Paleogene Strata Characteristics of Source-reservoir-cap Combination in Haibei Sub-sag

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Abstract. Based on the geochemical test and on the basis of core test and analysis, this article carries out the work of hydrocarbon source rock evaluation and reservoir evaluation in Haibei sub-sag Paleogene strata. Studies suggest that the study area has good organic type, high abundance of organic matter and a potential of hydrocarbon generation, good conditions for the development of reservoir and stable regional cap rocks distribution, good source-reservoir-caprock's spatial arrangement and efficiency high expelling-accumulation. According to their relative position and reservoir formation characteristics, formed five sets of source-reservoir-caprock combinations, and the two main types are upper source rocks and lower oil reservoirs, lower source rocks and upper oil reservoirs.

1. Regional Geological Background

Haibei sub-sag is located in the southwest of Hai'an sag in Subei basin. Hai'an sag developed in the Late Cretaceous, with an area of about 3500 km^2, and it is a dustpan-like rift lake basin of Cenozoic era under the influence of regional tension filed, and the basin is north fracture and south overlap[1]. It has developed fracture and fractured structural in the region, formed a strong segmentation pattern of one uplift and seven sags, leaded to oil and gas resources plane distribution more dispersed, and oil reservoir scale is small(Fig. 1). The thickness of Paleogene strata of Hai'an sag is more than 5000m, mainly terrigenous clastic deposits, bottom-up developed Paleogene Paleocene E_1t, E_1f, and Eocene E_2d, E_2s, missing Paleogene Oligocene[2,3] .

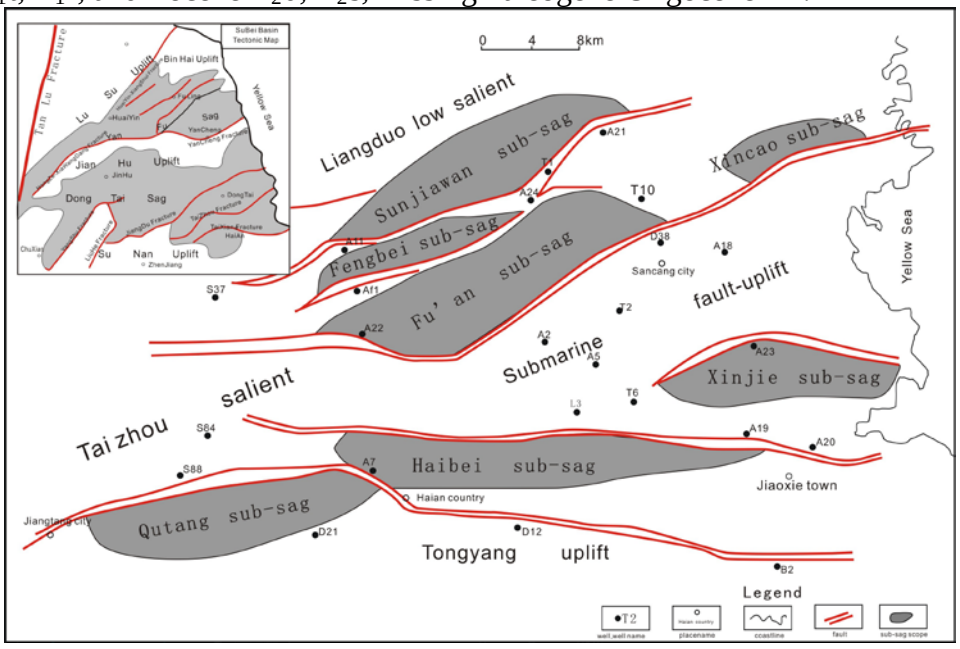

Fig.1 Division of structural unit in Hai'an Sag

2. Source-reservoir-cap Combination

2.1 Source Rock.

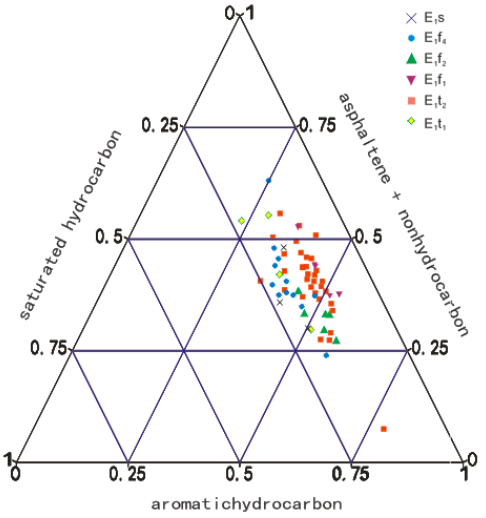

Fig.2 Source rock's group component triangle chart

The oil and gas have been found in the reservoirs, which mainly are from E_1t_2、E_1f_2 and E_1f_4. All the three sets of source rocks are deep lake subfacies sediment, the lithology is mainly the darkgrey mudstone, has high abundance of organic matter, maturation and widely distributed. The high effective source rocks from E_1f_2 are mostly developed in the middle to lower part of E_1f_2, which are mainly made of type I kerogen, the average organic carbon abundance is 1.65%, the potential for hydrocarbon production(S1+S2) is 6.8mg/g etc(Table.1), which belongs to the good hydrocarbon source rock. The high effective source rocks from E_1t_2 are mostly developed in the bottom of E_1t_2, which are mainly made of type I kerogen and type II kerogen(Table.1). The thickness of source rocks are around 25~40m, distributed with sag-wide oil-bearing depressions. The deep sag part of E_1f_4 has development of dark mudstone, which has high burial depth and great hydrocarbon potential(Table.1).

Table 1 Paleogene strata Organic matter abundance statistical table and Kerogen microscopic identification results

Strata	Thickness (m)	Organic carbon (%)	Chloroform bitumen"A" (%)	Total hydrocarbon content (%)	S1+S2 (mg/g)	Organic matter type
E_1f_4	10～35	0.95	0.0296	46.9	1.98	II_1+II_2
E_1f_2	150～250	1.65	0.1881	55.1	6.80	$I+II_1$
E_1t_2	25～40	2.94	0.1802	59.7	17.4	$I+II_{1+2}$

2.2 Reservoir Characteristics.

On the whole, the reservoir space of Paleogene system formation sandstone reservoir is mainly intergranular pore, including primary intergranular pore and intergranular dissolved pore, primary intergranular pore gradually decreased with the increased deep , and secondary solution pores increased conversely,reservoir physical property is dual controlled by the primitive sedimentation and diagenesis. According to the core sample test and analysis results(Table.2), the porosity of reservoir sand mainly distributed in 10.2%~28.9%, the permeability mainly ranges in $1.78\sim778\times10^{-3}\mu m^2$. The reservoir properties is better.

Table 2 Paleogene reservoir rocks general properties in Haibei Sub-sag

Strata	Depth (m)	sample numbers	Density (g/cm^3)	Por (%)	Perm ($\times10^{-3}\mu m^2$)	Sw (%)
E_1s_1	2700～3000	5	2.12	4.1~22.3	0.02~193	11.7~87.2
E_2d	2850～2950	10	2.09	11.8~28.9	1.78~778	54.1~64.3
$E_1f_3^2$	2400～2600	63	2.11	10.2~28.4	0.08~230	5.3~85.1
$E_1f_3^1$	3400～3700	99	2.17	4.0~27.2	0.02~214	13.1~85.5
E_1f_1	2400～3300	6	2.38	6.1~14.3	0.1~0.32	22.5~36.2
E_1t_1	3000～3300	4	2.48	7.3~8.3	0.05~0.13	48.9~76.6

E_1f_3: As the main reservoir in this area , it buried in depth of 2400~3700 m, which can be divided into two sets of sands formation. Rock types are mainly lithic arkose, followed by feldspar lithic sandstone. The diagenesis is mainly cementation, dissolution and metasomatism. Siliceous cementation is more common, mainly for quartz overgrowth cementation and pore filling cementing (Fig.3a, Fig.3b). Dissolution is very development, and improves the permeability of the reservoir (Fig.3c). Common metasomatism is calcite metasomatism of clay minerals and clay mineral metasomatism of feldspar (Fig.3d).

E_1d: The lithology is mainly sandy coarse grained lithic feldspathic sandstone, and the phenomenon of quartz and feldspar overgrowth are more common (Fig.3e), porosity includes intergranular dissolved pore, and has good connectivity (Fig.3f). According to core samples of test and analysis results of two wells, the physical property of E_2d reservoir is better in the region.

E_1s_1: The lithology is mainly the seriate feldspar lithic sandstone, calcite Dolomite cementation metasomatism particles, and the pore mainly includes intergranular dissolved pore, a small amount of dissolved inter-grain pores and kaolinite intercrystalline pore, so connectivity is poor (Fig.3g, Fig.3h).

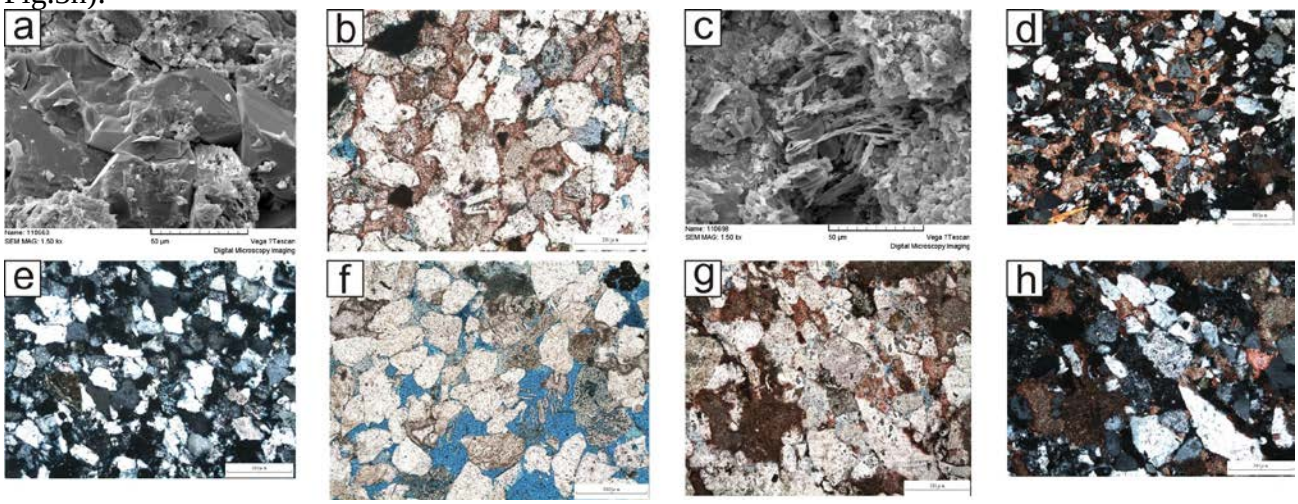

Fig.3 Paleogene reservoir SEM and casting thin sections test in Haibei Sub-sag

a. Quartz increase cementation; b. Calcite metasomatic particle and filling pore(plane polarized light); c. Feldspar leaching; d. Calcite metasomatic particle and filling pore (orthogonal polarization light); e. Quartz and feldspar secondary enlargement (orthogonal polarization light); f. Dissolved pores between grains (plane polarized light); g. quartz and feldspar secondary enlargement (plane polarized light); h. Dissolved pores between grains (orthogonal polarization light).

2.3 Regional Cap rocks.

The extensively developed regional cap rock of Haibei Sub-sag mainly includes: (1)Highstand system track of E_1t_2, mudstone thickness of 40~150m,widespread,is well regional cap rock of E_1t_1 reservoir; (2)Lacustrine transgressive system tracts of E_1f_2, stably developed, mudstone thickness of 100m~500m; (3)Because of denudation, E_1f_4 Mainly distributed in Hai'an area; (4)Lacustrine

transgressive system tracts of E_2s,mudstone thickness more than 800m,can form effective cover to all the overlying stratum.

The above-mentioned stratum is mainly deep-water sedimentary environment, with great thickness mudstone, strong spreading ability and good sealing ability, it can provide good barrier condition to oil-gas accumulation. Besides, the stable mudstone section formed in the period of water-transgression of E_2d, it can be the local seal to form block to sand body of E_2d.

3. Oil and Gas Migration and Source-reservoir-cap Combination

Several sets of source-reservoir-cap combinations have been developed in Haibei sub-sag , Hai'an sag, according to their relative position and reservoir forming characteristics, they can be divided into two main types and five kinds of source-reservoir-cap combination modes(Fig. 4):

(1)Lower source rocks and upper gas-oil reservoirs:

1. Regarding the source-reservoir-cap combination of E_1t_2 dark mudstone as source bed, oil and gas migrant upward through fault, the lower part of E_1f_1 sand body as oil reservoir and the upper of E_1f_1 and E_1f_2 mudstone as caprock, forming structural reservoir.

2. E_1f_2 and E_1f_4 dark mudstone are source bed which are controlled by lithology and fault, then they migrant upward through fault and unconformity, forming reservoirs within E_1f_3 delta sandstone reservoir because of sheltering from E_1f_3 and E_1f_4 mudstone.

3. E_1f_2 and E_1f_4 dark mudstone are source bed, oil and gas migrated upward along fault, forming lithology-structural oil reservoirs within E_2d and E_2s_1 delta sandstone because of sheltering from E_2s mudstone caprock. During accumulation process, E_1f_4 and E_2d mudstone will affect the migration and accumulation of oil and gas as local regional caprocks.

(2)Upper source rocks and lower gas-oil reservoirs:

4. E_1t_2 dark marlstone is both source bed and cap rock, oil source migrated downward through fault to E_1t_1 delta front sand body reservoirs. E_1t_2 lake transgression mudstone is both source bed and high-quality regional cap rock of underlying E_1t_1 reservoir, this section's source-reservoir-cap combination is well matched, expulsion-accumulation efficiency is high.

5. E_2f_2 oil source migrated down to E_1f_1 shallow lake sandbar reservoir through faults, E_1f_2 lake transgression mudstone is both source bed and high-quality regional cap of underlying E_1f_1 reservoir, it forms good combination of upper source rocks and lower oil reservoirs.

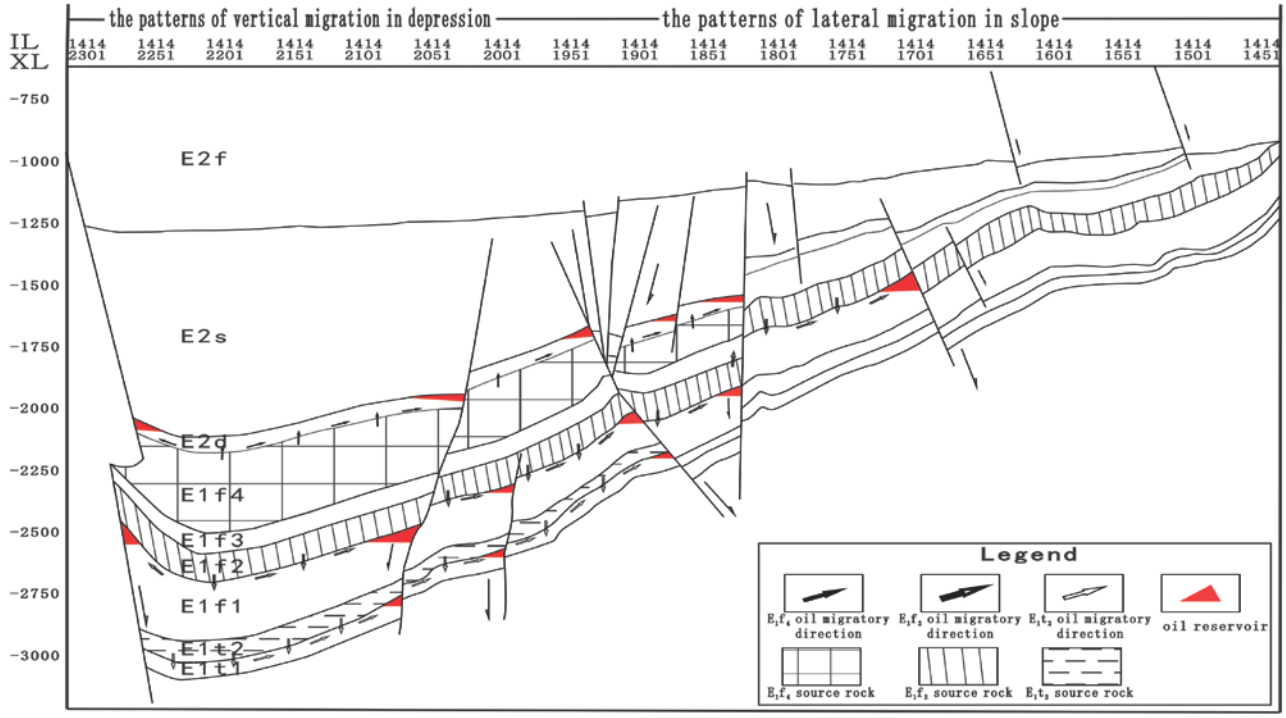

Fig.4 Pool-forming pattern of Paleogene formation in Haibei Sub-sag

4. Summary

(1)The main source rock in Haibei sub-sag Paleogene strata is E_1f_2, followed by E_1t_2, the two sets of source rocks are good organic types and high abundance of organic material. The two sets of source rocks have the ability to expelling hydrocarbon upward to overlying strata and downward to underlying strata, under the communication of oil source fault.

(2)The reservoir section of Paleogene strata in research area are E_1t_1、E_1f_3、E_2d、E_1s_1, E_1f_3、E_2d are the main reservoir section, the reservoir rock types are mainly debris-feldspar in every section, followed by feldspathic lithic sandstone, the diagenesis types are mainly cementation, dissolution, and recrystallization. The physical property characteristics are low-medium porosity, specific low-low permeability reservoirs.

(3)There are two types of source-reservoir-cap combination developed in Haibei Sub-sag, which are upper source lower reservoir and lower source upper reservoir, the type of upper source lower reservoir is the oil sources of E_1t_2, E_1f_2, E_1f_4 respectively through the fault and makes downward migration to the corresponding underlying reservoir, such as E_1t_1 and E_1f_3. The type of lower source upper reservoir is the oil sources of E_1f_2 and E_1f_4 through the fault and makes upward migration to the overlying reservoir, such as E_1f_3, E_2d and E_2s.

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