Petroleum Geology of Cuu Long Basin - Offshore Vietnam*

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Abstract

The Cuu Long basin is a Tertiary rift basin on the southern shelf of Vietnam. It covers an area of approximately 25,000 km^2 (250 x 100 km). The basin was formed during the rifting in Early Oligocene. Late Oligocene to Early Miocene inversion intensified the fracturing of granite basement and made it become an excellent reservoir.

In spite of some discoveries in the Oligocene-Miocene clastics and volcanic sections, fractured granite basement is still the main target of Cuu Long basin. Tectonic activities play a key role in creating and enhancing the fractures in the basement. Five major oil fields produce predominantly from the basement. The Bach Ho (White Tiger) is a giant oil field with recoverable reserve is 1.0-1.4 mmmbbls. The other oil fields are Rong (VSP), Rang Dong (JVPC), Ruby (Petronas) and Su Tu Den (CLJOC). Their recoverable reserves range from 100 to 400 mmbbls. The tops of these basement structures are usually at 2500 to 3000 mss with about 1000-1500 m oil column. Recently, another discovery was made by Hoan Vu JOC on the Ca Ngu Vang prospect, where the basement top is 3700 mss. This is the deepest basement structure in Cuu Long basin that has found oil. The DST flow rates from the main producing zone (4430 mss) are 2600 bopd, 6.8 mmscfgd, without water.

The basement rocks are usually overlain directly by a prolific and widespread Upper Oligocene source rocks. Geochemical data from many wells in the basin suggest that the oils found in the basin are of this source rocks.

The article notes the controls of the fractured reservoir in the basement of Cuu Long basin, the method to predict the fracture occurrence, and review the other factors of the petroleum system in the basin.

Geologic Setting of the Cuu Long Basin

The Cuu Long basin (Figure 1B) consists of four major structures:
1) The Southwest subbasin basin
2) The Southeast subbasin
3) The Central horst
4) The Northern subbasin.

The Southwest subbasin, located west of the Central horst, has E-W trending structure, deepening to the east. The Southeast subbasin, located east of the Central horst, is dominated by NE-SW-, ENE-WSW-, and E-W-trending structures. The Central horst, which separates these two subbasins, contains E-W- and N-S-trending faults (at Rong structure) and NE-SW and E-W trending fields (at Bach Ho structure). The Northern subbasin contains dominant NE-SW-trending faults and very minor E-W fault system. The thickness of sediments may be up to 8000m. The current oil fields are aligned along the NE-SW Central horst.

The tectonic evolution history of the Cuu Long basin can be summarized as follows:

a. Pre-Tertiary plutonism: Plutonism was widespread during the Mesozoic as a result of the northwestward-directed subduction of the Proto-Pacific plate under the East Asian continent to form Jurassic-Late Cretaceous magmatic bodies of granite-granodiorite. The sub-latitude and sub-longitude oriented fracture systems are thought to have formed in the plutons during that time.

b. Rifting phase - The initiation of the Cuu Long basin: The Cuu Long basin is a pull-apart basin that formed as a result of the extrusion and subsequent clockwise rotation of the Indochina block during the convergence between the India and Eurasia plates since Eocene. The basin has NE-SW orientation. The successive of lateral extrusion and rotation during Oliogcene developed secondary E-W-trending normal faults.

c. The Post-rift period: Inversion occurred locally in Cuu Long basin during Late Oligocene to Early Miocene. The stress field polarity is reversed from the NW-SE extension to NW-SE compression. It is this stage that creates the excellent fractured basement reservoir. Since Middle Miocene, the basin has undergone passive subsidence without any tectonic disturbance, except for the volcanic activities that occurred at some places in the Cuu Long basin. The present-day maximum NNW-SSE in-situ stress recorded by many wells in the basin indicates that the compression continues to date.

The development of the fracture system is summarized, as shown in Figure 2.

The stratigraphy of the Cuu Long basin is summarized inFigure 3.

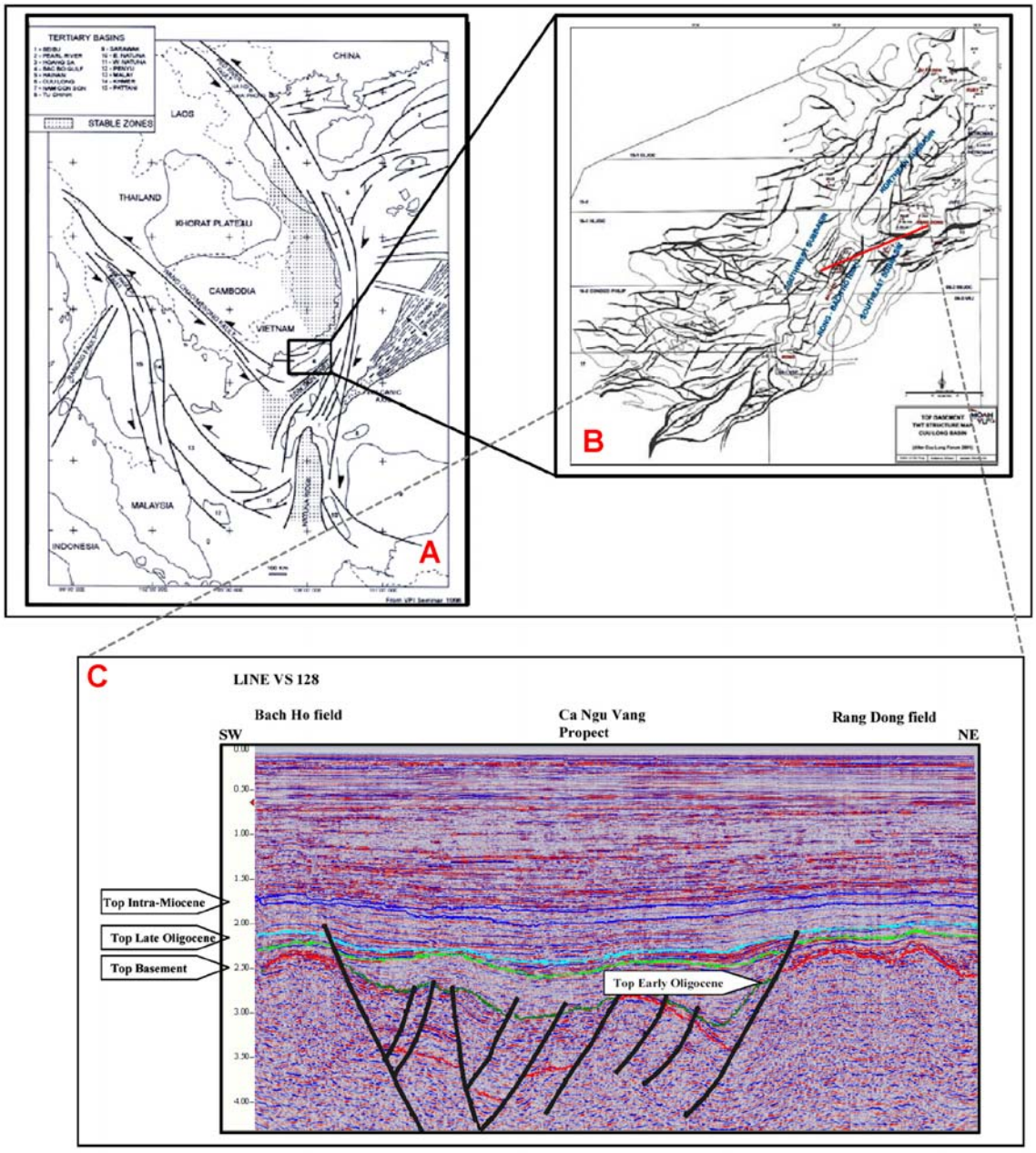

Figure 1. A. Tectonic map of Vietnam and environs, including Tertiary basins. B. Tectonic map of Cuu Long basin. C. Seismic line across two fields and prospect in Cuu Long basin.

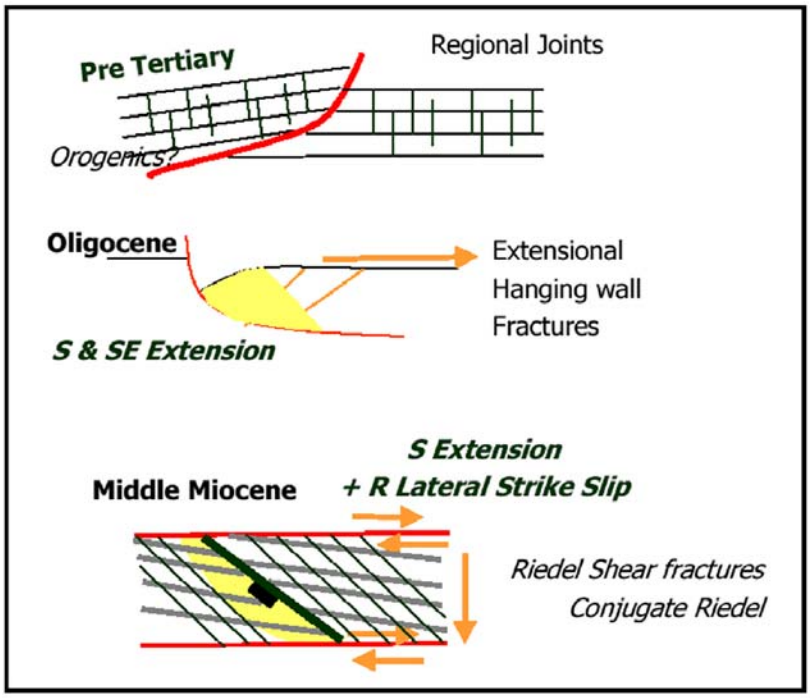

Figure 2. Diagrams showing various types of fractures: regional joints, those associated with extension, and those associated with strike-slip faulting.

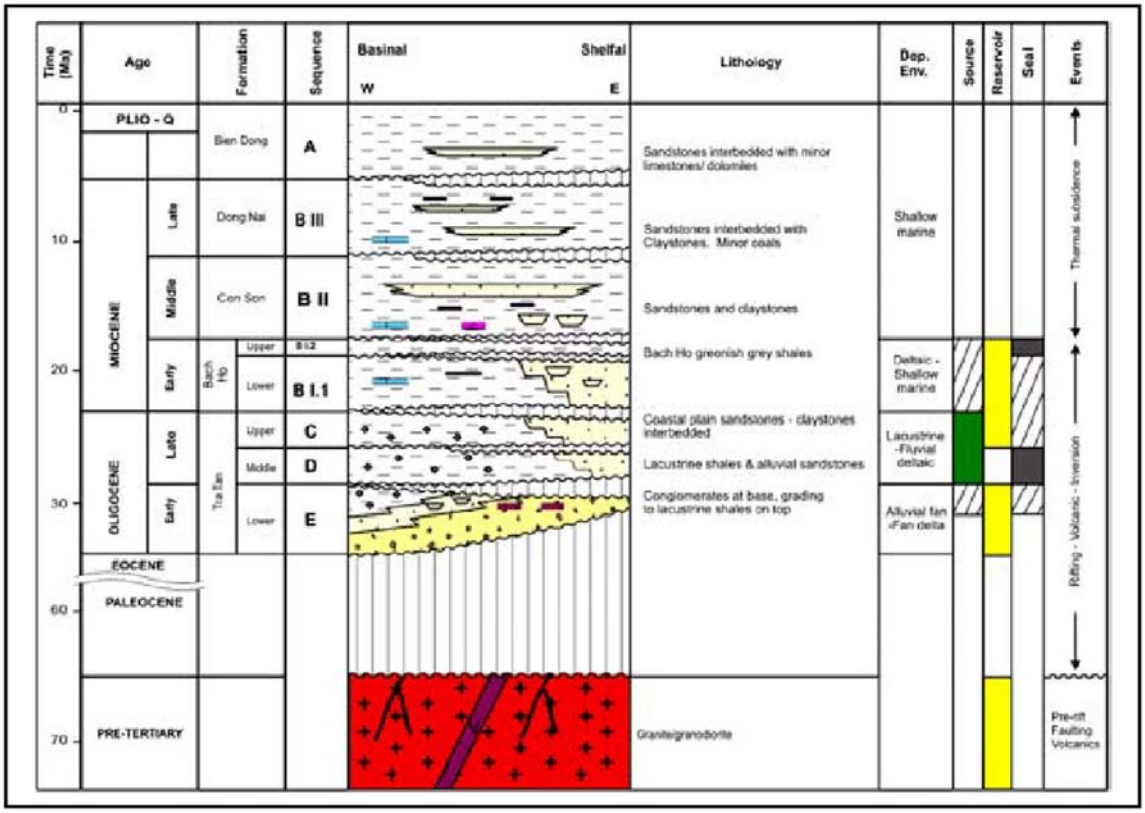

Figure 3. Stratigraphic section of Cuu Long basin.

Petroleum System

Play concept

The play concept for the Cuu Long basin is illustrated by Figure 4.

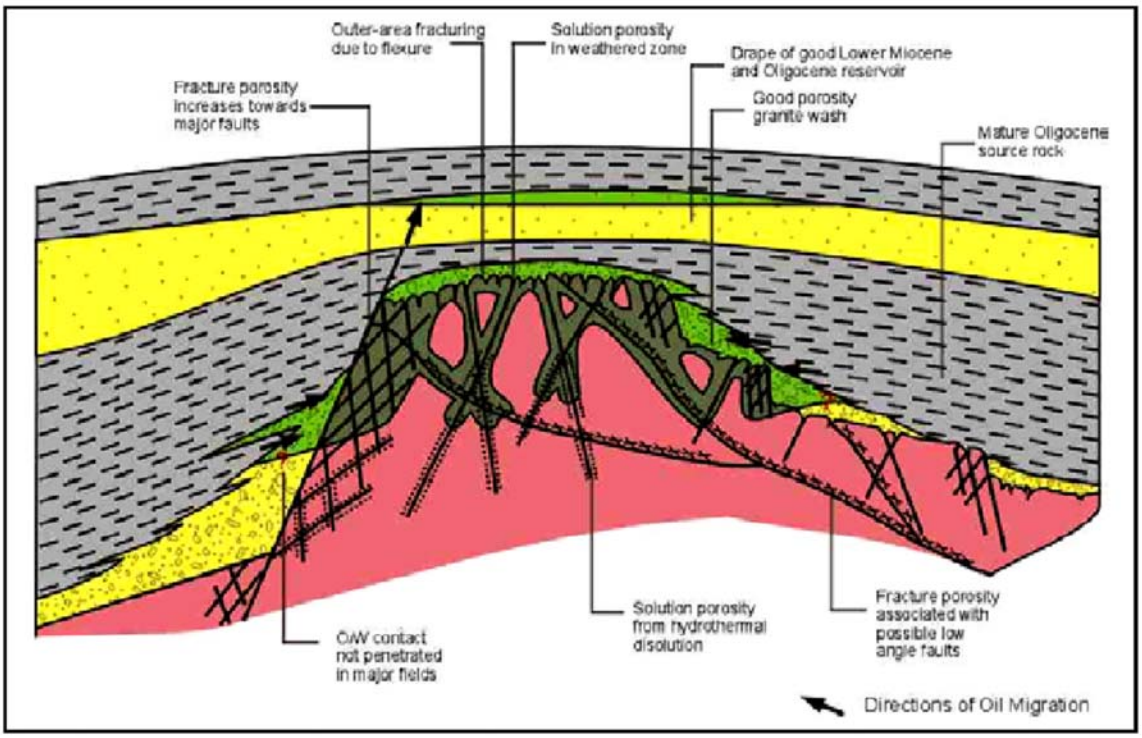

Figure 4. Two-dimensional model of the play concept for the Cuu Long basin.

Source Rocks

The effective source rocks are the Upper Oligocene shale that is present throughout the basin and the Lower Oligocene interbedded shale. They contain mostly kerogen type I/II generated from lacustrine sediments. The average TOC is from more than 1% up to nearly 10%; the hydrogen index ranges from 300 to more than 600 mg/gTOC (Figure 5).

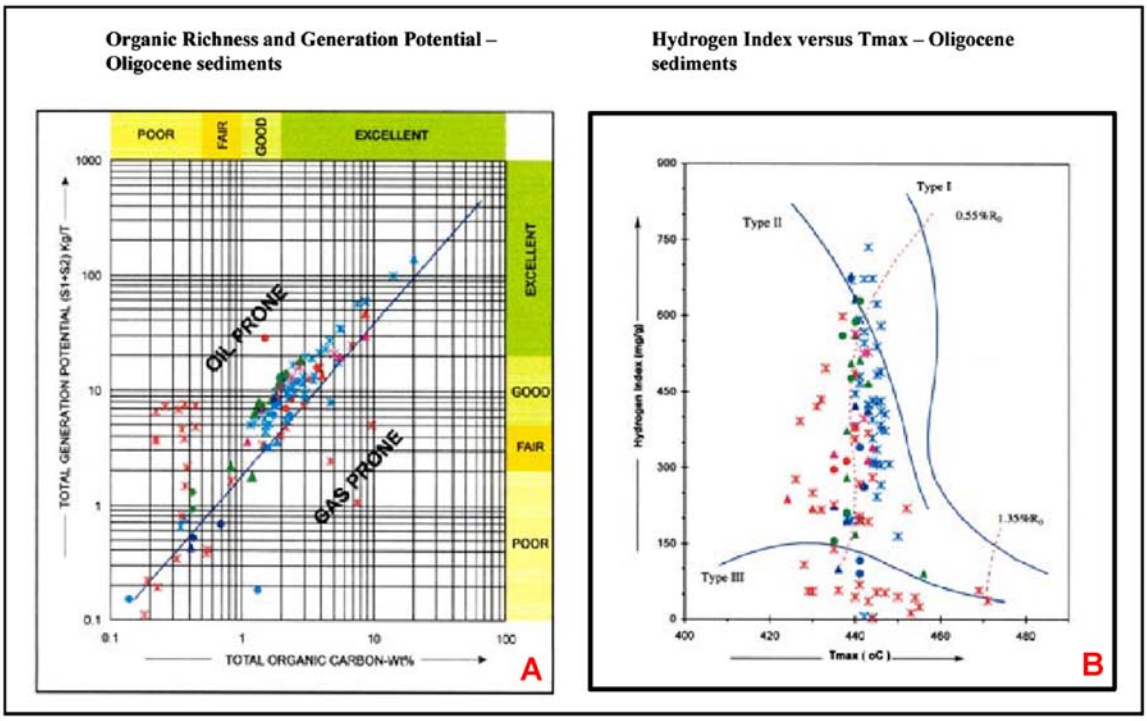

Figure 5. A. Organic richness and generation potential in Oligocene sediments. B. Hydrogen index versus Tmax , Oligocene sediments.

Fractured Basement Reservoir

Fractured basement reservoirs are the unique characteristics of the Cuu Long basin, although there are other oil discoveries in clastics and volcanics plays. The first oil discovery in basement was made by Vietsopetro in the Bach Ho field in 1988. Oil was stored in macro-fractures, micro-fractures, and vuggy pores. The matrix porosity of the magmatic body is negligible. Fractures inside the basement may originate from one or a combination of the following factors:

1) The cooling of the magmatic body
2) Tectonic activity
3) Hydrothermal processes
4) Weathering and exfoliation.

However, the tectonic activity and the hydrothermal processes are practically the main factors that control the porosity of the fracture systems. Recent studies (Cuong, T. X. 2001; Schmidt, J. et al., 2003) proved that the compression event that occurred during Late Oligocene reactivated the pre-existing faults/fractures and created effective porosity inside the granite basement. The compression probably resulted from the restraining band of a strike-slip motion along the E-W trending lineaments.

Most fractures inside the basement are of high dip angles (40-75^{o}). Their strike directions vary from one field to another, or even within a field. The permeability of these

reservoirs is normally very good to excellent (tens to thousands mD). Wells in fractured basement usually flow at very good rates (up to 14,000 bopd). The depth of the top of the basement reservoir is another issue. The basement tops of current oil fields are about 2500 - 3000 mss. Their oil columns range from 1000-1500 m.

Hoan Vu JOC has recently found oil at 4430 mss in the granite basement at 3700 mss at the Ca Ngu Vang prospect. It seems that the depth of top of basement is not a critical factor for exploring the oil in the basement.

Summary of Oil fields in Cuu Long Basin

Bach Ho (White Tiger) Field

This is a giant oil field with reserves up to 1.0-1.4 mmm bbls. Current production of this oil field is 250,000 bopd; 90% of which from the basement reservoir; the remainder is from Oligocene and Miocene clastics.

Rong (Dragon) Field

This field is located at the southern end of the Bach Ho field. Oil produces from both basement and volcanics sections. The estimated reserves are about 40 mmbbl.

Ruby Field

The Ruby field is located at the northeast part of the basin. Oil is produced dominantly from Miocene sandstones and Oligocene volcanics. Current production is about 20,000 bopd.

Rang Dong Fields

Oil is produced mainly from fractured basement. A minor amount is from Miocene sandstones. Current production is about 60,000 bopd.

Su Tu Den Fields

Oil was discovered in the Su Tu Den prospect in both basement and Oligocene and Miocene clastics. From field planning, production was expected to have begun by the end of 2003.

Ca Ngu Vang Prospect

This is characterized by the deepest basement reservoir, with flow rate of 2600 bopd and 6.8 mmscfgd. The Hoan Vu JOC is now conducting the appraisal of this prospect. The preliminary reserves of this prospect is 90 mmbbl.

Acknowledgments

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