PETROLEUM POTENTIAL OF SOURCE BEDS IN THE CUU LONG BASIN

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ABSTRACT: In the Cuu Long basin, three source beds are identified: Lower Miocene, Upper Oligocene, Upper Eocene + Lower Oligocene. They are separated from each other by sand-clay layers. Only Upper Oligocene and Upper Eocene + Lower Oligocene source beds are two main source beds supplying a great part of organic matter into traps. Petroleum source potential of Upper Oligocene source bed (66.30 billion tons) is greater than Upper Eocene + Lower Oligocene bed (29.88 billion tons). Total amount of hydrocarbon has ability to take part in accumulation process at the petroleum-bearing traps from Upper Oligocene and Upper Eocene + Lower Oligocene source beds is over 2.19 billion tons and below 1.16 billion tons respectively. Thus, in whole Cuu Long basin, source rocks have capacity to produce 96.18 billion tons of hydrocarbon in which accumulation is 3.35 billion tons making up 3.35% production quantity. Applying Monte - Carlo simulation method, using Crystal Ball software to calculate production potential and total amount of organic matter taking part into migration and accumulation process give rather appropriate result with difference level ≤ 1.25%. Prospecting levels are in the following order: (i) Central lift zone has the greatest prospects, next is Dong Nai lift zone, graben located in north west inclined slope, south east inclined slope, north east area of Tam Dao lift zone finally; (ii) Petroleum does not only accumulate in structural, combination traps but also in non-structural traps.

Key words: Source rocks, organic matter, kerogen, vitrinite reflectance, maturation, immaturation

INTRODUCTION

Cuu Long basin is located in Southern Vietnam continental shelf and the continental part belonging to Mekong estuarine area. It has oval shape emerged towards the sea and was along Vung Tau-Binh Thuan coast. Cuu Long basin is a typically closed sedimentary basin in Vietnam and is on characteristic transitional crust in South-East Asia continent. It was filled by terrigenous sediments aged late Eocene, Oligocene, Miocene and Pliocene-Quaternary terraces. In the center of the basin, these sedimentary layers have the greatest thickness reaching 7-8km.

RESEARCH METHODS

To identify source beds, it is necessary to use the complex of methods: geological, geophysical methods and specially, organic geochemistry methods.

Geological characteristics: The geological background determines the source beds relating to tectonic-geodynamic characters in study area, stratigraphic, petrographic and lithologic-paleographic features, to specify accumulative phases of source rocks. Results of geophysical data help to find clay layers that are probably source rocks.

Organic geochemistry:

Methods for research on source rocks

Groups of geochemistry methods enable to identify source rocks, their petroleum producing ability, quantitative and qualitative oils; organic matters as well as their maturity level in sedimentary basin.

To identify mature threshold of organic matters, previous study results were combined and relatively reasonable mature thresholds for young basins (Cenozoic) of Vietnam continental shelf are accepted as follows:

%Ro <0.6, and TTI <25, Tmax <440^{o}C: organic matters in immature phase

%Ro = 0.6÷0.8 and TTI = 25÷75, Tmax= 440÷446^{o}C: organic matters in mature phase

%Ro = 0.8÷1.35 and TTI = 75÷170, Tmax= 446÷470^{o}C: organic matters in oil- producing phase

%Ro = 1.35÷2.2 and TTI = 170÷500, Tmax >470^{o}C: organic matters in wet gas and condensate-producing phase

%Ro > 2.2 and TTI >500: matters in dry gas- producing phase.

Methods for evaluating potential of source beds

ANALYTIC RESULTS AND DISCUSSIONS

Lower Miocene source bed

The vertical and lateral geology-geochemistry cross sections (figure 1 and 2) display Lower Miocene sedimentary formation that is in immature zone, even at the deepest points (collapsed holes), 3000m ÷ 3400m. Because at the areas, the temperature is the lowest (the bottom is in TTI line =25).

Upper Oligocene source bed

Sediments mainly are in mature zone (TTI = 25 ÷ 75) that have spread out the edges of sedimentary.

However, the collapsed holes at the bottom of these zones have changed to oil- producing windows with TTI reaching value >75. These zones concentrated in eastern (figure 1) and Northern (figure 2) Bach Ho basin.

Upper Eocene - Lower Oligocene source bed

In this source bed, organic materials of Lower Oligocene sediments are commonly in oil -producing phase (oil -producing windows) specially at the upper part of Lower Oligocene strata. Even at the boundary of anticline in north-east or in southern west Ba Den area are presented Lower Oligocene sediments in oil -producing window (TTI = 75 ÷ 170). Whereas, in eastern and northern Bach Ho basin, only the half of upper part of Lower Oligocene is still in oil-producing zone, the other one in gas and condensate -producing phase (TTI >170).

In Upper Eocene bed, sediments are commonly distributed at synclines that are narrowly sunken areas. Recently, these sediments found in the south of western Bach Ho basin (figure 2) have still been in gas and condensate -producing zones; in the northern, western Bach Ho basin and a north part of western Bach Ho basin, the half of upper part of sediments are still in gas and condensate -producing phase (TTI = 170 ÷ 500). The other part is in dry gas-producing phase (TTI > 500).

Therefore, the amount of wet and dry gas, condensate is often supported to juxtapositional traps. That is the reason why oil with low density and high level of condensate appeared in basement rocks and Lower Oligocene sedimentary basin at Bach Ho, Rong, Su Tu Trang, Rang Dong and Ca Ngu Vang oil-fields. Additionally, at Su Tu Trang and Ca Ngu Vang structures, there are primary condensate mixing weak oil reserves.

On the base of study results, organic materials of Upper Eocene + Lower Oligocene sediments and bottom of Upper Oligocene have contributed the large amount of oil and gas to Cuu Long basin; the top of Upper Eocene and the bottom of Lower Oligocene sediments have supported the high amount wet gas and condensate. Whilst, the half of Lower part at Upper Eocene sediments accumulated in depressed areas, particularly sediments in eastern and northern Bach Ho basin have been in dry gas –producing phase. Therefore, juxtapositional traps are always supported the amount of wet gas, condensate and dry gas.

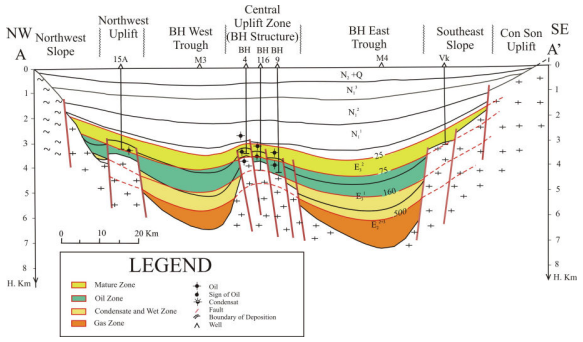

Figure 1 The geology-geochemistry lateral cross section "AA" of Cuu Long basin

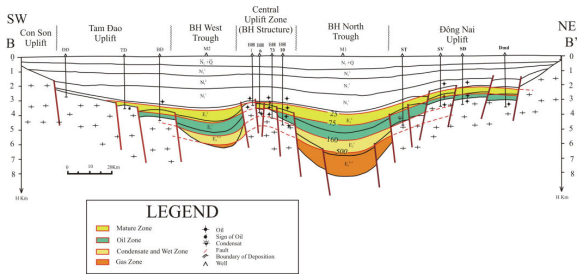

Figure 2 The geology-geochemistry vertical cross section " BB" of Cuu Long basin

The process of hydrocarbon transportation and accumulation

Presence of migration phase: The total volume of Oligocene source bed with TTI = 75 value at the 4300m-4800m depth has been at migration phase. Hence, a large volume of this source bed supported hydrocarbon to Cuu Long basin.

PI value: on the base of PI calculated results, a lot of PI points exceed limit more than 0.1. That shows the appearance of hydrocarbon migration.

Upper Oligocene source bed: As the results of TOC (%) distribution, the mature process of organic matters, direction of hydrocarbon migration in Upper Oligocene source bed was anticipated (figure 3). The process of hydrocarbon migration of this source bed has took only place in middle Miocene and specially in Lower Miocene up to now, as large amount of sediments in Upper Oligocene has gradually sank into oil -producing window (Ro = 0.8 ÷ 1.35%).

Upper Eocene+ Lower Oligocene source bed: As the results of TOC (%) distribution, the mature process of organic matters, direction of hydrocarbon migration in Lower Oligocene source bed was anticipated (figure 4). The process of hydrocarbon migration has also started at the late Lower Miocene and strongly at middle-Lower Miocene and Pliocene up to now. The process of violent migration of wet gas and condensate has happened, even added dry gas into traps.

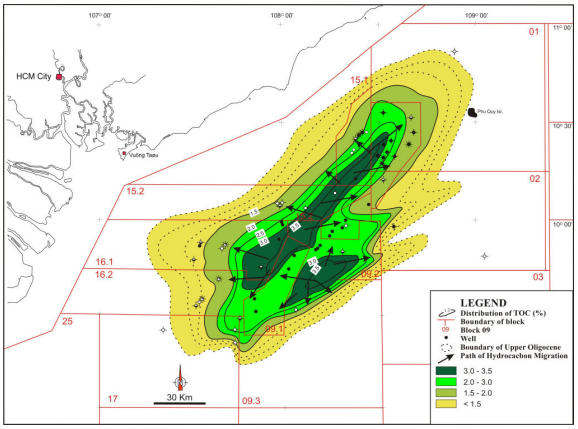

Figure 3 The migrate direction of hydrocarbon in Upper Oligocene source rocks

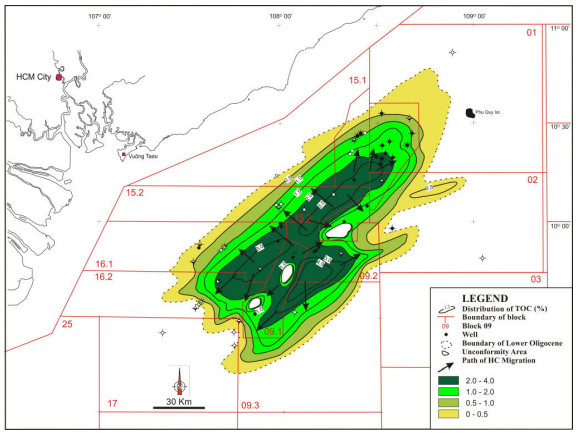

Figure 4 The migrate direction of hydrocarbon in Lower Oligocene source rocks

Prediction of oil and gas accumulation zones :

Based on analyzing of mature and migration processes, hydrocarbon accumulation in traps has been evidenced as follows:

The structural, combination traps

The traps are normally distributed in juxtapositional lift zones including exposed ancient basements and terrigenous traps such as (figure 5).

- Central lift zones : Bach Ho, Rong, Doi Moi, Cuu Long (Rang Dong), Vung Dong … structures.
- The anticline structures belonging to northern east lift zone.
- The north west graben belonging to Tra Tan structure (Hai Su Den), Te Giac Trang, et…
- The structures of Tam Dao anticline.

The non-structural traps: are sand bars, coastline sand dunes, ancient rivers located south east and north west incline slopes and incised valleys (figures 6, 7 and 8).

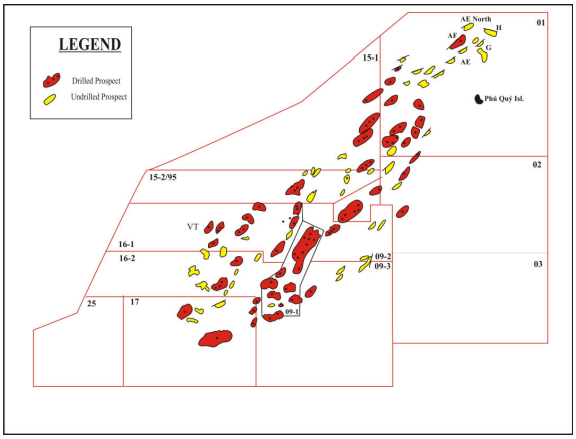

Figure 5 Scheme of structural traps in basement rocks of Cuu Long basin (referenced from Vietsovpetro)

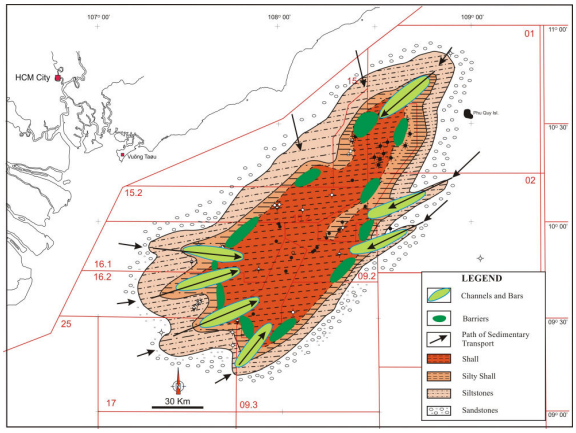

Figure 6 Scheme of distribution non-structural traps in Lower Miocene beds of Cuu Long basin (referenced from Trinh Xuan Cuong, 2008 and modified from Bui Thi Luan, 2009)

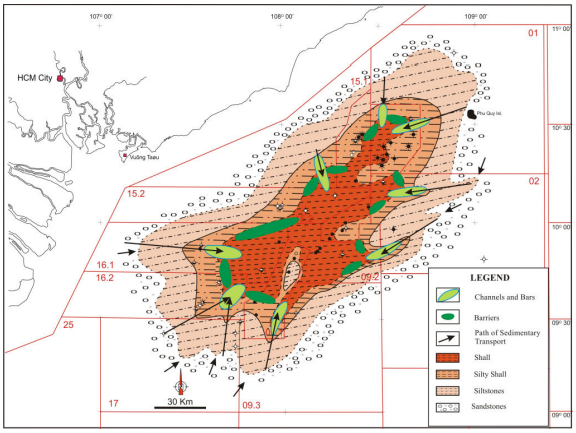

Figure 7 Scheme of distribution non-structural traps in Upper Oligocene beds of Cuu Long basin (referenced from Trinh Xuan Cuong, 2008 and modified from Bui Thi Luan, 2009)

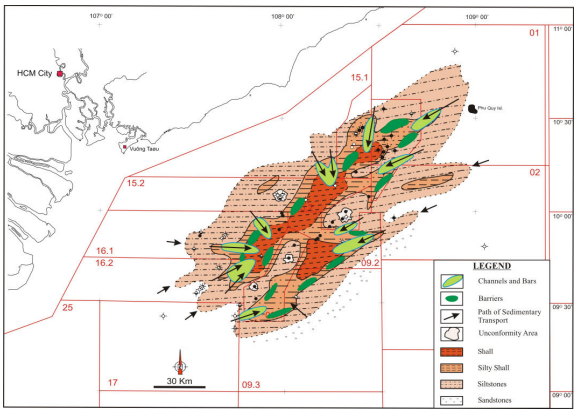

Figure 8 Scheme of distribution non-structural traps in Upper Eocene - Lower Oligocene beds of Cuu Long basin (referenced from Trinh Xuan Cuong, 2008 and modified from Bui Thi Luan, 2009)

Petroleum potential of source beds and prospects in Cuu Long basin

Oil-producing potential of source beds is based on volume -source methods and Monte-Carlo simulation by Crystal Ball software.

Volume -source methods

Upper Oligocene source beds:

- Oil-producing potential: 66.30 billion tons
- Hydrocarbon amount accumulated in traps: 2.19 billion tons.
- Hydrocarbon amount migrated: 10.32 billion tons.

Upper Eocene+ Lower Oligocene source beds:

- Oil-producing potential: 29.88 billion tons.
- Hydrocarbon amount accumulated in traps: 1.16 billion tons.
- Hydrocarbon amount migrated: 5.47 billion tons

The total volume of Upper Oligocene, Upper Eocene+ Lower Oligocene petroleum source beds: 5775.77 cubic kilometer (km^3).

The total hydrocarbon potential (Q_{TN}) of Upper Oligocene, Upper Eocene+ Lower Oligocene source beds: 96.18 billion tons

The total migrated hydrocarbon (Q_{DC}) of Upper Oligocene, Upper Eocene+ Lower Oligocene source beds: 15.78 billion tons.

The total accumulated hydrocarbon (QTL) of Upper Oligocene, Upper Eocene+ Lower Oligocene source beds: 3.35 billion tons.

As the results, the areas are capable to form and accumulate petroleum with large levels: eastern and western Bach Ho basin, collapsed slopes of central lift zones, next is Dong Nai inclined slope, southern east located eastern Bach Ho basin, northern Bach Ho finally, Dong Nai lift zone.

Monte-Carlo simulation by Crystal Ball software

Table 1 Comparing reserves caculated by two methods (Monte-Carlo simulation and Volume -source method)

Methods / Source rocks	Volume -source methods			Monte-Carlo simulation			Difference %
	Q_{TN}	Q_{DC}	Q_{TL}	Q_{TN}	Q_{DC}	Q_{TL}	
Upper Oligocene	66.30	10.32	2.19	66.31	10.31	2.2105	≤ 1.25%
Upper Eocene + Lower Oligocene	29.88	5.47	1.16	29.99	5.57	1.1813	
Total two-source rocks	**96.18**	**15.78**	**3.35**	**96.30**	**15.88**	**3.3918**	

Legend: Potential reserves (Q_{TN}); Reserves migration (Q_{DC}); Accumulated reserves (Q_{TL})

In brief, volume -source method have given plausible results. However, the method requires a lot of simultaneously analyzed data that extracted from wells and uniformly distributed on structured basin. While, Monte-Carlo simulation by Crystal Ball software calculates the amount of potential hydrocarbon, migrated hydrocarbon and accumulated hydrocarbon that brought quick results and applied specially, applying at the areas where there are a little data or use data from adjacent wells. The results of Monte - Carlo simulation method

give rather appropriate result with the volume -source methods. This evidenced that the volume -source methods have give rather appropriate results and the accumulated hydrocarbon quantity (3.35 billion tons) in traps are reliable.

CONCLUSION

1. Cuu Long basin have 3 source beds that are Lower Miocene, Upper Oligocene, Upper Eocene+Lower-middle Oligocene, separated into sand-clay units:

- Lower Miocene source beds contain the least organic matters. Mainly, kerogen is the III type, dominantly producing condensate and gas. Organic matters have been accumulated in continental environment and sub continent typically, lack of oxygen. On theory of source bed classification, Lower Miocene beds have organic matters at medium level.

- Upper Oligocene source beds have the best quantitative and qualitative organic, Kerogen is the II and I types, a little amount of the III type. Dominantly producing oil. Source beds bearing organic matters accumulated in estuaries, lagoon environments, typically lack of oxygen, released a small level of hydrocarbon out of source beds. This is rich organic matter source bed.

- Upper Eocene+Lower-middle Oligocene contain a large amount of organic matters which have dominantly formed oil, but a part of hydrocarbon got rid of source rocks. Organic matters are commonly the II type, a part of the I and III types, accumulated in estuaries, lagoon, flood plains in the lack of oxygen conditions. This means organic matters that have been well preserved from the early accumulation stage. This is rich organic matter source bed.

2. Three source rock beds mentioned above only Upper Oligocene and Upper Eocene+Lower Oligocene source rocks generated mainly oil and supported a large amount of hydrocarbon into traps. However, the bottom of Upper Oligocene have been partially sunk into forming oil phase and large amount of Upper Eocene+Lower Oligocene released hydrocarbon out of source rocks, remaining upper part and boundary basement have still formed oil. While the bottom of this bed has been sunk into mainly forming wet gas and condensate phases. The depressed areas reached more than 6.5 Km that have sunk into forming dry gas phase.

3. Petroleum potential calculated results of two source rocks formed oil and gas in Cuu Long basin (Upper Oligocene, Upper Eocene+Lower Oligocene) based on volume-source methods:

Petroleum source potential of Upper Oligocene source bed (66.30 billion tons) is greater than Upper Eocene + Lower Oligocene bed (29.88 billion tons)

Total amount of hydrocarbon has ability to take part in accumulation process at the petroleum-bearing traps from Upper Oligocene 2.19 billion tons and Upper Eocene + Lower Oligocene 2.19 billion tons.

Thus, in whole Cuu Long basin, source rocks have capacity to produce 96.18 billion tons of hydrocarbon in which accumulation is 3.35 billion tons making up 3.35% production quantity.

Applying Monte - Carlo simulation method, using Crystal Ball software to calculate production potential and total amount of organic matter taking part into migration and accumulation process give rather appropriate result with difference level $\leq 1.25\%$.

Besides, the areas have no data or a rarely data that apply possibly applying Monte - Carlo simulation method, using Crystal Ball software to calculate production potential.

In brief, volume -source methods brought out plausible results. The results of Monte - Carlo simulation method by Crystal Ball software calculated the amount of potential hydrocarbon, migrated hydrocarbon and accumulated hydrocarbon give rather appropriate result with the volume -source methods. This evidenced that the accumulated hydrocarbon quantity (3.35 billion tons) in traps are reliable by the volume -source methods.

4. Prospecting levels are in the following order:

- Central lift zone has the greatest prospect, next is Dong Nai lift zone, graben located in north west inclined slope, south east inclined slope, north east area of Tam Dao lift zone finally.

- Petroleum does not only accumulate in structural, combination traps but also in non-structural traps.

5. This is the first time using combination of geological and geochemical methods to evaluate source rocks with their characteristics and properties.

REFERENCES

Luan B. T., (2008). Features of Organic Distributions (TOC%) of Source Rock Beds in Cuu Long Basin. *Science and Technology Journal*, The Vietnam National University Ho Chi Minh City, 2008 (11): 5-11.

Luan B. T., (2008). Source Rock Beds in Cuu Long Basin. *Science and Technology Journal*, The Vietnam National University Ho Chi Minh City, 2008 (4): 28-39.

Luan B. T., (2009). Petrochemical Features of Lower Miocene Source Rock Beds in Cuu Long Basin. *PetroVietnam Journal*, 2009(7): 26-34.

Luan B. T., (2009). Organic Features of Lower Miocene Source Rock Beds in Cuu Long. *Science and Technology Journal*, The Vietnam National University Ho Chi Minh City, vol 12, 2009 (10): 78-88.

Luan B. T., (2009). Mature zone of organic matter and oil and gas process of Cuu Long basin. *Science and Technology Journal*, The Vietnam National University Ho Chi Minh City, 2009 (12): 60-72.

Tien H. D., Dung N. N., Chau H. T., Luan B. T., (2009). The factor forming and developing porosity and permeability of granitoid basement rocks in Cuu Long basin, Fractured basement reservoir. *Science and Technical Publishing,* PetroVietNam, 2008.

Tien H. D., Quynh N. T., (2003). Geochemical characteristics of sediments continental shelf of Vietnam. *PetroVietnam Journal*, 2003 (07).

Tien H. D., Quynh N. T., (2005). The change of some important geochemical indicators of oil and gas in the process of migration and exploitation. *PetroVietnam Journal*, 2005 (1).

Tien H. D., (2007). Mature zone of organic material in some Cenozoic sedimentary basins of Vietnam continental shelf. *PetroVietnam Journal*, 2007 (4).

Tien H. D., Quynh N. T., (2000). Conditions and mechanism of oil in Tertiary sedimentary basins of the continental shelf of Vietnam. *Collection Science and Technology Conference 2000 "The Oil and Gas of the 21st century"*. Youth Publishing, Hanoi: 359-375.