Evolution and characteristics of sedimentary systems during fault-depressed transition in Songliao Basin—Case study of the Denglouku formation in the southeast uplift region

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This study analyzes the sedimentary characteristics and evolution of Denglouku formation. There are 5 types of subfacies developed: alluvial fan, fan delta, braided river, braided river delta and lacustrine facies. Influenced by tectonic activity, the sedimentary facies types are different in different sedimentary periods. In the early stage of the transition period named D1 member period, the deposition is significantly controlled by the fault depression, resulting in rapid unloading of the sediments. Five large-scale divided faulted depressions and two small faulted depressions have been developed. During the late stage of the transition period named D2 member period, the unified sediment unloading area is formed, and the lake area expanded, which developed alluvial fan, fan delta, braided river, braided river delta and lacustrine deposits. Taking the community of the floodplain and lacustrine contact zone as a boundary, the western part mainly developed alluvial fan and braided river sedimentary system from the provenance highland in the western and northern, the east part mainly developed lacustrine facies massively. Among them, the fan delta front and braided delta front subfacies are the main enrichment reservoirs for oil and gas, which is the favorable subfacies of oil and gas exploration in the future.

[Keywords: Songliao Basin, the southeast uplift region, Cretaceous, Denglouku formation, Sedimentary facies.]

\textbf{Introduction}

The southeast uplift region is a first-order tectonic unit in southern Songliao basin. Due to the disproportionate and generally low exploration degree, the overall understanding of the southeast uplift region has been limited. Some researchers have studied the aspects of sequence stratigraphy\textsuperscript{1-4}, thermal evolution history, structural characteristics and reservoir and summarized many regularities\textsuperscript{5-12}. In reality, few research reports can be touched regarding to the evolution process and characteristics of sedimentary systems in the Denglouku formation of the southeast uplift region. However, in recent years, it has been proved by the exploration practice that there are various types of reservoirs in the Denglouku formation, and more industrial oil wells and stripper wells have been developed, which indicates great exploration potential\textsuperscript{13-17}. On the basis of previous studies, combining analyses of seismic data, core samples, logging data, and laboratory tests, the authors provide the detailed description of the characteristics of sedimentary systems and evolution process in the Denglouku formation, which are of great significance to benefit in the exploration and development of the reservoir formation in the southeast uplift region.

\textbf{Materials and Methods}

The southeast uplift region, an extremely special and important first-order tectonic unit, characterized by typical rift-depression dual structure, is located in the southern Songliao Basin, with about $3.6 \times 10^4$ km$^2$ in area. The study area\textsubscript{18}, composed of twelve second-order tectonic units with different scale (Fig. 1), extends in north-east trending; the southern part in this area is bounded by Jilin oil field, the western part is adjacent to the central depression, the southeast part is adjacent to the Songliao Basin, and the eastern is neighboring to the Yitong basin. The tectonic evolution of the basin went through 5 stages\textsuperscript{19-22}, including the faulted sedimentary stage from Shahezi to Yingcheng formation, the fault-
depressed transition sedimentary stage from Denglouku to Quantou formation, the depression sedimentary stage from Qingshankou to Nenjiang formation, the uplift and erosion stage from the end of Nenjiang to the Tertiary, and the depression consumption stage in Quaternary. It is a composite basin formed by some faulted basins in the lower, and superimposed a large depression basin in the upper, demarcated by the top of Denlouku Formation. During the faulted stage, early Cretaceous, the southeast uplift region developed 7 small-scale faulted basins, including Liutiao, Shiwu, Fulongquan, Halahai, Sheli, Dehui and Yushu basin. Each faulted basin had a relatively independent petroleum system. During the depression stage, late Cretaceous, these small-scale faulted basins changed to a large-scale depression basin, which indicates the fault-depressed superimposed structure. Among them, the lower Cretaceous Huoshiling Formation, Shahezi Formation, Yingcheng Formation, Denglouku formation and Quantou Formation are the main target layers in the southeast uplift region, and the upper layers are thin, developing to varying degrees. There are 345 drilled wells available in this area, which includes 71 industrial wells and 131 wells indicating oil and gas. The Denglouku formation is mainly gas-bearing reservoir, and oil reservoir in partially. It can be divided into the first member (D1 member) and the second member (D2 member), which are mainly composed of greyish white gravel-bearing sandstone (Fig. 2).

Analytical methods

27 representative sandstone samples of different wells were collected from the Lower Cretaceous Denglouku sandstone formation in the southeastern uplift region of the Songliao Basin of NE China. Before the experiment, the samples were crushed into pieces of less than 5 mm, and put them in sample bags marking well number, well depth, number and other information, respectively. Then the samples in the tray are ordered in sequence and baked more than 4
hours under high temperature in order to deplete the oil thoroughly. Then we put the samples into high temperature resistant porcelain bowl in sequence and injected 15% HCL, stirring accelerated the reaction. Samples were treated for 48 hours repeatedly by constantly adding HCL until the water washed to neutral. Samples after acid washing were put into the air dry oven to dry. We weighed 20g well-handled drying sample and grounded it until all the particles dispersed. The grinding samples were put into a 1000 ml measuring cup, flowrate was maintained at 110-130 mil/min, stirred slightly every 30 min until the water of the upper part of the cup became clear. keep for 3-5 min, poured out some water and put the sample into the drying oven. Dry samples after washing were weighed and poured into electric mechanical sieve shaker to filter for 10 min. After the experiment, the sand after filtering was poured into the vessel separately, weighed one by one, and analyzed and determined the grain size parameters.

After performing analysis on the heavy mineral samples indoor, take the samples with particle size between 0.1 to 0.25 mm into H₂O₂ and dilute HCl, and then separate heavy minerals by tribromomethane with density of 2.89 g/cm³. In order to obtain the heavy mineral with the density more than 2.89 g/cm³, the methods of identification of heavy minerals are chosen as stereomicroscope and immersion technique²³. Immersion method is actualized by the OR-THOCUX-POX-BX type polarizing microscope, produced by the Leitz company in German. The heavy mineral content is calculated by the method of particle statistical method, and each sample counts more than 400 grains particles. 26 kinds of heavy minerals were detected in sediment samples, and the types and contents of heavy minerals in each well were statistically analyzed.

Results and discussion
Types and Characteristics of Sedimentary Facies
Alluvial fan is characterized by its abundant sediment sources and short transport distance. Its rock composition is characterized as uneven grain size and poor sorting²⁴-²⁶. Its electric logging features...
resembles slightly dentate box-shaped or barrel-shaped. The continuity of seismic events is poor in the fan root and become better in its far-end. Core samples and logging data help us confirm that most of its rock composition is variegated gravel and glutenite mingled with brown mudstone, associated with extremely poor separation and roundness. The alluvial fan sedimentary system mainly developed during the period of Dengling formation, the fault-depressed transition stage. The fan body scattered across Changchun anticline belt, southwest of Dengling anticline belt, south of Wangfu sag and north of Diaoyutai uplift. According to the lithology, structure, grain size and sedimentary structure, the alluvial fan facies can be further classified as root fan, inner-middle fan and marginal fan.

Root fan

Root fan, a steep sedimentary slope appearance, formed by the rivers that cut into the alluvial fan, is located at the side of the beginning or at the cliff of the top of the downward extension of the alluvial fan. It consists of large sets of purple-red conglomerate, glutenite and mudstone conglomerate, in which thin layer brown mudstones are occasionally found. The gravels are disorderly arranged with poor component level and structure. Logging curves are characterized by low gamma and high resistance of thick layer dentate box-shaped profiles or bell-shaped profiles. The seismic section’s features are not obvious, which is usual in a clutter reflection structure.

Inner-middle fan

Inner-middle fan, a relatively slow sedimentary slope appearance, located in the middle of alluvial fan. The content of fine grained sediments is increasing with the decreasing of the single layer thickness, compared with fan root sediments. Its lithology refers to brownish red-brown sandy conglomerate intercalated by thin layers of purplish red-brown red mudstone as major components. The logging profiles features by the micro dentate box-shaped curves. Core samples are mainly composed of conglomerate, with intercalation of a small amount of thin layers of sand and mud. The proportion of gravels in conglomerate can commonly accounted for above 70%. The gravel is characterized as complex composition, low maturity, large grain size, generally more than 1 cm, dominated by medium and coarse gravel, poor sorting and grinding, angular gravel can be locally visible, lack of bedding structure, mainly in massive shape. The seismic reflection performance is shown as the progradation of sphenoid.

Marginal fan

Marginal fan is the outer edge of the alluvial fan. Compared to Inner-middle fan, it has a finer sedimentary and a wider distribution in the plane. Its lithology has the interbedding of the sedimentary of purple-red glutenite, siltstone and mudstone. It is developed from distributary channels of the marginal fan and sheet flood sedimentary microfacies of the fan, which is the advantageous facies belt for oil and gas formation. A classic study was carried out to investigate the area distribution of the Gujiadian area in the southern of this region, by using the data from well Fu 11 (Fig. 3). The electric logging curves are featured by low-amplitude bell-shaped profiles. The reflection characterization is disordered on the seismic section. The marginal fan is derived from
proximal to distal of the fan in a dome shape with a gradually ameliorating continuity. Core samples are mainly composed of moderate granularity of glutenite. The red-purple mudstones are visible under oxidation environment. Generally, the separation and the roundness are very poor. The granularity probability graph is shown as a ternary form with relatively low slope. In these graphs, the total amount of rolling and leaping are close. The intersection point is located at 1 ~ 2 Φ, where the gravity flow and the traction flow coexisted under sedimentation.

Fan delta is a coarse grain depositional system, often controlled by contemporaneous faults, was formed during the process of propulsion from alluvial fan to lake basin, generally developing in the steep slope of depression. It has a dual mechanism of the gravity flow and the traction flow. The grain size is coarse. Sandy conglomerate is interbedded with mudstone or mudstone intercalated by coal seam. Seismic reflection is wedge-shaped, converged in the lake basin, whereas, cluttered on land or at the bottom of fault. The subfacies are mainly composed of fan delta plain, fan delta front and pro-fan delta. Fan delta is mainly distributed in the northwest gentle slope belt and the southeast steep slope zone.

Fan delta plain is the land part of fan delta. Its microfacies are mainly recognized by branch river and distributary bay. In the case of well He 10 (Fig. 4), the lithology of branch rivers mainly consists of grey conglomerate, gravel-bearing sandstone, gritstone and fine sandstone, and characterizes by non-bedding, low compositional maturity, poor sorting and lower psephicity. The granularity probability graph can be divided into two stages with low slope. The total amounts of rolling and leaping are 70% and 30% respectively, with wider range of granularity. The intersection point is close to 2.0 Φ that is dominated by the amount of leaping, indicating that the rolling grains are filled by the components of fine grains after the transport and deposition; this is due to the weakening of geologic force/agents. It is shown that after the high energy rolling particles being transported and deposited, the fine grains are filled into the rolling grains component, which indicates the ability of gravity flow to carry sands into lakes is gradually reducing, and flow oscillation existence, reflecting the hydrodynamic features of the transition from the gravity flow to the traction flow. The sedimentary presents a positive cycle characterized by finer from the bottom to the top in the vertical direction, and the resistivity and gamma logging profiles mainly appear as the dentate box-shaped and bell-shaped curves. Interdistributary bay is formed by argillaceous sediment that consists of greyish-green mudstone and grey siltstone. The resistivity curves are in the shape of low flat fingers.

Compared with fan delta plain, fan delta front subfacies own finer deposition particles with a dark-grey and grey color, with a feature of great separation, roundness, various types of beddings and contents. The sandy content increased significantly. It was obviously washed out at the bottom, and mainly developed subaqueous distributary river, subaqueous interdistributary bay and sheet sand microfacies. The estuary dam is poor-developed, which probably related to the large energy of the subaqueous distributary river and the frequent diversion of the river channel. The subaqueous distributary river is the extension of the braided river channel under water, also the predominant microface. The lithology mainly
consists of glutenite and sandstone, with better sorting than it on land. The granularity probability graph can be divided into two stages. The intersection point is between $1.8 \sim 2.5 \Phi$. The total amounts of rolling are between 30% and 40%. It is dominated poor sorting, a dual mechanism of the gravity flow and the traction flow, an apparent feature of positive rhythm, box or bell shaped resistivity curves. The subaqueous interdistributary bay is located at the relative sag area among subaqueous branch rivers, communicating with lake. It is formed by waterway overflow or crevasse and mainly sedimented grey mudstone and sandstone with thin inter layers occasionally. The horizontal bedding is developed, and washed away by distributary channel in vertical ward. The sand sheet is distributed at the end of in the subaqueous distributary channel flows into the lake, which is a thin sand body reformed by the lake waves. The lithology refers to grey siltstone, argillaceous siltstone and mudstone, with anti-rhythm. The spontaneous potential curves are funnel or finger shaped.

**Braided river**

Braided river is characterized by multiple river channels, large wide and shallow gradient bed and rapid lateral migration. Moreover, it exhibits the braided characteristics of multiple branches and convergence. The river has a typical dual structure, where particles that located at the bottom are coarse. The deposition is under the control of tractive flow and the glutenite is well developed. According to characters of the combination of sedimentary grain size and lithology, braided river can be further divided into two subfacies: riverbed and floodplain.

The riverbed is formed by multiple upward thinning units of sedimentary member. Its bottom area is usually coarse glutenite sedimentary with obvious wash out and its top area is fine grained sandstone sedimentary, representing an evolution process of the flow from strong to weak. There are two main microfacies: channel bar deposits and channel-lag deposits. Channel bar deposits are also named as diara. Its formation is related to the hydrodynamic structure of the river. Its upstream is steep with coarse sediments and is suffering from erosion effect. On the other hand, its downstream is flat with sedimentation. Its granularity size probability curve can be divided into three stages, which is mainly composed of leaping amount.

Floodplain is the product of flooding periods. Its lithology is mainly reddish-brown mudstone under oxidation environment, associated with calcareous silty mudstone deposition. The electrical resistance response is characterized by little finger shaped combination of flat features.

**Braided river delta**

Braided river delta is a shallow water delta developed in the gentle slope of fault basin, which is formed by the braided river progression to the shore-shallow lake. Braided river delta, as the same as Fan delta, belongs to coarse grain delta. The sediments were mainly deposited by traction flow. It developed of scour-fill structures, cross bedding, parallel bedding and lenticular bedding. In the southeast uplift region, braided river delta is only developed in the period of D2 member, and compared to fan delta it has fine grain. It can be further divided into braided river delta plain and braided river delta front subfacies.

**Braided river delta plain**

Braided river delta plain is mainly composed of light colored gravel-bearing sandstone, sandy conglomerate and middle-fine sandstone, black mudstone and medium-thickness seam. Its interface is usually structured as scour surfaces and its bedding is generally parallel or groove cross. It can be further divided into two kinds of microfacies of braided stream and inter-channel deposition.

The rocks of braided stream are mainly composed by grey glutenite. In the case of well Nong 46 (Fig. 5). The logging curves are characterized by the high resistivity, low gamma and high-amplitude box-like shaped. Granularity probability curves can be divided into three stages with high slope, showing a good sorting. The overall content of rolling is about 40%. The intersection of the overall content of leaping and suspension are located at 3.0 ~ 3.5 Φ, reflecting the low disturbance intensity during transporting. The deposition is featured by the coexistence of the gravity flow and the traction flow. It illustrates that the hydrodynamic condition of braided river delta is weaker and the grain size is finer than that of fan delta.

**Braided river delta front**

Braided river delta front is the main body of braided river delta, which is the most developed and expansive sedimentary facies belt. According to the characters of rock-electrical responses, braided river delta front can be further divided into two kinds of
sedimentary microfacies, namely, subaqueous distributary channel and subaqueous interdistributary bay. The lithology of subaqueous distributary channel is similar to braided channel are, except more fine-grained. The lithology is mainly composed of gravelized sandstone and silty sandstone, with grey and light grey, developing massive bedding, trough cross bedding, wavy bedding, deformation bedding, and scouring surface and erosion surface are often recognized, containing mud gravel occasionally. Granularity probability curves can be divided into three stages or two stages, which are dominated by leaping. The logging curves are medium-high amplitude dentate bell-shaped or box-shaped. Subaqueous interdistributary bay deposits are located on both sides of the subaqueous braided distributary channel, mainly composed of mudstone, silty mudstone and argillaceous siltstone, appear the characteristics of thick layers of mud and thin layers of sand, with horizontal bedding, massive bedding and wavy bedding in common.

**Lacustrine**

Lacustrine deposit mainly includes shore-shallow lacustrine and deep lacustrine sediments. The deep lacustrine is located in deep-water areas of the lake basin. In the case of well DS 2, most of sediments are black mudstone with dark colors and pure lithology (Fig. 6). The shore-shallow lacustrine refers to shallow water sedimentary area near the low water surface and above the wave base. The interface refers to the scour contact between mudstone gravel-sized
grains and underlying mudstones. The lithology is characterized as dark-grey block mudstone with dark sandy mudstone and carbonaceous mudstone in thin layers. Curves are featured by a combination of flat and wavy profiles. Most of the bedding structures are continuous parallel bedding, wavy bedding, wavy cross-bedding, etc.

**Sedimentary Source Analysis**

In the distribution of heavy minerals, the stable heavy minerals such as zircon, tourmaline and garnet increase, and the content of unstable heavy minerals decreases in vertical. The distribution of heavy minerals in the plane has a certain partition and inheritance, and in each of the major fault depressions are multi source sediments. There are many kinds of heavy minerals in the D1 member (Fig. 7), with multiple mineral combination, and irregular distribution. The types of heavy minerals are relatively independent and stable in each fault depressions. Such as garnet-zircon-epidote combination in well Fu 11 of Denglouku anticline belt, and zircon-garnet-tourmaline combination in well He 10 and Bu 1 of southern Jiutai. The stable mineral content increases during the sedimentary period of D2 member (Fig. 8). The partition and inheritance are more obvious in the plane. The sedimentary system around the depression began to develop in large-scale. The stable heavy mineral extends into depressions, which indicated the sedimentary area is further enlarged.

The percentage of sandstone generally decreases along the main direction of provenance development. During the period of D1 member, there are five major fault depressions. Each of them is composed of multi-source sediments. The provenance has been flowing from the surrounding highlands into them, and the percentage of sandstone decreases gradually along the source area to the fault depressions. There are D2 member sediments all over the study area, except for a few small patches of highland. And the provenance flowed from the surrounding highlands or near or far into the shallow lake. Therefore, D2 member are also characterized as multi source sediments in this study area.

As shown in isopach maps in the studied area, distributions of sedimentary facies are controlled by the basin tectonic evolution. The material sources of
D1 and D2 members have the inherited characteristics of centrally gathering from surroundings, especially in northern direction with strong sources. The sand body is distributed around the sag, but it is relatively isolated in the landscape orientation. Among them, the Changchunling anticlinal belt, the Dengouku anticline belt, the Qingshankou anticline belt and the Wangfu depression have well developed sandstone. The thickest area of D1 member sandstone is located at Wangfu depression (Fig. 9). The thickness of the thickest sandstone is around 200 m. Compared to D1 member, the thickness of D2 member sandstone increases and the sandstone has a tendency southward migration (Fig. 10). Among them, the Qingshankou anticline belt and the Wangfu depression are the most developed ones. The sandstone thickness can be greater than 250 m.

**Plane distribution of sedimentary system**

**Member Plane distribution of sedimentary system**

D1 member is located in the lower part of the Dengouku formation, which is controlled by long-term inherited fractures. The tectonic subsidence happened with strong tensions, where material sources flowed to each fault depression from surrounding highlands and was filled fleetly. It developed five large-scale split fault depressions and two small-scale fault depressions in the period of D1 member (Fig. 11). The scattered alluvial fan is distributed in the intermountainous plain between the two northern fault depressions. Among them, the sedimentary system of the Changchunling anticline belt and the south sag region of the Wangfu depression are complete. The material sources developed alluvial fans, fan deltas and lacustrine deposits in the surrounding of lake basin. The southwest of the Dengouku anticline belt and the fault depression of the northern Diaoyutai uplift only developed clastic sediments of the alluvial fan body. The two small fault depressions developed shore-shallow lacustrine sedimentary deposits; the other three remaining big fault depressions mainly developed fan delta, shore-shallow lacustrine and deep lacustrine deposits.

**D2 member Plane distribution of sedimentary system**

D2 member is the upper sedimentary part of the Dengouku formation, which is in the end of the
period of fault depression transition. The uplift of the denudation area slowed down. The continuity of crustal stretches and fault activities expanded the enlargement of the lake basin. The decentralized fault depression of D1 member has begun to merge and unify with the retreat of sources. The sources of sedimentary system on the periphery of the depressions/sag started to accept deposits in large-scale, excepting the partial highlands of the northern and central regions. Basically, a uniform sediment unloading area was formed by detrital materials from the deposition of amaranth mudstone and grey sandstone interbedded with different thicknesses. There are various types of basin facies, including alluvial fans, fan deltas, braided rivers, braided river deltas and lacustrine deposits (Fig. 12). Under the influences of frequent water shocks, multiple sedimentary bodies of fan deltas and braided river deltas have been developed surrounding lake basin with various scales. At the boundary between floodplain and shore-shallow lacustrine, the D2 member sedimentary is regularly distributed. The alluvial fan and braided river sedimentary system of the west and the north source highlands was developed at the west of this boundary. On the other hand, at the eastern part of this boundary, lacustrine facies were developed in large-scale, associated with clastic sediments from highland source area, forming different retrograding fan deltas with various scales.

**The characteristics of sedimentary Evolution**

D1 member is in the preliminary period of the transition from fault depression to depression. The rift valley gradually closed in the early period with the gradual convergence of fault depression lake basin (Fig. 13). The basin boundaries coexist with fault depression boundaries and depression boundaries. In the early sedimentary period of D1 member, the basin began to settlement. The proximal source sediments were rapidly filled and were covered by the underlying part of the fault depression, which has paved the way for the transition from basin to depression. At this moment, the distribution areas of the basin are small and the thickness varies greatly. The maximum regional distribution of sedimentary

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**Fig. 9** — The sandstones thickness of D1 member in the southeast uplift region of southern Songliao Basin
Fig. 10 — The sandstones thickness of D2 member in the southeast uplift region of southern Songliao Basin

Fig. 11 — The diagram of the D1 member sedimentary facies in the southeast uplift region of southern Songliao basin
Fig. 12 — The diagram of the D2 member sedimentary facies in the southeast uplift region of southern Songliao basin

Fig. 13 — The mode diagram of the D1 member sedimentary facies in the southeast uplift region of the southern Songliao basin
thickness is located at the Denglouku anticline belt, where the sedimentary facies were alluvial fan and fan delta deposits. After that, a large-scale water-transgression period occurred with the upgrading of the base level. The containable space rapidly increased with the enhancement of the area of the water/lacustrine surface, providing a great environment for shallow lacustrine facies mudstone deposit and forming high-quality hydrocarbon source rocks at the southeast uplift region. In the late sedimentary period of D1 member, due to the continuous conversion tectonic activities of fault depression, the lake basin started to shrink. The fan delta gradually prograded to the center of the lake basin, reaching the maximum scale of the fan body.

In the sedimentary period of D2 member, the basin was in the last stage of the fault depression conversion. The fault depression in the early stage was completely covered by sediments in this period. Under the background of this ancient structure and terrain in this palaeo-tectonic and palaeo-topological context, compared to the D1 member, the lake basin expanded (Fig. 14). At this moment, the extended distance of basin sedimentary systems to the internal basin was farther, especially the braided river delta sedimentary from the northern water systems. In the early sedimentary period of D2 member, the continuous subsidence of the crust caused the consolidation of split fault depressions and the large-scale development of lake sedimentary environment. The basin went into the sedimentary period of transgressive tract. Basically, the deposition has entered into the early period of the depression that cannot be completely controlled by the faulted depression. The lake surface stably raised to the largest. Moreover, the stratigraphic distribution range significantly expanded at the southeast uplift region, except the regional loss at the northeast Yushu sag area. The studied areas were basically continuous with various thicknesses. Among them, the Shuangliao depression, the Lishu depression, the northern Wangfu depression have the largest sedimentary thickness, which are the hub of deposition and sedimentation. Each of alluvial fan, fan delta and braided river delta presents a retrogradated sedimentation. In the late sedimentary period of D2 member, the lake surface began to shrink and the water body became shallower. The detrital material continuously discharged into the lake basin. The sedimentary scope/depositional range of fan delta and braided river delta were further expanded with inferior continuity.

The significance of petroleum exploration

1. A precise anatomy of high-yield and low-yield wells in this area and its around indicate that the oil-bearing sand bodies of Denglouku formation are characterized by near provenance, large thickness sediment and resistance to compaction degree, strong compression and corrosion of rock solid ability. It plays a crucial role in enriching oil and gas.

2. Different types of sand bodies have different reservoir properties. The factors that were unfavorable
to accumulating oil and gas in alluvial fan include coarse grain size, hybrid structure, high shale content, adjacent to the basin boundary fault and lack of good cover, even though it developed thick glutenite. Braided river facies found in the upper reaches of the river. Due to the frequent channel diversion and heterogeneous lithology, thick massive sand at bottom, and thin and poor argillaceous sediment on the top are common. It shows that the reservoir has good physical properties. The far-sourced sandy braided stream usually exhibits better hydrocarbon bearing probability. The braided river delta is characterized by relatively homogeneous lithology, a large distribution area of single sand body, a great thickness of single layer. It mainly contains middle and fine sandstone, and locally pebbly. The reservoir physical properties are thus generally better. Among them, the channel sediment is believed to be the main reservoir. Fan delta sandstone sedimentary bodies are often surrounded by source rocks. The sand body connectivity is poor, while it multiply superimposed contiguous distribution and the oil-bearing area of the superimposed sand bodies is large. So, it can form lithologic oil reservoir enrichment zone.

(3) D1 member is developed split fault depressions sedimentary. The fault depression peripheral ancient bulge is the major developed area of the alluvial fan sedimentary system. The fan delta deposition distributed at the surrounding of the fault depression and the fan delta front extended to the location into the intern lake.

The fan delta front sand bodies in the period of D1 member are favorable subfacies belts, because of their moderate grain size, good reservoir properties and adjoining to the center of oil-gas source depression. During the period of D2 member, due to steady deposition, the conditions of structural trap are good. The coarse sand bodies of the fan delta and shallow lacustrine basin are a favorable subfacies belts as lithologic structural reservoirs.

Conclusions
Based on the comprehensive analyses of core, logging, seismic data and mud logging data, this study discusses the development process of five types of sedimentary facies, including alluvial fan, fan delta, braided river, braided river delta and lake facies. D1 member exhibits the characteristics of sedimentation with multiple isolated fault depressions. The Changchunling inclined belt and the south of Wangfugang sag region have complete/intact sedimentary systems. Alluvial fan, fan delta and lake facies developed around the lake basin from the source. Southwestern Dengelouk anticline belt and the northern Diaoyutai uplift of fault depression only developed alluvial fan body’s clastic sediments. Three remaining major fault depressions mainly developed fan delta and lake facies. Sedimentation of D2 member presents a regular distribution, which is bounded by the contact zone of floodplain and shore-shallow lake. In the west of this boundary, alluvial fan and braided river sedimentary system were developed from west and north highland source areas. In the east of this boundary, the deep lake was developed in a large-scale, associated with the gradually infusion of clastic sediments from highland source areas into the lake basin, forming retrogradation fan delta in various scales.

Considering the sandstone isopach map, sedimentary facies and tectonic evolution, this study explores the relationship between each sedimentary period and sedimentary evolution. D1 member is characterized by split fault depression sedimentation. Fault depression peripheral ancient bulge is the major developed area of the alluvial fan sedimentary system. The fan delta deposition distributed at the surrounding of the fault depression and the fan delta front extended to the location into the intern lake. D2 member is in the beginning period of basin depression sedimentation and developed alluvial fan, fan delta, braided river, braided river delta and lake sediment. Among them, the fan delta front and braided river delta front subfacies are the key areas of mid-deep formation oil and gas exploration in the future.

According to the sedimentary evolution of the southeastern uplift region, the studies suggest that the tectonic movement and the water depth are the main factors affecting the sedimentary evolution in this region.

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