Characteristics of Oligocene source rock and petroleum composition: Exploration implication in the northern Song Hong basin

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The exploration in the northern area of the Song Hong Basin, Offshore Vietnam was previously considered challenging. Most hydrocarbon discoveries had historically been made solely in Miocene Inversion clastics and fractured/karstified carbonate basement. Recently, further studies and extended exploration programs have been made successfully resulting in significant discoveries have been found in deeper section - Oligocene sandstone reservoirs overlying the basement. This has considered as the most significant hydrocarbon discoveries in the Northeastern Offshore area of the Song Hong basin.

Results analysis of Total Organic Carbon and Rock-Eval pyrolysis of cuttings from offshore wells indicate that the mudstones exhibit good to very good organic richness and show good to excellent hydrocarbon generation potential. Geochemical studies of oil samples from Oligocene reservoirs indicate oil generated from Tertiary lacustrine source rocks with contributions from predominant fresh water algae and higher land plant organic matter. Geochemical analysis of fluid samples and source rock correlations are both agreed that the oil are generated and expulsed from the nearby source kitchen. The discovery with commercial gas and condensate in Oligocene sandstone has been significant for the further exploration and development in the North Song Hong along with conventional pre-tertiary carbonate and Miocene sand in the Miocene inverted region.

Introduction

The Cenozoic Song Hong basin is located on the northern part of the continental shelf and regarded as one of petroliferous basins of Vietnam (Fig. 1). The Oligocene lacustrine syn-rift mudstones are considered to be the most important source rocks in the region and the organic rich rocks of Early - Middle Miocene ages may also have source potential (e.g. Nielsen et al, 1999; Petersen et al, 2001; Petersen et al, 2014).

Recently, a gas accumulation in Oligocene section was first discovered and tested good flow together with oil shows in various other stratigraphic intervals (e.g Son et al, 2017; Hung et al, 2017). In this study, cuttings and oil samples are used to investigate the source rock potential of the Oligocene lacustrine mudstones buried in grabens of the basin, characterize the detected oil and correlate the oil with potential source rocks.

Geological Setting

The study area is located in the northern part of Song Hong basin and undergone a long and complex regional tectonic history having complicated geological structures (Fig. 1). The area is located at intersection of NW-SE trending Song Hong shear zone and the NE-SW Bach Long Vi sub-basin in the Gulf of Tonkin, offshore northern Vietnam.

Study area appears to have been effected by the tectonic activities of the Song Hong and Bach Long Vi basin. Significant periods of structural inversion occurred in the Late Oligocene, Middle - Late Miocene and Pliocene times. In some cases, the tectonic inversion formed during these compressive episodes has modified the older structural configuration of the syn-rift successions. Hydrocarbon discovers found in structural traps formed in relation with tectonic events of basin have brought significant exploration in this region.

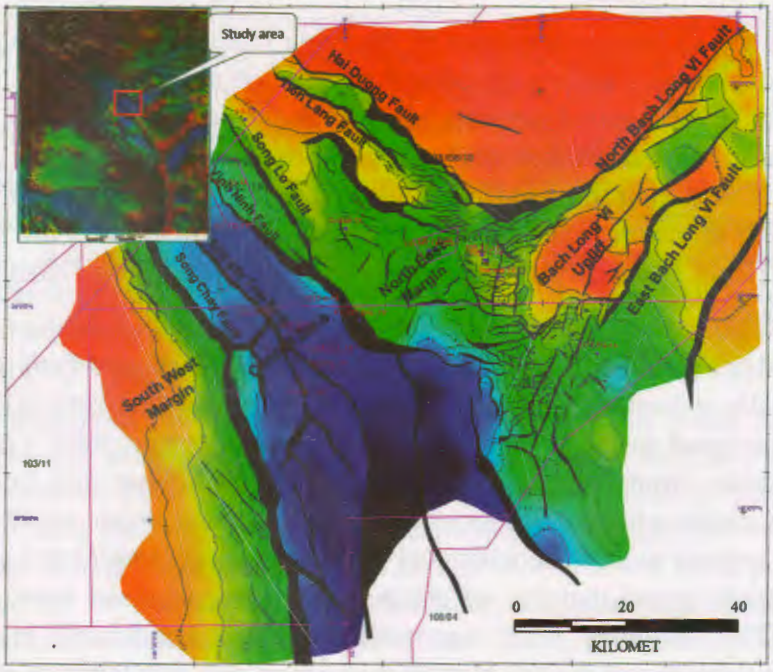

Figure 1. Location map of northern Song Hong basin

Samples and Methods

A cuttings and oil sample from Oligocene section in study area were analysed. The determination of total organic carbon (TOC) was carried out using a Leco CS-200 analyzer. Pyrolysis measurements were performed using a Rock-Eval 6. Soluble organic matter (SOM) from the samples was extracted using Soxhlet apparatus. Asphaltenes were precipitated by addition of n-pentane solvent and separated by centrifugation. Maltene fractions were separated into saturated hydrocarbons, aromatic hydrocarbons and heteroatomic polar compounds using HPLC instrument. The obtained saturated and aromatic fractions were analyzed by GC and GC-MS analyses.

Results and discussion

Potential of Source Rock

Based on geochemical data of samples from the Oligocene section, these

mudstones have a TOC content ranging 0.85-4.96% and Rock-Eval pyrolytic (S1 +S2) yields of 3.08-19.34 mg HC/g rock, with an average of 7.16 mg HC/g rock (Table 1). The S1 and S2 values indicate fair to good quantity of organic matter. Calculated hydrogen indices (HI) range from 325 to 552 mg HC/g TOC. These results suggest that the organic materials of source rocks belonging to the type I/II kerogen and potentially generating oil and gas. Tmax values increase downwards ranging 435-445 °C, suggesting the maturity stage of the organic matters.

Table 1. Total organic carbon and Rock-Eval pyrolysis parameters

Sample No	TOC (Wt.%)	S1 (mgHC/ gRock)	S2 (mgHC/ gRock)	S1+S2 (mgHC/ gRock)	HI (mgHC/ gTOC)	PI S1/ (S1+S2)	Tmax (°C)
No.10	0.9	1.1	3.31	4.41	368	0.25	435
No.09	0.63	0.84	3.48	4.32	552	0.19	436
No.08	0.94	1.14	4.53	5.67	482	0.2	438
No.07	1.32	1.85	6.06	7.91	459	0.23	438
No.06	0.51	0.66	2.42	3.08	475	0.21	438
No.05	0.62	0.77	2.77	3.54	447	0.22	438
No.04	1.02	0.87	3.8	4.67	373	0.19	435
No.03	1.28	1.5	4.45	5.95	348	0.25	437
No.02	2.41	3.11	9.6	12.71	398	0.24	443
No.01	4.86	3.53	15.81	19.34	325	0.18	442

Oil composition and Source Correlation

Asphaltene contents are low to moderate. Maltene fractions are generally dominated by saturated hydrocarbons with subordinate proportions of heteroatomic compounds and aromatic hydrocarbons. The saturated/aromatic hydrocarbon ratio is generally low.

Bishomohopane 22S/(22S + 22R) isomer ratios are essentially at equilibrium for oil samples, whereas C29 sterane 20S/(20S + 20R) isomer ratios are generally at or slightly below equilibrium, suggesting that the oils were generated from early- to mid-oil-window mature source rocks.

Similar biomarker fingerprints in m/z 191 and 217 mass chromatograms are further indications for good oil-source rock correlation. In general, the oil is derived from lacustrine source rock which known to contain a predominance of algal with the presence of higher plant organic matter.

Implication for hydrocarbon exploration

The biomarkers show that the Oligocene organic-rich mudstones have an excellent correlation with the discovered oils, confirming that the Oligocene mudstones are one of the principle source rocks in the Northern Song Hong Basin. Rock-eval parameters Tmax and molecular indicators of thermal maturity indicate the analyzed organic-rich samples from Oligocene section have mostly reached the early to middle stage of oil generation. Basin modeling shows that the Oligocene sediments at the northern part of basin reached the main stage of oil generation during the late Miocene,

and a major part of the source rock is now in the main stage of oil generation (Nielsen et al., 1999). Further exploration should investigate sandstone bodies within the Oligocene section, as well as traps in the Miocene section where the reservoirs have developed. Since those reservoirs occur in close proximity to the source kitchen, and have a good charge condition, they should be favorable exploration targets for future oil exploration.

Conclusions

The mudstones of Oligocene section contain high richness of organic matter and show good to excellent hydrocarbon generation potential.

Gas chromatography-mass spectrometry study on saturated and aromatic fractions indicates the contribution of algal, high land plant and bacterial sources to the organic matter deposited in constant less oxic conditions.

Biomarker distributions have shown that oil is derived from source rocks which is moderate thermal maturity. There is clearly a close affinity between the source rocks and the oil samples.

Keywords: *Oligocene source rock, oil composition, northeast Song Hong Basin*

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