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Sedimentary style and oil-gas field distribution in western Bohai Bay

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Abstract: The western Bohai Bay is tectonically part of the Bohai Bay Rift System, and includes the Qiku, Nanpu and Cangdong Depressions. Paleogene rift strata consist of three cycles. Usually, the sublacustrine fans or basalts formed at the initial stage of every cycle. The dark shales and turbidites developed at the high level of lacustrine transgression. However, the deltas or evaporates appeared at the regressive stage. The sublacustrine fans or deltas are generally distributed in the marginal part of a depression with humic type kerogen. The dark shales of deep lacustrine facies are located in the inner part containing sapropel type kerogen. The transitional zone consists of interbedded shales and sandstones, with mixed-type kerogen. The major oil and gas fields occur in the transitional zone, around the oil-generating "kitchen". The great oil and gas fields are formed in the areas where big drape anticlines are coincident with sublacustrine fan front or delta front sandstones and are sealed by shales or evaporites. Numbers of small overpressured oil reservoirs are subtley expressed in the mature source rocks in the depression center.

INTRODUCTION

Large quantities hydrocarbon resources occur in sediments of ancient rifts. In the western Pacific continental margins and adjacent mainland, the rift systems are well developed and oil-gas fields have been discovered in some of them. The controlling factors of hydrocarbon accumulation in rifts are tectonic, sedimentological, geochemical, thermodynamic and hydrological (Hu and Qia, 1983). However, such resource accumulation in rifts is mainly a result of interactions between rift forming and sedimentation processes, as examplified in the western Bohai Bay.

TECTONIC SETTING

The western Bohai Bay is located near Tianjin City and Yanshan Mountains. The study region covers approximately an area of 20,000 km^2. Tectonically, it is a part of Bohai Bay Rift System, and includes the Qiku, Nanpu and Cangdong depressions and their adjacent uplifts. The crustal thickness by gravity inversion in the study region is 33 to 36 km from depression to uplift. The crust thickness thins to 31 km in the central part of Bohai Bay (Fig. 1). The block-faulting occurred in the Tertiary and formed grabens and horsts. The Tertiary deposits filled the grabens. The underlying Mesozoic and Paleozoic strata have also been deformed by major tensional faults.

SEDIMENTARY CYCLE AND ENVIRONMENT

In the Bohai Bay Rift System, the Tertiary sedimentary clastics are up to 8 km thick in depressions. The lacustrine deposits in the Paleogene Period are thick, about 5–6 km, but the fluvial deposits in the Neogene Period are thinner, only 2–3 km. A regional unconformity lies between the two.

Generally speaking, the lacustrine facies deposits consist of three sedimentary cycles: (1) the Kongdian Formation (E_1k), (2) the Shahejie Formation ($E_2s_3 + E_3s_2$), and (3) the Dongying Formation ($E_3s_1 + E_3d$). Usually, the basalt and/or sublacustrine fans formed in the initial basal stage of every cycle. The dark shales of deep lacustrine facies and turbidites were deposited during the high stand of lacustrine transgression. However, the deltas and/or evaporites appeared at the regressive stage. The Neogene deposits are fluvial facies and cover all of the depressions and uplifts in Bohai Bay Rift System (Fig. 2).

More specifically, the first sedimentary cycle, Kongdian Formation (E_1k), was deposited in the Paleocene, mainly in Candong Depression, a semi-closed lake. A limited amount of clastic material entered the lake from the eastern uplift and formed a small sandbody near the lake bank, while the evaporates existed in the salination zone and behind sublacustrine uplift in the lake.

The Shahejie-3 Member, (E_2s_3), was deposited in the Eocene and represents the second sedimentary cycle. The sedimentary strata cover the entire lacustrine region which includes Qiku, Nanpu and Congdong Depressions. A large amount of clastic material entered the lacustrine region. The main sandbodies of the sublacustrine fans or fan deltas were distributed in the marginal zones of the depressions. However, the shales of the deep lacustrine facies and turbidites were deposited in the interior part of the depressions (Fig. 3).

The Shahejie-1 Member, (E_3s_1), was deposited in the early Oligocene and belongs to the lower part of the third sedimentary cycle. It contains broader shallow lacustrine facies and narrower deep lacustrine facies than the Shahejie-3 Member. Moreover, sand bars and bioclastic limestone beaches appear in shallow lacustrine environment.

The Dongying Formation, (E_3d), was deposited at the end of the Oligocene and is the third sedimentary cycle. It is a typical regressive deposit. The two biggest deltas in the Tertiary Period are deposited into the inner part of lacustrine region from north and south margins of the depressions. But, the distributive area of deep lacustrine facies is less in contrast to Sha-3 and Sha-1 Members, and is concentrated in the center areas of Qiku and Nanpu Depressions.

SEDIMENTARY FACIES AND OIL-GAS FIELDS

Generally, the sedimentary facies are associated with organic matter in the Bohai Bay Rift System. The marginal lacustrine facies are mainly coarse clastics intercalated with grey and green shales. The grey shales contain humic type kerogen (III type), and sometimes yield heavy oil or natural gas. The deep lacustrine facies in the depositional centers of depressions, are principally dark shales rich in sapropel type kerogen (I type). Because the organic matters have a higher maturity in the depression centers, dark turbidite shales produce overpressured light crude oil or condensate. Distinctly, the transitional zone between the marginal zone and depositional center has some features associated with the former two. The delta front and/or sublacustrine fan front sandstones are interbedded with dark shales. The content of the Paleogene sandstones is about 30–10% in the transition zone. The dark shales here abound in mixed type kerogen, namely humic sapropel type (II_1 type) and sapropel

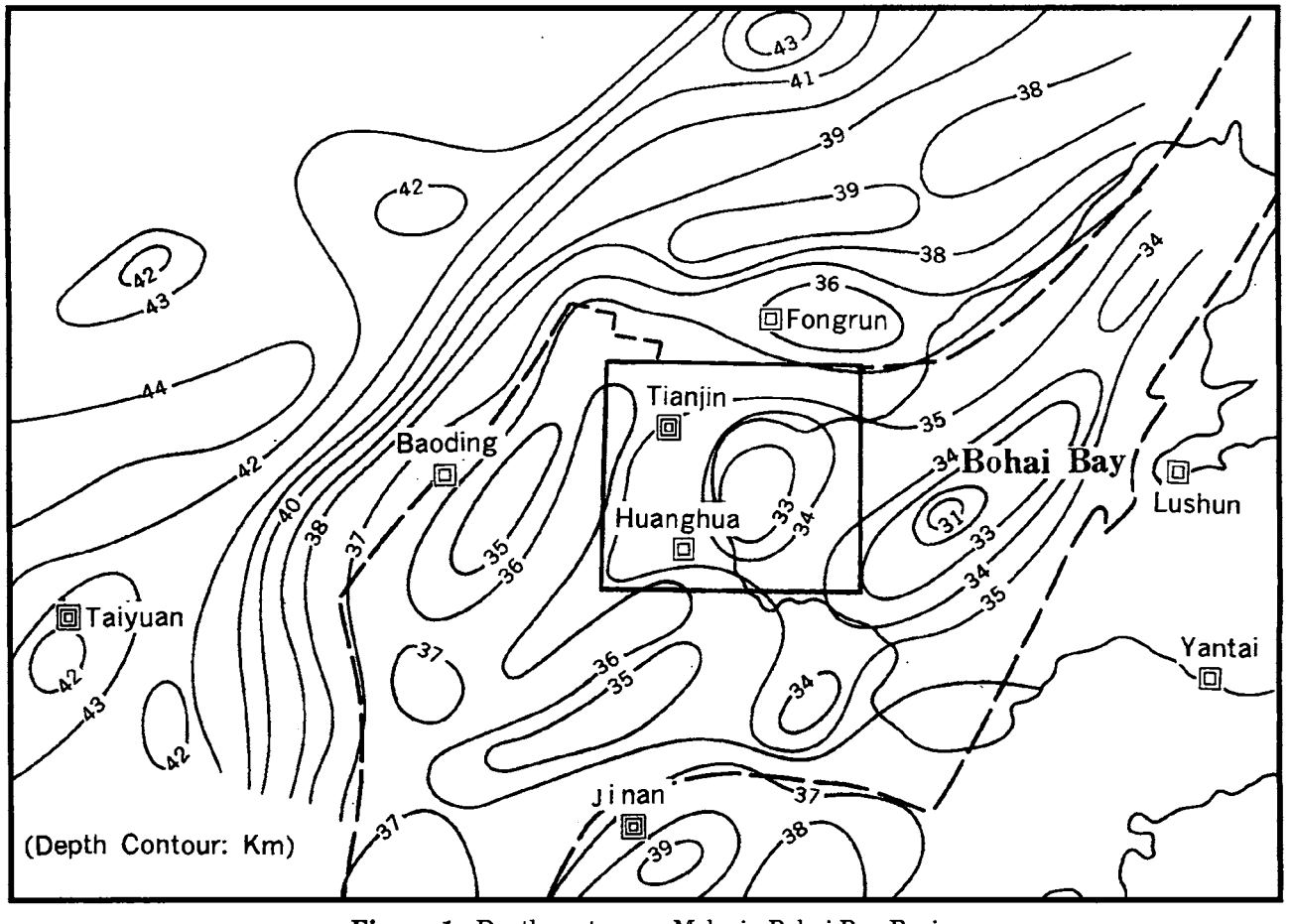

Figure 1. Depth contour on Moho in Bohai Bay Basin.

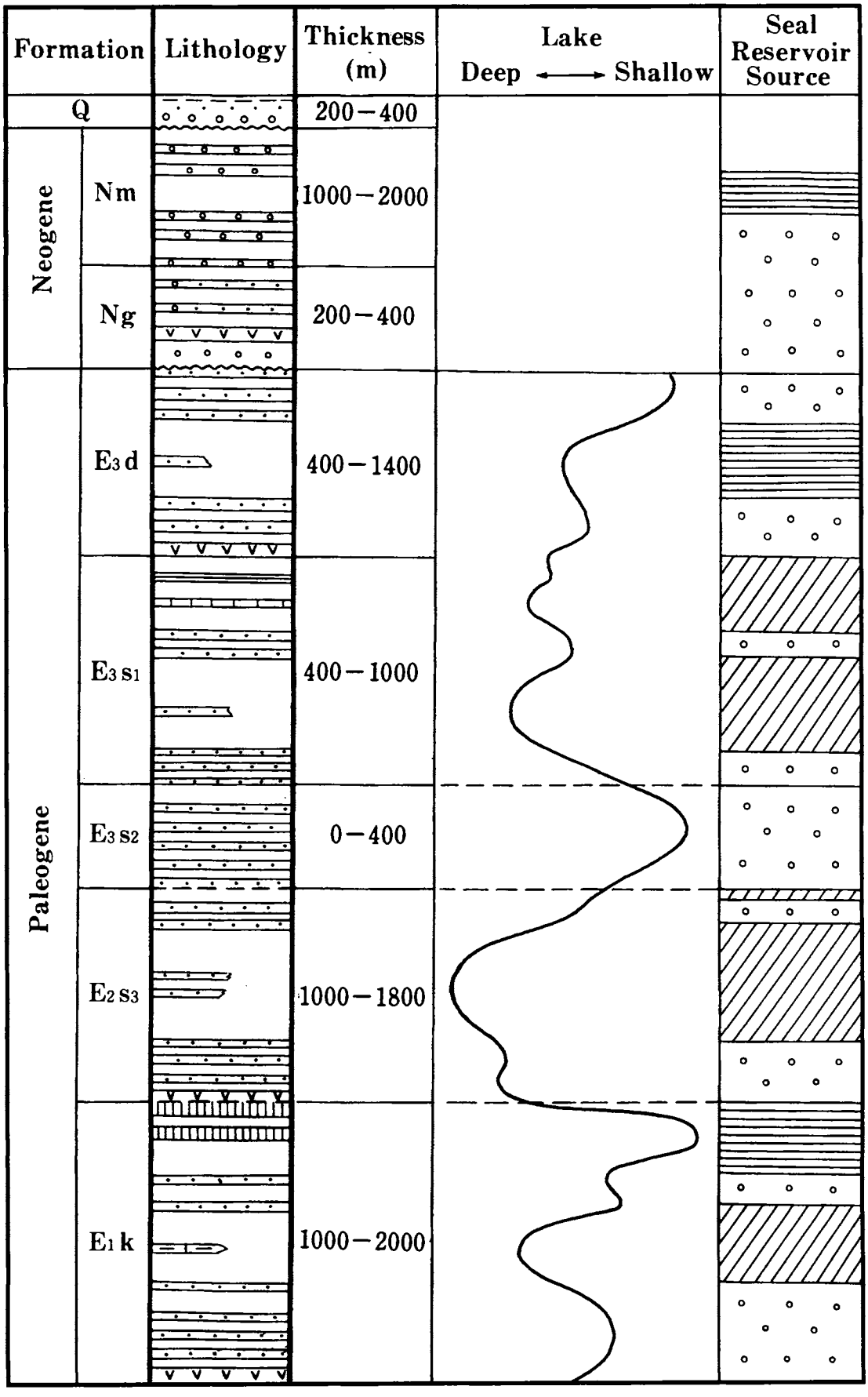

Figure 2. Tertiary profile in western Bohai Bay.

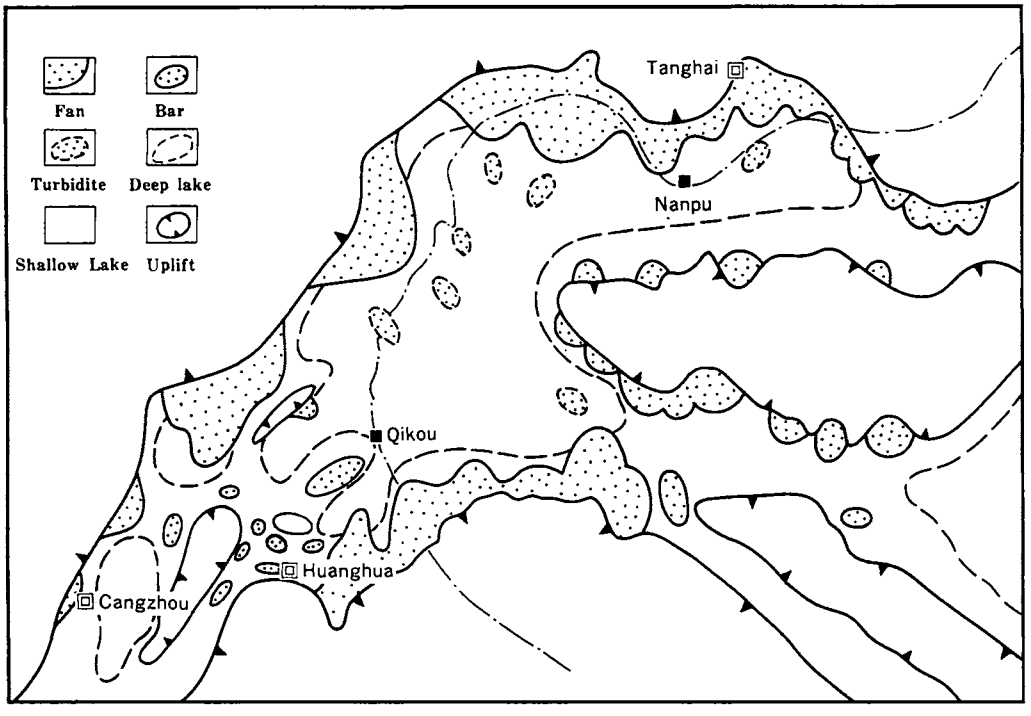

Figure 3. Sedimentary environment of Sha-He-Jie Formation (E_2s_3) in western Bohai Bay.

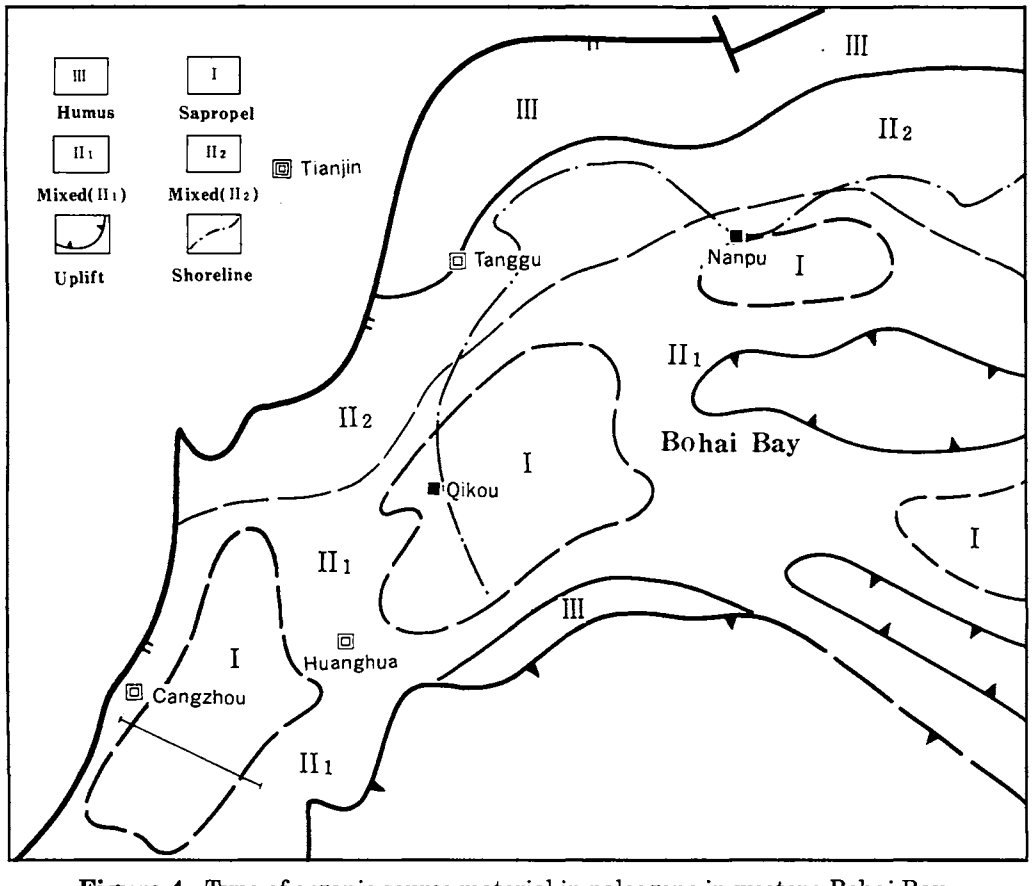

Figure 4. Type of organic source material in paleogene in western Bohai Bay.

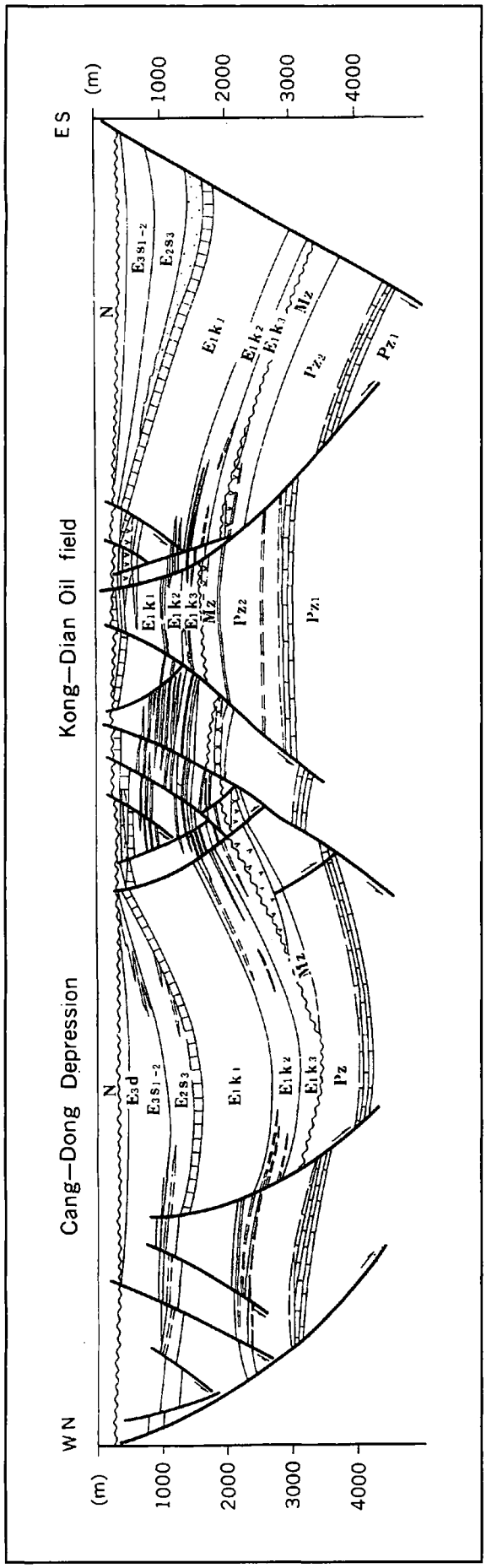

Figure 5. Kong-Dian oil field cross section through Cang Dong Depression.

humic type (II_2 type). Usually, the sandstones and bioclastic limestones are principal reservoirs in which conventional crude oil with solution gas is accumulated (Fig. 4).

In the western Bohai Bay, some large drape anticlines are located within the transitional zones between the marginal sand bodies and source rock depocenters. Because the bigger drape anticlines are usually associated with good source-reservoir-seal assemblages and have good migration-accumulation conditions, some large oil-gas fields formed at the transitional zones. From north to south, the oil-gas fields such as Gaoshangbu, Beidagang, Kongdian (Fig. 5) and so forth are distributed here. The proved reserve is over 1 x 10^8T for each great oil field. Around these oil fields, numerous bioclastic limestone and sandstone pinchouts were deposited around platform margins and adjacent slopes in the transition zones.

CONCLUSION

1. In the western Bohai Bay, the rift deposits are mainly basalts and lacustrine transgressive sediments, such as sublacustrine fans, turbidites and dark shales. The deposits in rift-quiescent period are composed of lacustrine regressive series, for example, fan deltas, prograding deltas or sometimes evaporites etc.
2. The marginal lacustrine facies contain humic type kerogen and sometimes produce heavy oil or natural gas. The deep lacustrine facies in the depocenters are rich in sapropel type kerogen, and where deposited by turbidites these produce overpressured light crude oil or condensate. The transitional zones abound in mixed type kerogen and sandstone reservoirs.
3. The transition zone between the margin zone and the depocenters have good source, reservoir, seal, migration and accumulation conditions. Sometimes, it is compounded with large drape anticlines, forming large oil-gas fields with conventional crude oil and solution gas.

REFERENCES

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