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ORIGINAL PAPER - EXPLORATION GEOLOGY

Differential control of syndepositional faults on sequence stratigraphy and depositional systems during main rift I stage in the southeastern fault zone of Qingxi Sag, Jiuquan Basin, Northwestern China

Chengcheng Zhang[1,2] · Hua Wang[1,2] · Yuantao Liao[1,2] · Zongsheng Lu[3] · Jianrong Tang[1,2]

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Abstract In active rift basins, syndepositional faults exert a major control on sequence stratigraphic patterns and depositional system features, which together determine reservoir distribution, geometry, and quality. In this study, we analyze syndepositional fault characteristics of the main rift I stage in the southeastern fault zone of the Qingxi Sag, Jiuquan Basin. The syndepositional faults are marked by boundary fault with high dip angle and strong activity in the western section, and both boundary fault and associated secondary fault with relatively low dip angles and weak activity in the eastern section. In response to these different fault patterns and activity intensities, the resulting sequence stratigraphic and depositional system features are different in the western and eastern fault zones. The southeastern basin margin is divided into steep slope fault belt in the west and fault terrace belt in the east, and two corresponding types of sequence stratigraphic patterns developed. Contrastive analysis of the depositional systems highlights that they differed in sediment dispersal patterns, distribution scales, development positions, and sediment physical properties. Reservoirs associated with the depositional systems were further differentiated into four types. Analyzing the characteristics of the four types of reservoirs and their corresponding traps provides a useful reference for the deployment of future hydrocarbon exploration in the study area.

Keywords Jiuquan Basin · Qingxi Sag · Syndepositional faults · Sequence stratigraphy · Depositional systems

Introduction

Tectono-sedimentology is the study of sedimentary response to tectonic movements (Frostick and Steel 1993). It can be applied at multiple time scales to research the sedimentary records of changing tectonic activity rates (Pascucci et al. 2006; Contardo et al. 2008; Zhu et al. 2013). In tectonically active basins, syndepositional structures, especially syndepositional faults, are well developed and widely distributed. Various combinations of syndepositional faults and intensity of activity not only directly control the sequence stratigraphic patterns, but also affect the development of provenance systems, paleo-current systems, sand dispersal systems and depositional systems (Ravnas and Steel 1998; Lin et al. 2000; Hans et al. 2002; Feng 2006). Within a sequence stratigraphic framework, comprehensive analyses of sedimentary infill and syndepositional tectonism are the key to revealing spatial and temporal distributions of source rocks, reservoirs, and cap rocks (Xu et al. 2008; Huang et al. 2012). A relatively new idea in tectono-sedimentology that has been successful in hydrocarbon exploration is to analyze response relationships between syndepositional faulting and sequence stratigraphic patterns, sedimentary infill features, and the configuration of source, reservoir and seal (Gawthorpe and Leeder 2000; Devault and Jeremiah 2002; Lin et al. 2005; Liao et al. 2012).

✉ Chengcheng Zhang
zhangcc3614@foxmail.com

[1] Key Laboratory of Tectonics and Petroleum Resources, Ministry of Education, China University of Geosciences, Wuhan 430074, China

[2] Faculty of Earth Resources, China University of Geosciences, Wuhan 430074, China

[3] Faculty of Earth Sciences, China University of Geosciences, Wuhan 430074, China

The Qingxi Sag is the most hydrocarbon-rich sag in the Jiuquan Basin. After several decades of production, increasing hydrocarbon demand has spurred the pursuit of new reservoirs within old oil fields of the Qingxi Sag. As a result, renewed exploration for subtle reservoirs has been carried out in the southeastern fault zone, which is the optimum location for subtle trap development and also the favored region for hydrocarbon accumulation in the Qingxi Sag. However, existing drilling in the southeastern fault zone indicates a discrepancy: the western section (Liudong area) has inferior exploration findings to the eastern section (Yaxi area). A deep understanding of geological characteristics in these two areas is essential to effective and efficient oil exploration and exploitation. Since previous studies mainly focused on the tectonic evolution, sediment infill, and hydrocarbon accumulation of the southeastern fault zone in the Qingxi Sag (Pan et al. 2006; Wang et al. 2005; Chen et al. 2014; Chen et al. 2001a, b; Han et al. 2007; Li et al. 2010), there are few studies, if any, about syndepositional fault characteristics and their relationship with sequence stratigraphy and depositional systems. Therefore, the main aims of this paper were to document syndepositional fault characteristics, and then illustrate how they control sequence stratigraphic patterns and depositional systems, and finally discuss reservoir and trap features, which may optimize petroleum exploration in the southeastern fault zone.

Geological setting

The Jiuquan Basin on the northern edge of the Qilian orogenic belt is one of the most economically important oil prospecting regions in the Hexi Corridor basin group of northwestern China (Fig. 1) (Pan et al. 2012). It is a superimposed basin that experienced an Early Cretaceous rifting graben phase and a Cenozoic foreland depression phase (Liu 1986; Wang et al. 2005, 2008; Chen et al. 2014). The Jiayuguan Uplift in the center subdivides the basin into two first-order negative tectonic units: the Jiudong Depression in the east and the Jiuxi Depression in the west (Fig. 1) (Wang et al. 2005; Cheng et al. 2006; Chen et al. 2014).

The Qingxi Sag, situated in the western Jiuxi Depression, covers an area of 280 km^2. It is bordered by the South Uplift to the southeast, the Yabei Uplift to the northeast, the Qingxi Low Uplift to the northwest, and the Qilian Mountain to the southwest (Chen et al. 2001a, b). Controlled by northeast-trending syndepositional marginal faults in the Early Cretaceous, the Qingxi Sag stretches along the northeast orientation and shows an asymmetric half-graben structure, with faulting in the southeast and overlapping in the northwest. The Liudong area is in the western section of southeastern fault zone of the Qingxi Sag, while the Yaxi area is in the eastern section, and both are adjacent to the South Uplift (Fig. 1).

On the basis of 3D seismic, logging, drilling and paleontological data, the sequence stratigraphic framework of the Early Cretaceous in the Qingxi Sag has been constructed, dividing the Early Cretaceous into three formations from base to top (Chijinpu, Xiagou, and Zhonggou) (Chen et al. 2014). The Xiagou Formation reaches a maximum thickness of 3000 m and is the primary depositional unit of the Early Cretaceous basin fill. It consists of three third-order sequences: SQK1g0, SQK1g1, and SQK1g2+3, in ascending order (Fig. 2).

Similar to other rifting sags, such as Qikou Sag in Bohaiwan Basin (Chen et al. 2012), Fushan Sag in Beibuwan Basin (Liu et al. 2014) and Changchang Sag in Qiongdongnan Basin (Song et al. 2014; Liao et al. 2012) in Eastern China, the Qingxi Sag presents features of multiphase tectonic evolution during the Early Cretaceous (Wang et al. 2005; Pan et al. 2006). The syn-rift stage can be subdivided into the initial rift stage (SSQK1c), main rift I stage (SQK1g0), main rift II stage (SQK1g1, SQK1g2+3), and late rift stage (SSQK1z) (Fig. 2). Our study interval is the main rift I stage when SQK1g0 deposited, comprising the main hydrocarbon-bearing strata as well as the most important source rocks in the sag (Sun et al. 2006). During the main rift I stage, the Qingxi Sag underwent its most active tectonic subsidence. A set of thick mudstones was deposited in a deep lacustrine environment. Fan deltas and small turbidite fans formed on the active side of the southeastern fault zone close to the lacustrine mudstone (see Fig. 9) (Chen et al. 2014), which are the main exploration targets in the Qingxi Sag at present (Li et al. 2010).

Materials and methods

The data sets used in this study include new 3D seismic data, lithology data, logging data, and drilling cores provided by PetroChina Yumen Oilfield Company. The new seismic cube comprises a region of approximately 285 km^2, fully covering the oil prospecting districts in the Qingxi sag.

Syndepositional fault patterns and activity data are based on 3D seismic interpretations, which were used in combination to calculate fault throw. The interpreted horizons of SQK1g0 in the 3D seismic cube were transformed from time domain to depth domain based on the synthetic seismogram and seismic wave velocity before being used for fault throw calculations (Chen et al. 2014). According to the stratum back stripping analysis, the initial geomorphology of the Qingxi Sag in main rift I stage has

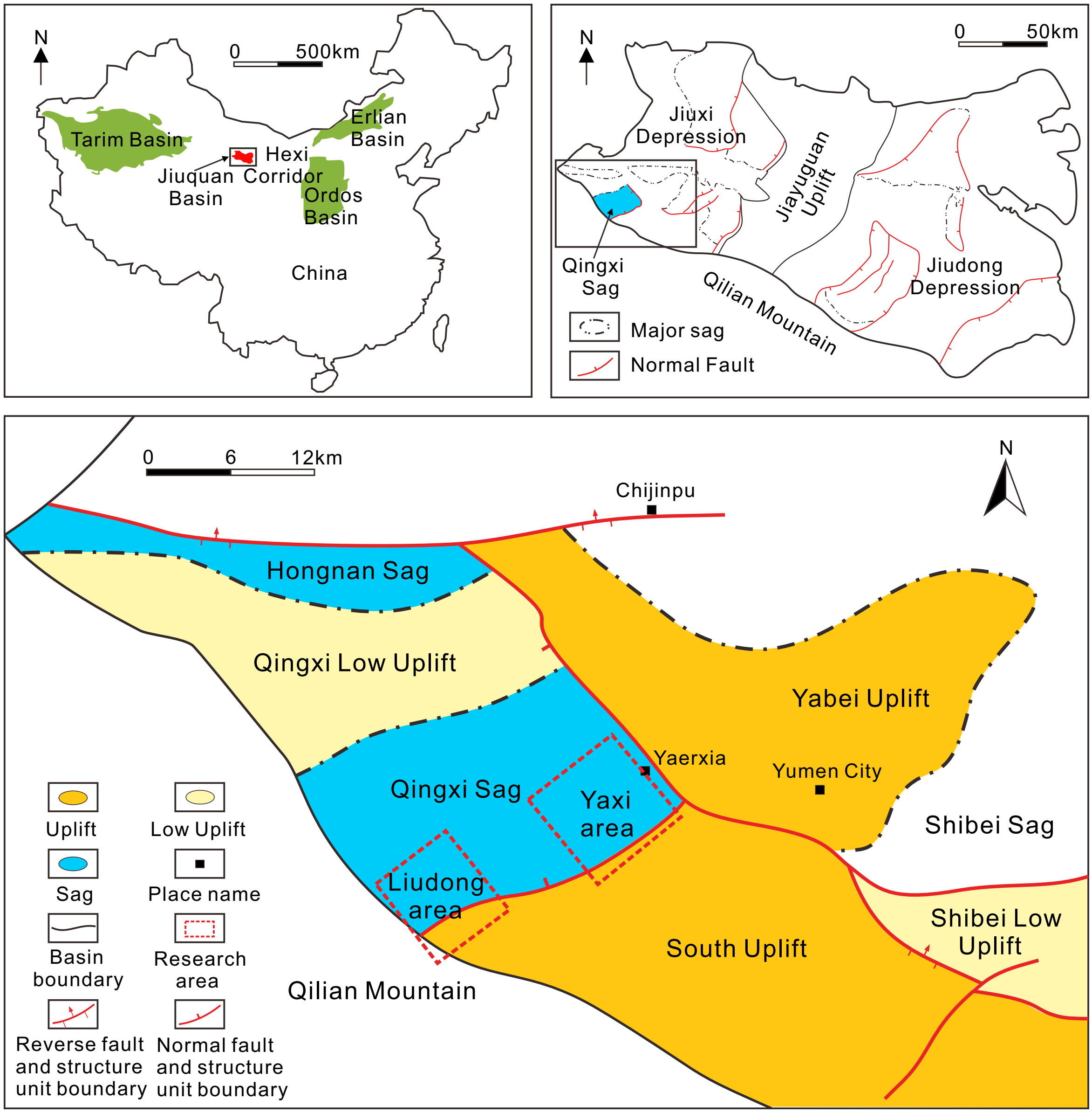

Fig. 1 Geographic location and regional geological settings of the Qingxi Sag, Jiuquan Basin, Northwestern China (Cheng et al. 2006; Wen et al. 2007; Pan et al. 2012; Chen et al. 2014)

been presented quantitatively. Identification of sequence boundaries (sb), transgressive surface (ts) and maximum flooding surface (mfs) are based on analysis of 3D seismic reflection including onlap, downlap, toplap and truncation reflections, and complemented by well lithology and logging curve combination style variations. The integration of point (well)-line (cross sections)-plane (planforms), using lithological data, logging data (GR, RD, and LLD log curves), seismic profile and geomorphology, was applied to build up the sequence stratigraphic patterns (see Figs. 6, 7). Drilling cores from four wells (L11, L10, L13, and Y1) were used to determine the sedimentary facies and indicate their distribution range, combined with lithological statistics from 32 wells (see Figs. 8, 9).

Characteristics of syndepositional faults in the southeastern fault zone

Syndepositional fault patterns

In the Early Cretaceous, the Jiuquan Basin began to rift due to the NW–SE regional extension stress, resulting in a series of NNE and NE extensional normal faults and

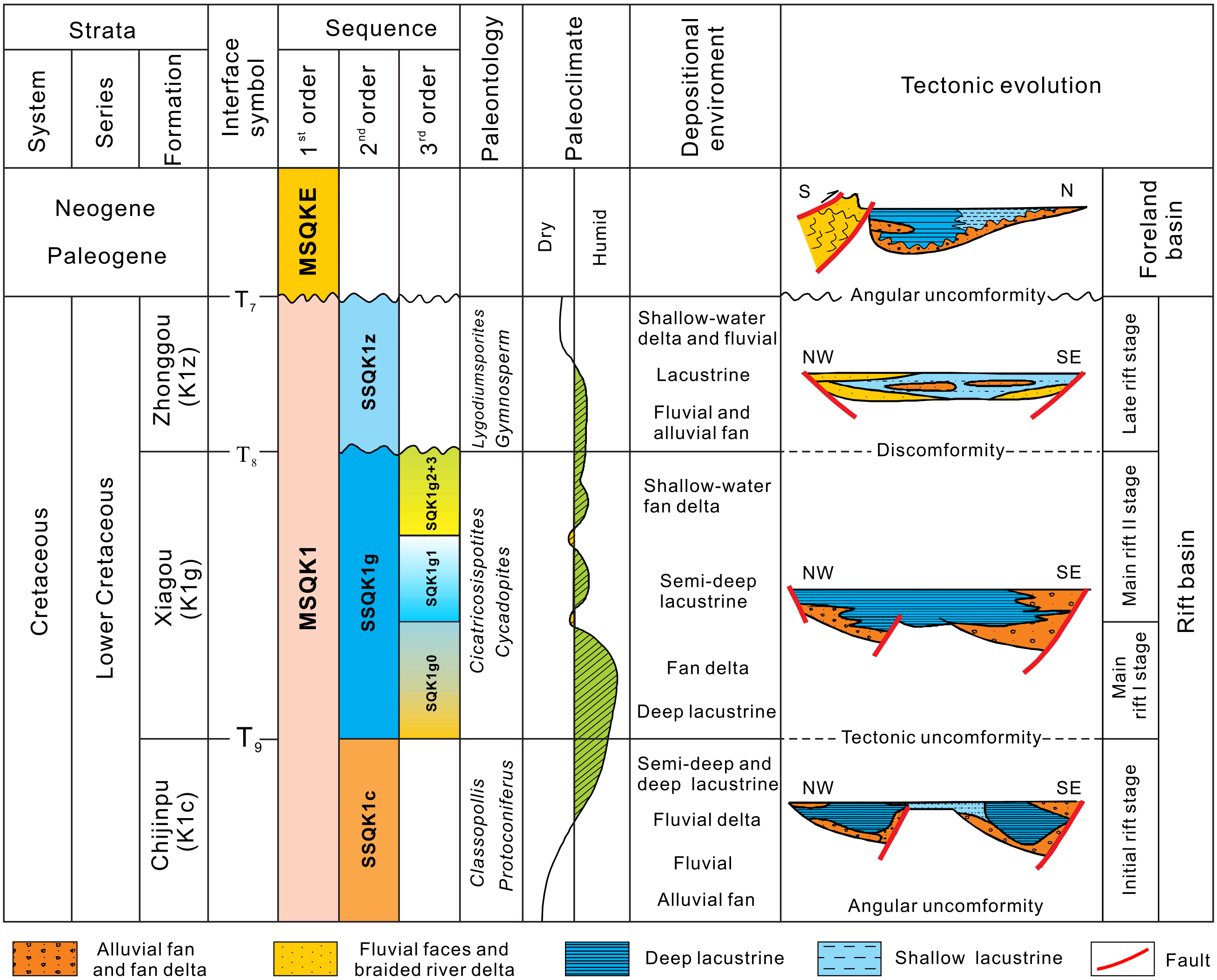

Fig. 2 Stratigraphic sequence division, depositional environment and tectonic evolution of the Qingxi Sag (Liu 1986; Wang et al. 2005, 2008; Chen et al. 2014)

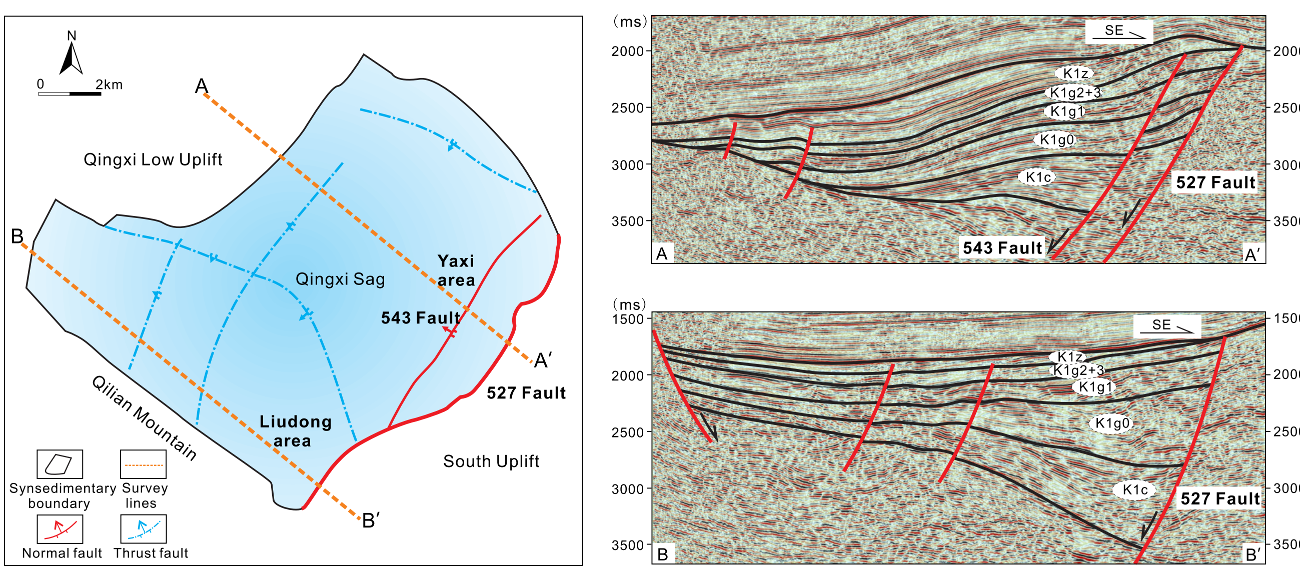

Fig. 3 Planar and profile views of syndepositional faults in the Liudong and Yaxi areas (Chen et al. 2014)

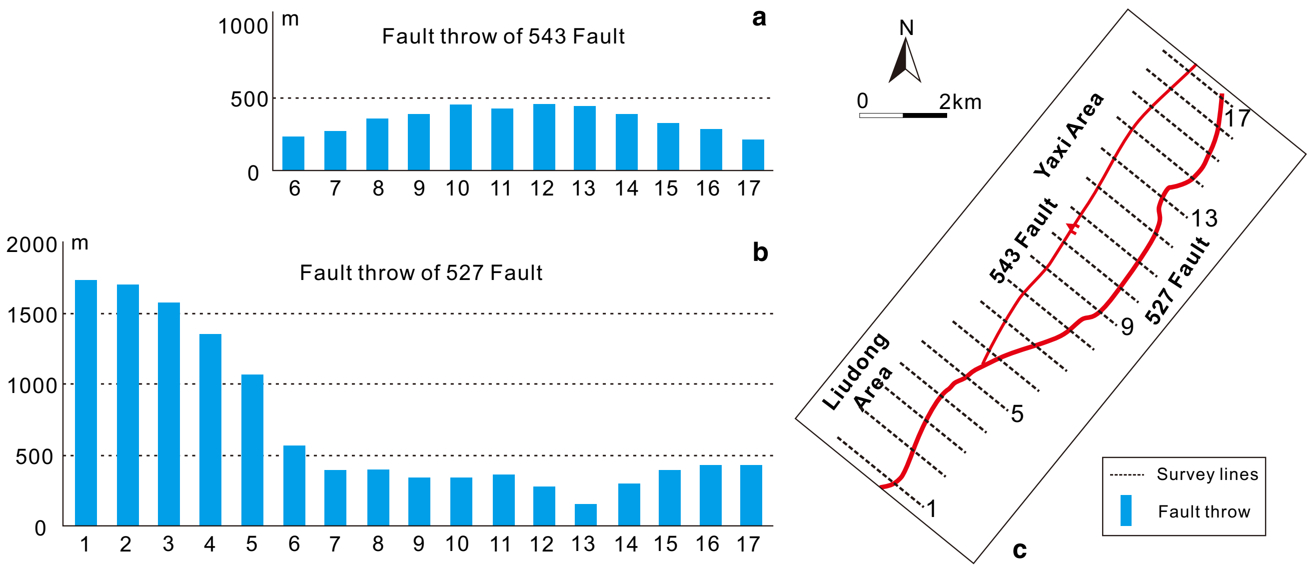

Fig. 4 **a** Fault throw of 543 Fault in main rift I stage, **b** fault throw of 527 Fault in main rift I stage, **c** sketch map of the locations of survey lines

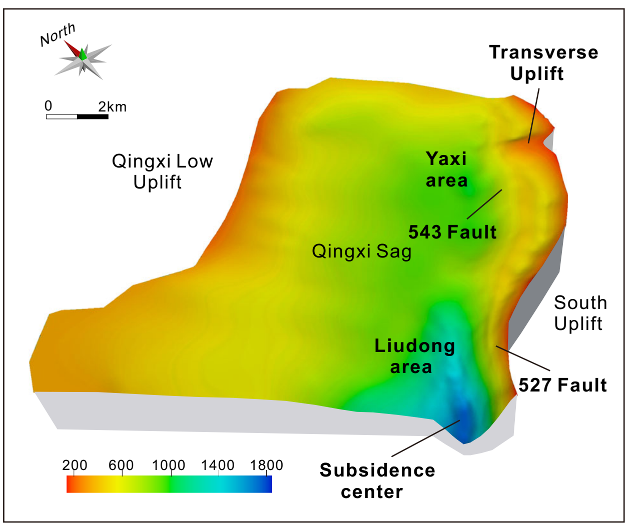

Fig. 5 Geomorphology of the Qingxi Sag in main rift I stage

associated secondary faults (Li et al. 2006). In the southeastern margin of the Qingxi Sag, 527 Fault and 543 Fault developed. The Liudong area was controlled only by the western section of the 527 Fault, while the Yaxi area was controlled by both the eastern section of the 527 Fault and the 543 Fault (Fig. 3).

The 527 Fault was segmented in the initial rift stage and became a continuous fault in the Qingxi Sag in the main rift I stage. In planar view, the strike of 527 Fault trends NNE, but bulges toward the sag where the initial segmented faults linked together in the Yaxi area (Fig. 3). In profile view, the 527 Fault manifests as a listric normal fault, with a larger dip angle in the western section than in the eastern section (Fig. 3). The 543 Fault that developed near the 527 Fault is a secondary normal fault, with nearly concordant strike and dip to that of the eastern section of 527 Fault (Fig. 3).

Characteristics of syndepositional fault activities

Syndepositional fault throw is frequently used to reflect activity intensity (Zhao and Dai 2003). Fault throw can be approximately expressed by thickness differences between the depositional strata on the hanging wall and footwall. The fault throws of 527 Fault and 543 Fault in the main rift I stage were calculated according to the 17 selected seismic survey lines, to analyze their activity characteristics (Fig. 4).

The different sections of 527 Fault had different activity intensities during the main rift I stage. The western section in the Liudong area exhibits intense activity, while the activity of the eastern section in the Yaxi area was relatively weak. The sum of the fault throws of 527 Fault and 543 Fault in the Yaxi area (850 m on average) is smaller than the fault throw of 527 Fault in the Liudong area (1500 m on average) (Fig. 4).

Syndepositional fault activity generates a major control on basin architecture and geomorphology (Gawthorpe and Leeder 2000; Leeder 2011). Syndepositional fault activity causes the obvious altitude difference on geomorphologic units of hanging wall and footwall especially in main rift stage (Lin et al. 2004). Hence, geomorphology restoration is an effective approach for showing syndepositional fault activity. As can be seen from the geomorphology map (Fig. 5), the 527 Fault is characterized by significant subsidence in the western fault zone and less subsidence toward the eastern fault zone. The subsidence center of the

Qingxi sag is located in the Liudong area. The transverse uplift is located in the Yaxi area where both the strata thickness and the fault throw of 527 Fault are smallest (see line 13 in Fig. 4).

Syndepositional fault controls on sequence stratigraphy

Researchers have found that long-term active syndepositional faults are the predominant controlling factor in formation of various structural slope break belts in continental rift basins (Lin et al. 2000; Wang et al. 2004; Ren et al. 2004; Feng 2006). A structural slope break belt is a pivotal zone of sudden geomorphology gradient changes, constituting demarcations of paleostructural units (Wang et al. 2003). These belts directly constrain changes in accommodation space and have important impacts on the internal makeup of sequences, the development of depositional systems, and the distribution of sand bodies (Hou et al. 2012). On the basis of sequence stratigraphic framework and syndepositional fault patterns, two types of structural slope break belts are recognized in the southeastern basin margin: the Liudong steep slope fault belt and the Yaxi fault terrace belt. These belts provide diverse controls on the configuration of stratigraphic sequences and the stacking patterns of depositional system tracts in combination with regular lake level fluctuations.

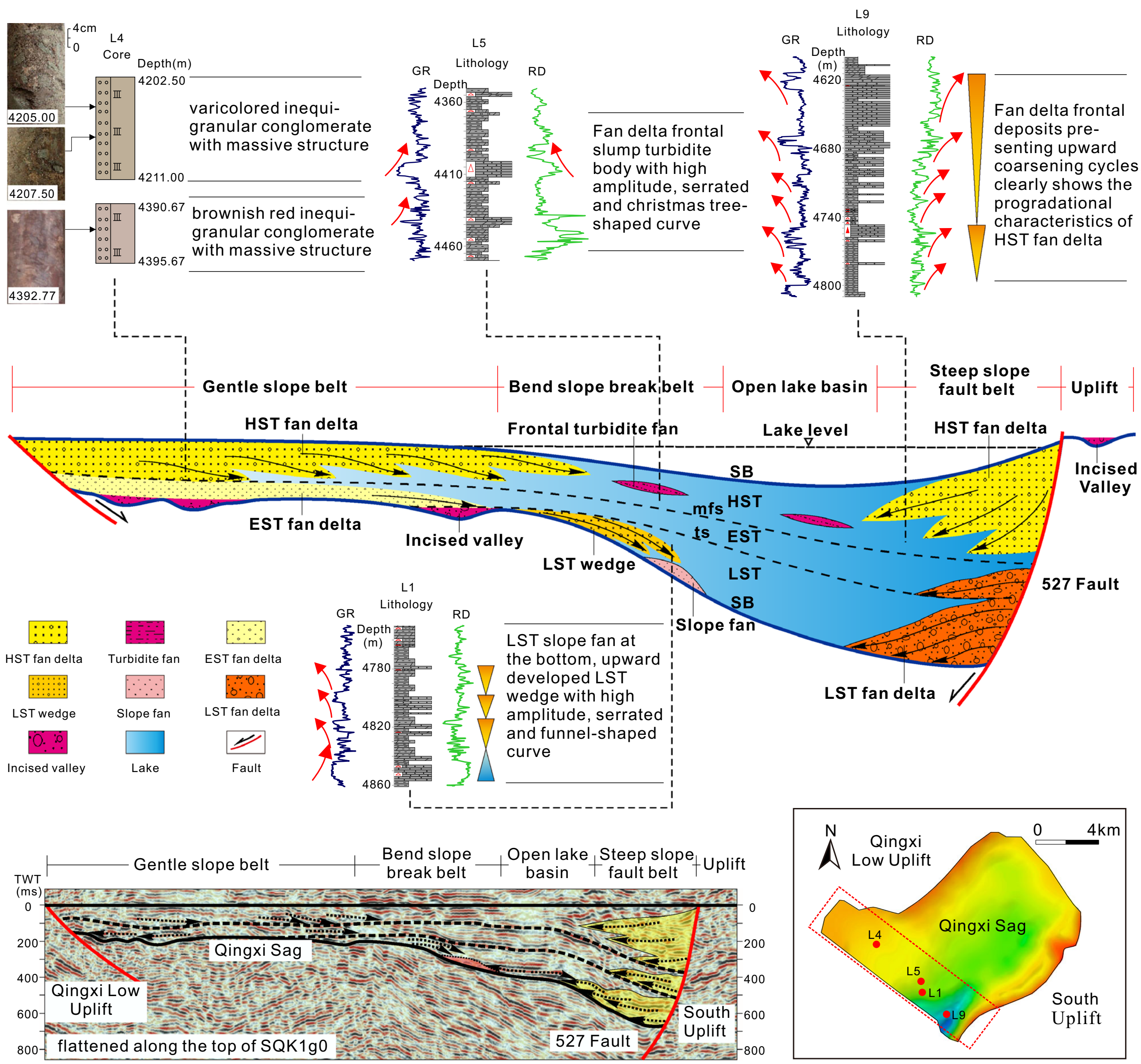

Fig. 6 Filling sequence model for the steep slope fault belt of SQK1g0 in the Qingxi Sag

Sequence stratigraphic pattern in the Liudong area

The western section of 527 Fault in the Liudong area was very active in the main rift I stage, causing strong normal faulting throughout this area and forming a steep slope fault belt. This activity also led to the deformation of the hanging wall of 527 Fault, making a distinct change in depositional gradient at the front edge of the gentle slope belt and forming a bend slope break belt. The formation of the bend slope break belt caused the steep slope fault belt to become an up-dip foot slope belt (Fig. 6).

During the lowstand system tract (LST), the lake level declined and the lake shrank. The sediments from the South Uplift were immediately transported into the deep lake near the root of the boundary fault, generating inshore petticoat-shaped fan deltas in the steep slope fault belt. In the bend slope break belt, the position of maximum curvature acted as the LST depositional shoreline break. Erosion surface and incised valley developed on the gentle slope belt and slope fan and a lowstand wedge developed concurrently on the bend slope break belt, together making up the LST combination facies. During the lacustrine

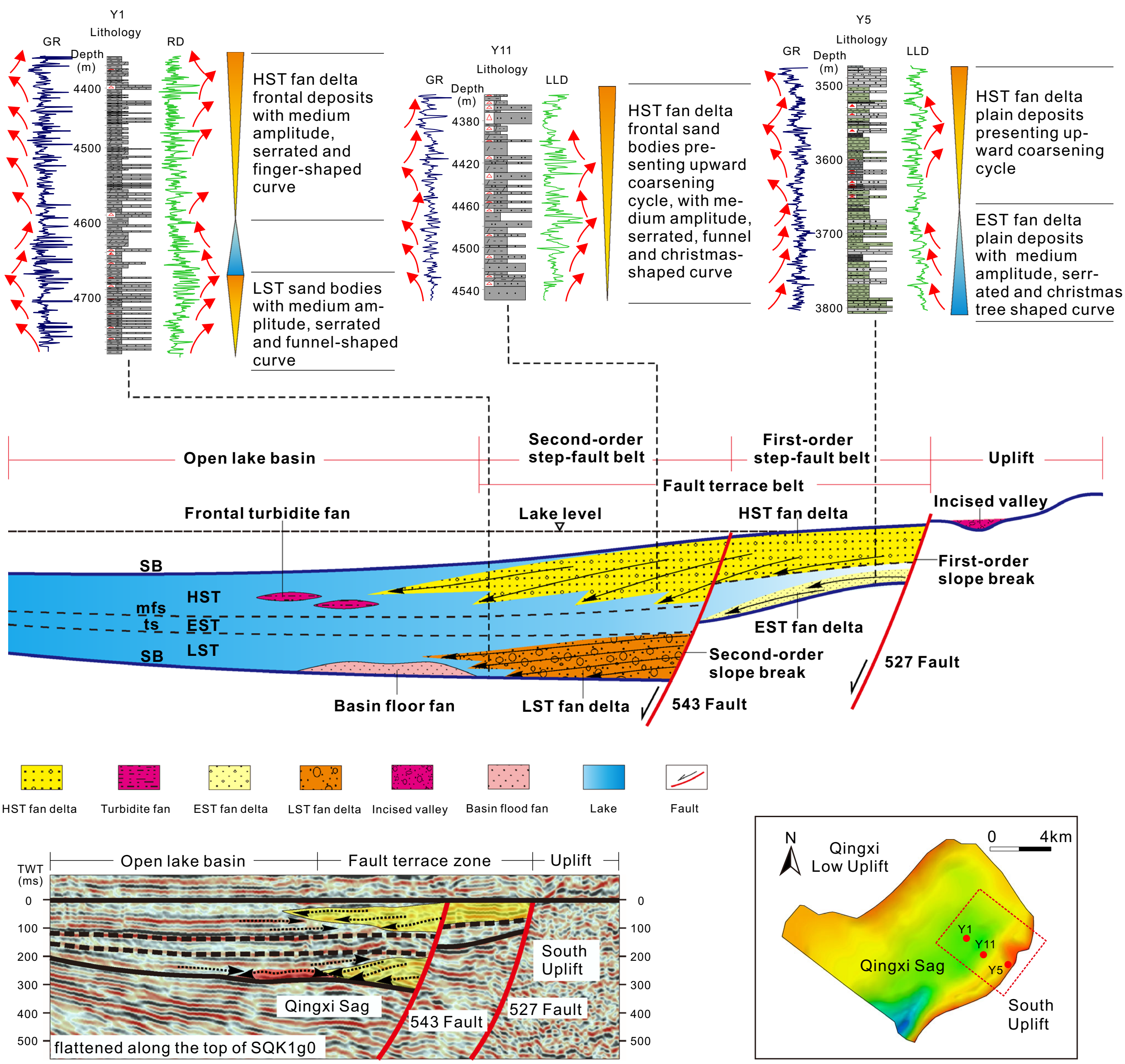

Fig. 7 Filling sequence model for the fault terrace belt of SQK1g0 in the Qingxi Sag

expanding system tract (EST), the lake level rose quickly and the accommodation space of the lake expanded. The sediment supply was temporarily insufficient. Therefore, the fan delta in the steep slope fault belt retrograded and diminished in size, and a mass of deep lacustrine mudstone was deposited in the open lake basin and the bend slope break belt. During the highstand system tract (HST), the lake level reached a maximum and began to fall. The rate of sediment supply started to increase. HST fan deltas formed in the steep slope fault belt and gradually prograded basinward. Meanwhile, sediments at the fan delta fronts were retransported to form turbidite fans in the deep lake as a result of gravity slumping.

Sequence stratigraphic pattern in the Yaxi area

The fault terrace belt in the Yaxi area is jointly controlled by the eastern section of the boundary 527 Fault and by the secondary 543 Fault. These two parallel faults served as the first- and second-order slope breaks and their hanging walls are the first- and second-order step-fault belts. The resulting multilevel fault terrace belts not only created multilevel delivery paths for clastic transportation, but also controlled the distribution of depositional facies from a shallow water into a deep lake environment (Hou et al. 2012) (Fig. 7).

During the LST, the lake level sank below the first-order step-fault belt, and the second-order slope break restricted the depositional boundary of the lake. The region landward of the second-order slope break was exposed, which led to denuding of the underlying strata but supplied the second-order step-fault belt with sediments. The LST fan delta was deposited adjacent to the second-order slope break and a basin floor fan formed in the central part of the lake. Subsequently, the lake level rose to the first-order step-fault belt during the EST and the facies belts receded. The first-order slope break defined the border of the basin while the second-order slope break defined the deep water area of the lake, which respectively controlled the distribution of the EST fan delta and the deep lacustrine mudstone. During the HST, the sediment supply rate gradually increased and exceeded the rate of accommodation space formation. The accommodation space near the first-order step-fault belt was soon filled. Then the sediments went over the second-order slope break and prograded toward the central basin, forming the progradational HST fan delta and frontal slip turbidite fans.

To summarize, only EST and HST deposition occurred on the first-order step-fault belt, but a complete set of system tracts developed on the second-order step-fault belt.

Syndepositional fault controls on depositional systems

In syn-rift phase, depositional system development characteristics are closely related to syndepositional faults. In general, syndepositional faults control depositional systems in the following ways. (1) Tectonic subsidence created by syndepositional fault activity determines the size of the accommodation space, and thereby controls the stacking thickness and the distribution of depositional sand bodies (Deng et al. 2008). (2) Structural deformation triggered by syndepositional boundary fault activity influences the geomorphology, which further controls master drainage system sites, sediment entry points, and sand body dispersal patterns (Qi 2007). (3) Elevation differences between the hanging wall and the footwall on the basin margin determine potential energy differences between the proximal provenance and the sink, which directly affect denudation rates, hydrodynamic conditions, sediment supply rates, and even clastic properties (Song et al. 2013).

Sediment dispersal patterns and depositional system distribution scopes

Analyses of sand content and depositional system indicate that sediment dispersal pattern and distribution scope of the fan deltas in Yaxi area clearly differ from those of the fan deltas in Liudong area (Figs. 8, 9). The extension of the fan deltas in Yaxi area was approximately perpendicular to the strike of the syndepositional faults (Fig. 8). The fan deltas grew quite large, and especially on the hanging wall of 543 Fault, the fan delta front extended quite far and had a wide

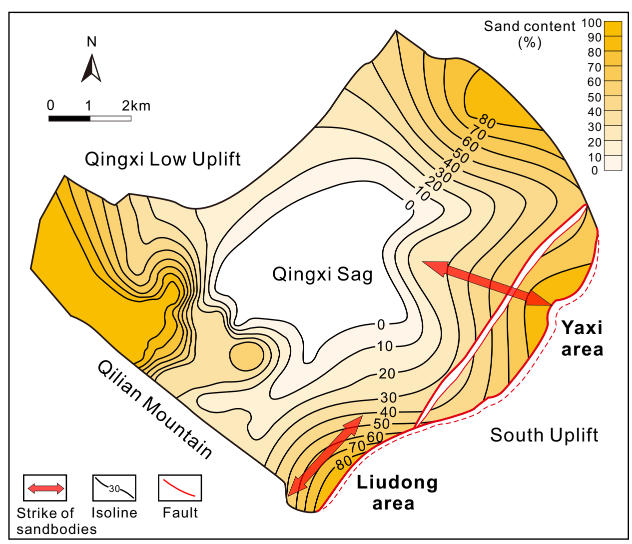

Fig. 8 Sand content contour map for SQK1g0 in the Qingxi Sag

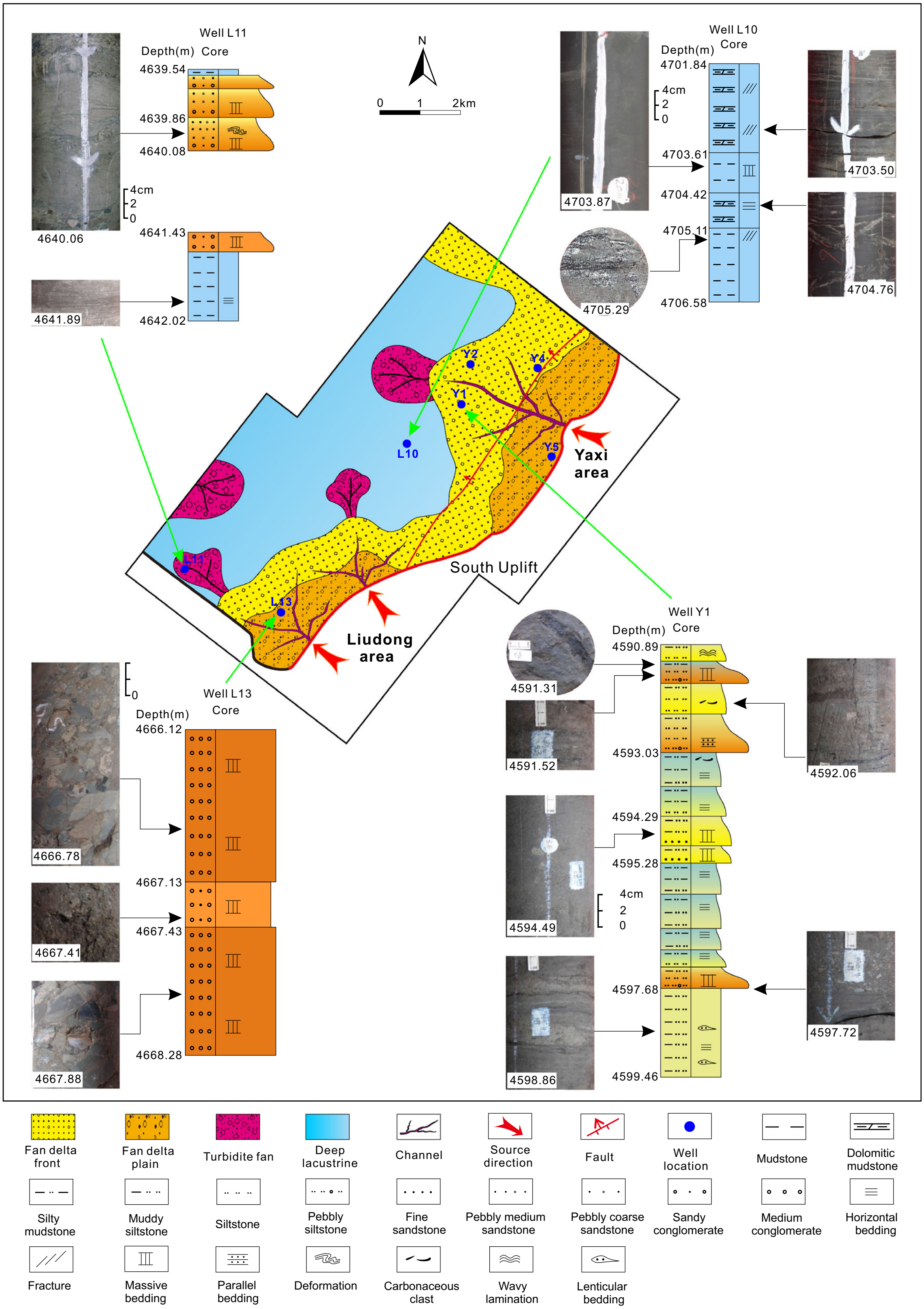

Fig. 9 Depositional system distributions for SQK1g0 in the Liudong and Yaxi areas, and drilling core columns and core photos of wells L11, L10, L13 and Y1

depositional facies belt (Fig. 9). However, the fan deltas in Liudong area spread parallel to the strike of the syndepositional fault (Fig. 8) and had large accumulation thicknesses, narrow facies belts and small distribution scope (Fig. 9).

The above differential features of the fan deltas in these two areas are associated with syndepositional fault characteristics. More specifically, the weaker syndepositional fault activity in Yaxi area resulted in less tectonic subsidence near the basin margin, so the major accommodation space was close to the central basin. With sustained supply of sediments, the fan deltas continually extended basinward. In comparison, the syndepositional fault activity in Liudong area was stronger, so the major accommodation space was adjacent to the boundary fault. Therefore, the potential energy of the clastic material entering the basin sharply decreased. Deposits were rapidly unloaded near the root of the boundary fault and could not be driven farther. Moreover, the bend slope break belt opposite the steep slope fault belt also blocked the forward extension of fan deltas but contributed to their left and right extension.

Depositional system development positions

Previous studies have revealed that the structural deformation of basin marginal zones is related to boundary fault throw in rift basins (Wang et al. 2011). In a regional sense, structural deformations are defined as a coordinated system preserving regional extension or extensional strain. Normally, the hanging wall uplifts and the footwall isostatically sinks where the fault throw is smaller than it is at either side, whereas the hanging wall sinks and the footwall isostatically uplifts where the fault throw is greater than it is at either side (Jiang et al. 2010). These resulting geomorphologic units at basin margins significantly affect depositional system development positions.

In the transverse uplift zone of Yaxi area, the weaker activity of the boundary fault produced a relative lowland on the footwall, creating drainage divides that forced the main drainage systems to converge and enter the basin (Fig. 10a) (Hou et al. 2012). Consequently, the transverse uplift controlled the main entrance for sediments and the preferred development position of the fan delta. As is shown in the sand content map for SQK1g0 (Fig. 8), the master channel for sand entering Yaxi area was located at the hinge zone of the transverse uplift.

In contrast, the boundary fault in Liudong area is characterized by a high dip angle and intense activity with significant fault throw. Therefore, the elevation of the footwall was high and the marginal slope was quite steep. Erosion on this topographic highland was extremely strong, which was conducive to the formation of eroded valleys at the basin margin (Xu 2013). These valleys acted as

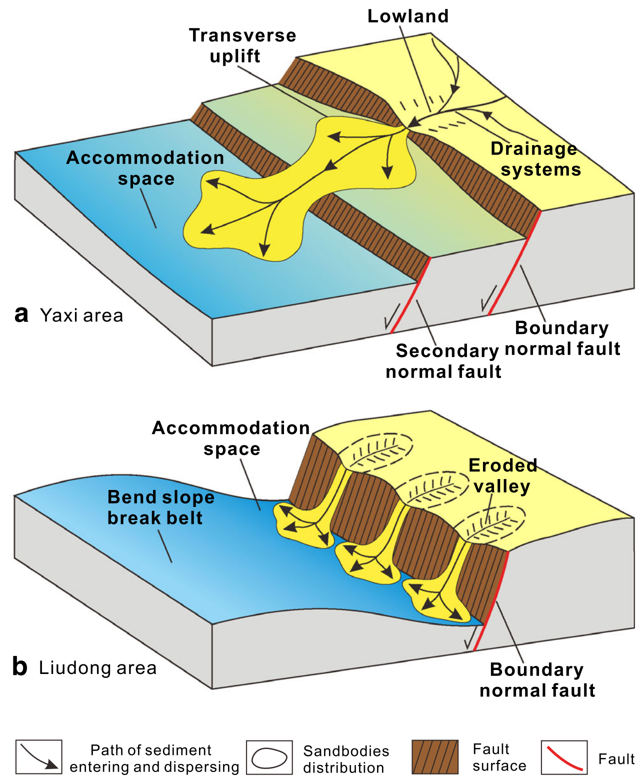

Fig. 10 Models showing the development position and strike of fan deltas: **a** fan delta development model in the Yaxi area, **b** fan delta development model in the Liudong area

favorable conduits for sediments entering the basin; thus, multiple fan delta lobes developed at the slope toe of the boundary fault in Liudong area (Fig. 10b).

Physical properties of depositional bodies

Boundary fault activity intensity has a significant impact on hydrodynamic conditions of the currents importing sediment to the basin. Depositional bodies originating from different hydrodynamic conditions differ in characteristics such as lithofacies, internal heterogeneity, clastic makeup, shale concentration, grain size, sorting, and rounding. In other words, different fault activity intensities would probably lead to different physical properties of the depositional bodies (Tang et al. 2007). Compared with the Yaxi area, the Liudong area had a steeper slope and more intense syndepositional fault activities. The hydrodynamic conditions were very strong but unstable. These conditions shortened the time available for mechanical differentiation of transported sediments and resulted in chaotic accumulations of clastic materials, with a high percentage of poorly sorted and rounded coarse-grained material, such as conglomerates and pebbly sandstones, with common matrix fillings (Fig. 9). As a consequence, the physical properties of the fan delta sediments in Liudong area were less favorable than those in Yaxi area. For example, the average porosity of the sandy conglomerates in Liudong area is 3.72 % and the average permeability is $1.652 \times 10^{-3} \mu m^2$, while in Yaxi area the average porosity and permeability reach 9.74 % and $15.189 \times 10^{-3} \mu m^2$ respectively.

To sum up, depositional systems developed in Yaxi area and Liudong area differed in sediment dispersal patterns, distribution scales, development positions and sediment physical properties, owing to the differential control of syndepositional faults.

Discussion

Reservoir and trap types

The syndepositional faults in the study area not only control the different sequence stratigraphic patterns, but also strongly influence the different depositional system characteristics. The reservoirs associated with these depositional systems differ in spatial distributions, sizes, geometries, and physical properties. To make an appropriate exploration plan to be adopted in the study area, it is essential to differentiate the various reservoirs by their features. These reservoirs can form different types of traps within the different sequence stratigraphic patterns.

The fan delta front sand bodies, deposited in the second-order step-fault belt in Yaxi area, constitute the type-I reservoirs. Those sand bodies extend quite far toward the central basin and occupy a wide facies belt. During deposition, the sediment is relatively well sorted and rounded, yielding good reservoir physical properties. These reservoirs pinch out laterally within the deep lacustrine mudstone and the up-dip direction is cut by the 543 Fault, which has a good sealing effect during the quiescent period of no fault activity. These reservoirs are favorable to form the fault-lithologic traps (Fig. 11).

The LST basin floor fan and the HST turbidite fans in Yaxi fault terrace belt, along with the HST turbidite fans in Liudong steep slope fault belt, make up the type-II reservoirs. These reservoirs are far from the syndepositional faults. The sand bodies undergo long-distance transportation or re-transportation, and are generally rich in fine-grained sediments, with relatively high textural and compositional maturity. In addition, these reservoirs are deposited in deep lacustrine mudstone and surrounded by source rock, providing advantageous conditions for formation of lentiform lithologic traps (Fig. 11).

The HST sand bodies in the first-order step-fault belt in Yaxi area are type-III reservoirs. These reservoirs mainly consist of coarse sandstones and sandy conglomerates, and are sealed by faults on both sides, forming fault-block traps (Fig. 11).

The fan delta front sandy conglomerates in Liudong steep slope fault belt compose the type-IV reservoirs. These reservoirs have a large proportion of poorly sorted

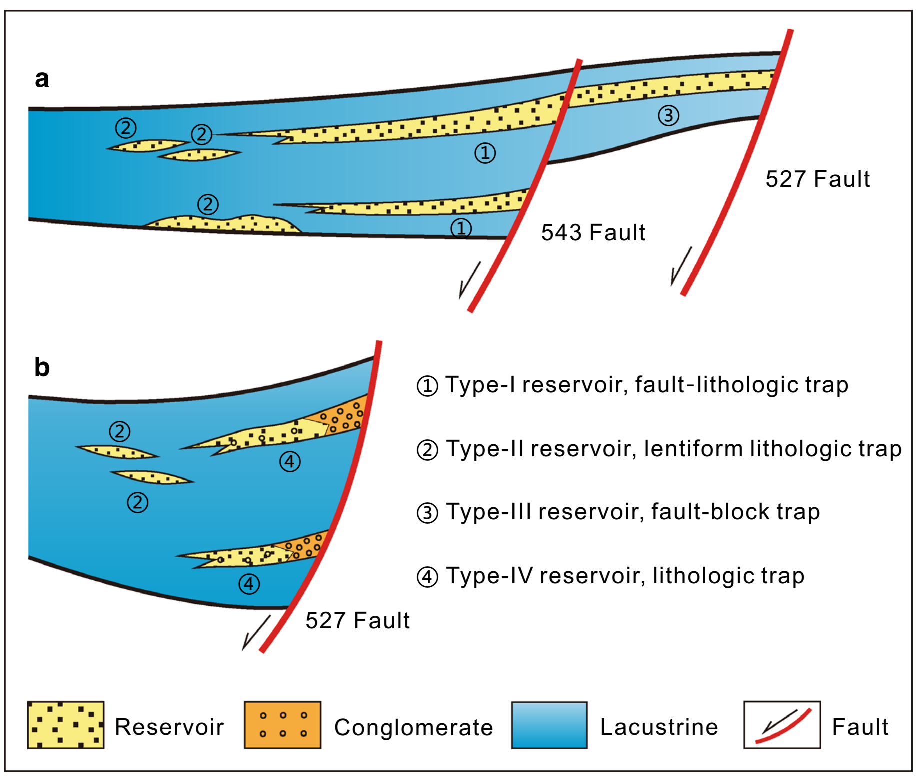

Fig. 11 Models showing the reservoirs and traps in the Liudong and Yaxi areas: **a** reservoirs and traps in fault terrace belt, **b** reservoirs and traps in steep slope fault belt

coarse-grained clastics and occupy a narrow facies belt but have large vertical stacking thicknesses. Moreover, the fan delta plain conglomerates, especially those close to the escarpment margin, have even less favorable physical properties and could play an effective role in lateral sealing (Sui et al. 2010; Liu et al. 2010). Hence, they together make up another kind of lithologic trap (Fig. 11).

Exploration direction

As the most important mature source rock interval in the Qingxi Sag, the SQK1g0 has produced abundant oil and gas, feeding the traps in the sag (Chen et al. 2001a, b). To achieve good exploration results, it is of great importance to take the different reservoir and trap types into consideration, and our proposed models may provide a useful reference for future hydrocarbon exploration. On the whole, the deployment of future exploration should be conducted at different levels in the study area: the type-I and type-II reservoirs and the corresponding traps are economically important exploration targets and should be given priority, followed by the type-III reservoirs; It is suggested that more detailed research is required prior to selecting an exploration target for the type-IV reservoirs because of serious reservoir heterogeneity.

Conclusions

These two syndepositional faults occurred in the southeastern fault zone of the Qingxi Sag are marked by two different patterns and activity characteristics during the main rift I stage. The western section of the southeastern fault zone in Liudong area is merely controlled by the 527 Fault which has a high dip angle and strong activity, while its eastern section in Yaxi area is jointly controlled by the 527 Fault and the 543 Fault, which both have a relatively low dip angle and weak activity.

On the basis of different syndepositional fault patterns, the structural slope break belts in the study area can be subdivided into the Liudong steep slope fault belt and the Yaxi fault terrace belt. Each type of fault slope break belt formed its own characteristic sequence stratigraphic pattern. In response to distinct syndepositional fault activities, the development characteristics of the Liudong fan deltas are different from those of the Yaxi fan deltas. The fan deltas deposited at the slope toe in the Liudong area extended parallel to the strike of the fault and had large vertical stacking thickness but narrow facies belts, with relatively unfavorable physical properties. The development position of fan deltas in the Yaxi area was controlled by transverse uplift, and the fan deltas extended perpendicularly to the strike of the fault and had large distribution scale and wide facies belts, with favorable physical properties.

Four types of reservoirs are differentiated according to spatial distribution, size, geometry, and physical property. Their corresponding traps are fault-lithologic traps, lentiform lithologic traps, fault-block traps, and lithologic traps. Analysis of the different reservoir and trap types can effectively guide future hydrocarbon exploration in the study area.

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