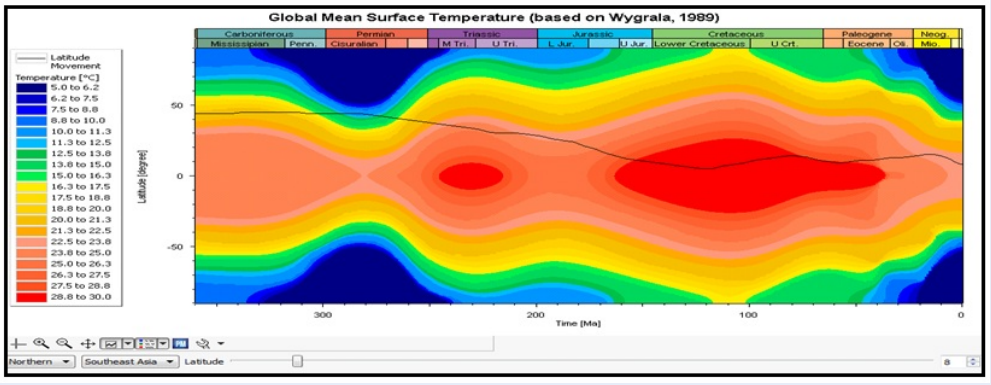

Figure 13: Surface temperature of study area 8 ^{0} N (Wygrala, 1989)

atmospheric temperature in that area. Usually, the aleo-sea surface temperature is referenced according to the study of global Paleo-temperature and the history of the basin's geological development. The water level depth at the time of the formation of sedimentary sequences also reliable reference data for determining Paleo-sea surface temperatures[6]. During the modeling process, users can adjust the paleo-sea surface temperature according to the depositional environment or the stages of sediment lifting/erosion and paleo-water depth. When building 3D models using PetroMod software, the sediment water interface temperature is calculated according to the model of Wyglar,1989. This calculation is based on the study area's current location and the corresponding sea level depth (Southeast Asia, 8^{o}N) (Figure 13).

Data calibration

Based on the synthesis of data on the results of geochemical analysis and well test at some drilling wells in the study area, the authors proposed to build a 1D model for 05 wells and the location of the wells evenly distributed over the areas of block 04-3. The above wells include: two main parameters calibrate TU-2X, TU-4X, BC-A-1X; the model results: vitrinite reflectance (% Ro), temperature (^{o}C) measured in the wells. Correction of the above parameters takes a vital role in the history of the basin development in each geological period. Calibrate for a 1D model to correct input parameters for boundary condition values (HF, PWD). The 1D marker extracted from the 3D simulation results corresponding to the wells at the vital location is proven by matching the well itself; the matching results between the two sets of data have demonstrated the reliability of the input data for the 3D model (Figure 14).

MODELING RESULTS AND DISCUSSION

Maturation of petroleum source rocks and the amount and timing of hydrocarbon generation

Simulation results of the 3D oil and gas system model show that the maturity of sedimentary sequences varies from advanced zones to deep basins. At the central basin of the NCS (the southern sub-basin of block 04-3), the most extensive burial depth of the sediment is over 6 km (however, the research area covers only a small part of the southern basin). Most Oligocene source rocks in the Central basin are in the dry gas generation phase; the area is higher as in the Bo Cau formation area and Dai Hung field, the source rock is in the mainly oil generation phase[7]. The results of the restoration of maturity over time from 25 million years ago to the present time show that the degree of maturity increases gradually from the southern region to the north region of block 04-3, proving that the primary source of producer for the accumulation is the production migrated from the Southern basin. Lower Miocene sediments belong to the H-80 are mostly in the late oil generation phase to oil windows. The lower Miocene sediment has also entered the wet and dry gas generation phase (Figs. 15).

To further clarify the HC generation of source rock in the research area, the results of the 3D oil and gas system model were used to assess the thermal maturity of the source rock according to timelines from the past to the present, identifying the earliest oil phase area and being the primary source rocks for hydrocarbon accumulations. In Block 04-3 area, there are two main sub-basin which are south and north sub-basin, but the results of the model of maturity show that the southern sub-basin is the main HC supply for potential accumulations as well as oil and gas fields that have been detected in block 05-1a, 05-1b and 05-1c[8]. For Oligocene source rock, at the time 10.5 Ma was mostly in the late oil phase to wet gas, 5.5 Ma was a dry gas phase, some areas of the protrusion (Bo Cau structure) had entered the late oil phase. Thus, the period from 10.5 Ma to 5 Ma is the vital HC generation stage of Oligocene source rock

Displacement model results and hydrocarbon accumulations

According to the results of the interpretation of 3D seismic data and geological structure revision after drilling bc-A-1X well, in the area of block 04-3, in addition to 3 structures that have conducted exploration drilling (Bo Cau, Thien Ung- Mang Cau, Dai Bang-Ung Trang) also discovered some other potential structures. The result has allowed the successful construction of a map to distribute potential structures in Hai Au, Hoang Hac structures.

The 3D petroleum system model allows forecasting the existence or not of hydrocarbon accumulations in prospective structures with characteristics such as time of accumulation, volume, and migration direction. The results of well tests in the structures that have been detected are used for comparison. The results of 3D simulations of the research area allow identify potential hydrocarbon accumulations in the H-150, H-80, H-30 reservoirs and confirm that the probability of accumulation in H-20 is trivial.

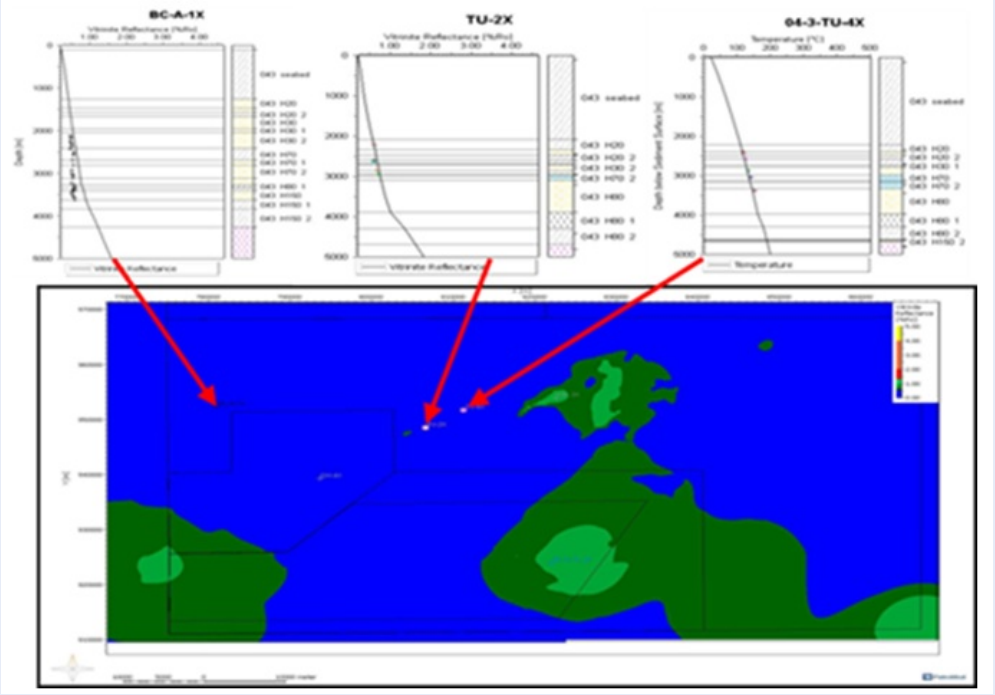

Figure 14: 1D marker extracted from the 3D model to compare with the calibration values of vitrinite and temperature at the wells

In addition to the potential HC accumulations detected by the results of the interpretation, accumulations in another areas have been confirmed by exploration wells in Thien Ung, Mang Cau, Bo Cau, Dai Bang-Ung Trang structures, block 04-3[9] and adjacent areas such as Thanh Long (05-1b-TL-2X), Dai Hung (DH-4X), Dai Nguyet. The model results will be matched with the actual discoveriess from the well test results. The forecasting of the size and category of hydrocarbons of the above potential targets depends on 3D modeling (within the scope of the paper, the research area has not yet expanded to deeper interval of HC generation) and selection of kinetics for source rocks in the study area (selection only kinetics type for source rock in the library of the software has the same characteristics as the source rock at the research area). It is precisely because these factors affect the type of HC that exists in the potential targets that have been detected (mainly the reservoirs in the lower Miocene slice (H-80, H-30, H-20) has the gas product, the gas-oil mixture is predominance, when in Oligocene section (H-150) is the gas reservoir, and this is also consistent with the source rock characteristics in the study area, the degree of maturity map as well as the degree of conversion of kerogen to HC of source rock at times 10Ma, 5.5 Ma and currently in the block 04-3 area.

The simulation results are based on the assumption that the open fault occurs between 16.5 MA and 10.5 Ma and closed after 10.5 Ma (time activity, inactivation of faults determined by the rifting phases of the sedimentary basin) shows the location of the accumulations (Figures 16, 17 and 18) by the results of well test and the interpretation in the research area, block 04-3. Therefore, this discovery will be used in the process of analyzing the data as well as evaluating the results of the research model.

CONCLUSION

Based on studying the role and contribution of hydrocarbon composition of the source rock, the migration direction, the paper clarifying the generation process, the trend of distribution, and the assessment of the mechanism and migration of hydrocarbon in block 04-3 area

The results of data digitalization on the geochemical analysis of effective source rock, building facies modeling and the sedimentary environment, boundary conditions models, and 1D models have successfully simulated the 3D petroleum system model. The simulation results allow to draw the following conclusions:

-Hydrocarbon generation potential: there are two formations of source rock: Oligocene (H-150) and lower

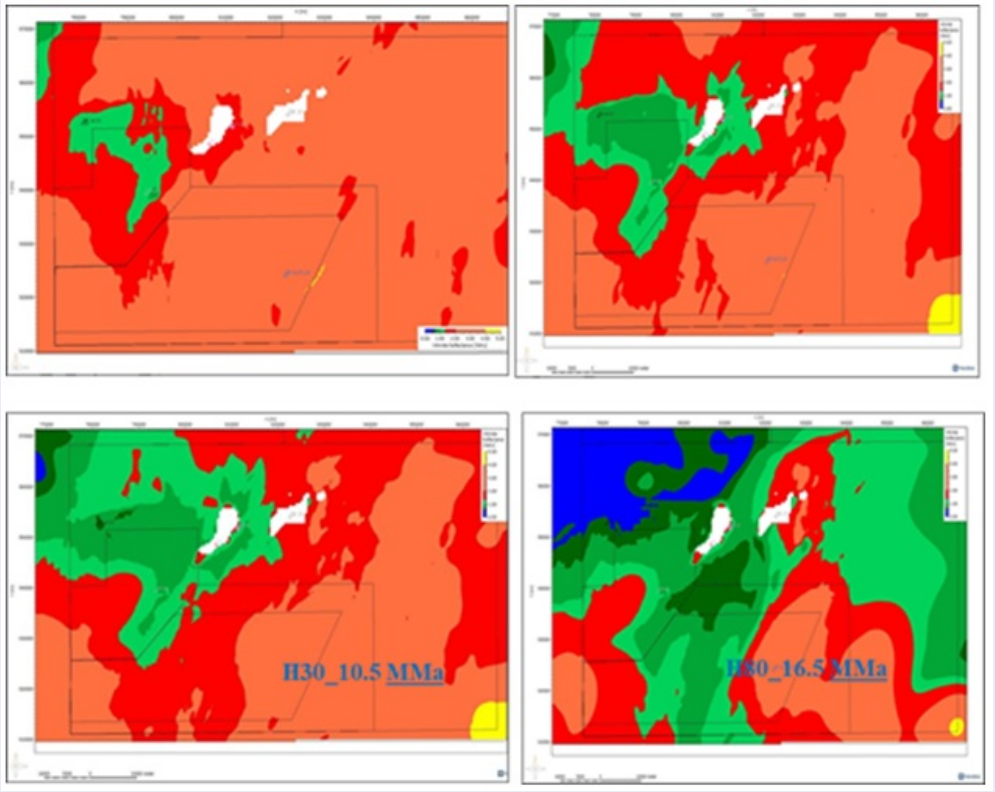

Figure 15: Source rock maturity in block 04-3

Miocene (H-80), in which the source rock belongs to the Oligocene sediment section at 16.5 Ma in the oil generation phase and 10.5 Ma - 5 Ma mostly in the late oil to wet gas and condensate generation phases, this source rock plays crucial role in providing HC production for potential accumulations detected in block 04-3.

-Generation mechanism of hydrocarbon accumulations: potential hydrocarbon accumulations formed in the suitable trap mechanism with Oligocene and Miocene periods formed in the with channel deposits, deltaic (fluvio-deltaic) environmets, preserved in stable conditions until hydrocarbon accumulation are produced from Oligocene source rocks, and part of the lower Miocene, distributed mainly in the South sub-basin (Nam Con Son Center basin), hydrocarbon compositions show the contribution mainly from Oligocene-aged claystone source rocks and a small part from the Lower Miocene source rock.

-The forecast results show that there are two potential accumulation groups exist in block 04-3: the Hai Au structure and the Hoang Hac structure with the Oligocene, lower Miocene, and middle Miocene reservoirs. Besides, there are several other potential accumulations in the vicinity and accumulations that have been confirmed by well data.

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CONFLICT OF INTEREST

I'm the main author of the manuscript publicing the research results: "Study of mechanism for petroleum generation, migration and accumulation, block 04-3, Nam Con Son basin". I hereby undertake the following:

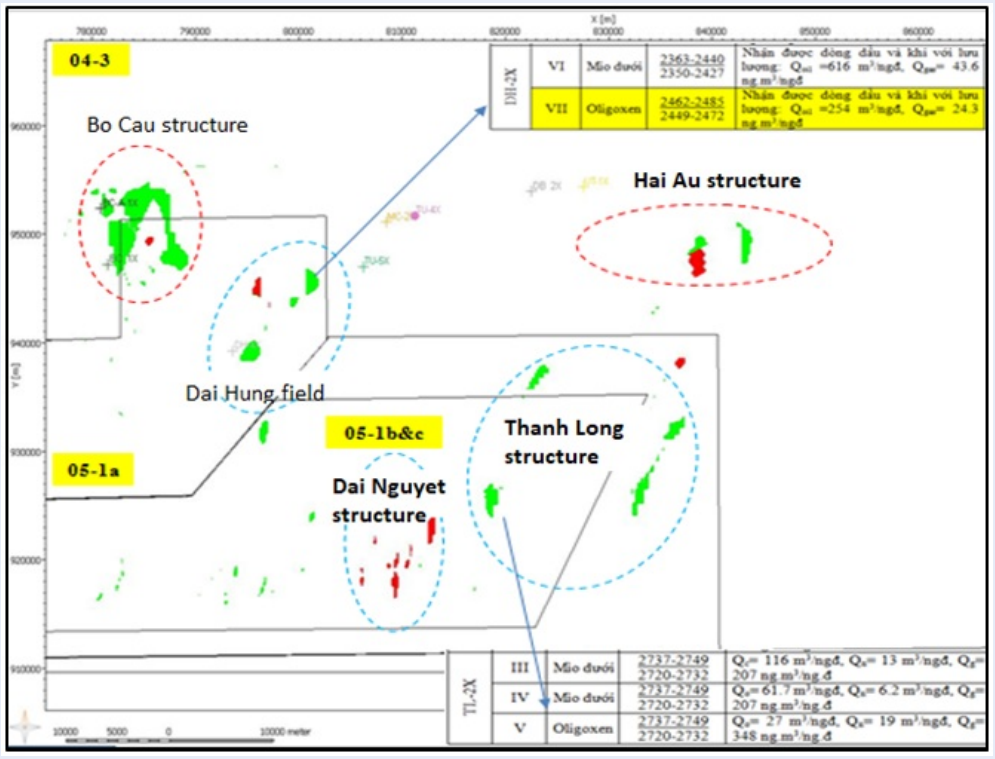

Figure 16: The distribution of Oligocene potential accumulations (H-150)

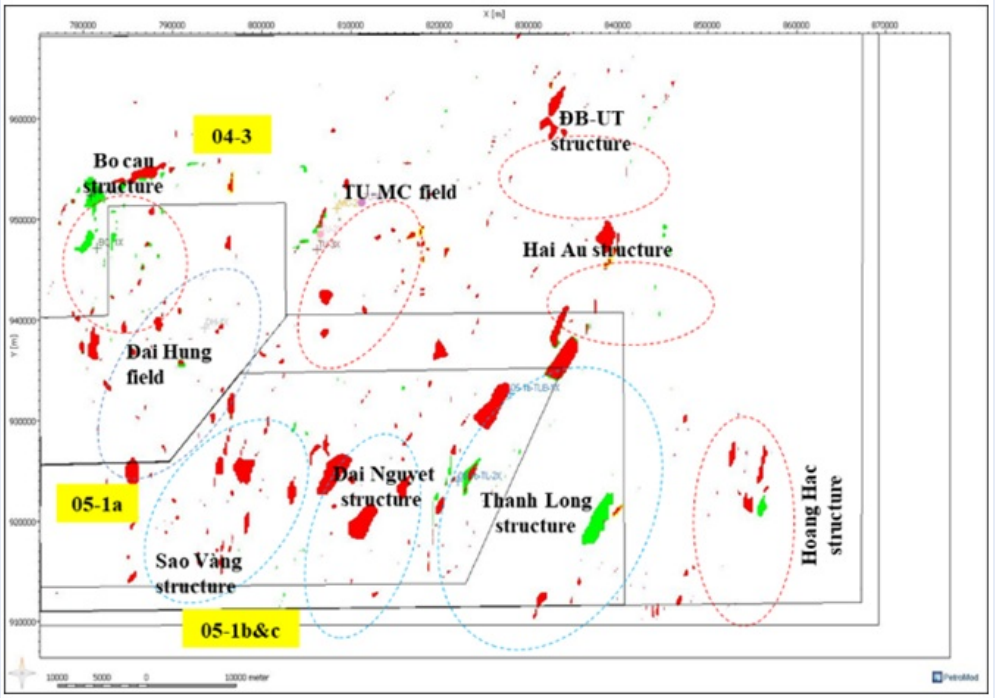

Figure 17: The distribution of lower Miocene potential accumulations (H-80)

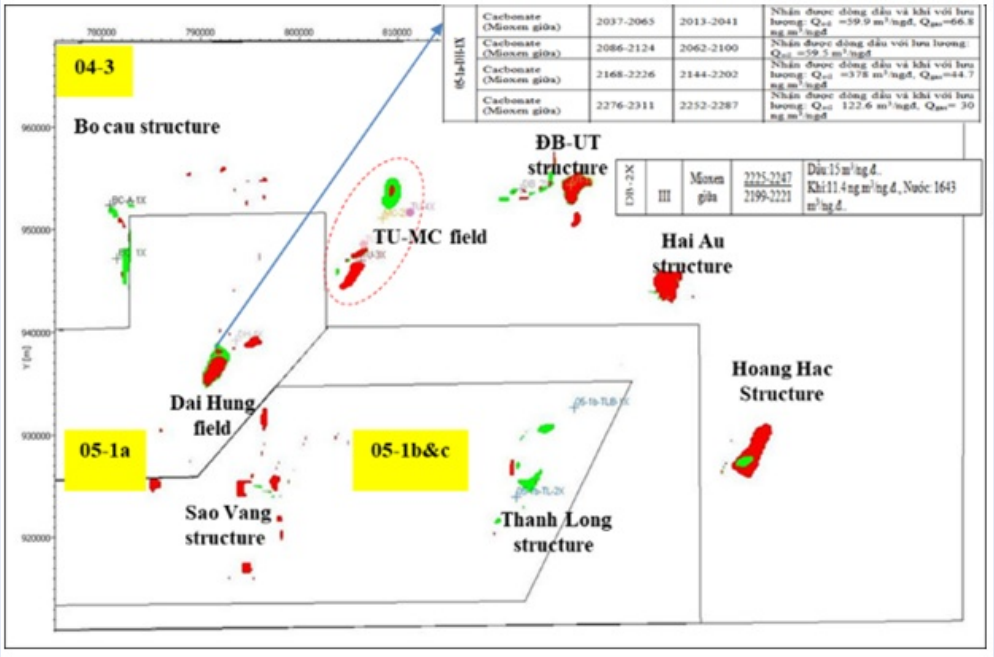

Figure 18: The distribution of middle Miocene potential accumulations (H-30)

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• All authors named in the article have read the manuscript, agreed to the order of authorship, and agreed to submit the article to the journal STDJET.

• This work does not have any conflicts of interest between the authors in the article and with other authors.

AUTHORS' CONTRIBUTION

• Tran Van Xuan: Lead author of the manuscript, who drafted the paper, designed the study, and performed the basic and statistical analysis.

• Pham Viet Au: Participates in research design and implementation, interprets data, collects data, and performs fundamental and statistical analysis.

• Nguyen Tuan: Involved in the design and implementation Research, analyze, interpret data, collect facts, and perform fundamental and statistical analysis.

• Truong Le Hieu Nghia: Contributed to data interpretation and data collection, and checked the article.

• Truong Vu: Participated in editing the manuscript, advising the research process since the work just started.

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Bài nghiên cứu

Cơ chế hình thành, di cư và tích tụ dầu khí lô 04-3, bể Nam Côn Sơn

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TÓM TẮT

Kết quả tìm kiếm thăm dò khai thác dầu khí lô 04-3 đã khẳng định tiềm năng dầu khí trên cấu tạo Thiên Ưng-Mãng Cầu. Các cấu tạo tiềm năng còn lại chưa có giếng khoan thăm dò cần được tiếp tục triển khai nghiên cứu, đánh giá triển vọng dầu khí. Mục tiêu của bài báo là tích hợp và số hóa dữ liệu từ kết quả của nghiên cứu tướng đá, môi trường, đặc tính vật lý thạch học, và tài liệu địa hóa nhằm mô phỏng mô hình hệ thống dầu khí để xác định quá trình hình thành, di cư, cơ chế nạp cho bẫy dầu khí, và phân bố tích tụ dầu khí.

Trên cơ sở thực tiễn thành công của tìm kiếm và thăm dò dàu khí lô 04-3, đã thiết lập quy trình xây dựng mô hình hệ thống dầu khí 3D với 4 bước chính là nhập dữ liệu đầu vào kết hợp với điều kiện biên, chạy mô phỏng, kiểm tra kết quả mô hình và hiệu chỉnh số liệu. Thông qua nghiên cứu vai trò và sự đóng góp các hợp phần hydrocacbon của đá mẹ, quy luật di cư đã làm sáng tỏ quá trình hình thành, quy luật phân bố cũng như đánh giá sự di cư và cơ chế nạp bẫy dầu khí khu vực lô 04-3. Kết quả số hóa các dữ liệu về phân tích địa hóa các tầng đá mẹ hiệu dụng, xây dựng mô hình tướng đá và môi trường, mô hình điều kiện biên, mô hình 1D đã mô phỏng thành công mô hình hệ thống dầu khí 3D.

Kết quả nghiên cứu cụ thể cho thấy: trong khu vực này có 02 thành hệ đá mẹ Oligoxen (H-150) và Mioxen sớm (H-80) trong đó đá mẹ trong lắt cắt trầm tích Oligoxen đã rơi vào pha sinh dầu 16,5 triệu năm trước đây (Ma), từ 10,5 đến 5 Ma là pha chủ yếu sinh dầu muộn, khí ướt, đá mẹ này đóng vai trò cốt yếu sinh dầu khí; các tích tụ dầu khí được hình thành trong cơ chế bẫy thuận lợi thời kỳ Oligoxen và Mioxen trong trầm tích sông, môi trường tam giác châu, được bảo tồn đến khi hình thành tích tụ dầu khí trong đó đá mẹ sét kết tuổi Oligoxen đóng vai trò chính; tại khu vực lô 04-3 đã chứng minh được sự hiện diện của hai nhóm tích tụ tiêm năng trong cấu tạo Hải Âu và Hoàng Hạc bao gồm các vỉa chứa trong Oligoxen, Mioxen hạ, và Mioxen trung.

Kết quả mô hình sẽ được sử dụng để xuất lựa chọn vị trí giếng khoan thăm dò phục vụ thẩm định các tích tụ dàu khí tiềm năng còn lại trong khu vực lô 04-3. Hơn nữa, kết quả nghiên cứu không chỉ tập trung đánh giá các tập đá mẹ hiệu dụng, xác định vùng nạp dầu khí chính, quá trình di cư và cơ chế nạp bẫy, mà còn góp phần làm sáng tỏ vai trò của đá mẹ hiệu dụng trong việc sản sinh dầu khí cấp cho các tích tụ dầu khí tiềm năng khu vực nghiên cứu.

Từ khoá: Cơ chế hình thành, tích tụ dầu khí, tiềm năng, mô hình hóa, mô phỏng

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