

CHARACTERISATION OF CRUDE OILS AND GAS IN BLOCKS 05-2 AND 05-3 - NAM CON SON BASIN USING BIOMARKERS, GAS CHROMATOGRAPHY AND CARBON ISOTOPE ANALYSIS

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Summary

Research on petroleum systems is the basis for evaluating the potential of a sedimentary basin during exploration and exploitation processes. In this, results from analysed samples are very useful. In the Nam Con Son basin offshore Vietnam, several oil and gas fields have been found such as Dai Hung, Thanh Long, Bo Cau, Nguyet Thach, Moc Tinh, Hai Thach, Lan Tay, Lan Do, etc. However, the origin of organic matter and the distribution of crude oils in Nam Con Son basin still pose difficult problems for petroleum geologists. Certain questions remain to be answered, such as the origin and transformation level of organic matter, depositional conditions, rate of sedimentation or even why geologists have not discovered oil accumulations leading to gas being found more than oil. In this paper, the authors use advanced analysis technology and combine effective analysis parameters to evaluate and classify the origin of oil and gas in Blocks 05-2 and 05-3. According to the results of GC, GCMS and carbon-13 isotope analysis, crude oil at the Nguyet Thach well is believed to be generated from a low maturity source rock containing lacustrine organic matter.

Evaluating and classifying oil groups based on the results of physical characteristics, chemical composition analysis and more detail analysis such as GC, GCMS of crude oils and condensates can indicate the depositional and degrading environments of organic matter as well as the maturity level of source rock which generated these oils and condensates. Specially, the results of carbon isotope analysis of crude oil and gas samples clearly prove the origin of oil and gas as well as gas-oil and oil-oil correlation. In Blocks 05-2 and 05-3, oils have been found in Late Miocene, Middle Miocene and Early Miocene aged reservoirs at wells 05-2-HT-2X, 05-3-MT-1X, 05-2-NT-1X, 05-2-B-1X, 05-2-KCT-1X, 06-LD-1X, and 06-LT-1X OBS1.

1. The primary physical and chemical characteristics of oil and condensate

The physical characteristics and chemical composition analyses of oil and condensate samples in Blocks 05-2 and 05-3 are listed in Table 1.

Of the 21 samples taken from Block 05, there are 8 oil samples and 13 condensate samples which have API more than 45 (Table 1). Both DST#3 oil sample (2,874 - 3,004m) in Block 05-1a and RFT5 sample (2,864.5m) are heavy oils ($^{\circ}$ API

< 25), 6 samples are normal oils with API varying from 25 - 45. Almost all oil samples in the Nam Con Son basin have low sulfur, vanadium and nickel contents. This is typical for oils derived from mainly higher plant organic matter.

The relationship between sulfur content and API shows that oil samples belong to B, C, D and E types. In addition, the Pr/Phy ratios also illustrate type D and E of these samples. According to the oil classification of BP Reach (Table 2), if a crude oil has an amount of saturate hydrocarbon fraction more than 70%, it will belong to D type and vice versa. In Table 1, all crude oils and condensates of Block 05 belong to type D which were generated from source rocks containing mainly higher plant organic matter.

2. Gas chromatography and gas chromatography-mass spectrometry

The results of gas chromatography and gas chromatography-mass spectrometry analysis are used as fingerprints to identify the type of organic matter in oil and rock samples. Pristane and Phytane are separated from fractions of Chlorophyll. The presence of these components reflects the increase in activity of bacteria in a primary

Table 1. The primary physical and chemical characteristics of oil and condensate in Block 05, Nam Con Son basin

Well name	Sample	Depth (m)	Reservoir formation	Type of sample	°API	S (%)		HCsat (%)		HCaro (%)		NOS (%)		Pr/Phy	Pr/nC ₁₇	Phy/nC ₁₈	Vanadium (ppm)	Nickel (ppm)	
05-1b-TL-2X	RFT	3,198.5	Middle Miocene	Crude oil			76.09	20.23	3.68	5.33	1.48	0.24							
	DST#3	3,217.3 - 3,222.5		Crude oil	32.86		0.086	72.63	25.43	1.94	5.57	1.49	0.24					<1	<1
	DST#2	4,092.2 - 4,097.3	Early Miocene	Condensate	38.06	0.058	72.02	26.17	1.81	5.52	0.85	0.16						<1	<1
	DST#1	4,559 - 4,575	Oligocene	Condensate	40.50	0.046	78.60	20.23	1.17	5.20	0.63	0.12						<1	<1
	MDT	2,956.5	Late Miocene	Condensate	36.15	0.05	89.50	10.50	6.82	6.82	1.21	0.17						<0.1	2.45
05-2-HT-1X	MDT	3,195.8	Middle Miocene	Condensate	35.90	0.05	82.70	17.20	0.10	6.31	1.30	0.19						<0.1	2.82
	MDT	3,497.2		Condensate	36.40	0.05	93.10	6.90		6.93	1.38	0.19						<0.1	1.84
	MDT	3,617	Early Miocene	Condensate			89.00	10.90	0.10	6.78	1.22	0.18							
	MDT	3,765		Crude oil	32.80	0.10	75.70	24.10	0.20	5.43	1.84	0.33						<2	5
05-2-NT-1RX	RFT5	2,864.5	Early Miocene	Crude oil	17.30	0.20	48.80	40.20	15.00			0.75						<2	31.00
	DST#6	2,594 - 2,605			30.90					5.65	1.11	0.20							
05-1a-DH-4X	DST#6A	2,594 - 2,637			34.00					5.95	0.98	0.17							
	DST#5	2,651 - 2,663	Early Miocene							6.50	0.91	0.14							
	DST#4	2,737 - 2,749			39.20					6.04	0.87	0.14							
	DST#3	2,874 - 3,004			25.20					6.26	1.07	0.17							
	DST#2	2,984 - 3,004			30.20					4.32	0.76	0.18							
05-2-KCT-1X	RFT	3,057	Middle Miocene	Crude oil	36.18	0.096	82.68	8.66	9.66	6.40									
		3,069			31.75	0.049	78.05	13.82	8.13	5.34									0.02
05-3-MT-1RX	RFT	2,849.5mBRT	Late Miocene	Crude oil	35.10	0.01	73.41	19.94	6.64	4.48	1.39	0.26							
	DST#2	3,075.5			38.10	0.03	66.17	18.92	85.09	14.91	5.92	5.92	1.36						
05-3-MT-1X	DST#1C	3,136.5			37.44	0.02	65.16	20.00	85.16	14.84	6.14	1.37							

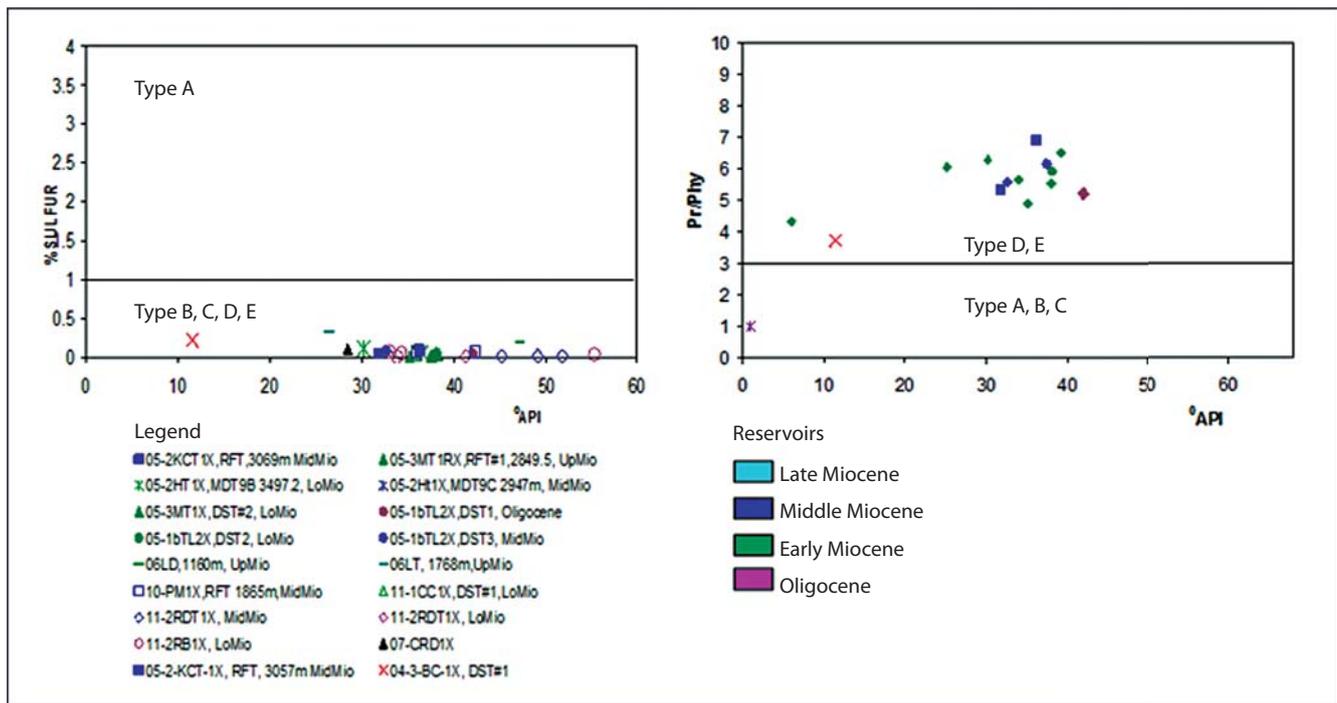


Fig.1. Relationship diagram of API versus sulfur content as well as Pr/Phy ratio of Blocks 05-2 and 05-3 and surrounding areas

Table 2. Oil classification of BP Research Centre, Sunbury [3]

Oil class	Organic matter input into kerogen	Deposition environment of source	Effects on oil properties		
			Organic matter input	Deposition environment	Either/Both of there
A	Phytoplankton Bacteria	Marine (carbonate and other non-siliciclastic)	Low content	High content	Most other inspection properties are controlled by a (sometimes poorly understood) combination of factors
B	Phytoplankton Bacteria	Marine (Siliciclastic sediment)	Low content	Moderate content	
C	Phytoplankton Bacteria	Lacustrine (fresh water)	High wax content	Low content	
D	Higher land plant (Angiosperm dominated) Debris, Bacteria	Non marine	High wax content	Low content	
E	Higher land plant (gymnosperm dominated) Debris, Bacteria	Non marine	High wax content	Low content	

oxidising environment. However, this ratio is influenced by changes in rocks containing organic matter. Moreover, in the maturity process, Phytane is generated faster than Pristane. Therefore, this ratio decreases with maturity level. Pr/Phy ratio of isoprenoid chain is used to evaluate the origin and environment of organic matter [3].

Biomarkers in Triterpane and Sterane distributions of GCMS analysis help geochemists determine that the source of organic matter is higher plant, lacustrine algal or marine algal. Furthermore, we can also know the time that source rocks generated oils and that source rocks are Tertiary aged or older. These results play an important role in research on the depositional environment, building calibration parameters for a maturity model of source rocks

as well as identifying the oil-oil and oil-source rock correlation. It is a useful tool in exploration and exploitation processes.

The results of GC analysis from 21 samples show that these samples have similar organic matter origin which related to source rocks containing terrestrial organic matter, deposited and degraded under oxidising and weakly reducing conditions (Fig.2). The Oleanane and Ts/Tm ratio diagram (Fig.3) was used to distinguish lacustrine algal and fluvio-deltaic source of organic matter. In this figure, almost all crude oils and condensates found in block 05 and surrounding areas locate at the estuarine-fluvio deltaic zone and mix of lacustrine and fluvio-deltaic zone, with only a few samples in the lacustrine zone.

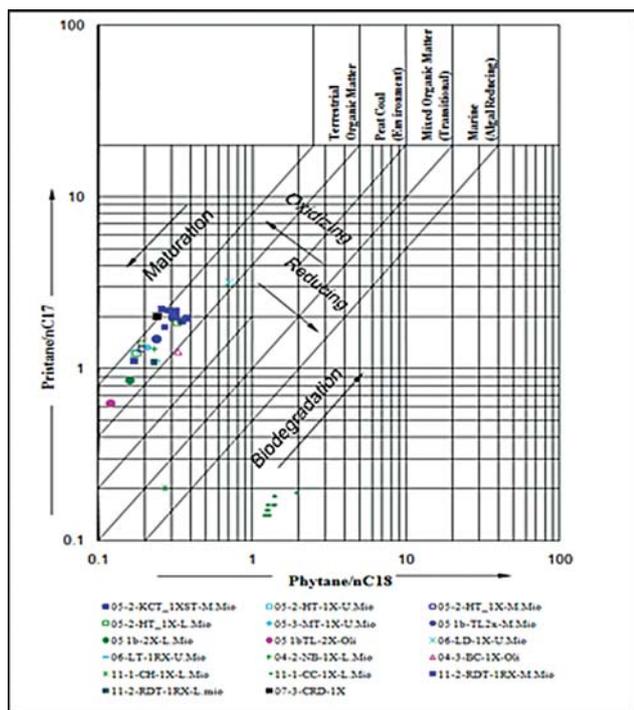


Fig.2. Pr/n_{C17} and Phy/n_{C18} ratio diagram

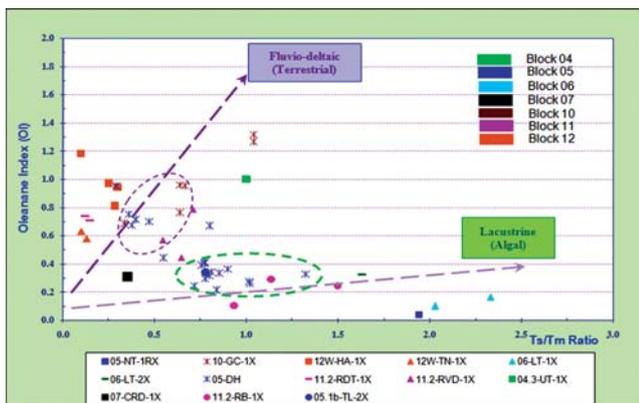


Fig.3. Oleanane and Ts/Tm ratio diagram

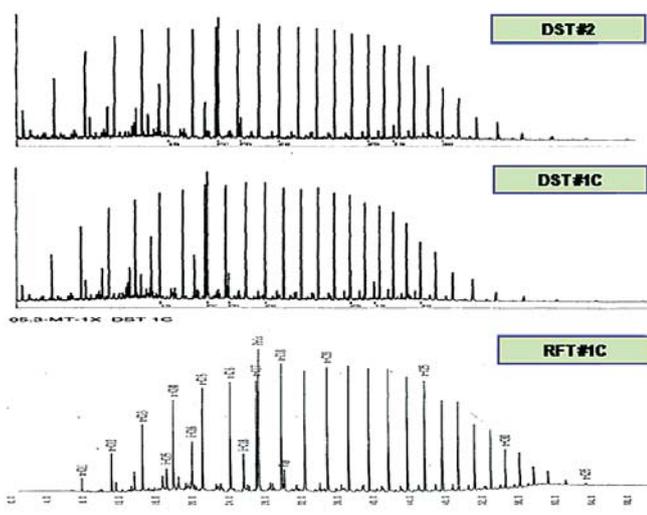


Fig.4a. C15+ gas chromatography of crude oils in Moc Tinh structure [2]

In the Moc Tinh structure, crude oils were found at the MT-1X and MT-1RX wells. According to the results of GC analysis for the saturated hydrocarbon fraction of 2 crude oil samples DST#1c and DST#2 at the 05-3-MT-1X well and RFT#1c sample at 2,849.5mBRT at the 05-3-MT-1XR well, all three samples have C15+ distribution of saturated hydrocarbon in arch shape. This is typical for mature organic matter (Fig.4a). In addition, all these samples have high Pr/Phy ratios (6.14; 5.92 and 4.48 respectively). Therefore, the source rocks have been mature and contained mainly higher plant organic matter (with kerogen type 3).

In Triterpane distribution in m/z 191 fraction, Moretane and Oleanane constituents are typical for organic matter derived from higher plants. All samples have Oleanane (peak B) and Bicadinane constituents which are reliable signals of terrestrial organic input. Bicadinane is related to plants containing resinite which was found in oils of Southeast Asia. Oleanane which is related to Angiosperms was found only in Cretaceous or younger aged oil and rock samples (Figs.4b and 4c).

In Sterane (m/z 217) distribution, the domination of C₂₉ with C₂₇ and C₂₈ shows the abundance of terrestrial organic matter. Ts and Tm constituents (Figs.4b and 4c) are parameters for evaluating the maturity. In fact, when the maturity increases, the Tm transforms into Ts. Both oil samples have an amount of Ts higher than that of Tm, that means these oils were expelled from highly mature source rocks.

In the Kim Cuong Tay structure, two RFT crude oil samples were found at 3,057m and 3,059m in Middle Miocene reservoirs. Both of them have high Pr/Phy ratios (6.4 and 5.34 respectively).

The Sterane (m/z 217) and Triterpane (m/z 191) distributions of these samples are shown in Figs.5a (RFT 3,057m) and 5b (RFT 3,059m). These distributions have a large amount of Bicadinanes and Oleananes. The Ts/Tm ratios suggest that both of them were generated from source rocks in the oil window phase. The Hopane distribution (Fig.5b) is different from extended Hopane distribution in which the height of C₃₁ to C₃₅ peaks decrease with the increase of the number of carbon atoms. It also illustrates that these source rocks were deposited and degraded in a stronger reducing environment.

Four condensate samples and one oil sample were found in the Hai Thach structure. The results of saturated hydrocarbon GC analysis of these samples show that they have abundant n-alkane fraction and rather high

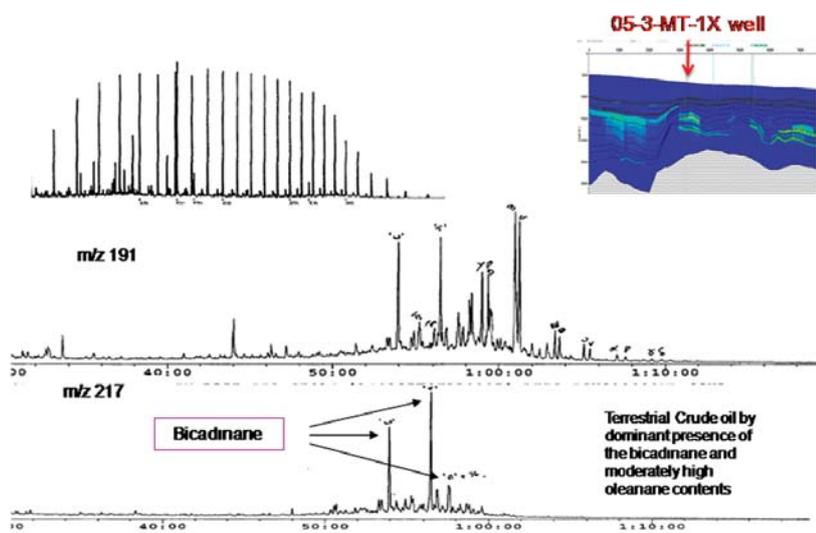


Fig.4b. The results of GC and GCMS analysis of crude oil sample (DST#2 - 3,075.5m) in Miocene reservoir at the 05-3-MT-1X well [2]

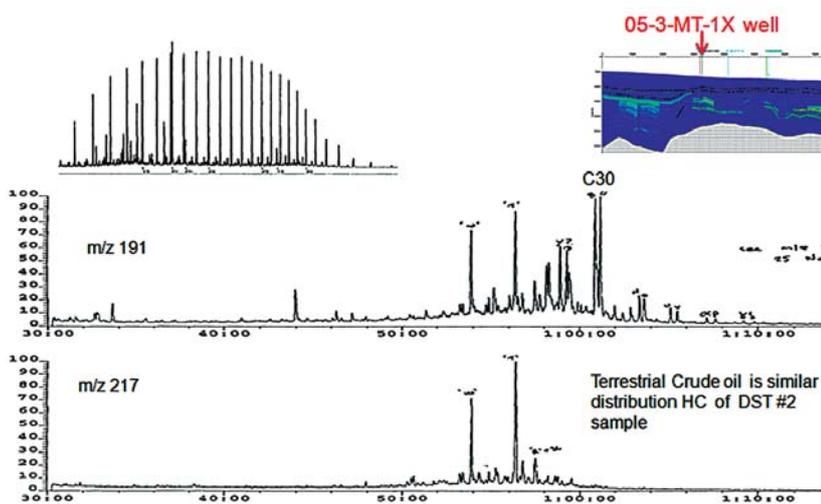


Fig.4c. The results of GC and GCMS analysis of crude oil sample (DST#1C, 3,136.5m) in Miocene reservoir at the 05-3-MT-1X well [2]

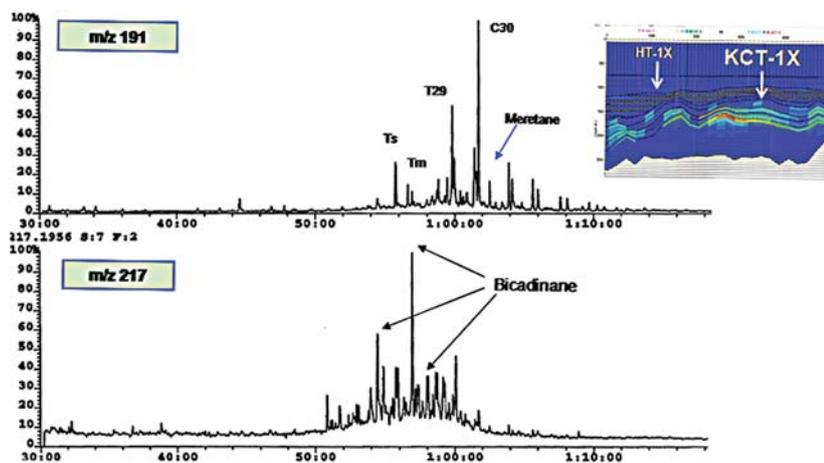


Fig.5a. The results of GCMS analysis of crude oil sample (RFT, 3,057m) in Middle Miocene reservoir at the 05-2-KCT-1X well [2]

Pr/Phy ratios (from 5.43 to 6.93). Therefore, their source rocks contained mainly organic matter derived from higher plants (Table 1).

They also have similar Sterane (m/z 217) and Triterpane (m/z 191) distributions which have abundant Bicadinanes and Oleananes. Very clearly seen are the very high Oleanane/C30 ratios of all these samples (from 114.68 - 130.79). In addition, the Ts/(Ts + Tm) ratios, also rather high (0.4 - 0.47), show that these samples were derived from highly mature source rocks.

The differences between condensates and oil in the Hai Thach structure and oils/condensates in the Moc Tinh, Kim Cuong Tay and Nguyet Thach structures are the majority of C₂₉ in Triterpane (m/z191) distribution and the presence of C₂₅ and C₃₀ Norhopane. These are bio-signals of marine organic input.

The results of whole oil GC analysis of the RFT oil sample at 2,864m in 05-2-NT-1X clearly show that the light hydrocarbon fraction was lost. The Pr/Phy ratios from the saturated hydrocarbon GC analysis are low. This is different from those of oils above.

The presence of C₃₀ 4 methyl Steranes and Diasterane constituents is typical of the Stearane distribution which shows the trace of lacustrine organic matter and rich shale environment. In Triterpane distribution, Bicadinane constituent is quite rich, in contrast, Oleanane is absent. In general, oils could be generated from lacustrine source rocks containing mix of algal and higher plant organic input.

3. The results of carbon isotope analysis of gas and crude oil samples

In the relationship diagram between carbon-13 isotope of Methane and Ethane (Fig.8a), the gas sample of the MT-1RX well is related to associated gas in the oil window phase.

Meanwhile, gas of the HT-1X well was generated in the dry gas phase. The results of carbon isotope analysis of DST and RFT gas samples from wells such as 06-LT-OBS1, 06-LT-1XR, 06-LT-2X (1,662 - 1,672m), 06-LT-1XR and 06-LT-2X (1,682m) show that gas samples of 06-LT-1XR and GK 06-LT-1XR wells are a mix of petroleum gas and biogas. The presence of biogas in these gas samples suggests that the structures are open.

Gas of the 06-LT-OBS1, KCT-1X ST1 and LT-1X wells are related to the oil window phase. On the other hand, gas of the HT-1X well was generated in the dry gas phase.

The carbon isotope analysis of gas samples shows various things as follows:

- There were two sources of gas:
- + Gas was generated in the transformation processes of organic matter in source rocks;
- + Biogas.
- The hydrocarbon accumulation potential of reservoirs.

In the exploration process, evaluating the generating potential is one of the three basic factors to study about petroleum systems. In the exploitation, identifying the interformation capacity in product fields plays an important role in modeling the fields. Moreover, the results of carbon-13 isotope analysis of oil samples are useful data for classifying the origin of oils.

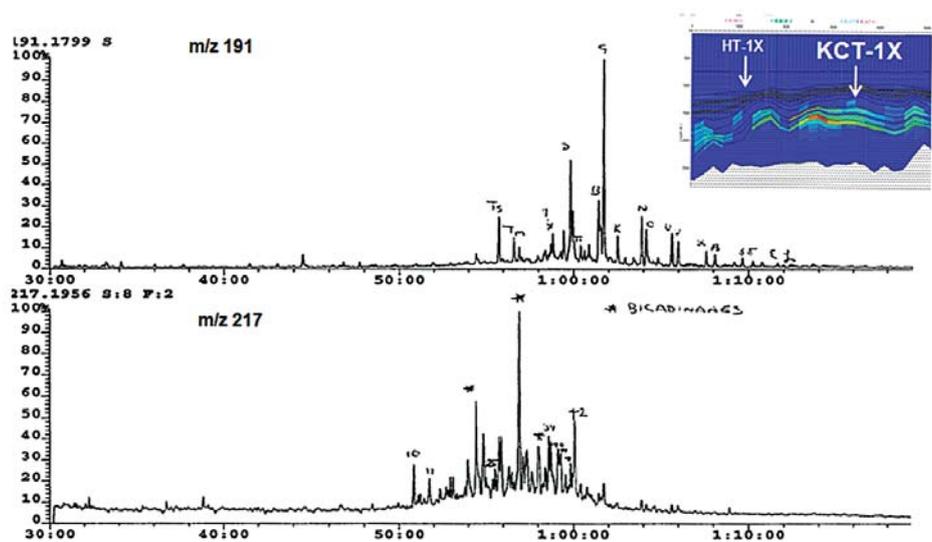


Fig.5b. The results of GCMS analysis of crude oil sample (RFT, 3069.5m) in Middle Miocene reservoir at the 05-2-KCT-1X well [2]

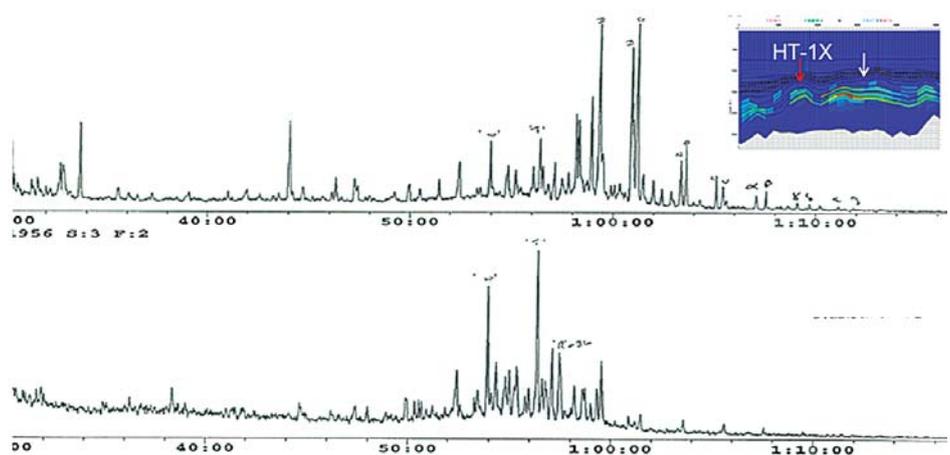


Fig.6a. The results of GCMS analysis of condensate sample (MDT#2 - 2,956m) in Middle Miocene reservoir at the 05-2-HT-1X well [2]

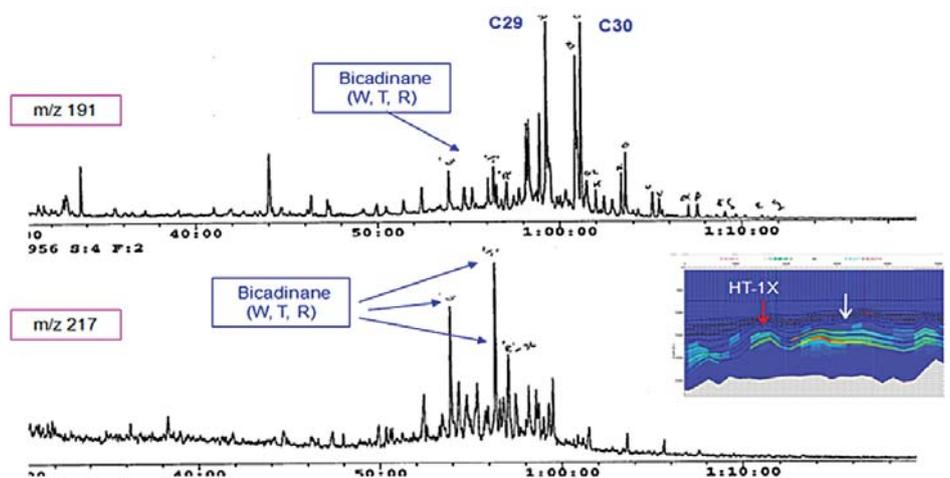
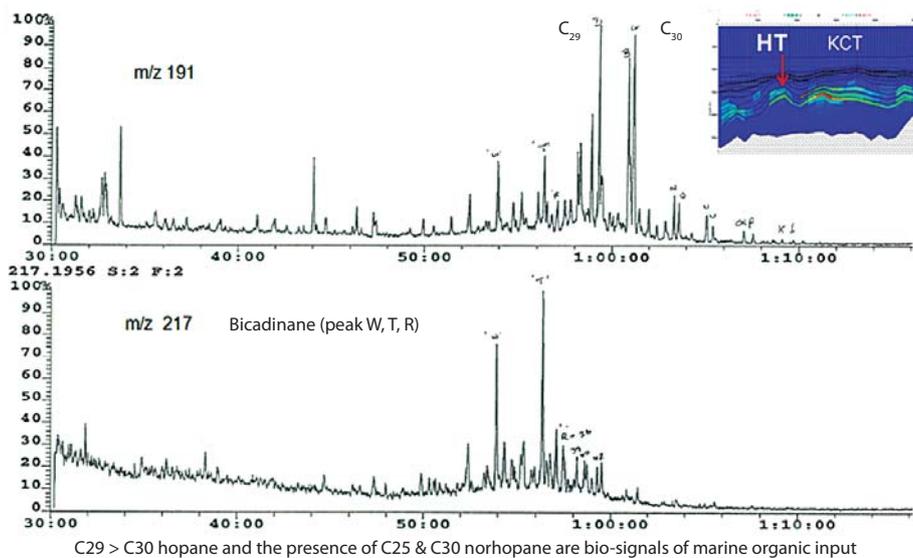


Fig.6b. The results of GCMS analysis of condensate sample (MDT#2 - 3,195.8m) in Middle Miocene reservoir at the 05-2-HT-1X well [2]



C29 > C30 hopane and the presence of C25 & C30 norhopane are bio-signals of marine organic input

Fig.6c. The results of GCMS analysis of condensate sample (MDT#2 - 3,497.2m) in Early Miocene reservoir at the 05-2-HT-1X well [2]

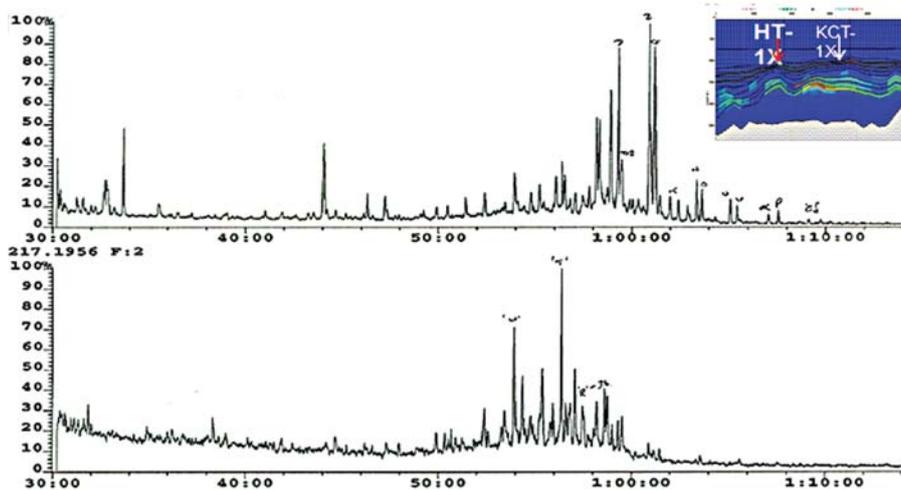


Fig.6d. The results of GCMS analysis of condensate sample (MDT#2 - 3,617m) in Early Miocene reservoir at the 05-2-HT-1X well [2]

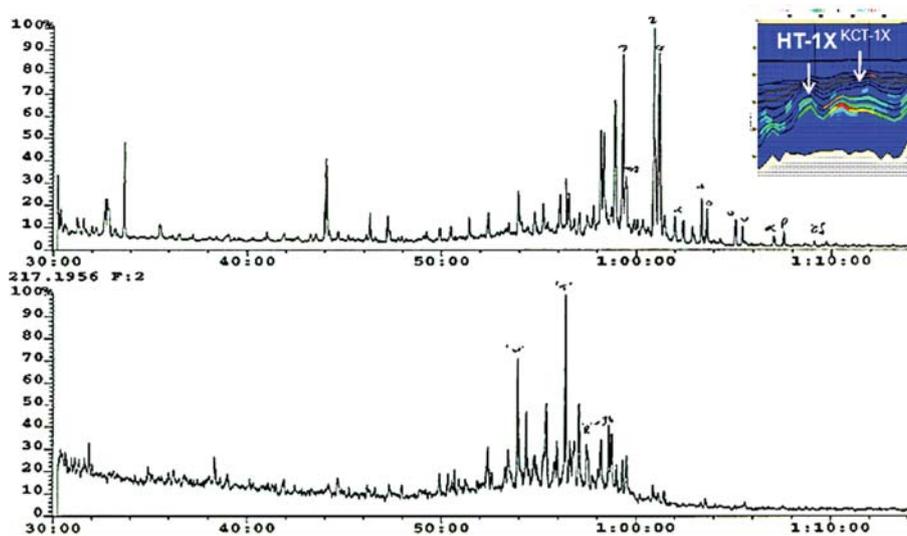


Fig.6e. The results of GCMS analysis of condensate sample (MDT#2 - 3,765m) in Early Miocene reservoir at the 05-2-HT-1X well [2]

Fig.8b (the relationship diagram between the Pr/Phy ratio from GC analysis of saturated hydrocarbon fraction and the results of carbon-13 isotope analysis of crude oils) shows the lacustrine origin of organic matter in source rocks generating oils at the NT-1RX well. Source rocks which generated oils at the HT-2X, MT-1X and KCT-1X wells contained mainly higher plant organic input. This is appropriate to the results of GCMS analysis listed above.

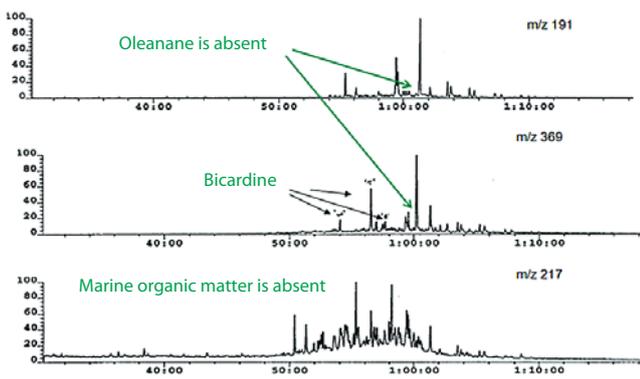
4. Conclusions

- The results of GC and GCMS analysis of crude oil and condensate samples as well as carbon-13 isotope of oil and gas samples are reliable data. The combination of these data is a useful tool to evaluate the origin of organic matter of oil and gas.

- The analysis results, namely GC component of groups, the characteristics of oils and condensates and bio-markers show that oils and condensates found in the Moc Tinh and Hai Thach structures have the following features:

- + Oils and condensates in the Moc Tinh and Hai Thach structures were generated from highly mature source rocks which contained mainly organic matter from higher plants and were deposited and degraded under oxidising and weakly reducing conditions.

- + However, all 5 oil samples in the Hai Thach structure have signals of marine organic input. This means that they originated in fluvio-deltaic source rocks.



The RFT oil sample at 2864m is related to lacustrine source rocks which were deposited and degraded in reducing environment

Fig.7. The results of GCMS analysis of crude oil sample (RFT#2 - 2,864m) in Early Miocene reservoir at the 05-2-NT-1X well [2]

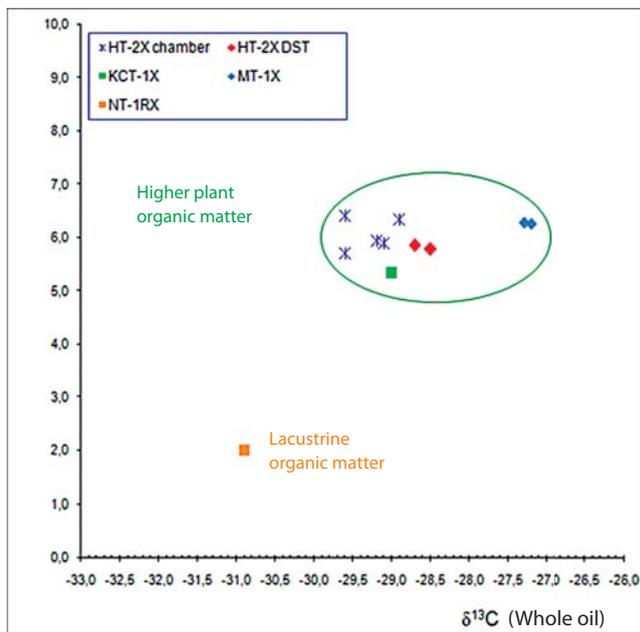


Fig.8b. Classifying the origin of oil by carbon isotope data in Blocks 05-2 and 05-3

- Oils in the Nguyet Thach structure were generated from lower maturity source rocks which contained a mix

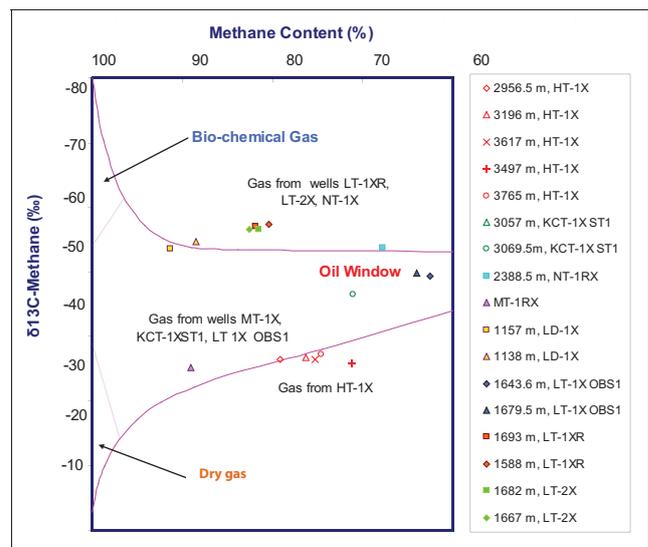


Fig.8a. Classifying origin of gas by the relationship diagram between carbon isotope of methane and methane contents in Blocks 05-2, 05-3 and surrounding areas

of lacustrine and higher plant organic matter, deposited and degraded under reducing and weakly oxidising conditions. The RFT oil sample at 2,864m was destroyed.

- Crude oils and condensates in Blocks 05-2 and 05-3 were generated from Tertiary aged source rocks.

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