Lower Cretaceous stratigraphic characteristics and tectonic control of the eastern depression, North Yellow Sea Basin, North China

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<th>Journal:</th>
<th>Canadian Journal of Earth Sciences</th>
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<td>Manuscript ID</td>
<td>cjes-2019-0074.R1</td>
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<tr>
<td>Manuscript Type:</td>
<td>Article</td>
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<tr>
<td>Date Submitted by the Author:</td>
<td>08-Jan-2020</td>
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<tr>
<td>Keyword:</td>
<td>North Yellow Sea Basin, eastern depression, Lower Cretaceous, stratigraphic characteristics, transtension-transpression, tectonic control</td>
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<td>Is the invited manuscript for consideration in a Special Issue?</td>
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Lower Cretaceous stratigraphic characteristics and tectonic control of the eastern depression, North Yellow Sea Basin, North China

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Abstract

The Lower Cretaceous of the eastern depression in the North Yellow Sea Basin is a set of residual strata, K$_1$sq1 and K$_1$sq2 can be divided effectively. There are four lithology-lithofacies architectures summarized in the third-order sequences of wells W5, W3, W1, W9, W16, W7, W8 and W10, and they are the coarse-fine-coarse, asymmetric coarse-fine, asymmetric fine-coarse and interbedded coarse and fine. F1, F4, F6 and F7, which are strike-slip faults, were dominant during the Early Cretaceous, and controlled the eastern depression to undergo right-lateral movement from transtension to transpression. The tectonic movement controlled different stratigraphic structure in different area, and the fan bodies deposited along the basin margin and progradated into the basin center. The sequence models under extensional and strike-slip setting were established respectively. The transtension - transpression movement controlled the development of the sandstones in the Lower Cretaceous, and improved the quality of the reservoir rocks.

Keywords: North Yellow Sea Basin; eastern depression; Lower Cretaceous; stratigraphic characteristics; transtension-transpression; tectonic control

1. Introduction

The North Yellow Sea Basin is a Meso-Cenozoic continental sedimentary basin located between the Tan-Lu fault and the Sulu-Imjingang orogenic belt (hereinafter...
referred to as the belt) (Fig. 1a). It has been an important region for offshore oil and
gas exploration in China, and the eastern depression located in the east of the basin
(Fig. 1b) is the most prospective hydrocarbon area (Liu et al., 2013; Liu et al., 2014;
Wang et al., 2016). The Meso-Cenozoic strata comprise Upper Jurassic-Lower
Cretaceous (including two structural layers (Fig. 1c) (Zhang et al., 2018)), Lower
Cretaceous, Eocene, Oligocene and Neogene. The Upper Jurassic-Lower Cretaceous
dark mudstone is the main oil source rocks (Zhang et al., 2009; Liu et al., 2013; Zhao
et al., 2016), the Lower Cretaceous sandstone is potential high-quality reservoir rocks
(Wang et al., 2016), and the Eocene thick mudstone is good regional oil cap (Gong et
al., 2009). So far the eastern depression has carried out oil and gas exploration for
more than 50 years, yet to yield a large hydrocarbon discovery. The study of the
sequence stratigraphy, sedimentary characteristics and tectonic evolution is the basic
geological problem for a breakthrough in oil and gas exploration in the eastern
depression, North Yellow Sea Basin.

Tectonic movement is the main controlling factor for the development of
continental basins (Li et al., 1992; Gu et al., 2005; Wang, 2008), and it controlled the
filling succession in the sequence framework. Different stratigraphic structures
develop in different tectonic settings (Allen and Allen, 1990; Xie et al., 1996; Tao et
al., 2001; Horton et al., 2004). The typical coarse-fine-coarse filling succession
develops in the extensional setting (Lai et al., 2016; Chlachula and Krupyanko, 2016;
Naby et al., 2016). However, it exits coarsening upward sequence and fining upward
sequence in the eastern depression because of the strike-slip movement, and these
sequences had been reported in Paleogene of Yitong Graben, Eastern China (Lu et al., 1999). On the basis of the previous studies, this paper clarifies the control action of strike-slip extensional activities to the Lower Cretaceous strata in the eastern depression, and has guiding significance for oil and gas exploration.

2. Regional geology

The tectonic evolution of Eastern China were mainly controlled by the subduction of the Pacific plate to the Eurasian plate in the Jurassic - Cretaceous (Tian et al., 1992; Li et al., 1995; Griffin et al., 1998; Ren et al., 2002; Wang et al., 2016). In the Late Jurassic, the Pacific plate subducted northwestward beneath the eastern margin of the Eurasian plate (Richards, 1999; Voo et al., 1999; Otsuki and Ehiro, 2009), affected by it, the tectonic regime of Eastern China changed from intracontinental compressional orogeny to intracontinental extensional rift (Kim et al., 2012; Xu et al., 2013), so Eastern China was in extensional deformation and rift environment (Ren et al., 2002; Meng, 2003; Liu et al., 2017), and formed a large-scale NNE strike-slip regional fault system (Li et al., 2010). Under this tectonic setting, a series of NE-trending fault basins developed in Eastern China, e. g. the Bohai Bay Basin, the Jiaolai Basin and the North Yellow Sea Basin (Fig. 1a), the evolution of these basins were affected remarkably by the tectonic activity of the Tan-Lu fault and Sulu-Imjingang orogenic belt (Cheng et al., 2018).

The left-lateral strike-slip on the Tan-Lu fault occurred in the Late Jurassic-the
Early Cretaceous (Xu, 1980; Xu and Zhu, 1994; Wang et al., 2000; Mercier et al., 2007). There are many studies about the tectonic movement of the Sulu-Imjingang orogenic belt, Cho et al. (1995) and Zhai et al. (2007) surmised the belt as a roughly east-west fold-thrust belt, Ree et al. (1996) documented the south-vergent contraction, top-down-to-the-north normal faulting in the belt, Ren (1999) concluded that the belt had undergone folding at the end of the Jurassic and beginning of the Cretaceous, Chough et al. (2000) analyzed that the contractional deformation followed by extensional deformation in the belt, Hou et al. (2008) reported two stages of tectonic deformations in the belt during Mesozoic: NW and NE thrust-shearing in the early Mesozoic and SWW extension-decoupled shearing in the late Mesozoic. Zhang et al. (1989), Xia et al. (1994), Gao et al. (2015) and Ma et al. (2016) pointed out that it exits NE transpression-thrusting and right-lateral wrench movement in the South Yellow Sea Basin (located on the south side of the belt (Fig. 1a)) during the Late Jurassic-Early Cretaceous. Xie et al. (2004) pointed out that the same tectonic stress area is affected by external forces in the same way, and its internal and external tectonic environments have similar characteristics, so the main stress direction of the same tectonic stress area is generally consistent. According this theory and the above studies, we speculate that left-lateral strike-slip movement occurred in the Sulu-Imjingang orogenic belt at that time. The left-lateral strike-slip of the belt and Tan-Lu fault controlled the development of the Bohai Bay Basin (Allen et al., 1997; Wu et al., 2005; Qi and Yang, 2010; Li et al., 2012), the Jiaolai Basin (Wang et al., 2016; Zhang et al., 2003), the North Yellow Sea Basin (Li, 2007; Chen et al., 2008;
Wang et al., 2014; Zhang et al., 2018) and the South Yellow Sea Basin (Zhang et al.,
1989; Shang et al., 2002; Gao et al., 2015), all basins underwent extensional and
strike-slip movement.

There existed right-lateral tectonic stress field in the North Yellow Sea Basin,
which was controlled by the left-lateral strike-slip of the Sulu-Imjingang orogenic belt
and Tan-Lu fault. Most faults strike-slip and wrench, and the NNE right-shear fault
developed in the basin (Li et al., 2006). The eastern depression was NE-trending and
controlled by tension faults, reverse faults and strike-slip faults (Molnar and
Tapponnier, 1977; Tapponnier et al., 1982; Wang et al., 2014). NE, NW and EW
faults mainly developed in the depression, they were larger in scale, had longer
extension distance and developed earlier than those in other directions, and controlled
the structural framework of the eastern depression (Fig. 1b). The strike-slip activity
and wrench activity of the basin-controlling faults resulted in the assembly
configuration of similar to 'flower' in the eastern depression (Fig. 1c). The extensional
activity and strike-slip activity of the basin-controlling faults controlled the eastern
depression to undergo right-lateral movement from transtension to transpression
during the Late Jurassic - Early Cretaceous. The eastern depression uplifted and part
of the strata were denuded due to the tectonic inversion at the end of the Late
Jurassic-Early Cretaceous, there was another trans-extension in the depression during
the Early Cretaceous (Zhang et al., 2018).

3. Stratigraphic development and sequence structure

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The Lower Cretaceous was uplifted and eroded due to the tectonic inversion during the late Early Cretaceous or the Late Cretaceous-Palaeocene (Li, 2007; Chen et al., 2008; Wang et al., 2014), preserving only part of the Lower Cretaceous, so the Lower Cretaceous of the eastern depression is a set of residual strata. The Lower Cretaceous is divided into $K_1^{sq1}$ and $K_1^{sq2}$ effectively, based on the filling succession, boundary characteristics and boundary distribution. The sequence is composed of LST (lowstand systems tract), TST (transgressive systems tract) and HST (highstand systems tract), and represented in wells W5, W3, W1, W9, W16, W7, W8 and W10 (well locations are showed in Fig. 1, Fig. 7 and Fig. 8). We describe the third-order sequences in detail below.

(1) $K_1^{sq1}$

$K_1^{sq1}$ is present in wells W5, W3, W16 and W8.

$K_1^{sq1}$ of Well W5 is composed of LST, TST and HST (Fig. 2a). The LST is composed of glutenite and fine sandstones intercalated with mudstones interpreted as fan delta front gravity channel, mouth bar and mudstones deposits. The TST comprises glutenite, coarse sandstone, fine sandstone, siltstones and argillaceous siltstones intercalated with mudstones, developing incomplete Bouma sequence (Fig. 3), interpreted as underwater fan deposits. The HST consists of fine sandstones intercalated with siltstones interpreted as fan delta front mouth bar and distal bar deposits. This sedimentary sequence presents the coarse-fine-coarse architecture (Fig. 2a), which resulted from a steady sediment supply under extensional tectonic
conditions, and coarse-grained sediment had a large degree of progradation.

\[ K_1 \text{sq} 1 \] of Well W3 is composed of LST, TST and HST (Fig. 2b). The LST is composed of fine sandstones and siltstones intercalated with mudstones interpreted as fan delta front deposits. The TST comprises mudstones intercalated with fine sandstone and argillaceous siltstones interpreted as shallow lake mudstones and turbidite deposits. The HST consists of conglomerate, glutenite (Fig. 4), gravel bearing sandstones, fine sandstones and siltstones intercalated with mudstones interpreted as fan delta front deposits. This sedimentary sequence is similar to that of \[ K_1 \text{sq} 1 \] in Well W5, presents the coarse-fine-coarse architecture (Fig. 2b).

\[ K_1 \text{sq} 1 \] of Well W16 is composed of LST, TST and HST (Fig. 2c). The LST is composed of glutenite, fine sandstones intercalated with mudstones interpreted as fan delta front deposits. The TST and HST comprises mudstones, silty mudstones intercalated with argillaceous siltstones and fine sandstone interpreted as shallow lake mudstones and turbidite deposits. This sedimentary sequence presents the asymmetric coarse-fine architecture (Fig. 2c), and Well W16 is located at the basin margin, which reflects that the strike-slip faulting on the boundary faults resulted in the decline in coarse-grained sediment supply in the late stage.

\[ K_1 \text{sq} 1 \] of Well W8 is composed of LST and TST (Fig. 2d), the HST is absent because of denudation. The LST and TST are composed of mudstones, silty mudstones intercalated with argillaceous siltstones interpreted as shallow lake mudstones and turbidite deposits. This sedimentary sequence exhibits the interbedded coarse and fine architecture (Fig. 2d), and Well W8 is located at the basin margin,
reflecting that Well W8 is located in a deep-water area controlled by the strike-slip activity, and the coarse-grained sediment supply was insufficient.

(2) $K_{1sq2}$

$K_{1sq2}$ is present in wells W5, W3, W1, W9, W16, W7 and W10. $K_{1sq2}$ of Well W5 is composed of LST and TST (Fig. 5a), the HST is absent because of denudation. The LST and TST are composed of mudstones intercalated with siltstones interpreted as shallow lake mudstones and turbidite deposits. The character of $K_{1sq2}$ in Well W5 is similar to that of $K_{1sq1}$ in Well W8, but Well W5 is located in the basin center, this sedimentary architecture is the result of insufficient coarse-grained sediment supply to the basin center under an extensional tectonic regime.

$K_{1sq2}$ of Well W3 is composed of LST and TST (Fig. 5b). The LST is composed of glutenite, gravel bearing sandstones and fine sandstones intercalated with siltstones and mudstones interpreted as fan delta front deposits. The TST comprises mudstones intercalated with fine sandstones, siltstones and argillaceous siltstones interpreted as shallow lake mudstones and turbidite deposits. This sedimentary sequence presents the asymmetric coarse-fine architecture (Fig. 5b). The HST is absent because of denudation caused by the tectonic inversion, we speculate that the coarse sediments would have dominated the HST. This sequence is similar to that of $K_{1sq1}$ in Well W3, which resulted from a steady sediment supply under extensional tectonic conditions.

$K_{1sq2}$ of Well W1 is composed of LST, TST and HST (Fig. 5c). The LST is composed of glutenite and fine sandstones intercalated with siltstones and mudstones
interpreted as fan delta front deposits. The TST and HST comprises mudstones, silty mudstones intercalated with fine sandstones and argillaceous siltstones interpreted as shallow lake mudstones and turbidite deposits. This sedimentary sequence presents an asymmetric coarse-fine architecture (Fig. 5c). The architecture of K$_{1}$sq2 in Well W9 is similar to that in Well W1 (Fig. 5d), and both wells were close to the basin margin, which suggested that the sediment source was far away from wells W9 and W1 due to the strike-slip activity, and the coarse-grained sediment supply was sufficient in the early stage and decreased in the late stage.

K$_{1}$sq2 of Well W16 is composed of LST, TST and HST (Fig. 5e). The LST and TST are composed of mudstones intercalated with argillaceous siltstones interpreted as shallow lake mudstones and turbidite deposits. The HST comprises gravel bearing sandstones, fine sandstones (Fig. 6) and argillaceous siltstones intercalated with mudstones interpreted as fan delta front deposits. This sedimentary sequence presents the asymmetric fine-coarse architecture (Fig. 5e). Wells W1, W9 and W16 were all close to F6, however, their sequence architectures were opposite (Fig. 5), controlled by the different coarse-grained sediment supply due to the strike-slip faulting.

K$_{1}$sq2 of Well W7 is composed of LST and TST (Fig. 5f), the HST is absent because of denudation. The LST is composed of alluvial fan conglomerates. The TST comprises gravel bearing sandstones intercalated with mudstones interpreted as fan delta front deposits. This sedimentary sequence presents the coarse architecture on the whole (Fig. 5f), which resulted from the sufficient coarse sediment supply at the basin margin under extensional tectonic conditions.
$K_{1}\text{sq2}$ of Well W10 is composed of LST, TST and HST (Fig. 5g). The LST and TST consist of mudstones and sandy mudstones intercalated with limy siltstones interpreted as shallow lake mudstones and turbidite deposits. The HST comprises argillaceous sandstone, sandy mudstones and limy mudstones interpreted as fan delta front deposits. This sedimentary sequence is similar to that of $K_{1}\text{sq2}$ in Well W16, presents the asymmetric fine-coarse architecture (Fig. 5g), which resulted from the change of sediment supply due to the strike-slip faulting at the basin margin.

During $K_{1}\text{sq1}$, the coarse-fine-coarse architecture presented in wells W5 and W3, which were located in the basin center, reflected the strong extensional faulting; the architecture presented in wells W16 and W8, which were located at the basin margin, reflected that the strike-slip faults began to move, and controlled the asymmetric coarse-fine architecture and interbedded coarse and fine architecture to develop. During $K_{1}\text{sq2}$, the architecture presented in wells W1, W9, W16, W10 and W7 reflected the strong strike-slip faulting, resulting in different architectures developed in different positions at the basin margin. The strike-slip faulting in $K_{1}\text{sq2}$ were stronger than that in $K_{1}\text{sq1}$.

4. Tectonic framework

The basin-controlling faults and their assembly configurations were inherited and differential in the eastern depression in different tectonic periods (Fig. 7 and Fig. 8). We analyze the faults activities and tectonic styles of the two sequence stages in the
Early Cretaceous and study the tectonic movement.

(1) \(K_{1}\text{sq1}\)

The boundary faults, F1, F4, F9, F6, F7 and F5 controlled the “T” geometry of the basin, and double-fault graben and single-fault half graben patterns of the depression during \(K_{1}\text{sq1}\) (Fig. 7). In profile a, it exhibits half graben pattern, controlled by F4. The growth faulting rate of F4 is 84m/Ma, and the sedimentary rate is 28m/Ma. While the strata of the hanging wall of F9 was eroded, which reflects that it occurred extensional movement in the early stage and strata denudation caused by compressional faulting in the late stage. In profile b, it exhibits graben pattern, controlled by F1 and F7. The growth faulting rate of F1 is 65m/Ma, and the sedimentary rate is 32m/Ma, the growth faulting rate of F7 is 52m/Ma, and the sedimentary rate is 20m/Ma, reflecting that the extensional faulting on the west was stronger than that on the east. In profile c, it exhibits graben pattern, controlled by F6 and F1. The growth faulting rate of F6 is 78m/Ma, and the sedimentary rate is 48m/Ma, the growth faulting rate of F1 is 65m/Ma, and the sedimentary rate is 26m/Ma, reflecting that the extensional faulting on the north was stronger than that on the south. In profile d, it exhibits two half graben patterns, controlled by F7 and F5 respectively. The growth faulting rate of F7 is 52m/Ma, and the sedimentary rate is 49m/Ma, the growth faulting rate of F5 is 64m/Ma, and the sedimentary rate is 36m/Ma, which reflected that it occurred extensional faulting on F7 and F5, controlling the thick sedimentary strata. The growth faulting rate and sedimentary rate on the west and north were larger than those on the east and south on the whole,
reflecting that the extensional faulting on the west was stronger than that on the east. The tectonic movements on the all areas reflects that it occurred right-lateral movement from transtension to transpression in the depression during K$_1$sq1.

(2) K$_1$sq2

The boundary faults, F1, F4, F9, F3, F6 and F7 controlled the “T” geometry of the basin, and double-fault graben and single-fault half graben patterns of the depression during K$_1$sq2 (Fig. 8). In profile a, it exhibits two half graben patterns, controlled by F4 and F6 respectively. The growth faulting rate of F4 is 97m/Ma, and the sedimentary rate is 62m/Ma, the growth faulting rate of F6 is 92m/Ma, and the sedimentary rate is 57m/Ma. The part of the strata of the hanging wall of F9 was eroded caused by compressional faulting in the late stage. In profile b, it exhibits half graben pattern, controlled by F1, the growth faulting rate of F1 is 71m/Ma, and the sedimentary rate is 40m/Ma, which reflects that the extensional faulting on the west was stronger than that on the east. In profile c, it exhibits graben pattern, controlled by F6 and F1. The growth faulting rate of F6 is 92m/Ma, and the sedimentary rate is 32m/Ma, the growth faulting rate of F1 is 71m/Ma, and the sedimentary rate is 20m/Ma, which reflects that the extensional faulting on the north was stronger than that on the south. In profile d, it also reflects that the extensional faulting on the north was stronger than that on the south. In general the extensional faulting on the west and north was stronger than that on the east and south. The tectonic movements on the all areas reflects that it occurred right-lateral movement from transtension to transpression in the depression during K$_1$sq2.
K₁sq2 was inherited from K₁sq1, and the growth faulting rate and sedimentary rate in K₁sq2 were bigger than those in K₁sq1. F3 moved again, and the northeast of F6 moved obviously in K₁sq2, reflecting the extensional and strike-slip faulting in K₁sq2 were stronger than that in K₁sq1, leading to a larger and deeper faulting depression with thicker sediments infilling during K₁sq2. The basin extended continuously in the early stage, and part strata was eroded because of compressional faulting in the late stage, reflecting that it occurred another right-lateral movement from transtension to transpression during the Early Cretaceous.

F1, F4, F6 and F7 were the key faults and strike-slip, controlled the right-lateral movement of the eastern depression during the Early Cretaceous. The Lower Cretaceous was the result of a trans-extensional movement, representing the period of basin contraction during the Mesozoic. Multidirectional fault orientations were recorded during K₁sq1 and K₁sq2 (Fig. 9a, 9b), reflecting the kinematics of wrench faulting.

5. Tectonic control and sequence response

(1) K₁sq1

It presents “T” geometry during K₁sq1, and the main sedimentary area is located in the west of the depression (Fig. 7). There are only part of residual strata on the hanging wall of F5. The strata on the hanging wall of F9 was eroded. The large proportion of the hanging wall of F6 was eroded, and there are only part of residual
strata in the southwest.

During K₁sq1, the growth faulting rate and sedimentary rate on the west and north were larger than those on the east and south in general, and controlled fan delta developed in the west and north, and delta developed in the east. The fan sediments in the north and west are progradational, and the others deposited along the basin margin during K₁sq1. The coarse-fine-coarse architecture presented in wells W5 and W3 reflected the strong extensional faulting. The interbedded coarse and fine architecture presented in Well W8, close to F7, reflected that the strike-slip faulting on F7 resulted in the deep-water area occurred at the basin margin. The asymmetric coarse-fine architecture presented in Well W16, located at the basin margin, reflected the strike-slip faulting on F6. What’s more, the mudstone thickness of Well W16 is bigger than that of wells W5 and W3 (Table 1), the migration of the deposition center also reflected the strike-slip faulting on F6.

(2) K₁sq2

The depression extended continuously during K₁sq2, and K₁sq2 has a greater aerial extent than K₁sq1, identified by the sediments onlap at the basin margins, indicating an extensional setting. F3 moved again, and the lacustrine sedimentation developed on the hanging wall of F3. The fan sediments on the northeast indicated the strong extensional faulting on F6, and the coarse-grained sediment supply was sufficient. The east of F1 moved again, and controlled the depression extended eastward.

The growth faulting rate and sedimentary rate in K₁sq2 were bigger than those in
K₁sq1, and controlled fan delta developed widely, but also alluvial fan developed on
the hanging wall of F5. The fan sediments in the west were progradational, and the
others deposited along the basin margin during K₁sq2. The interbedded coarse and
fine architecture presented in Well W5, located in the basin center, reflected the
strong extensional faulting. The architecture character of K₁sq2 is opposite in wells
W1, W9 and W16 (Fig. 5), all close to F6, suggested the right-lateral strike-slip
faulting on F6 and resulting in the change of the sediment provenance and supply.
The asymmetric fine-coarse architecture presented in Well W10 reflected the
strike-slip faulting on F1. The thick conglomerates and sandstones in Well W7
suggested the strong extensional faulting on F7.

6. Discussion

6.1. Sequence model

There were four types of lithology-lithofacies architecture: coarse-fine-coarse,
asymmetric coarse-fine, asymmetric fine-coarse and interbedded coarse and fine in
the Lower Cretaceous in the eastern depression. The stratigraphic structures in
different positions reflected different tectonic settings. Tectonic movement is the main
controlling factor in the continental fault basins, and the ratio (A/S), where (A) is the
rate of accommodation space growth and (S) is the rate of sediment supply, presented
corresponding changes, and controlled different lithology-lithofacies architectures in
the sequence stratigraphy (Table 2). The sequence models under extensional and
strike-slip setting were established to illustrate the controlling effects of tectonic
movements on sequence and sedimentation.

(1) Extensional setting: LST, the faults began to move, and the intensity was
weak, the accommodation space was small, $A/S < 1$, the fan delta low-level fan body
developed on the hanging wall of the faults, the sediments thickness reduced
gradually from the faults to the basin center. TST, the faults activity was stronger, and
the accommodation space increased rapidly, $A/S > 1$, developing retrograding
lacustrine sedimentation, with small-size underwater fan or turbidite deposits,
dominated by mudstones. HST, the faults activity weakened gradually, and the
accommodation space decreased, $A/S < 1$, the fan delta prograded again (Fig. 10).
There existed steady sediment supply, $A/S < 1$, then $A/S > 1$, to $A/S < 1$, and
controlling the lake level rise to fall, developing coarse-fine-coarse architecture in
extensional tectonic conditions.

(2) Strike-slip setting: LST, the strike-slip faulting was weak, and the sediment
supply was sufficient, developing fan delta or underwater fan. TST, the strike-slip
faulting was stronger, and the sediment source area deviated, resulting in the
coarse-grained sediment supply insufficient, dominated by lacustrine mudstones, till
HST (Fig. 11). $A/S < 1$, then $A/S > 1$, and controlling the lake level rise to fluctuate,
developing asymmetric coarse-fine architecture in strike-slip conditions.

The strike-slip faulting resulted in the sediment source area deviation, and the
coarse-grained supply changed, developing asymmetric fine-coarse architecture as
well. The strike-slip movement controlled the sediment area presenting the horizontal
migration of the sedimentary facies (fan bodies deposited along the basin margin) and
the migration of the sediment center.

(3) It presented A/S > 1, and dominated by lacustrine mudstones, with turbidite
deposits (Fig. 12), developing interbedded coarse and fine architecture in the
basin-center deep-water area under an extensional tectonic regime or in the
depth-water area (located in the basin center or at the margin) under a strike-slip
setting.

6.2 Effects of tectonic on hydrocarbon accumulation

The eastern depression underwent trans-extensional tectonic movement from the
Late Jurassic to the Early Cretaceous (Zhang et al., 2018), controlling the big tectonic
subsidence. It was dominated by lacustrine deep-water sediments, developing thick
dark mudstones (Fig. 13). The mudstones had wide distribution, big thickness and
deep burial, providing good material basis for source rocks.

There was another trans-extension in the depression during the Early Cretaceous,
controlling the development of fan delta, delta and underwater fan (Fig. 13). The sand
sediments is in large scale, and progradated into the basin center and deposited along
the basin margin. The sandstones are potential reservoir rocks.

The primary physical property of the reservoir rocks of the Mesozoic strata is
poor in the eastern depression, this result is effected by the sedimentary environment
and diagenesis (Gao et al., 2018). Unconformity surface, fracture and crack generated by tectonic movement can improve the physical property of the reservoir rocks and promote the oil and gas migration in this condition. On the one hand, two periods of transpression occurred at the end of the Late Jurassic-Early Cretaceous and during the period of after the Early Cretaceous-before the Eocene, resulted in the strata uplift. The unconformity surface or erosion surface between the middle supersequences and upper supersequences and between the Lower Cretaceous and the Eocene are the important positions where secondary porosity developed, which remarkably improve the physical property of the reservoir rocks and provide pathway for the oil and gas migration. On the other hand, the break and crack generated by tectonic movement (Fig. 14a, 14b) directly improve the permeability of the reservoir rocks. What’s more, the grain corrosion (Fig. 14c) and the interstitial matter dissolution (Fig. 14d) promote the development of the secondary porosity as well. Therefore, it existed many secondary porosity development belts in the Mesozoic strata, the belts remarkably improved the quality of the reservoir rocks, and the reservoir types include break type and pore type. Moreover, the strike-slip movement resulted in the formation of deep-water area in the basin center and at the basin margin, which contributes to the development of the source rocks. The reservoir rocks and source rocks can make up the “self generation, self accumulation" and "lower generation, upper accumulation" two patterns of hydrocarbon pools in the eastern depression.

7. Conclusions
(1) The Lower Cretaceous strata of the eastern depression in the North Yellow Sea Basin is divided into two third-order sequences effectively.

(2) There are four types of lithology-lithofacies architecture: coarse-fine-coarse, asymmetric coarse-fine, asymmetric fine-coarse and interbedded coarse and fine.

(3) The strike-slip faults dominated and the eastern depression underwent right-lateral movement from transtension to transpression during the Early Cretaceous.

(4) The fan sediments progradated into the basin center and deposited along the basin margin.

(5) It existed many secondary porosity in the reservoir rocks.

Acknowledgements

This study was supported by funds from the China Geological Survey Program (GZH200700405, DD20190582, DD20190629). We deeply appreciate the reviewers and editors for their comments, which significantly improved the original manuscript in both scientific levels and clarity.

Reference


Horton, B.K., Constenius, K.N., and Decelles, P. G. 2004. Tectonic control on


destruction of the North China Craton. Earth Sciences Frontiers, 17(4): 64-89.

(In Chinese with English abstract.)


Table 1. Statistical list of strata thickness and mudstone thickness of the wells in K1sq1

<table>
<thead>
<tr>
<th>Well</th>
<th>Strata thickness (m)</th>
<th>Mudstone thickness (m)</th>
<th>Mudstone to strata ratio (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>W16</td>
<td>570</td>
<td>391.35</td>
<td>68.66</td>
</tr>
<tr>
<td>W5</td>
<td>167.6</td>
<td>26.5</td>
<td>15.81</td>
</tr>
<tr>
<td>W3</td>
<td>486</td>
<td>159.37</td>
<td>32.79</td>
</tr>
</tbody>
</table>

Table 2. Stratigraphic structures and its characteristics of the Lower Cretaceous in the eastern depression

<table>
<thead>
<tr>
<th>Stratigraphic structures</th>
<th>Tectonic control</th>
<th>A/S</th>
<th>Lake-level change</th>
</tr>
</thead>
<tbody>
<tr>
<td>coarse-fine-coarse</td>
<td>normal tensile</td>
<td>&lt;1~&gt;1~</td>
<td>rise-fall</td>
</tr>
<tr>
<td></td>
<td>extensional</td>
<td>&lt;1</td>
<td></td>
</tr>
<tr>
<td>interbedded coarse and fine</td>
<td>normal tensile</td>
<td>&lt;1~&gt;1~</td>
<td>fluctuation</td>
</tr>
<tr>
<td></td>
<td>strike-slip</td>
<td>&gt;1</td>
<td></td>
</tr>
<tr>
<td>asymmetric coarse-fine</td>
<td>strike-slip</td>
<td>&lt;1~&gt;1~</td>
<td>rise-fluctuation</td>
</tr>
<tr>
<td>asymmetric fine-coarse</td>
<td>strike-slip</td>
<td>&gt;1~&lt;1~</td>
<td>rise-fall</td>
</tr>
</tbody>
</table>