The Difference Between the Tectonic Frameworks of the Onshore and Offshore and Its Cenozoic Evolution: A Case Study from the Qikou Sag in the Bohaibay Basin, China

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Abstract

Qikou Sag is the most important sub-sedimentary and petroliferous unit in Huanghua Depression of Bohaibay Basin, China. Although this basin has been explored for nearly 50 years, the discovery of new reservoirs increased quickly in recent years.

The coast line divides Qikou Sag into west onshore part and east offshore part. Based on detailed interpretation of 3D seismic data covered most area of Qikou Sag, we found a big difference of the tectonic framework between offshore and onshore part of Qikou Sag. From the seismic profiles, the onshore part is characterized by a series of half-graben as domino style and they are separated by rotational fault-blocks controlled the Cangdong fault which is the regional detachment fault. The north boundary of these half-graben are large listric faults and the strata are thinned towards southeast and overlap on the buried fault-blocks. Most structure belts extended NE or NNE at onshore. The seismic profiles from the offshore show a big scale complex graben defined by nearly EW striking faults. At the hanging wall of the north boundary fault, the strata were bent and formed a huge roller fold which is the most potential structure trap in Qikou Sag. The structure trace at offshore is appeared EW or nearly EW tendency.

The difference of the tectonic framework between the onshore and offshore of Qikou Sag is closely related with the regional geodynamics. The subsidence history analysis of Qikou Sag showed that the Cenozoic evolution could be divided into rifting stage and post-rifting stage, meanwhile, the rifting stage were episodic. During the Palaeocene to Eocene, the interaction among the Indian plate, Pacific plate and Eurasia plate caused the upwelling and intensely rifting in Bohaibay Bain. Normal faults rifted along the NE and NNE striking Mesozoic structures at onshore. Several subsidence and deposit centers formed in Qikou Sag. The sediment transported from the Yanshan, Cangxian and Chengning uplift deposited in the half grabens at onshore. At the Oligocene, the opening of Japan Sea and the movement of Philippine Sea strengthened dextral strike slip in the east China. The deep basement fault under the Qikou Sag enhanced the rifting of the EW fault and the depocenter concentrated at the offshore. From the Miocene, the basin was in the thermal subsidence with litter inversion.

The break-slope belt at the coast line and the buried hills around the offshore depocenter are most interest of exploration.

1 Introduction

The Qikou Sag is the most important sub-sedimentary and petroliferous unit in the Huanghua Depression in the middle of the Bohaibay Basin in the eastern China. To the north is the Yanshan Mountain. To the west is the Cangxian uplift which separates the basin from the Jizhong depression. To the south is the Chengning uplift. At the east, it is the Shaleitian rise which is part of the Haizhong uplift besides the Bozhong depression (Fig. 1). Although this basin has been explored for nearly 50 years, the discovery of new reservoirs increased quickly in recent years.

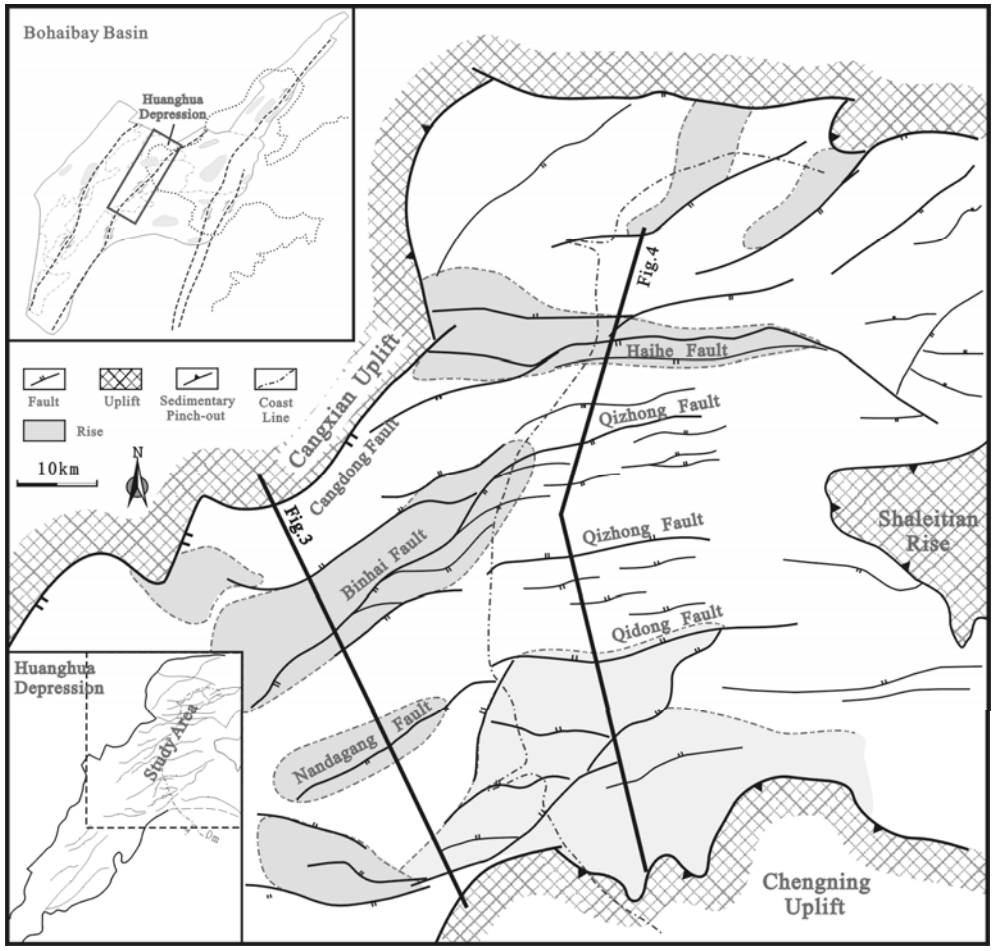

Fig. 1 Geological setting of the Qikou Sag

Paleogene synrift and Neogene-Quaternary postrift megasequences comprise the Cenozoic stratigraphic succession in the Qikou Sag (Fig. 2). The synrift megasequence consists of the Shahejie and Dongying Formation. But there is a loss of the Kongdian Formation (Ek) and the fourth member of the Shahejie Formation (Es4) compared to another areas in the Bohaibay Basin. Combined with the results of the subsidence rate, we divided the rift stage into two episodes. From middle to late Eocene, the third member of the Shahejie Formation (Es3) is widely distributed, whereas the second member (Es2) is present very locally. From early to late Oligocene, the first member of the Shahejie Formation spread widely again and the Dongying Formation was uplifted stably with the shallower lakes. Meanwhile, above the bottom surface of the Guantao Formation is the postrift sequences which are mainly consisted of fluvial and alluvial facies.

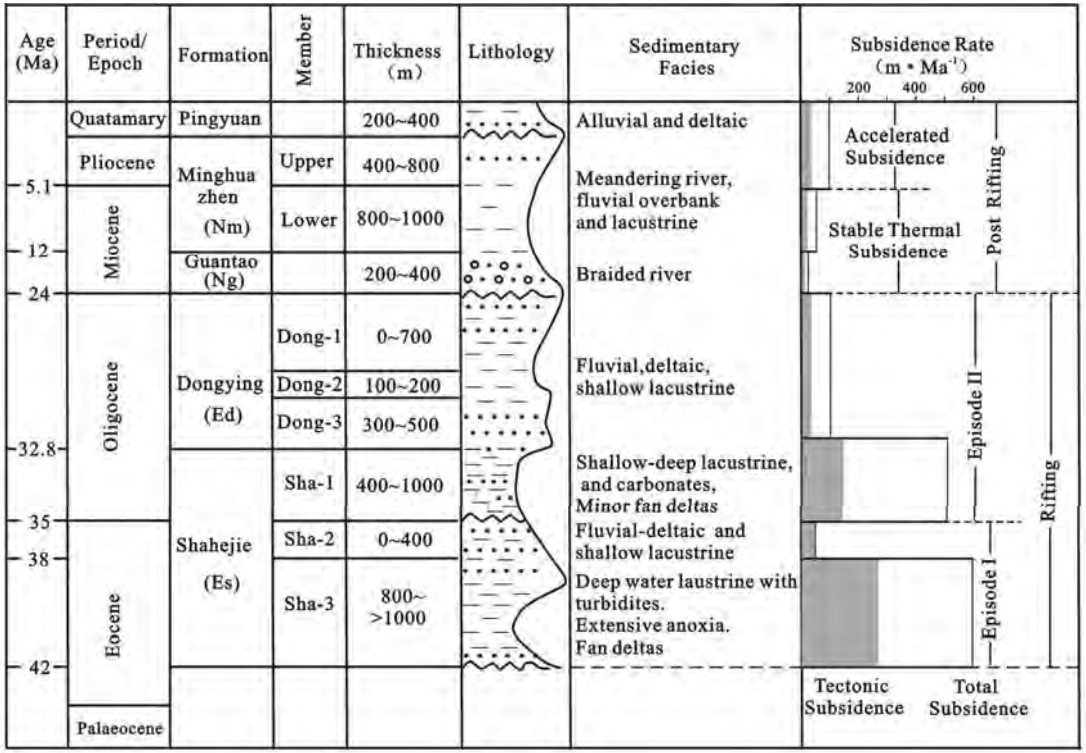

Fig. 2 Tectonic-stratigraphic chart for the Qikou Sag

2 Different tectonic frameworks of the Qikou Sag

The coast line divides the Qikou Sag into west onshore part and east offshore part. Some gravimetric and magnetic maps show there is a regional berried strike-slip fault near the coast line. Based on detailed interpretation of 3D seismic data covered most area of the Qikou Sag, we found a big difference of the tectonic framework between offshore and onshore part of the Qikou Sag.

From the seismic profiles, the onshore part is characterized by a series of half-grabens as domino style and they are separated by rotational fault-blocks controlled by three main faults (Fig. 3). These NE striking and SE dipping faults become gentler from shallow to deep，showing as listric faults. At depth, these faults convergent on the Cangdong fault which is the west boundary and regional detachment fault. In the extension during the Paleogene, the hanging wall blocks of the three large listric faults slipped and counterclockwise rotated, and then formed as tilted buried hills. The syn-riftting strata are thinned towards south, overlap on the gentle slope and formed as wedge. Most structure belts extend NE or NNE at the onshore.

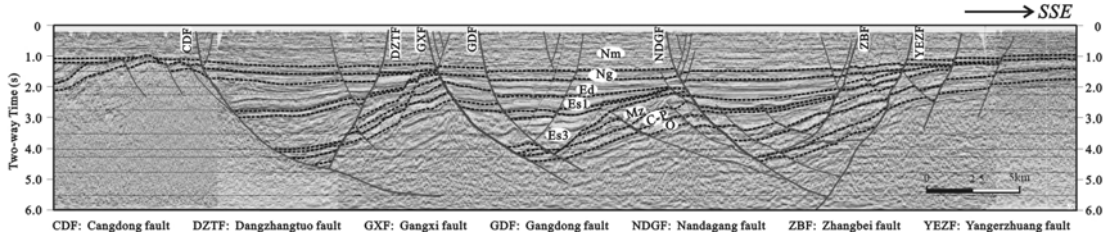

Fig. 3 Interpreted seismic section for the onshore in the Qikou Sag

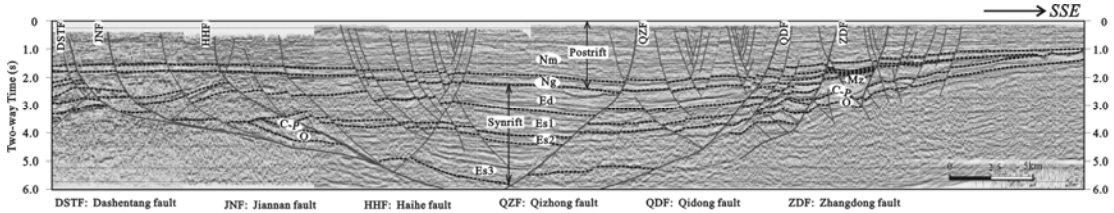

Fig. 4 Interpreted seismic section for the offshore in the Qikou Sag

The NS seismic section of the offshore shows a huge complex graben defined by several listric faults (Fig. 4). At the north side, the three faults

control the extremely thick Paleogene deposition and the blocks rotated between these basement-involved faults. On the hanging wall, a large gentle roller fold formed and was complicated by a flower structure at the top. The south side was consisted by serials of faults step down from the gentle slope to the deep basin. The structure trace at offshore is appeared EW or nearly EW tendency.

3 Structure of the basement

The Mesozoic basement of the Qikou Sag underwent Yinzhi movement at early and Yanshan movement at late. The structures of Yinzhi appear large gentle anticlines and thrusts which trace nearly EW or NWW. The structures of Yanshan extend NE or NNE which are recognized at the onshore and Kongnan area at the southwest of the Qikou Sag . Most of them reacted as normal faults and controlled Cenozoic evolution.

4 Cenozoic evolution

The difference of the tectonic framework between the onshore and offshore of the Qikou Sag is closely related with the regional geodynamics. The Tanlu fault is the most important regional strike-slip fault and transfer the interaction between Pacific and Eurasia plate to the Bohaibay basin. The interactions among the surrounding plates cause the episodic evolution in the basin. During the Palaeocene to early Eocene (Ek-Es4), the subduction roll-back of Pacific plate from Eurasia plate triggered the initial and intensely rifting in the Bohaibay Bain. But the deposition was very locally and the Qikou Sag was still a rise (Fig. 5). Then, from middle to late Eocene (Es3-Es2), the subduction from Pacific to Eurasia plate rotated from NW to nearly W and the speed slowdown to a half (Fig. 6). This caused Tanlu fault to dextral strike slip intensively and formed an NS extentional overlap at the offshore of the Bohaibay basin with the western Lanliao fault. But, in this rift episode, the Qikou Sag is out of the overlap, was still underwent NW extension, and normal faults rifted along the NE and NNE striking Mesozoic structures at onshore. These normal faults controlled several subsidence and deposit centers in the Qikou Sag (Fig. 5). The sediment from the Yanshan, Cangxian and Chengning uplift deposited in the half grabens at onshore. At the Oligocene (Es1-Ed), the subduction speed doubled and this strengthened dextral strike slip in the east China (Fig. 6). The extentioal overlap expanded and contained the Qikou Sag in the rifting episode II. A lot of faults striking EW began to rift strongly at the offshore and the active of NE striking faults decreased at the onshore. The depocenters migrated from the onshore to the offshore (Fig. 5), compared to the rifting episode I. Meanwhile, the deep basement fault under the Qikou Sag enhanced the rifting of the EW fault. From the Miocene, the basin was in the thermal subsidence with litter inversion, but the accelerated subsidence was discovered which need more researches.

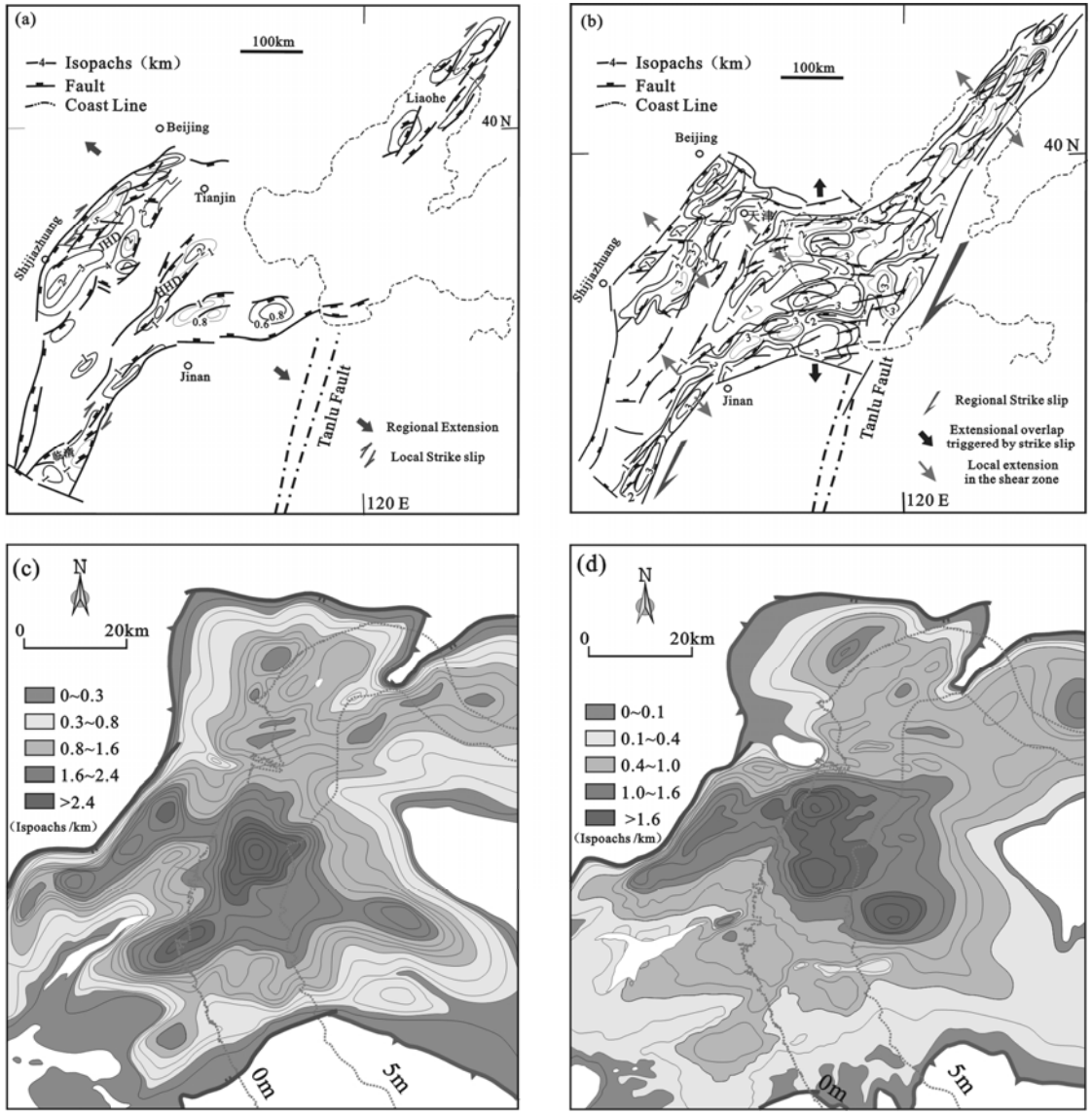

Fig. 5 Tectonic framework and stress field for the Kongdian formation (a) and Es3 member (b) in the Bohaibay Basin (Modified from Allen, et al., 1997, 1998; Tian, et al., 2000), and Deposition for the Es3 (c) and Es1 member (d) in the Qikou Sag

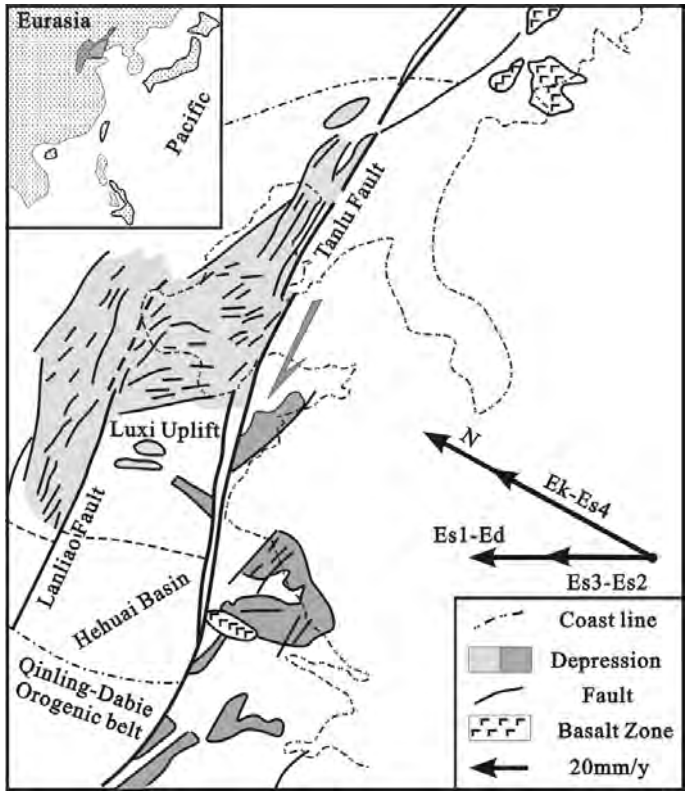

Fig. 6 Change of the subduction from Pacific to Eurasia during the Paleogene (Modified from Northrup, et al., 1995; Yu, et al., 2008).

5 Different hydrocarbon accumulation type at the onshore and offshore

The break-slope belt at the coast line and the buried hills around the offshore depocenters are most interest of explorations. The faults cut into the Es3 and Es1 formation which is the good source rocks and conduct the hydrocarbon to the high position of the buried hill on where the Neogene strata covered. At the offshore, a large faulted-fold was formed at the hanging wall of the Haihe fault. Faults transfer hydrocarbon to the shallow and fault-screened reservoirs are formed with the shielding of the mudstone beds.

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