Organic Inclusions as an Indicator of Oil/Gas Potential Assessment of Carbonate Reservoir Beds

SHI JIXI (施继锡) AND LAN WENBO (兰文波)

[*Institute of Geochemistry (Guangzhou Branch), Academia Sinica, Guangzhou, 510640*]

Abstract

Organic inclusions could be formed at the stages of either primary or secondary migration of hydrocarbons so long as mineral crystallization or recrystallization takes place in the sediments, presenting a direct indicator of oil/gas evolution, migration and abundance. Based on the study of organic inclusions in carbonate-type reservoir beds of commercial importance from North China, Xingjing, North Jiangsu, Jianghan, Sichuan and Guizhou in China, many inclusion parameters for oil/gas potential assessment of carbonate reservoir beds are summarized in this paper, including: 1) Types of organic inclusion: Commercially important oil beds are characterized by inclusions consisting of either pure liquid hydrocarbons or liquid plus minor gaseous hydrocarbons, while commercially important gas reservoirs are characterized by inclusions consisting of either pure gaseous hydrocarbons or gas plus minor liquid hydrocarbons. 2) Quantity of organic inclusions: The number of organic inclusions in commercially important oil/gas reservoirs is over 60% of the total inclusion percentage. 3) Temperature of saline inclusions: The homogenization temperatures of contemporaneous saline inclusions in oil reservoirs range from 91−161 ℃, while in gas reservoirs from 150−250 ℃). 4) Inclusion composition: In commercially important oil reservoirs, $C_1/C_2=2-10$, $C_1/C_3=2-4$, $C_1/C_4=2-21$, $(C_2-C_4)/(C_1-C_4)(\%)>20$, $(CH_4+CO+H_2)/CO_2$ (molecules/g) $=0.5-1.0$, and in $C_2-C_3-nC_4$ triangle diagram there should be an upside-down triangle with the apex within the ellipse, while in commercial gas reservoirs, $C_1/C_2=10-35$, $C_1/C_3=14-82$, $C_1/C_4=21-200$, $(C_2-C_4)/(C_1-C_4)(\%)<20$, $(CH_4+CO+H_2)/CO_2>1$, and there would be an upright triangle with the apex within the ellipse.

The above-mentioned parameters have been used to evaluate a number of other unknown wells or regions and the results are very satisfactory. It is valid to use organic inclusions as an indicator to assess the oil/gas potential during oil/gas exploration and prospecting. This approach is effective, economic, rapid, and easy to popularize.

Key words: organic inclusion; oil and natural gas; carbonate; organic geochemistry

Purpose and Significance of This Study

Oil/gas reserves in marine carbonate rocks account for a quarter of the total in the world. Carbonate rocks are distributed widely in China, with a long geological history of development and a great thickness. However, they are characterized as being old in geologic age and low in abundance but high in maturity of organic matter. Thus, it is still a problem to be solved urgently how more oil/gas resources could be found in the regions of carbonate rocks as rapidly as possible, especially in such regions as non-tectonic, gently tectonic and highly matured regions. Therefore, it is of great significance to strengthen exploration methodological studies while strengthening the theoretical study of oil/gas generation. The purpose of this study is to make use of organic inclusions as a tool for potential assessment of oils and natural gases, and provide a new approach to oil/gas exploration and prospecting in carbonate rocks.

Grounds for Oil/Gas Potential Assessment

Mineral inclusions are the primary samples for the study of the geneses of rocks and minerals. They could be formed at the stage of either primary migration or secondary migration so long as mineral crystallization or recrystallization takes place in the sediments. Organic inclusions would be formed when the host minerals crystallize in the oil/gas-containing fluids. For this reason, they are a direct indicator of oil/gas migration and the evolution and abundance of organic matter, hence providing an effective tool for oil/gas potential assessment. It is well known that after their formation inclusions have not been subjected to addition of extraneous materials or removal of materials of their own. In addition, either surface samples or core samples to be analysed can all be taken into consideration, regardless of the abundance and evolutionary level of organic matter.

Results and Discussion

A number of inclusion parameters for oil/gas potential asses sment have been established on the basis of a comparative study of the organic inclusions form commercially important and oil/gas-barren reservoir beds in carbonate rock-distributed areas of China.

Types and characteristics of organic inclusions

The basic characteristics of hydrocarbons in ore-forming fluids such as their nature and maturity could be reflected directly or indirectly by the types and characters of inclusions. Commercially important , oil/gas-barren reservoir beds bear inclusions of different types and characters. The types of organic inclusions are presented in Table 1, and for detailed descriptions, see Shi Jixi et al. (1988, 1991). The characteristics of organic inclusions include phase-state, color, shape, fluorescence, etc. Listed in Table 2 are the types of organic inclusions from oil/gas reservoir beds of commercial importance.

Table 1. Classification of organic inclusions

	Type	Composition	Evolution stage	Examples
Hydrocarbon inclusions	1) Pure liquid hydrocarbon inclusions	Consisting of one kind of liquid hydrocarbons	Immature or low mature	Jianghan, Pingquan
	2) Multi-phase liquid hydrocarbon inclusions	Consisting of two or more kinds of liquid hydrocarbons	Low or highly mature	Guangxi, North China
	3) Liquid hydrocarbon inclusions	Consisting of liquid + minor gaseous hydrocarbons	Every stage, but chiefly in the highly mature stage	North China, Jiangsu
	4) Gaseous hydrocarbon inclusions	Consisting mainly of gaseous + minor liquid hydrocarbons	Mainly in the stage of condensate-wet gas	Sichuan, North Guizhou
Hydrocarbon-bearing inclusions	5) Asphalt inclusions	Consisting mainly of solid asphalt, with minor liquid or gaseous hydrocarbons	In the stage of methane	Guangxi, South Guizhou
	6)Pure liquid HC-bearing inclusions	Consisting of liquid HC and saline solutions	Immature or low-mature	Jianghan
	7) Liquid HC-bearing inclusions	Consisting of liquid and gaseous HC and saline solutions	Highly mature	Renqiu
	8) Gaseous HC-bearing inclusions	Consisting of gaseous HC with saline solutions	Wet gas stage	Sichuan

HC Hydrocarbons.

Table 2. Types and characters of organic inclusions in oil/gas reservoir beds of commercial importance

Reservoir beds	Organic inclusion type	Characters of organic inclusions				
		V/L (%)	Color	Shape	Fluorescence	Freezing
Gas reservoir beds of commercial importance	1. PLHC consisting of pure liquid HC	0	Yellow, brownish-yellow, colorless	Longbar-shaped, irregular	Bright yellow, yellow green	<-140 ℃
	2. LHC consisting of liquid + minor gaseous HC	5−60	Brownish-yellow	Elliptic, irregular	Brownish-yellow, blue	ibid.
	3. TC consisting of liquid and gaseous HC with asphalts	10−20	Brownish yellow liquid+grey gas+black asphalt	Nearly round	Brownish-yellow	ibid.
	4. LHCB consisting of liquid HC+saline solutions		Brownish-yellow liquid HC +colorless saline solution	Irregular	Brownish-yellow	ibid.
Oil reservoir beds of commercial importance	1. PGHC consisting of gaseous HC	100	Grey, brownish-grey	Round, elliptic	No	No freezing
	2. GHC consisting of gaseous and minor liquid HC	95	Greyish-black gas and brownish-yellow liquid	Round, elliptic	Liquid with dark blue fluorescence	Liquid frozen at <-140 ℃
	3. GHCB consisting of gaseous HC and minor saline solutions	90−95	Greyish-black gas and colorless liquid	Round, elliptic	No	Liquid frozen at −0 ℃
	4. GHC consisting of gaseous HC and minor asphalts		Greyish black gas and black asphalt	Irregular	No	No freezing

HC: Hydrocarbon;
V/L(%): $=V_g/(V_g+V_l)\times 100$;
PLHC: pure liquid hydrocarbon inclusion;
LHC: liquid hydrocarbon inclusion;
TC: thick-walled and copper coin-shaped organic inclusions;
LHCB: liquid hydrocarbon-bearing inclusion;
PGHC: pure gaseous hydrocarbon inclusion;
GHC: gaseous hydrocarbon inclusion;
GHCB: gaseous hydrocarbon-bearing inclusion.

Quantity of organic inclusions

The abundance of oil/gas in reservoir beds is highly expected, in some sense, to be reflected directly by the quantity of organic inclusions consisting of liquid or gaseous hydrocarbons. The absolute quantity of inclusions is dependent on the amount of crystal defects on the surface. The relative quantities of organic inclusions to the contemporaneous saline inclusions, however, are dependent on the abundance of oil/gas in the ore-forming fluids. If the fluids are predominated by hydrocarbons, organic inclusions would exceed saline inclusions in number. Therefore , we can make use of the quantities of organic inclusions to assess the abundance of oil/gas in reservoir beds. Listed in Table 3 are the statistical results of the quantities of organic and saline inclusions in various carbonate reservoir beds. Generally, the quantities of organic inclusions in commercially important reservoir beds are over 4 times greater than those in oil/gas-barren reservoir beds.

Paleotemperature

The expelling of hydrocarbons from source rocks and their accumulating to form an oil or gas pool are both closely related with the temperature and pressure. As the temperature rises, organic matter will be converted to liquid hydrocarbons, and the liquid hydrocarbons begin to disappear, resulting in gases as the temperature continues increasing. Thus, the paleotemperature is also an indicator of oil/gas potential assessment. Presented in Table 4 are the homogenization temperatures of the contemporaneous saline inclusions from various carbonate reservoir beds. It can be seen from Table 4 that the temperature values for commercially important gas reservoir beds range from 150 to 250 ℃ , while for commercially important oil reservoir beds from 97 to 161 ℃ .

Composition of inclusions

The composition of inclusions may shed light on the original composition of diagenetic fluids from which the inclusions were formed. Prospective practice shows that regular changes in compositions of inclusions would take place, as reflected in their redox parameter, humidity, percentage of gaseous hydrocarbons and light hydrocarbon ratios as the crude oils evolved from the low maturity stage to the final stage of methane. Listed in Tables 5 and 6 are the compositions and parameters of inclusions from oil/gas reservoir beds of commercial importance. From Tables 5 and 6 we can see that in commercially important oil reservoir beds the redox parameter is less than 1.0, the humidity is greater than 10, and the light hydrocarbon ratios are: $C_1/C_2=2-10$, $C_1/C_3=2-14$ and $C_1/C_4=2-21$; while in commercially important gas reservoir beds the redox parameter is greater than 1.0, the humidity is less than 10, and the light hydrocarbon ratios are : $C_1/C_2=10-35$, $C_1/C_3=14-82$, and $C_1/C_4=21-200$. According to the geochemical exploration results of Lin Renzi et al. (1985)[1)] and Li Benchao (1990), the light hydrocarbon ratios plotted in the semi-logarithm diagram can be used to distinguish directly the oil-bearing or gas-bearing from oil/gas-barren reservoir beds, as shown in Fig. 1.

Furthermore, on the basis of the percentages of ethylane, propane and n-butane, a triangle diagram could be constructed as follows: the base lines could form a base triangle ABC, while the percentage values of ethylane, propane and n-butane in inclusions can form a new diagnostic triangle A' B' C'. If the apex C' is upright, it implies that the reservoirs are gas-bearing, otherwise oil-bearing. Additionally, if the intersection of AA' with BB' is within the ellipse, it suggests that the reservoirs are oil/gas-bearing (see Figs. 2 and 3).

The inclusion parameters for oil/gas potential assessment are summarized in Table 7.

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1) Lin Renzi and Li Maowen, 1985, Geochemistry of Light Hydrocarbons.

Table 3. Quantities of organic inclusions in oil/gas reservoir beds of commercial importance

Reservoir	Sample locality	Age	Quantity of organic inclusions: Gaseous HC inclusion	Saline inclusion	Liquid HC inclusion
Gas reservois beds of commercial importance	Well at Huangchaoxia in eastern Sichuan	Tf	60	45	5
	Well at Fuchenzhai in eastern Sichuan	Tf	70	20	10
	Well at Bandong in eastern Sichuan	P	80	20	0
	Well at Tieshan in eastern Sichuan	C	90	10	0
	Well at Weiyuan in southern Sichuan	Z	85	15	0
	Well at Taihe in northern Guizhou	S	80	15	5
	Well at Wanglong in northern Guizhou	P	75	10	15
Oil reservoir beds of commercial importance	North China oilfield	Z	0	10	90
	Subei oilfield	T	few	5	95
	Well in eastern Sichuan	T	5	25	70
	Well in central Sichuan	J	0	10	90
	Well in Xinjiang	T	0	15	85

HC: Hydrocarbons.

Table 4. Homogenization temperatures of inclusions from various reservoir beds

Reservoir bed	Sample locality and age	Homogenization temperature
Oil bed	Tertiary, Jianghan	61−110
	Sinian, North China oilfield	120−145
	Permian, Jianghan oilfield	146−161
	Triassic, Subei oilfield	109−130
	Tertiary, Dagang oilfield	100−134
	Triassic, Xinjiang	122−137
Gas bed	Permian, western Sichuan	190−260
	Triassic, Permian, and Carboniferous, eastern Sichuan	150−255
	Sinian, southern Sichuan	158−320
	Permian and Silurian, northern Guizhou	130−200

Table 5. The gas composition of inclusions and redox parameters

Sample occurrence	Reservoir	Composition(ppm): H_2O	CO_2	CH_4	H_2	O_2	N_2	CO	Redox parameter
S#[a] Permian, Jianghan	Oil	380	12.5	0.65	0.19	m[b]	0.37	m	0.53
A#, Sinian, North China	Oil	200	320.0	6.00	0.80	m	20	40	0.65
H1#, Triassic, E. Sichuan	Gas	425	110.0	84.6	m	m	52	m	2.11
H2#, Triassic, E. Sichuan	Gas	15	10.0	2.00	2.0	m	3.70	4.1	1.19

Redox parameter = $(CH_4 + CO + H_2)/CO_2$(molecules/g).

a: well number; b: minor.

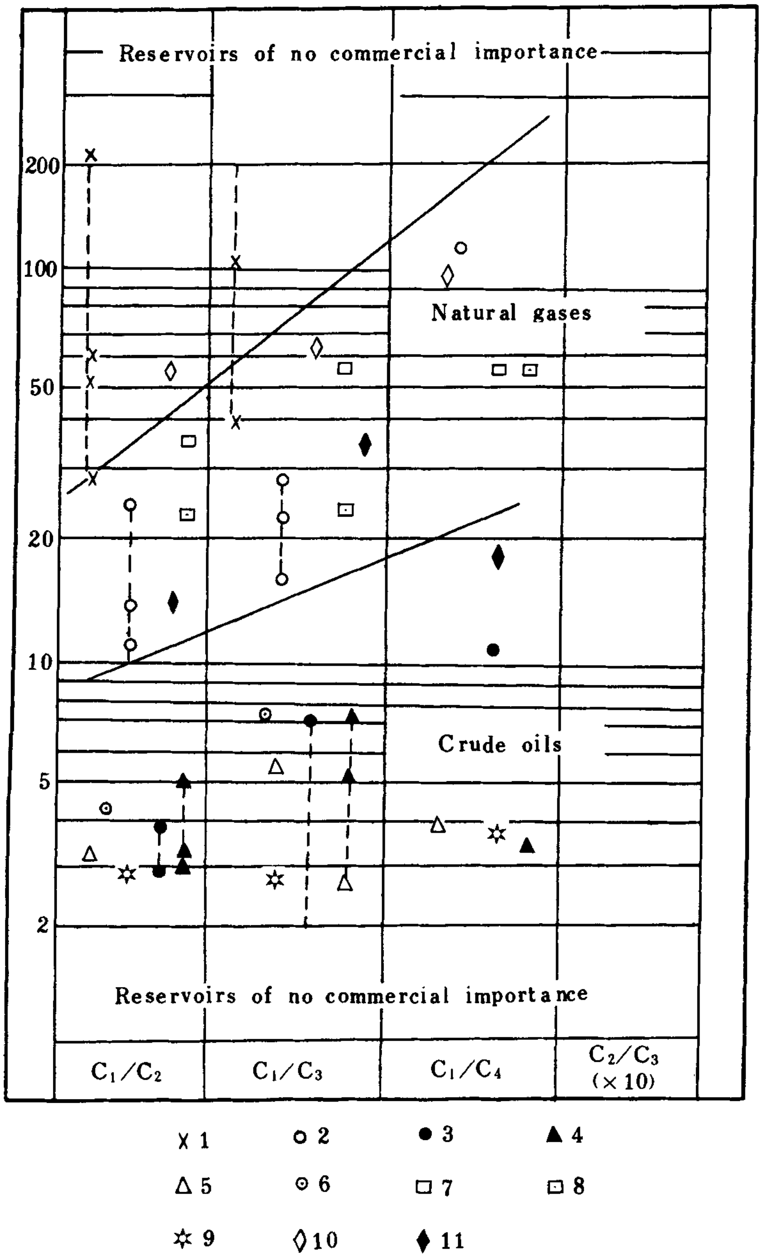

Fig. 1. The semi-logarithm diagram of light hydrocarbon ratios.
1. Guizhou (Z); 2. S.Sichuan (Py); 3. Subei (T) 4. Jianghan (P_1); 5. Jianghan (P_1); 6. E. Sichuan (Tf); 7. E. Sichuan (P_2); 8. E. Sichuan (C_2); 9. well K2#; 10. well K2#(P_1); 11. well K2#(C_2).

Table 6. Constituents and ratios of gaseous hydrocarbons in inclusions

Sample occurrence	Constituent (%)				C_1/C_2	C_1/C_3	C_1/C_4	$(C_2-C_4)/(C_1-C_4)^b$	Reservoir bed
	CH_4	C_2H_6	C_3H_8	nC_4					
D#[a], Triassic, E. Sichuan	62.9	10.3	14.6	12.2	6.63	4.09	13.11	32.0	oil
T5#, Triassic, E. Sichuan	37.9	9.4	5.62	6.0	4.21	7.07	6.60	34.0	oil
G#, Triassic, Subei	87.4	17.2	9.40	3.4	3.90	7.20	14.60	32.6	oil
S#, Permian, Jianghan	56.0	17.0	11.0	11.0	3.30	5.10	3.70	44.0	oil
Q#, Triassic, E. Sichuan	83.0	2.5	16.0	16.0	33.9	50.9	52.66	6.4	gas
T4#, Carboniferous, E. Sichuan	81.6	3.7	3.2	12.0	22.2	25.5	67.93	8.8	gas

a: well number;

b: humidity value=$(C_2-C_4)/(C_1-C_4)$(%).

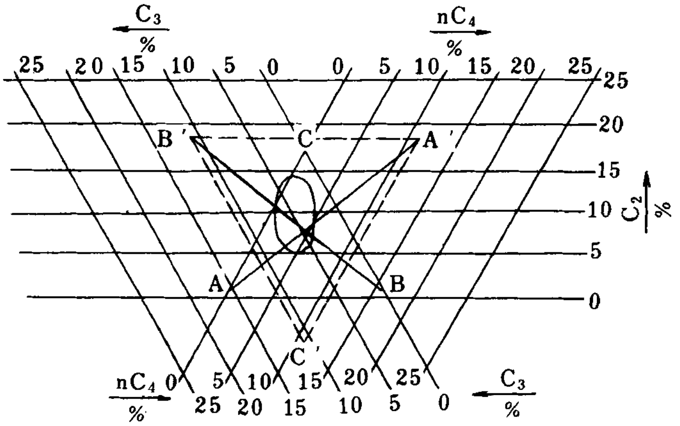

Fig. 2. Triangle diagram of gaseous hydrocarbons in inclusions from oil-bearing reservoir beds, S#(P_1), Jianghan.

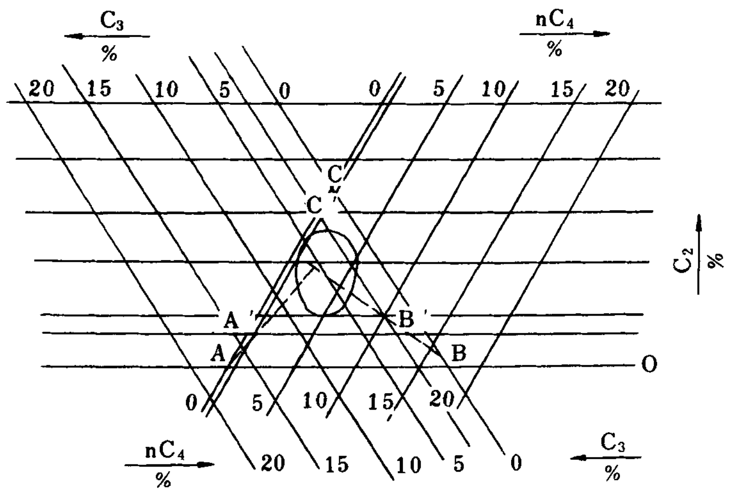

Fig. 3. Triangle diagram of gaseous hydrocarbons in inclusions from gas-bearing reservoir beds, T#(C_2), E. Sichuan.

Examples

Oil/gas potential assessment of the Jurassic, Permian and Carboniferous strata in well K3# under drilling has been made on the basis of the results of inclusion analysis of samples from well K2#, which is 5km far away from well K3# in the same geological structure, i. e., the K-structure in the Sichuan Basin.

Diagenesis and diagenetic sequences

The main purpose of the study of diagenesis and diagenetic sequences is to understand the distribution of organic inclusions so as to determine the homogenization temperatures of the contemporaneous saline inclusions and to collect samples for precise compositional analysis. The diagenetic sequences and inclusion distribution in well K2# are characterized by the following aspects:

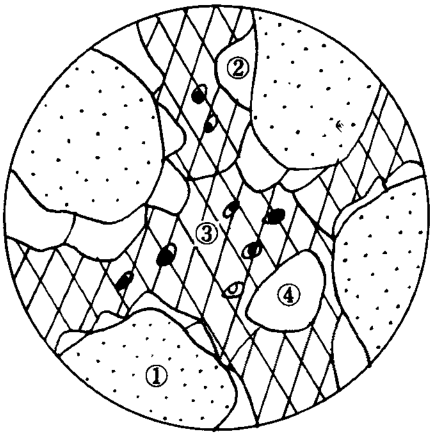

Fig. 4. Bitumen-bearing sugar-like dolomite from well K2#(C_2).
① Dolomite grain; ② semi-euhedral dolomite; ③ sparitic calcite; ④ quartz.

(1) The Da'anzhai Formation of the Jurassic system (Jd): characterized by intercalations of shales with shell limestones in lithology, with calcite filling the shell hides, where a great number of organic and saline inclusions occur.

(2) The Yangxin system of the Lower Permian series (Pl^3): characterized by breccioid micritic limestone in lithology. Fractures are well developed in the rocks, and calcite veins are commonly seen, in which organic inclusions are observed.

(3) The Huanglong Formation of the Middle Carboniferous series (C_2): consisting of bitumen-bearing sugar-like dolomite. Three kinds of minerals occur around the dolomite breccia, whose crystallization follows the order of semi-euhedral dolomite, sparitic calcite and quartz. A great number of organic and saline inclusions are observed in the calcite, as shown in Fig. 4.

Table 7. Inclusion parameters for oil/gas potential assessment

Reservoir	Type of organic inclusion	N[a] (%)	Th[b] (℃)	Gaseous constituents						
				C_2	C_1 – C_3	C_1 – C_4	$\frac{(C_2-C_4)}{(C_1-C_4)}$	Apex[c]	P[d]	RP[e]
Oil reservoir beds of commercial importance	Inclusions consisting chiefly of pure liquid or liquid+ minor gaseous hydrocarbons	>60	60–160	2–10	2–14	2–21	710	Upside-down	Within the ellipse	0.15–1.0
Gas reservoir beds of commercial importance	Inclusions consisting of pure gaseous or gaseous+ minor liquid hydrocarbons or gaseous hydrocarbons with bitumen		151	10–35	14–32	21–200	<10	Upright	Within the ellipse	>1

a: N=percentage of organic inclusions over the total;
b: Th=homogenization temperatures of the contemporaneous saline inclusions;
c: Apex=the apex of the triangle $C_2-C_3-nC_4$ diagram;
d: P=the intersection point of AA' with BB' (see the text);
e: RP=redox parameter, i. e., $(CH_4+CO+H_2)/CO_2$(%).

Types, characteristics and homogenization temperatures of saline inclusions

The results are listed in Table 8. The types and quantities of saline inclusions, especially pure liquid inclusions, and the gas/liquid ratios in the inclusions are all related directly with the temperature. For instance, as the temperature rises, the number of pure liquid inclusions will decrease but the ratio of gas to liquid will increase. From Table 8 we can see that the organic matter in the Da'anzhai Formation strata has evolved to the stage of oil generation as the Th values fall within the range of temperatures of oil-bearing reservoir beds of commercial importance, while in the strata of the Yangxin system and Middle Carboniferous series to the stage of condensate-wet gas as the Th values fall within the range of temperatures of gas-bearing reservoir beds of commercial importance.

Types and quantities of organic inclusions

The results are listed in Table 9.

The Da'anzhai Formation: liquid hydrocarbon inclusions occur mainly in shell limestones and account for 80% of the total, indicative of oil-bearing reservoirs of commercial importance. The inclusions are very small in size($3-5\mu$), but give off strong bright yellow fluorescence (Photo 1). They are difficult to recognize under transmitted light.

The Yangxin system: liquid and gaseous hydrocarbon inclusions are observed in the fillings of calcites of the bio-limestones, which account for 25% and 15% of the total, respectively. The total quantity of organic inclusions is out of the range within which oil/gas-bearing reservoirs of commercial importance fall (see Photo 2).

The Huanglong Formation (C_2): organic inclusions occur in the sparitic calcites of the sugar-like dolomites. They are predominated by those consisting of pure gaseous or gaseous hydrocarbons, accounting for 30−40% (see Photo 3). These inclusions fall out of the range indicative of gas-bearing reservoirs of commercial importance. But in some individual samples organic inclusions come up nearly to 80% of the total (see Photo 4).

Table 8. Types, characteristics and homogenization temperatures of saline inclusions from well K2#

Age	Depth (m)	Inclusion occurrence	Inclusion characteristics				
			Type	PL[a] (%)	V/L (%)	Th (℃) Range	Th (℃) Most cases
Jd	2391	Calcite in shell hides	PL	15	0	105−	110
			WL[b]	5	10	120	
Pl³	4615	Calcite in fractures	PL	5	0	163−	165
			WL	55	5−10	168	
C_2	4198	Early dolomite in dissolved pores	PL	50	0		
			WL	50	5		
		Mid calcite in dissolved pores	PL	3−5	0	173−	175
			WL	45	10−20	179	
	4927	Late calcite in fractures	PL	3−5	0	180−	181
			WL	45	10−20	183	
		Quartz in residual pores	PL	20	0		
			WL	80	5−10		

a: PL=pure liquid inclusion;
b: WL= saline solution inclusion.

Table 9. Types, characteristics and quantities of organic inclusions in well K2#

Age	Depth (m)	Inclusion occurrence	Inclusion characteristics: Type	Quantity (%)	Phase state (%)	Fluorescence: Color	Intensity
Jd	2391	Calcite in shell hides	OL	80	OL, 90 OV, 10	Blue, yellow	Strong
Pl^3	4615	Calcite in fractures	OL OV	25 15	OL, 80−90 OV, 80−60	Dark yellow; no f.	Weak
C_2	4918 4927	Early dolomite in dissolved pores	n				
		Mid calcite in dissolved pores	OL OV	10 30−40	OL, 90−80 a, 5−10 OV 80−100	Blue, green; no f.	Weak
		Late calcite in fractures	OL OV	10 30−40	OL, 90−80 OV, 80−100	Green, blue; no f.	Weak
		Quartz in residual pores	n				

OL: Liquid hydrocarbon;
OV gaseous hydrocarbon;
a: bitumen;
n.: no organic inclusion;
no f.: no fluorescence.

Table 10. Gaseous hydrocarbons in inclusions from well K2#

Stratigraphy	Gaseous HC composition (μl/g): CH_4	C_2H_6	C_3H_8	iC_4	nC_4	C_1/C_2	C_1/C_3	C_1/C_4
Jd	125.88	43.13	42.97	14.01	32.91	2.92	2.93	3.83
C_2	6.20	0.41	0.20	0.05	0.35	15.12	31.00	17.71
Pl^3	12.99	0.23	0.23	0.08	0.14	56.48	56.48	92.79

HC: Hydrocarbons.

Table 11. Light hydrocarbon constituents and humidity values of inclusions from well K2#

Stratigraphy	Reservoir	Analytical value: CH_4 (%) (1) (2)	C_2H_6 (%) (1) (2)	C_3H_8 (%) (1) (2)	C_4 (%) (1) (2)	Total (2)	Humidity $\frac{(C_2-C_4)}{(C_1)-(C_4)}$
Jd	Oil	(1) 46.0 (2) 125.85	(1) 15.8 (2) 43.13	(1) 15.7 (2) 42.97	(1) 11.7 (2) 32.91	272.47	48.3
Pl^3	Gasshows	(1) 89.1 (2) 12.99	(1) 1.6 (2) 0.23	(1) 1.6 (2) 0.23	(1) 0.96 (2) 0.14	14.58	4.4
C_2	Water gasshows	(1) 76.3 (2) 6.20	(1) 50 (2) 0.41	(1) 2.3 (2) 0.20	(1) 4.3 (2) 0.35	8.13	13.5

(1) Percentage of gaseous hydrocarbons in inclusions;
(2) mass unit of gaseous hydrocarbons is μl/g.

The composition of inclusions

The analytical results for gaseous hydrocarbons in inclusions, together with light hydrocarbon ratios, percentages and humidity values, are listed in Tables 10 and 11. Figs. 5, 6, and 7 are the $C_2-C_3-nC_4$ triangle diagrams. The ratios of light hydrocarbons are plotted in Fig. 1. From these parameters and figures it can be seen clearly that the Da'anzhai Formation strata are oil-bearing while the strata of the Yangxin system and Huanglong Formation (C_2) are gas-bearing, but of no commercial importance.

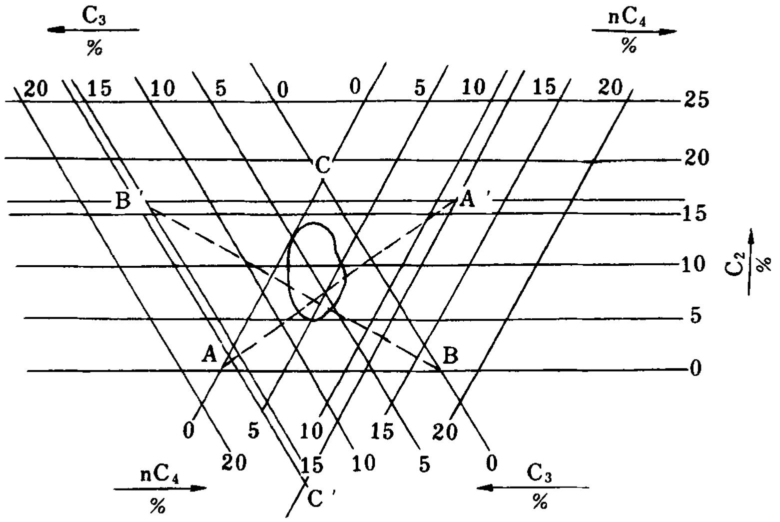

Fig. 5. Triangle diagram of gas constituents in inclusions from well K2#(Jd).

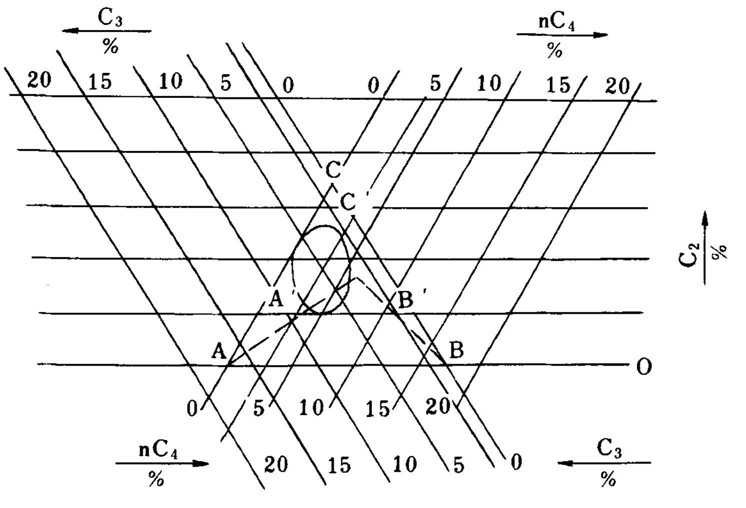

Fig. 6. Triangle diagram of gas constituents in inclusions from well K2#(Pl3).

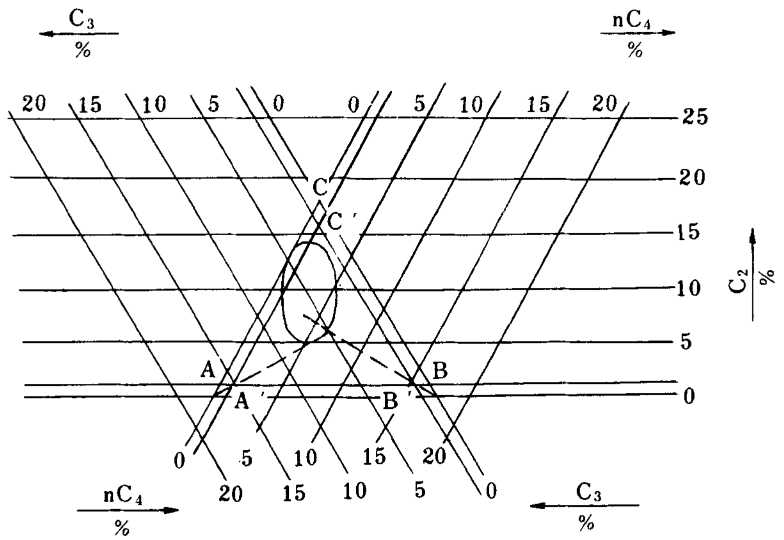

Fig. 7 . Triangle diagram of gas constituents in inclusions from well K2#(C_2).

Conclusions

Inclusion studies have shown that the Da'anzhai Formation strata(Jd) in well K2# are oil-bearing reservoirs of commercial importance, and the strata of the Yangxin system (Pl^3) and Huanglong Formation (C_2) in well K2# are gas-bearing but of no commercial importance. This is in good agreement with the prospective results. Because well K3#, which is close to well K2# in the same geological structure, is consistent with well K2# in diagenetic environments, lithology and porosity, hence of little potential for oils and gases.

Moreover, organic inclusion studies also have shown that it is valid to use organic inclusions as a new approach to make oil/gas potential assessment. This approach is economic, rapid and easy to popularize.

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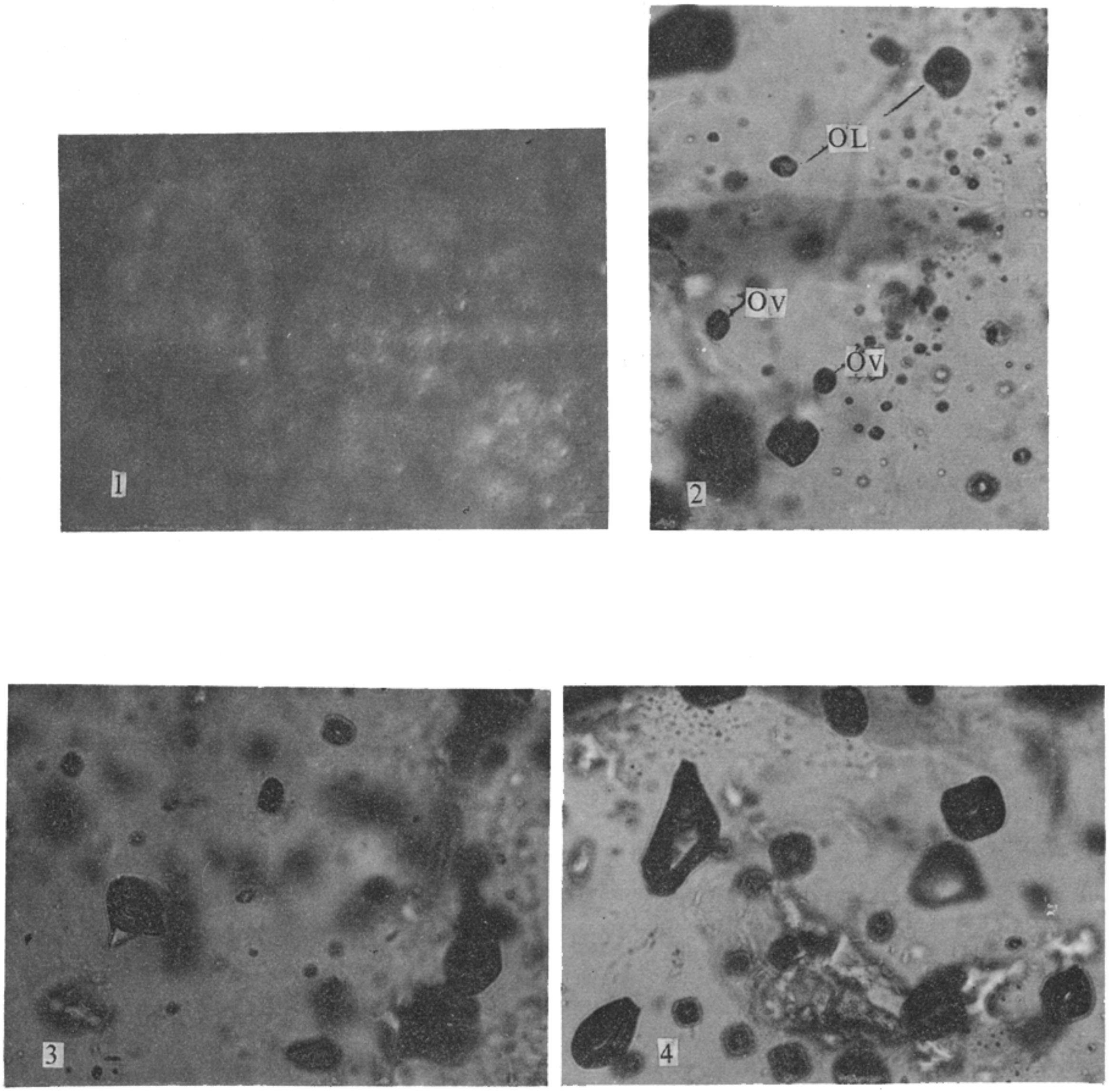

Photos 1−4: 1. Liquid hydrocarbon inclusions in calcite of the sell limestones from well K2# (Jd) (under fluorescent light, x 40). 2. Liquid(OL) and gaseous(OV) inclusions in calcite veins of the bio−limestone from well K2#(P_1^3)(×250). 3. Gaseous hydrocarbon inclusions in late por-efilling calcite of the suger-like limestone from well K2#(C_2), which account for 30−40% in content(×250). 4. Gaseous hydrocarbon inclusions in late pore-filling calcite of the suger-like limestone fromwell K2#(C^2), which account for 80% in content(×250).