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RESEARCH ARTICLE

# Differences in sedimentary filling and its controlling factors in rift lacustrine basins, East China: A case study from Qikou and Nanpu sags

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**Abstract** The rift lacustrine basin is characterized by a variety of sediment sources, multiple sedimentary systems, and complex filling, and its sediment supply is largely influenced by climate change. The sedimentary filling and its controlling factors have always been the focuses in basin analysis. This paper first reviews the recent advancement in rift lacustrine basin investigations with an emphasis on the structural controlling on lacustrine configuration, accommodation, and directly structural controlling on basin filling characteristics. The paleogeography resulted from spatial configuration of structural styles, and the sediment supplies synergically determine the types and distribution of depositional systems. The sedimentary filling characteristics of the fourth-order sequence record the evolution of cyclic climate. The case studies are followed on the basis of the sedimentary filling analysis in typical Nanpu sag and Qikou sag in Huanghua rift lacustrine basins in East China. The comparison of sedimentary fillings within sequence stratigraphic frameworks in the two sags shows the different episodic tectonic activities, and their resulting structural frameworks mainly controlled the different sequence stratigraphic developments, their internal architectures, and depositional systems distribution. Qikou sag has more complicate sedimentary filling controlled by episodic activities of boundary and intrabasin secondary faults and sediment supplies. Based on the studies from our own and the formers, we suggest that the sedimentary filling study in rift lacustrine basin should be under the guidance of sequence stratigraphy, use high resolution seismic and all available geological data, combine tectonic evolution and structural styles to build the sequence framework, and then reconstruct the paleo-structure and paleogeography. Studying the relationship between paleogeography and paleo-sedimentary filling can favor the understanding of the characteristics of sedimentary systems development and help in predicting the potential reservoir distribution. The result of this work can be applied directly to the exploration of energy resources.

**Keywords** rift lacustrine basin, East China, different sedimentary filling, sequence stratigraphy, controlling factors, Qikou sag, Nanpu sag

## 1 Introduction

Study on sedimentary filling and its controlling factors is the core of basin analysis. Further study on the differences in sedimentary filling between basins and main controlling factors can predict favorable reservoir distribution, which can be directly applied to coal and hydrocarbon exploration and give impetus to basin filling analysis in reverse.

## 2 Recent advancements in sedimentary filling in lacustrine basin

It is commonly accepted that the basin architecture, filling succession, sedimentary system types, and their dimensions and spatial distribution are controlled by regional tectonic evolution, climate cycle, sea or lake level changes, and sediment supply sources (Blair and Bilodeau, 1988; Vail et al., 1991; Posamentier and Allen, 1993; Van Wagoner, 1998; Cantalamessa et al., 2006; Carpentier

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et al., 2007; Catuneanu et al., 2009). In different types of basins, the main controlling factors are different. The sedimentary filling in passive margin basins is controlled by global sea level change (Posamentier and Allen, 1993; Vail et al., 1987). For stable sedimentary basins, such as cratonic basins, climate and sediment supply are the main controlling factors. In tectonic active basins, tectonic activities and climate change are fundamental factors for sedimentary filling and sedimentary system distribution. Tectonic activities play an important role in denudation and sedimentation (Lin et al., 2000; Smith and Jacobi, 2001; Egger et al., 2002; Frimmel et al., 2002; Lin et al., 2004; Deng et al., 2008). For different scales of stratigraphic units, the main controlling factors are different. The megasequence (1st order sequence) and supersequence (second-order sequence) are mainly controlled by tectonic activities; the former is related to plate tectonic activities and the latter is linked to the regional tectonic activities. The fourth- and fifth-order sequences are probably controlled by paleoclimate and astronomical period cycles. As for the third-order sequence, the controlling factors are relatively complex (Vail et al., 1977; Posamentier and Vail, 1988; Li et al., 2002; Dabard et al., 2007).

The lacustrine basin is characterized by rapid subsidence, complicated sedimentary process, compartmentation in different regions, and most basins appear the multistages of tectonic activities. Variation of stresses is spatially conspicuous. All these factors influence the sequence stratigraphic framework styles. The unique characters for rift lacustrine basins are multisedimentary sources, multisedimentary systems, complex filling styles, and variation of sediment supply with climate change. All these factors make it difficult to study the characteristic of sedimentary filling and predict favorable facies in the rift lacustrine basin.

Most basins in East China are of rift lacustrine basin and are currently enriched in oil and gas. For the following long period of time, the booming economy in China will still depend on the supply of energy. This driving force makes China launch a lot of studies on East China's rift lacustrine basins. Plentiful and substantial achievements have been obtained on sedimentary basin filling and hydrocarbon exploration in these rift lacustrine basins.

It is found that syndepositional faults of different types play an important role in the development of sedimentary system tracts and the distribution of sand bodies in Bohai Bay basin. The structural slope break controls the changes in accommodation (Lin et al., 2000; Lin et al., 2004). These structural slope breaks, e.g., comb structure, brush structure, and fork structure (Fig. 1), control the distribution of sandy deposits. From the margin to the center, the basin can be divided by major structural zones into different structural slope break units, such as uplift-gentle slope margin, gentle slope-depression margin, steep slope-depression margin, uplift-steep slope margin, etc. These structural units control the distribution of specific facies zones and sand bodies. Ren et al. (Ren et al., 2002; Ren et al., 2004) discussed the forming mechanism of slope breaks in rift lacustrine basins and found out that different syndepositional activities can create different structural slope breaks including structural slope break caused by through-cut fault and flexure slope break caused by buried fault. The geometric characteristics of listric boundary fault control the geometry of structural styles and bending slope in the gentle slope (Fig. 2). The spatial distribution, evolution, and combination styles of structural slope breaks determine the basin accommodation and sediment

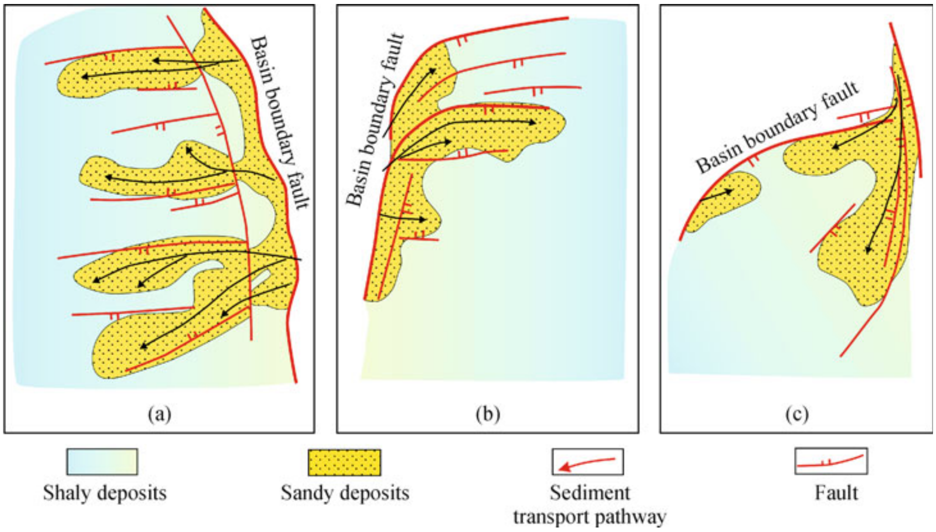

**Fig. 1** Syndepositional faults of different types ((a) comb shaped, (b) brush shaped, (c) fork shaped) to control the spatial distributions of sand fan delta (Lin et al., 2000)

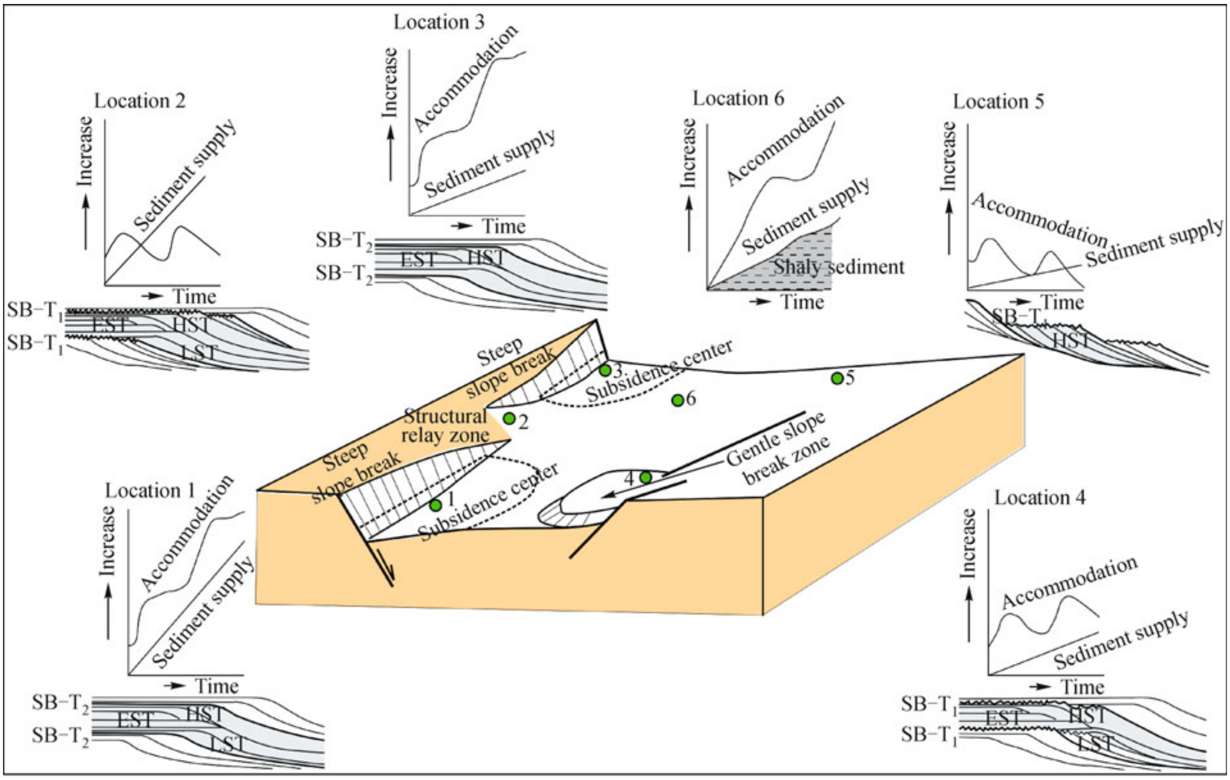

**Fig. 2** Sequence stratigraphic architectures in different locations of a rift lacustrine basin (Ren et al., 2004). The accommodation and sediment supply vary in different locations. LST-lowstand systems tract; EST-Expanding systems tract; HST-highstand systems tract

supply systems, and control the different sequence architecture and depositional system development. These forms the basic theory of structural slope break controlling sand geobody distribution (Ren et al., 2004).

Studies by Deng et al. (2008) on Bohai Bay basin show that the sequence stratigraphic architecture in rift lacustrine basin is the synergic influence by dynamic factors, such as tectonic activities, paleoclimate, lake level changes, and sediment supply. Of all these factors, tectonic activities play the key role in the forming of sequence boundaries and internal sequence architecture: 1) Fault activities restrict the sedimentary accommodation and sequence stratigraphic architecture by its controlling on basement movement; 2) structural relay zone or adjustment zone controls dominant sediment supply pathways and distribution of sedimentary systems; 3) fault activities and its resulting paleogeography control the sedimentary system and sand bodies distribution. Generally speaking, the basin boundary fault controls basin framework, relay zone controls sediment pathways, and paleogeography controls sand distribution (Fig. 3).

Jiang et al. (2002) studied the sequences of members 3 and 2 of Oligocene Shahejie formation and discussed the cause of formation. They considered that the sedimentary filling and sequence stratigraphy formation were controlled early by tectonic activities and, later, by climate and sediment supply.

Ji et al. (2005) discussed the controlling factors of sedimentary filling from the volume change rate of accommodation (ratios between lacustrine paleogeography and accommodation change to total accommodation). The result revealed that the basin topography and volume change rate of accommodation had significant influences on sequence stratigraphic architecture. During the same period, different volume changes of accommodation would result in different sequence architectures.

The studies on sedimentary filling pattern in Oligocene Dongying depression in Jiyang sag by Yu et al.(2007) showed that for rift lacustrine basins, the main controlling factor on sedimentary filling was tectonic setting, with the secondary being the sediment supply, and climate and lake level change also played an important role in sedimentation. Of all these factors, the tectonic characteristics controlled the sedimentary filling, and climate mainly controlled the sedimentary properties (composition, color, fabric, etc.), while the sedimentary compensation and lake level fluctuation mainly controlled the spatial distribution pattern of sedimentary filling, and their interactions formed different sedimentary system types (Fig. 4).

All the above studies and more recent studies indicate that in rift lacustrine basins, the regional tectonic activities control the types of lacustrine basin and the accommodation, which acts as the principal role in sedimentary basin filling, and the paleogeography (e.g., slope break types) resulted from structural combination, and the sediment

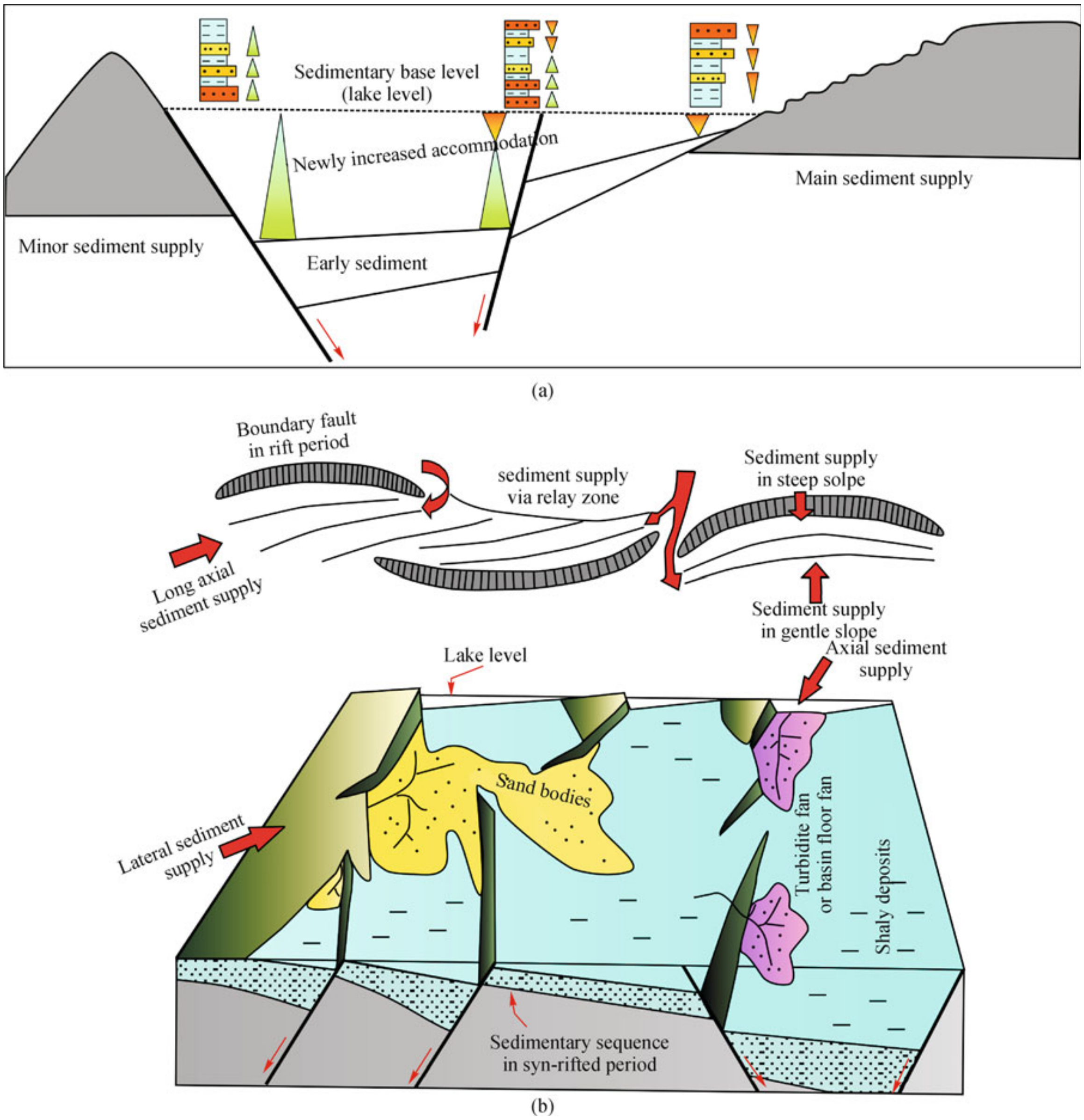

**Fig. 3** Sequence stratigraphic framework in rift lacustrine basin and sand body distribution (Deng et al., 2008). (a) Faults in half graben and their controls on sequence framework; (b) the relay zones in rift lacustrine basin and their controls on sediment supply and delivery

supply jointly influence the sedimentary types and spatial distribution of sand bodies. Since it is relatively limited extent in size, the rift lacustrine basin is very sensitive to climate changes, so the filling characteristic of the fourth-order sequence can record the evolution of climate cycles (Ji et al., 2005; Lin, 2006; Deng et al., 2008).

The research results of the controlling factors of the sedimentary filling in rift lacustrine basins of East China have been successfully applied to prospect generating, favorable reservoir prediction, and subtle or stratigraphic trap exploration. These applications and production practicing facilitate the forming of some exploration theories in lacustrine basin, including slope break controlling sand body distribution, complex conduit system, multifactors control, and key factor reservoir. These theories have brought significant economic effectiveness (Li et al., 2003; Pan et al., 2003; Feng et al., 2004; Li et al., 2004; Wang et al., 2004; Zhang et al., 2004; Liu et al., 2006). For example, the application of slope break and its controlling on low-stand fan resulted in the discoveries of large-scale subtle reservoirs with reserves of more than $1\times10^7$ ton in Shengli oilfield. This theory also helped the exploration breakthrough of thousands of million ton oil equivalent in Nanpu oilfield. These achievements demonstrate the significant contribution of sedimentary filling study in East China basins.

Along with the further research on controlling factors of sedimentary filling, not only did the theoretical research

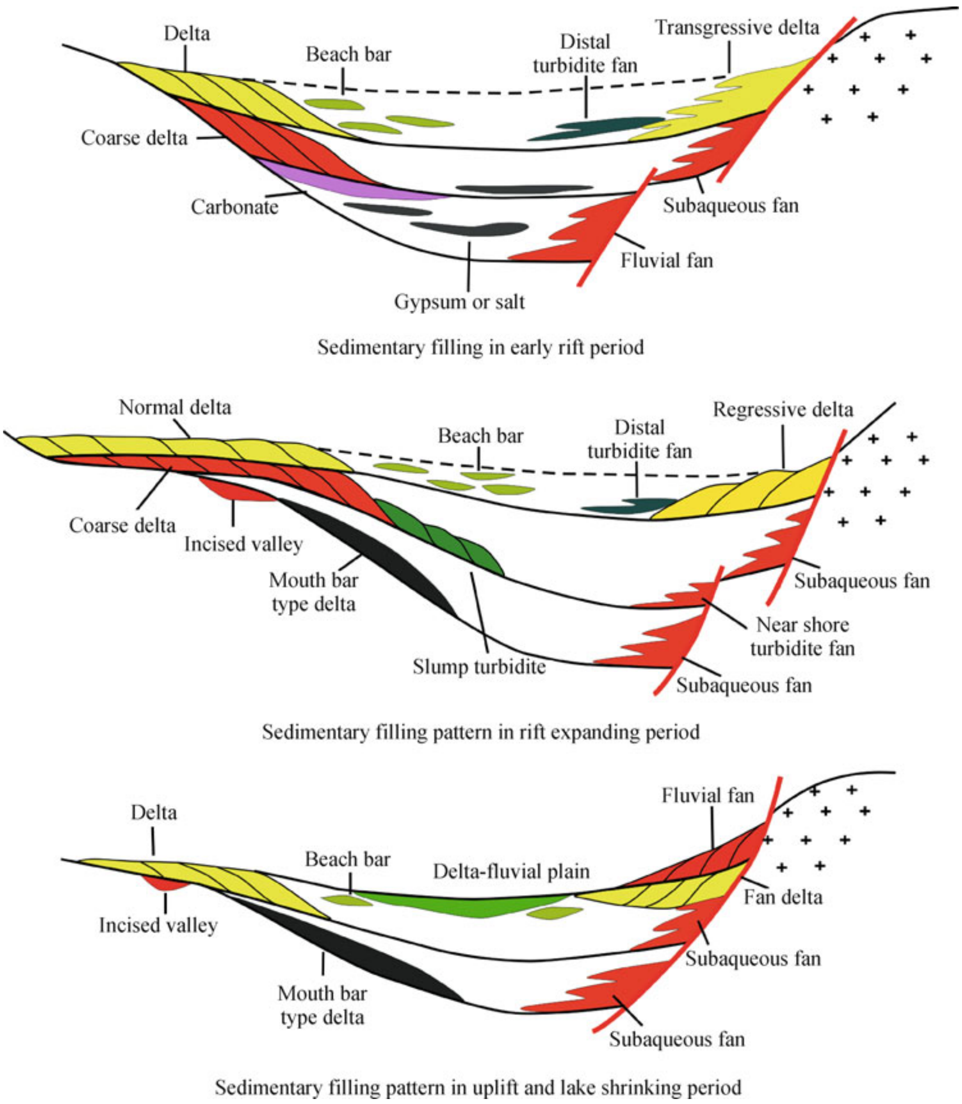

**Fig. 4** Sedimentary filling models during different episodes in rift period, Oligocene Dongying depression, in China (Yu et al., 2007). This shows that the tectonic activity mainly controls the sedimentary filling, while the sedimentary compensation and lake level fluctuation mainly control the spatial distribution pattern of sedimentary filling

improve, but also many new research methods emerged. Especially, many geophysical methods have been extensively applied; they enriched the geological research ways and improved the research accuracy, e.g., recent seismic sedimentology provided new methods to study sedimentary process, which is helpful in exploration (Zeng et al., 2001; Zeng and Hentz, 2004; Dong et al., 2006; Zeng, 2007; Lu et al., 2008). The main trend for future research is detailed 3D seismic processing and interpretation, detailed sequence stratigraphy interpretation, inversion constrained by sequence framework, AVO analysis, spectrum decomposition, seismic attributes, time-frequency, 3D visualization, and integrated study by combined with seismic, well logs, and geological data. These methods will be effective for subtle and stratigraphic trap exploration (Li et al., 2002; Feng et al., 2004; Zhu et al., 2007).

## 3 Case studies

This paper takes two neighbor structural units, i.e., Nanpu and Qikou sag in Huanghua subbasin in Bohai Bay basin province, for examples to study the sedimentary filling and its controlling factors. The two sags are situated in one subbasin and have similar climate conditions.

### 3.1 Geological setting of Nanpu and Qikou sag

In the Mesozoic period, the westward subduction of Pacific plate disturbed the mantle thermal convection and created a series of NNE trending rifts in the East China continental crust. The Paleozoic and Pre-Cambrian platform broke up, and the upper mantle rose along crustal rupture. The upwelling extent of upper mantle reached several hundred of kilometers, which is equivalent to the basin ranges in East China. A series of Meso-Cenozoic fault-depression basins developed above the upwelling areas (Li, 1986).

The Meso-Cenozoic Bohai Bay faulted basin province was developed from the Paleozoic crystalline basement in North China platform, and the basin transformed to downwarp depression since Neogene. The Bohai Bay basin is characterized by fault block structure zone caused by rifted activities. The Cenozoic rifting activities created the tectono-framework, characterized by multifaults, multisteps, and alternative distribution of grabens and horsts. The Qikou sag and Nanpu sag are located in the North-west and North in the Huanghua subbasin in Bohai Bay basin province, respectively (Fig. 5). The two sags are bounded by Jiannan buried hill and exhibit totally different features of structural evolution and sedimentary filling.

### 3.2 Comparison of sedimentary filling

Qikou sag experienced four stages of tectonic activities during Paleogene and formed Eocene Kongdian formation (Ek), Oligocene Shahejie formation (Es), and Oligocene Dongying formation (Ed). The Eocene Kongdian formation period represents initial rift (Fig. 6). The sedimentary systems mainly consist of alluvial and fluvial facies in this initial rift period. Oligocene Shahejie period is the peak stage of tectonic activities and can be further divided into two episodes; the early period of shore-shallow lake to semideep lake and the late period of deep lake. Oligocene Dongying period is syn-rift to postrift thermal subsidence transitional period, and the sediments are mainly shore-shallow lake deposits (Qi et al., 1995; Wang et al., 2003).

By contrast, Nanpu sag missed Eocene Kongdian formation. In this period, the main subsidence center was proposed to be located in the south-west of Huanghua depression, and the north-eastern portion was mainly the denudation area. The Oligocene Shahejie formation and Dongying formation were fully developed, and this stage can be further divided into four tectonic activity episodes (Jiao and Zhou, 1996). Rift episode I is the initial lake development, and the sedimentary types transit from alluvial to shore-shallow lake. Rift episode II is the peak period of lake development, during the period, the lake extent expanded, and the sediments are mainly semideep to deep lake deposits. Rift episode III is the steady development phase for the lake basin, and the sedimentary filling is mainly shallow to semideep lake deposits. Rift episode IV is the waning stage of rift activities, and the water body became shallower, and fans developed extensively.

The volcanic activities occurred in every sedimentary stage in Nanpu sag, especially, at the base of Guantao formation featured by the thick volcanic accumulation. The volcanic activities in Qikou sag are relatively weak. During

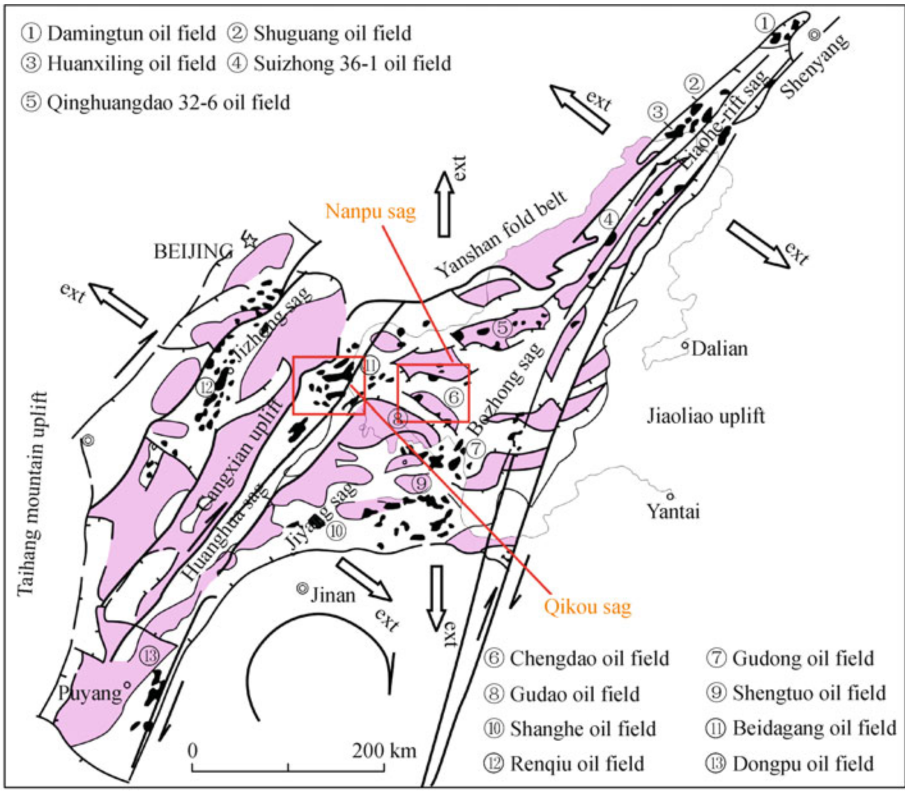

**Fig. 5** Location of Qikou sag and Nanpu sag and their geologic setting (Li, 2004)

the early Oligocene Shahejie 1 period (Es1), there existed large scale of carbonate deposits in the uplift of Qikou sag, but only little carbonate developed in local Gaoliu area. Meanwhile, the thickest deposit part in Oligocene Dongying period is member 1 of Oligocene Dongying formation (Ed1) in Qikou sag, but in Nanpu Sag, member 3 of Oligocene Dongying formation is the thickest.

### 3.3 Comparison of sequence stratigraphic frameworks

The development scope, combination styles, temporal and spatial configuration of boundary fault, and its associated adjustment faults control the strata distribution, internal filling form, and sedimentary system types. The complicated structure will definitely result in the diversity of both internal structures and sedimentary filling in the basin.

Qikou sag is controlled by multiple sets of NE trending faults, which forms many half grabens with boundary faults dipping south. The buried low relief structure along the shoreline divides the sag into offshore part and onshore part. The fault distribution makes the sag take the form of ribbon form from north to south and form of subregions from east to west (Fig. 7). The sedimentary filling in Qikou sag has the following characteristics:

1) The main boundary faults in the north controlled the subsags including Cangdong fault, Gangxi and Gangdong fault, and Nandagang fault. They created the fault controlling steep slope in the north margin of the sag and formed the single faulted half graben.

2) The Dazhangtuo fault in southern limb of Banqiao subsag and Zhaojiabao fault in southern part of Qinan subsag were very active. As a result, multisteps faults were

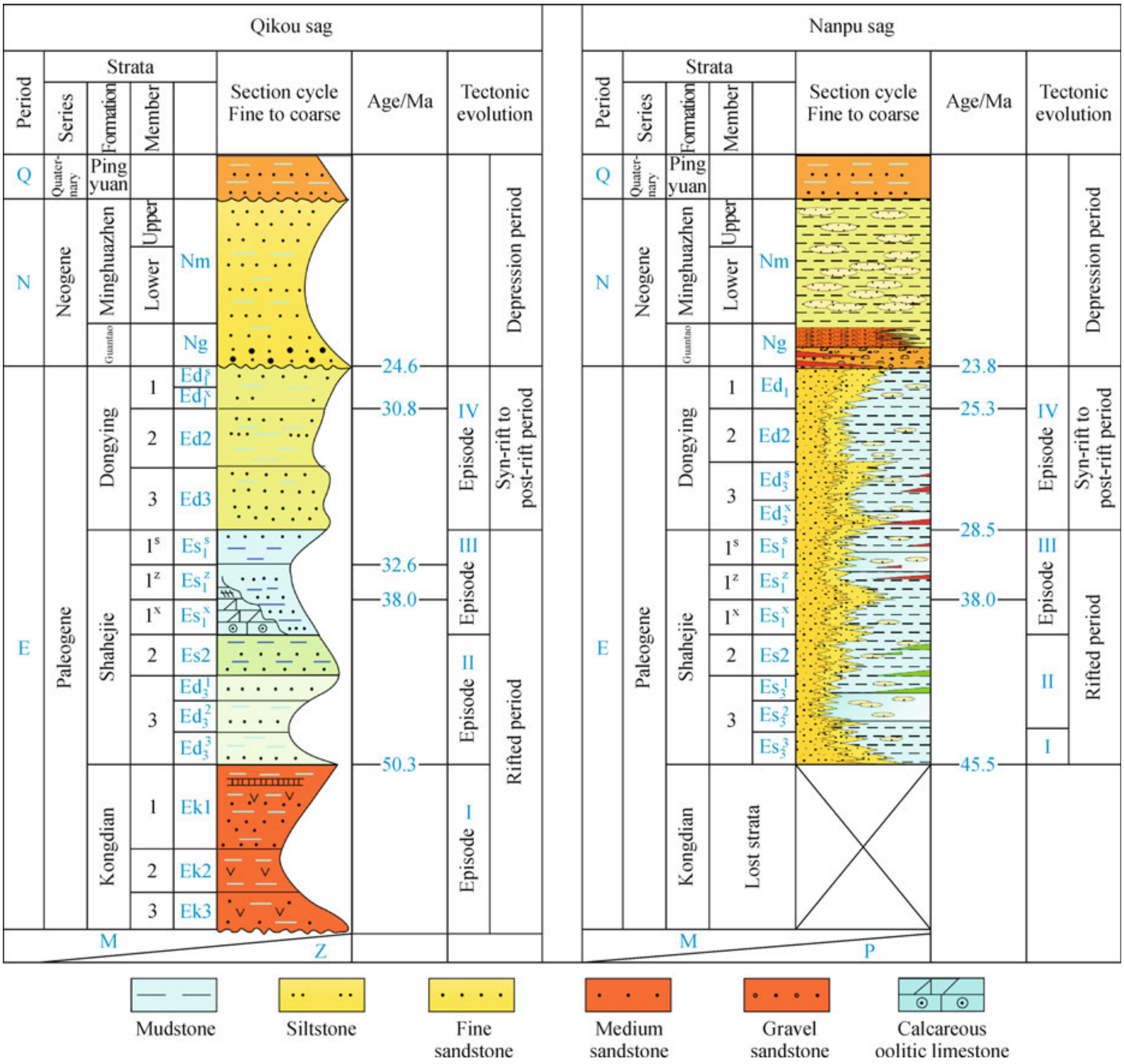

**Fig. 6** Comparison of the sedimentary filling succession between Qikou sag and Nanpu sag

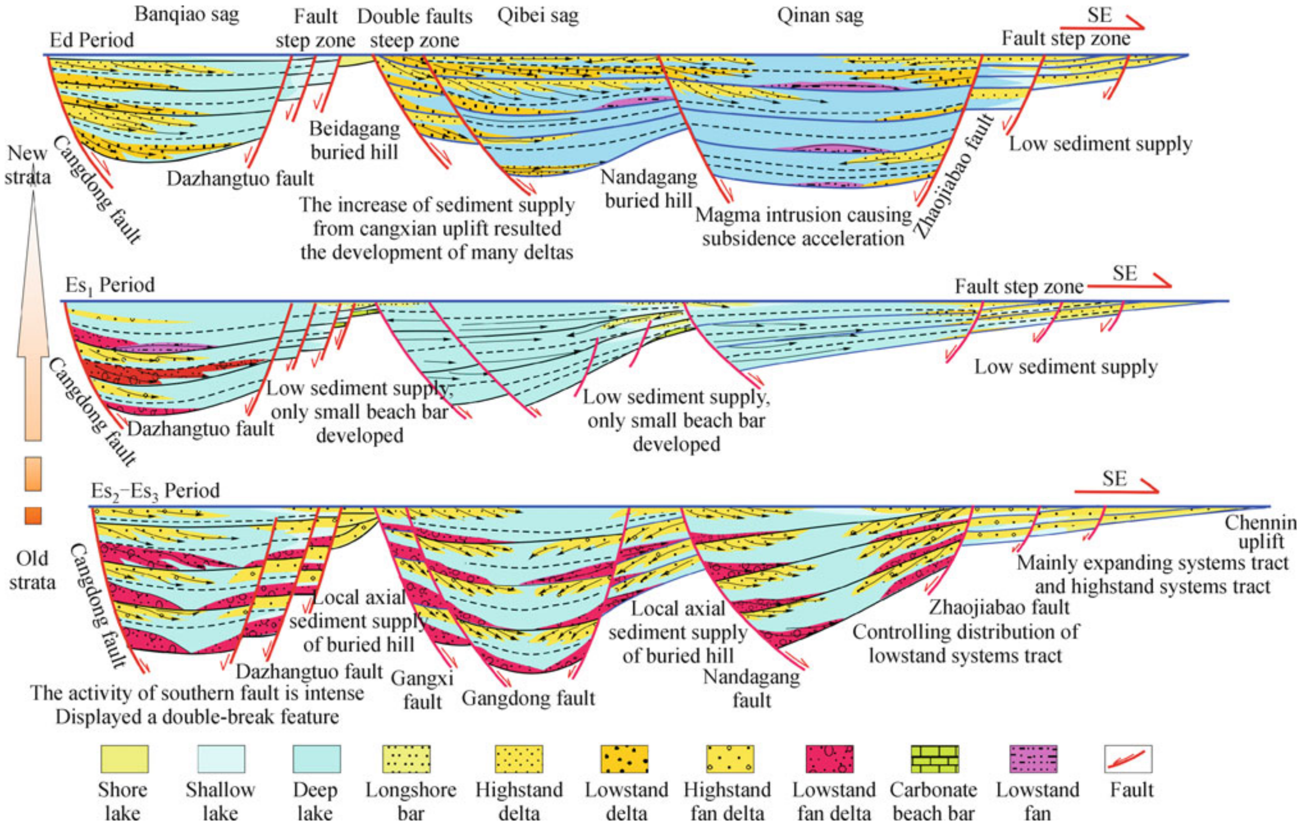

**Fig. 7** Sequence stratigraphic evolution in Qikou sag. From bottom to top: three stages of the sequence framework are shown, i.e., members 3 to 2 of Oligocene Shahejie formation, member 1 of Oligocene Shahejie formation, and Oligocene Dongying formation. The sedimentary system distribution in the sequence framework shows the sediment supply and faults that control the systems tract and sandbodies distribution

formed in the southern part of the sag. Dazhangtuo fault and Zhaojiabao fault controlled the distribution of lowstand systems tract, and above the fault-step slope break expanded to develop highstand systems tract. The southern slope of Qibei sag is of gentle gradient. The strata from member 1 of Oligocene Shahejie formation to member 2 of Oligocene Dongying formation onlapped the gentle slope.

3) Distinct depositional systems were formed in different evolution stages. From members 3 to 2 of Oligocene Shahejie formation, the near-shore subaqueous fan and fan delta developed in lowstand systems tract in steep slope zone, while fan delta developed in highstand systems tract. The braided river delta developed in the gentle slope zone.

During the deposition of member 1 of Oligocene Shahejie formation, fan delta developed in steep slope and delta developed in gentle slope and fault-terrace zones. The carbonate beach bar developed as a marked horizon at the base of member 1 of Oligocene Shahejie Formation. The content of sediment supply is generally low in this period, and the sand bodies are small except for the local larger sedimentary bodies in Banqiao sag.

Delta system is well developed in Oligocene Dongying formation, and the content of sediment supply in the north is larger than that in the south. The scale of sand bodies is larger in member 1 of Oligocene Dongying formation. The sand bodies are distributed all over the sag.

4) As to the subsidence magnitude, from members 3 to 2 of Oligocene Shahejie formation, the largest amount is in Qibei sag. During the deposition period of member 1 of Oligocene Shahejie formation, the intensity of tectonic activities decreases in the following order, i.e., Banqiao > Qibei > Qinan. In Oligocene Dongying deposition period, the subsidence was intensified in Qinan sag due to the magma intrusion, and its total subsidence amount is the largest.

The fault orientations in Nanpu sag are mainly N-NEE trending, similar to those in Qikou sag, but the faults in Nanpu sag have their own characteristics. The Gaoliu fault played an important role in the development of Nanpu sag. In the initial period, the Gaoliu fault undeveloped, and the boundary faults of Xi’nanzhuang and Bogezhuang to the north controlled the development of the half graben with boundary fault dipping south (Fig. 8). Since the beginning of the deposition of member 1 of Oligocene Shahejie formation, the Gaoliu fault began to activate. The Gaoliu fault controlled the framework of the whole basin and divided the Nanpu sag into northern and southern parts. When the Oligocene Dongying formation began to

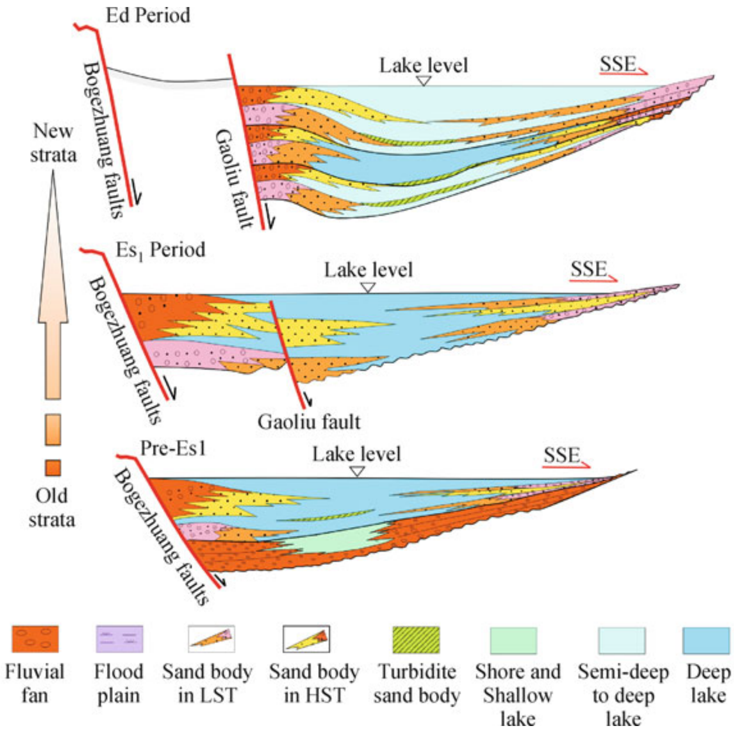

**Fig. 8** Sequence stratigraphic evolution in Nanpu Sag from Es3 to Es1 through Ed, showing stratigraphic distribution controlled by faults at different times. Es3: the period corresponding to member 3 of Oligocene Shahejie formation, Es1: the period corresponding to member 1 of Oligocene Shahejie formation, Ed: Oligocene Dongying period, LST: Lowstand systems tract, EST: Expanding systems tract, HST: Highstand systems tract, Ed: Oligocene Dongying Formation, Es1: the first member of Oligocene Shahejie Formation

deposit, the Gaoliu fault activated more intensively, replaced the part of Xi'nanzhuang and Bogezhuang faults, and became the boundary fault.

It is notable that the two sags have similar features in structural orientation or inherited structures and regional tectonic setting. It is proposed to be caused by regionally deeply buried Lanliao fault that controlled the structural history of the two sags (Wang et al., 2003). The fault activities in Qikou sag is more intensive than those in Nanpu sag and divided the sag into multistructural units. Although there are lots of faults in Nanpu sag, only Gaoliu fault and the secondary faults have larger throws and controlled the sedimentation. These major faults created the compartment situation in the basin, and the basin partition acts as the key role in controlling the accommodation change, sediment supply pathways, and sand body distribution in the basin.

For the episodic tectonic evolution, Qikou and Nanpu sag developed under similar tectonic settings with disequilibrium development. The development of unconformities shows differences in occurring scale and time. Generally, every key stage of basin development is later in Nanpu sag than that of Qikou sag; it is related to the different response to regional tectonic stress in time and intensity. On the other hand, the basements of the two sags have differences in lithology, thickness, intensity, temperature, pressure, etc., and the local faults will show differences in activity, intensity, and ways. The location of the sag in regional stress field is another important influencing factor. Qikou sag belongs to western tectonic regime in Bohai Bay basin, and it mainly underwent extensional forces and was influenced by buried strike-slip. The strike-slip action made the sag exhibit brush structure style in map view and flower structure in the cross section, and the strike-slip activities extended further deeper and formed extensive volcanic structures.

### 3.4 Comparison of basin evolution scale

Under the control of episodic tectonic activities, every tectonic episode underwent the activity cycle of initiation-acceleration-deceleration, and their corresponding sedimentary fillings show paleo-lake evolution from expanding to shrinking. The different activity intensities in tectonic episodes resulted in different basin scales and sedimentary thicknesses among different episodes. At the same time, the complexity of secondary faults will result in different sedimentary framework for correlative episodic activities among basins, which will cause the migration of subsidence center.

Qikou sag is jointly controlled by many secondary faults, and the temporally and spatially different activities of these secondary faults controlled the evolution of sequences in the whole sag. There are many sedimentary

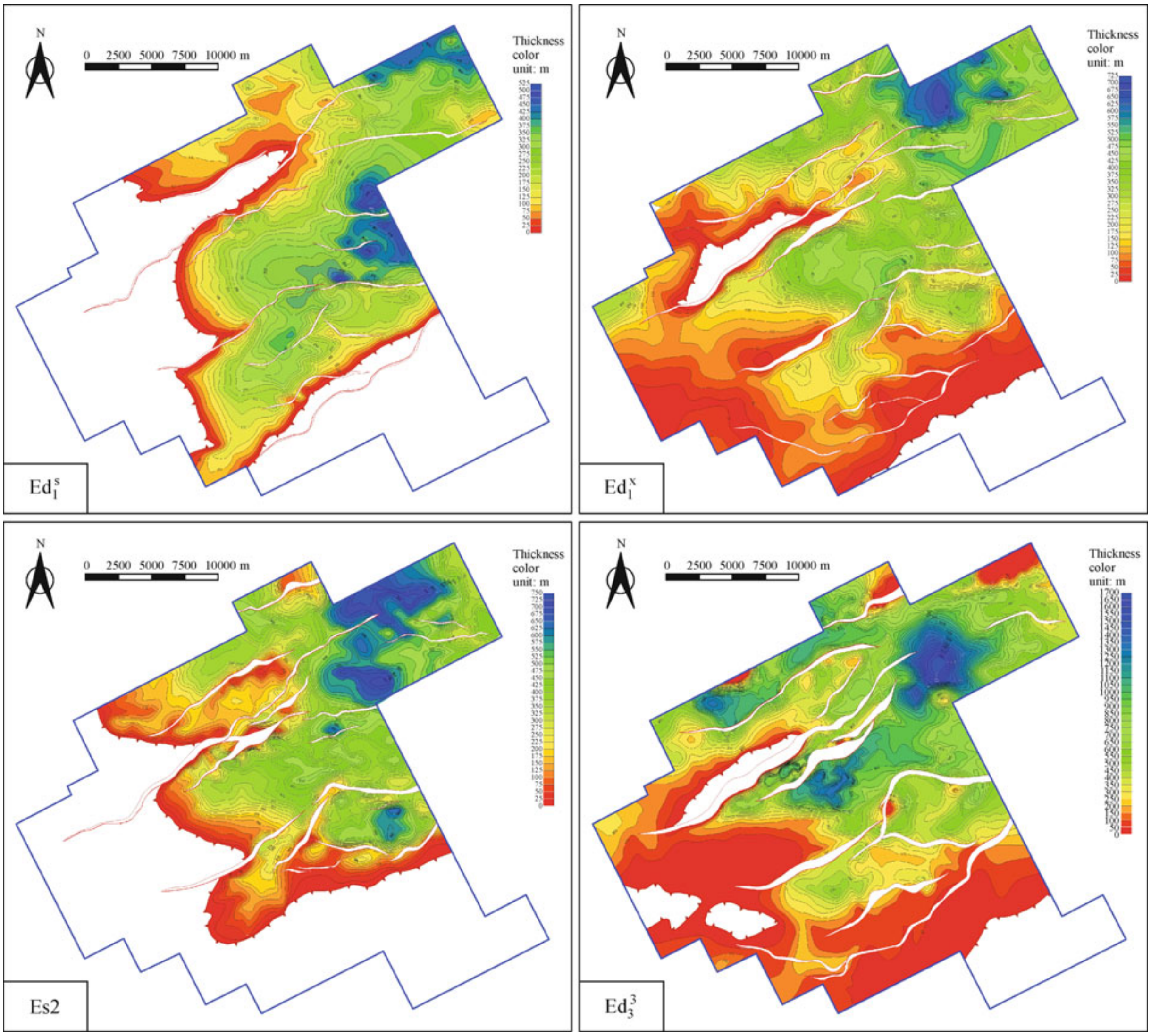

**Fig. 9** Sedimentary thicknesses in main periods of basin development in Qikou Sag. The hot color means thin strata, and the cold color represents thick strata. Ed$_1^s$ = member 1$^s$ of Oligocene Dongying formation; Es$_1^x$ = member 1$^x$ of Oligocene Shahejie formation; Es2 = member 2 of Oligocene Shahejie formation; Es$_3^3$ = member 3$^3$ of Oligocene Shahejie formation

centers in the member 3 of Oligocene Shahejie (Es3) strata that have larger sedimentary scope. In member 2 of Oligocene Shahejie (Es2) period, the whole sag was uplifted; afterwards, it shrank rapidly. In member 1 of Oligocene Shahejie (Es1) period, the rift episode III reached the peak, and then, the sag expanded again. The sedimentary center became centralized because the activities of internal faults migrated eastward. Later, in member 1 of Oligocene Dongying (Ed1) deposition period, the sag shrank again, and it became highly relieved. These factors made the fluctuation in the basin scope, lake level, and sedimentary filling in Qikou sag, along with the episodic tectonic activities (Fig. 9).

In contrast, the Nanpu sag was not intensively partitioned by internal faults, and the sag evolution was mainly controlled by boundary faults (Zhou and Wei, 2000; Dong and Zhou, 2003). In the early member 3 of Oligocene Shahejie period, the Xi'nanzhuang fault was not active, and the sag was controlled by Bogezhuang fault. The strata were faulted to the east and onlapped to the west. During member 2 of Oligocene Shahejie deposition period, although the sag was entirely uplifted, the strata were distributed extensively because of the strong controlling by boundary faults. In member 1 of Oligocene Shahejie period, the sag ranged to a larger area with thick deposits. In this period, the activity of Gaoliu fault divided the sag into northern and southern parts. During member 2 of Oligocene Dongying deposition period, the Gaoliu fault was very active and resulted in the shrinking and disappearance of northern sag, and the northern basin boundary was relocated (Fig. 10).

In comparison between the Nanpu and Qikou sags, for

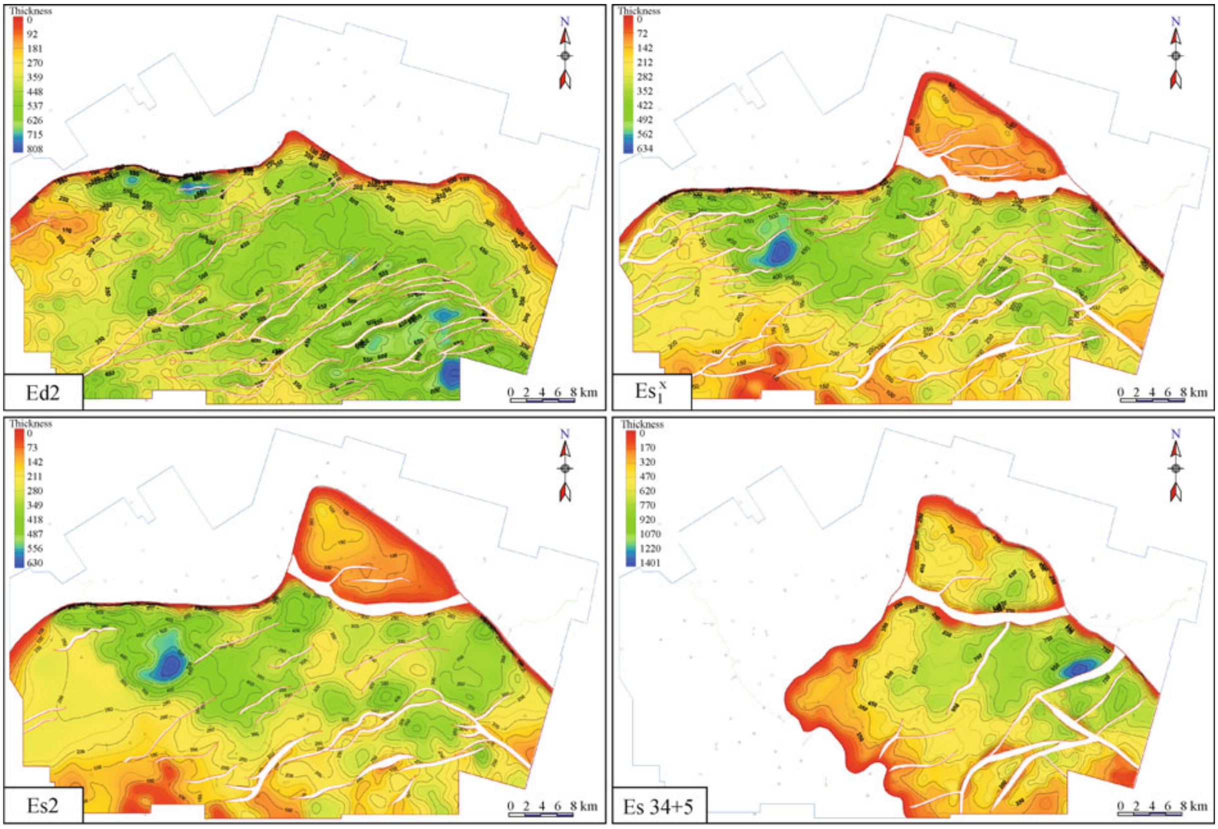

**Fig. 10** Sedimentary thickness in the main periods of the basin development in Nanpu Sag. The hot color means thin strata, and the cold color represents thick strata. Ed2 = member 2 of Oligocene Dongying formation; Es$_1^x$ = member 1$^x$ of Oligocene Shahejie formation; Es2 = member 2of Oligocene Shahejie formation ; Es34 + 5 = member 3 $^{4+5}$ of Oligocene Shahejie formation

sags with internally complicate structure, the sedimentary filling exhibits complexity and diversity during the structural evolution.

While for internally simple sags, the structure evolution of boundary faults is the main controlling factors during sedimentary filling evolution. Although Nanpu sag is small, it has favorable environments for favorable source rocks due to the stable sedimentary centers and continuous distribution of sedimentary systems. For Qikou sag, it ranges extensively and can be divided into many subsags. Even though each subsag has an extensive area, the sedimentary systems vary and distribute complicatedly due to the internally complex structure evolution.

## 4 Discussion and conclusions

Through the comparison of the two typical sags (Qikou and Nanpu sags) in lacustrine basins of East China, the following results can be gotten:

1) The episodic tectonic activities controlled the second-order sequence stratigraphic development. These second-order sequences are regionally correlative among basins, but there are differences in the exact ages and development scales of similar sequences.

2) Under similar tectonic setting, the basins responded differently to the tectonic activities. These differences are related to the locations of the basins, the basement properties, etc. The direct results are the various scopes and styles for local faults. Moreover, these differences will result in the diversity of sedimentary systems, filling succession, and scope among basins.

3) The secondary intrabasin faults play the key roles in the sedimentary filling and can be considered as the internal complex structure to influence the hydrocarbon occurrence in the basin. For small basins, the simple basin structure means stable sedimentary center, and this is one important condition for effective source rock development. For large basins, complicated internal structure and intensive tectonic activities will create multiple sedimentary centers and diverse distributions of sand bodies, which can contribute to various hydrocarbon migration and accumulation.

From the study and many others (Lin et al., 2000; Lin et al., 2004; Ren et al., 2004; Ji et al., 2005; Deng et al., 2008; Huang et al., 2008), it can be summarized that the sedimentary filling in rift lacustrine basin is mainly controlled by tectonic activity, with other factors, e.g., climate, sediment supply, and lake level change, also considered as important. The controls of these factors vary in different times (Fig. 11).

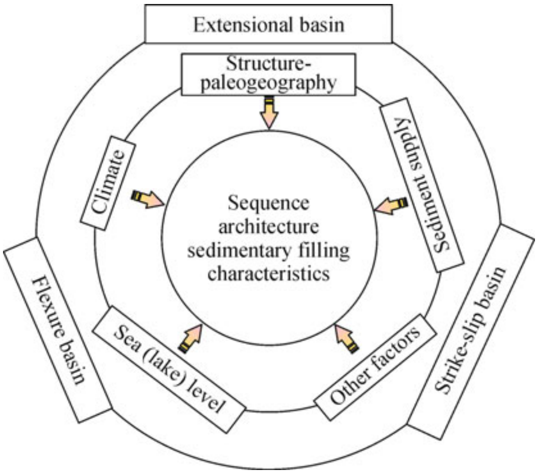

**Fig. 11** Diagram showing the controlling factors of sedimentary filling in lacustrine Basin, which shows that the sedimentary filling is the synthetic results from interactions between tectonism, lake level, climate, and sediment supply

In general, studies on the sequence stratigraphy and sedimentary system evolution based on the structure and basin evolution analysis can not only explain the genetic relationship between structure and sequence stratigraphy but also reveal the spatial configuration between structure and facies distribution. That can further combine sequence stratigraphic study with reservoir, source rock, and trap evaluation to guide the hydrocarbon exploration (Hu, 2004).

The common view that resulted from many systematic and in-depth studies is that the integrated analysis of basin tectonic activities and sedimentary sequence plays key roles in investigating the sedimentary filling and sequence forming mechanism. A study by Lin et al. (Lin et al., 2004) shows that all the accommodation, sedimentation rate, sediment supply, etc., can be influenced by episodic tectonic activities, change in tectonic subsidence, and syndepositional structures. Lin (2006) also presented that "We should study how syndepositional structural activities and their resulting paleogeography control the distribution of sandy dispersal systems and sedimentary systems tract by combining the sequence stratigraphic analysis in lacustrine basins." Deng et al. (Deng et al., 2008) also suggested that "Tectonic activities play the critical role in sequence boundary forming and intra-sequence architecture in lacustrine basin" and "tectonic-sequence analysis should be considered as the core in continental sequence stratigraphic study, i.e., sequence architecture and internal filling characteristics can be revealed by the analysis of tectonic controls on sequence forming and evolution."

From our points of view, the sedimentary filling in rift lacustrine basins of East China is controlled by various factors, and these factors change with time and space. The sequence architecture and sedimentary filling are different for the same basin in different stages and even different areas at the same time. Therefore, the sedimentary filling is a dynamic and variable process; it is the result of jointly control by many factors. The tectonic factor is the dominant factor for basin filling. Regional tectonic setting controls the spatial framework of the lacustrine basin. The boundary fault controls the sedimentary center, and the differences in intrabasin structural framework influence the distribution of subsidence center, which further affects the distribution of sand bodies. Sediment supply system is controlled by paleogeography resulted from paleo-structure, and the paleogeography controls the sediment transport pathways and regimes and leads to the formation of different sedimentary systems with different extents. Tectonic (structure)-paleogeography is the main controlling factor for sedimentary filling in rift lacustrine basins. Therefore, under the guideline of sequence stratigraphy, conducting study on the interaction of paleogeography and paleo-sedimentation by using high resolution seismic data are the main methodology to discuss sedimentary filling, predict favorable facies, and guide the hydrocarbon exploration. Recently, seismic sedimentology, seismic geomorphology, and paleogeography reconstruction within sequence framework have been the new focus for research (Zeng et al., 2001; Carter, 2003; Posamentier and Kolla, 2003; Sawyer et al., 2007).

We have been focusing on sedimentary filling study in basin analysis for many years, and realize that studies on structural paleogeography integrated with sequence stratigraphy, tectono-stratigraphy and applied sedimentology and using seismic, well logs, and geologic data can build a high-resolution sequence framework and then reconstruct the paleogeography within paleo-structure framework by using back-stripping, calculation on erosion amount, compaction correction, extension coefficient, and paleo-water depth. The sedimentary filling study, constrained by sequence framework, should be combined with traditional geology and modern technology, e.g., sedimentary system and microfacies, and sandy systems can be studied in detail by lithofacies, electrofacies, seismic facies, seismic attribute, time frequency analysis, seismic inversion constrained by sequence framework and well logs, and 3D visualization, and then, we define the vertical and areal facies characteristics and establish the sedimentary facies model.

The temporal and spatial coupling analysis, between structural palegogeography (paleogeomorphology), paleo-lake, structure styles, sequence stratigraphic architecture, and sedimentary systems, can predict stratigraphic trap (subtle trap) distribution, provide basis for hydrocarbon accumulation model building, and analyze the impact of main faults upon hydrocarbon reservoirs. The result can

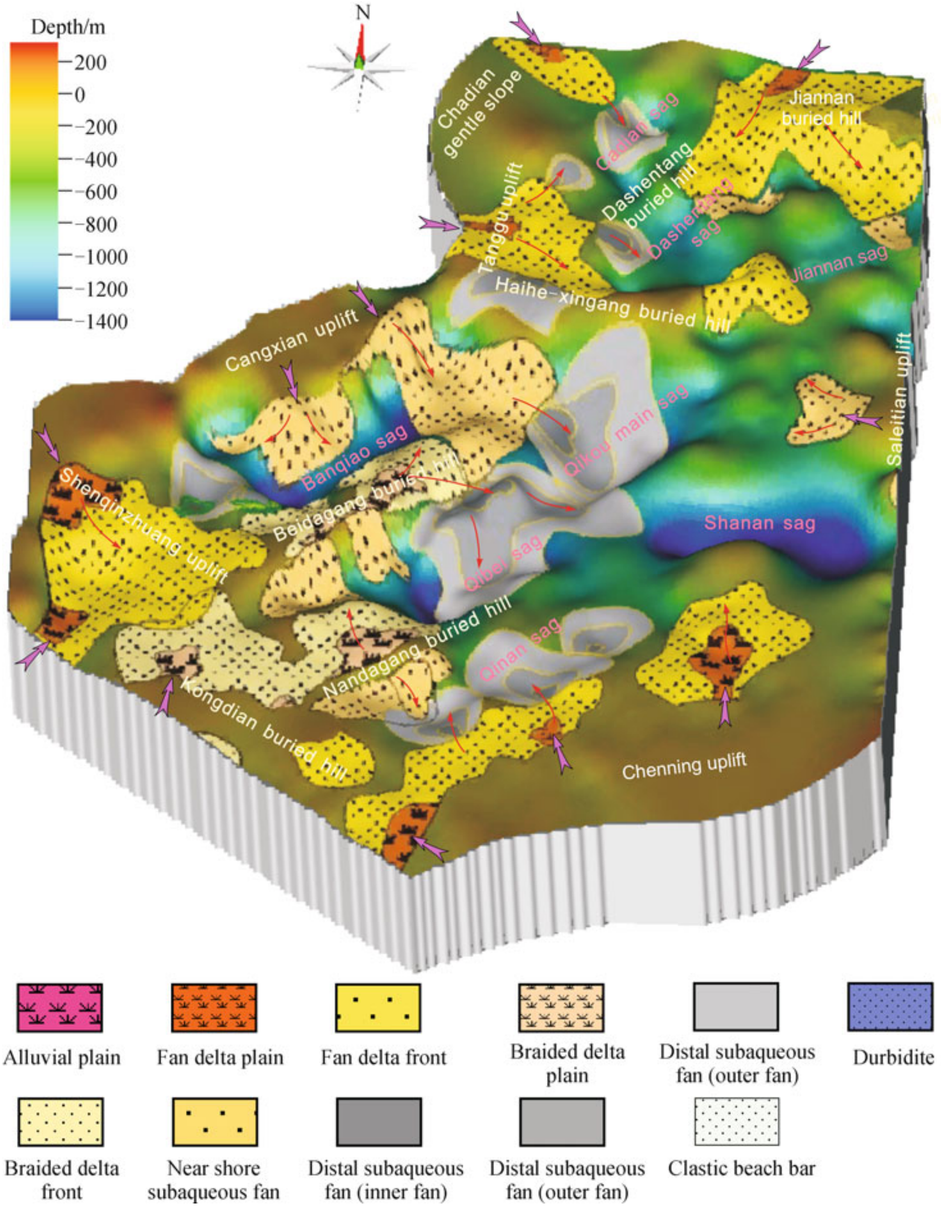

**Fig. 12** Overlapping of structural paleogeography and sedimentary system in member 3 of Oligocene Shahejie formation in Qikou sag, showing controls of the paleogeography on sediment transportation and sedimentary system distribution

also predict the plays, prospects, and even target selection.

Paleogeography and depositional system analysis are important predictive tools because they result in a better 3D geometrical framework and help to sort out the temporal and spatial distribution of depositional facies, including those that are reservoir-, source-, and seal-prone. The paleo-surfaces and sedimentary geobodies delineated by the sequence stratigraphic approach provide us with starting and ending points of tectonic activity-driven models with specific sand body distribution pattern. The geologists will have an edge on predicting stratigraphic/subtle traps because they have a keen understanding and visualization of the strata geometries and the associated types of sedimentary facies from sediment source to sink. For example, Fig. 12 is the 3D block diagram illustrating the overlapping of paleogeography and sedimentary system in the deposition of member 3 of Oligocene Shahejie formation in Qikou sag, which clearly shows that the paleogeography in this period controlled the sediment transportation and deposition, and potential reservoir distribution.

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