Analysis of sedimentary facies characteristics and source reservoir allocation of fault depressed Lake Basin—Taking Xu-Xi area of Songliao Basin as an example

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Abstract. At present, Xu-Xi area is in the primary stage of exploration, and its sedimentary characteristics and distribution law are not clear. In this study, based on the analysis of regional structural background, through core observation and description, grain size analysis, well logging and seismic and other technical means, the sedimentary facies types and spatial distribution characteristics of Shahezi Formation in Xu-Xi area are studied. It is believed that there are three types of sedimentary systems in Shahezi Formation in the study area: Fan Delta, braided river delta and lake. The fan delta is mainly developed in the steep slope belt in the west of Xu-Xi area, while the braided river delta is mainly developed in the gentle slope belt in the East and the axial belt in the north, and the lake facies is developed in the depression belt between them. On the whole, the sedimentary pattern shows the obvious characteristics of "North-South block, east-west belt". From the West steep slope to the East gentle slope, the sedimentary facies type transits from fan delta to deep lake semi deep lake and then to Braided River Delta. Combined with the study of reservoir forming conditions, it is found that the sand bodies of fan delta front and braided river delta front have good reservoir physical properties and are often adjacent to large-scale high-quality source rocks in the upper and lower or lateral directions. The reservoir forming conditions are superior and are favorable for oil and gas accumulation facies belt.

1. Introduction

In continental faulted basin, fan delta and braided river delta are very important oil and gas reservoir[1-6]. Shahezi Formation in Xu-Xi area is a new field of oil and gas reserves increasing in Daqing exploration area[7,8]. Recently, the first industrial gas was obtained in Xushen 46H well and Xushen 6-302 well, it is proved that Shahezi Formation in Xu-Xi area has great exploration potential. Previous scholars have little knowledge about the geology of Xu-Xi area and mainly focus on the direction of oil sourcer. The distribution characteristics and sedimentary types, the microfacies of high quality reservoir and the favorable oil and gas bearing facies belts are still unknown; it restricts the further deployment of oil and gas exploration. In this study, the author carefully studied the sedimentary system types of the Shahezi Formation in Xu-Xi area, summarized the microfacies types of high-quality reservoir and the characteristics of favorable oil and gas occurrence facies belt, and guided the further exploration of oil and gas potential of the Shahezi Formation in Xu-Xi area to a certain extent.
2. Geological situations
Xujiaweizi, as an important gas-bearing depression in Songliao Basin, is rich in tight sandstone gas. Xu-Xi area is the main hydrocarbon generating sag in Xujiaweizi sag, which is located in the west of Xujiaweizi fault depression. On the whole, it is a NNE trending fault depression with high northwest and low southeast. The western part is a paleo central uplift belt, which connects fengle low uplift and Chaoyanggou uplift in the South and Xuzhong fault in the North and East. The Shahezi Formation, with a thickness of 600-1500 meters, is the primary hydrocarbon generating strata in Xu-Xi area. The developed sedimentary facies include three types: Fan Delta, braided river delta and lake. In Shahezi Formation, high-quality source rocks and thick glutenite reservoirs are formed alternately, and the source and reservoir are integrated. The tight hydrocarbon accumulation conditions are very favorable (Fig. 1).

![Figure 1. Structural unit division and stratigraphic histogram of Xujiaweizi fault depression](image)

3. Types of sedimentary facies
Based on the study of lithofacies, logging facies, seismic section and other related data, It is considered that the sedimentary facies of the Shahezi Formation in the study area include fan delta, braided river delta and lake.

3.1 Fan delta
Most fan delta deposits are accompanied by sizeable synsedimentary fault zones, which are mainly caused by tractive current. The grain size of the deposits is coarse, and the sorting and rounding are poor. The grain size probability curve is characterized by "two-stage" or "two-stage transition". In Xu-Xi area, the fan delta depositional system is mainly developed in the West steep slope zone, which can further identify two surfaces: plain and front edge. Fan delta plain subfacies are the upper water parts of fan delta sedimentary system, including two microfacies, namely distributary channel and inter distributary channel. The underwater part of the fan delta sedimentary body is called fan delta front and main part of fan delta, which can be divided into six microfacies. The underwater main
channel microfacies can be used as the channel for transporting debris materials to indicate the extension direction of fan body. The watercourses in different periods can be seen to be overlapped with each other, forming variegated or grayish green sand conglomerate with particle support as the main support and well sorted and rounded, and scour filling structure is developed at the bottom.

3.2 Braided river delta
The braided river delta deposits of Shahezi Formation in Xu-Xi area are mainly formed by tractive flow mechanism, which are developed in the eastern gentle slope zone and the northern axial zone. The grain size of the sediments is relatively fine, with parallel bedding, cross bedding, scour filling structure, etc. The seismic reflection form has obvious progradation characteristics, and the grain size presents typical three-stage curve, which is typical tractive drainage sedimentary characteristics. Two subfacies are identified: braided river delta plain subfacies and front subfacies. The braided river delta plain subfacies developed in the Shahezi Formation in Xu-Xi area can be divided into three types of sedimentary microfacies: braided channel, natural dike and inter braided channel. The braided river delta front subfacies can be divided into four microfacies: underwater distributary channel, underwater inter distributary channel, sheet sand and mouth bar.

3.3 Lake
The lake is a place with relatively low topography and flowing water on the continent. The lacustrine facies in the study area are mainly developed in the central trough area. Its lithology is mainly grayish black mudstone with fine grain size, mixed with siltstone, siltstone mudstone and argillaceous siltstone. The main types of sedimentary structures are wavy bedding, horizontal bedding, massive bedding and deformed bedding. The grain size probability curve is a two-stage, with no rolling part, reflecting the medium sorting and fine lithology. Seismic attributes are characterized by strong amplitude, good continuity, subparallel and sheet parallel reflection, and local lenticular. It can be divided into two subfacies: deep lake-semi deep lake subfacies and shore shallow lake subfacies. Grey mudstone and siltstone are mainly developed in shore shallow lake subfacies, small cross bedding and horizontal bedding can be seen; Grey black and black mudstone is developed in deep lake-semi deep lake subfacies and massive bedding is mainly developed in sedimentary structure. It is characterized by a relatively straight curve in electrical.

4. Plane distribution of sedimentary system
During the SQ1 period, Xu-Xi area was in the initial extension stage of the basin, with shallow sedimentary water, mainly developed fan delta, braided river delta and shore shallow lake deposits. Under the comprehensive influence of sediment source and geomorphic height difference, the eastern and Northern axial zones of the study area are weakly affected by faults, and braided river delta deposits are developed. The West steep slope zone is strongly influenced by the structure and mainly develops fan delta deposits. The shore shallow lake sediments are mainly distributed in the central part of the sag, with a small distribution range (Fig. 2). During the SQ2 period, rapid subsidence occurred due to the strong influence of controlled depression faults in Xu-Xi area, and the distribution of sedimentary system is inherited from that of SQ1: fan delta is mainly developed in the west, braided delta facies is developed in the Eastern and Northern axial areas, and the lake basin scope is obviously larger than that of SQ1 period, with deeper water body and local development. During the SQ3 period, Xu-Xi area entered a relatively stable tectonic subsidence stage, and the sedimentary range increased as a whole. The range of the lake basin is enlarged, and the fan delta deposits in the West and braided river delta deposits in the East are obviously retrogradated. SQ4 is located at the end of Shahezi Formation. Due to the internal stress inversion and tectonic uplift during this period, the strata suffered serious erosion, and two independent depressions were formed in the South and North. The scope of the lake basin shrinks and the water body becomes shallow. Fan delta deposits are developed in the west of the study area, and braided delta deposits are developed in the Eastern and Northern axial direction, which are obviously progradated compared with SQ3 period (Fig. 3).
5. Analysis of source reservoir configuration and favorable facies

There are different reservoir facies belts in different sedimentary systems in Xu-Xi area, and the reservoir capacity is also different. In this study, after the detailed description of the sedimentary system and distribution characteristics of the study area, combined with the characteristics of source rocks, the favorable enrichment facies are predicted.

The Western steep slope zone of Xu-Xi area has a large source supply intensity and a wide range of sandbodies. The fan delta front deposits developed along the intersection of steep slope fault zone are "flower like" deposits. Due to the influence of tectonic activity, several under compacted belts have been formed. The reservoir performance of different belts is quite different, and only some facies belts are high-quality reservoirs. Based on the porosity and permeability data of 293 cores from 55 wells in the study area, the correlation characteristics between sedimentary facies types and reservoir physical properties in the area are comprehensively analyzed. It is found that the underwater distributary channel microfacies in the fan delta front mainly develop medium porosity and medium permeability reservoirs, their porosity is generally greater than 15%, which is better than other types of microfacies. The followed by braided channel microfacies of braided river delta front subfacies, with medium low porosity and medium permeability reservoirs, are favorable reservoir facies belts (Fig. 4). Further combining with the relationship between sand bodies and source rocks, it can be found that the organic matter abundance of semi deep lake and deep lake facies dark mudstone of Shahezi formation is high, with an average organic carbon content of 2.43%, mainly I-type kerogen, Type II 1 is next, with an average hydrocarbon generation potential of 15.30 mg / g, which is a high-quality source rock. The underwater distributary channel sand body and high-quality source rock form a source reservoir configuration relationship of self generation and self storage, and the reservoir forming conditions are
very favorable. Therefore, the underwater distributary channel microfacies of fan delta front subfacies are the most favorable oil and gas enrichment facies zone, in which XS46H and XS6-302 have obtained high-yield industrial gas flow. The braided channel reservoir of the braided river delta front subfacies in the Eastern has good physical properties and lateral contact with high-quality source rocks. The source reservoir configuration relationship is superior, and it also has great exploration potential (Fig. 5).

![Image](image1.jpg)

**Figure 4.** Changes of physical properties in different facies zones of Shahezi Formation in Xu-Xi area

![Image](image2.jpg)

**Figure 5.** Oil and gas accumulation model in Xu-Xi area

6. Conclusion

(1) Based on the analysis of regional tectonic background, the sedimentary facies types and spatial distribution characteristics of Shahezi Formation in Xu-Xi area are studied by means of core observation description, grain size analysis, logging and seismic techniques. It is considered that there are three types of sedimentary systems in Shahezi Formation: fan delta, braided river delta and lake.

(2) Fan delta is mainly developed in the steep slope zone in the west of Xu-Xi area, braided river delta is mainly developed in the gentle slope zone in the East and the axial zone in the north, and lake facies is developed in the trough zone between them. On the whole, the sedimentary pattern is characterized
by north-south block and east-west zone. From the West steep slope zone to the East gentle slope zone, the sedimentary facies type transits from fan delta to deep lake semi-deep lake and then to braided river delta.

(3) The underwater distributary channel microfacies in fan delta front mainly develop medium porosity and medium permeability reservoirs with the best physical conditions, followed by braided channel microfacies in braided river delta front with medium low porosity and medium permeability reservoirs. Combined with the analysis of reservoir forming conditions, it is found that underwater distributary channel microfacies and braided channel microfacies are often in close contact with high-quality source rocks of deep lacustrine facies up and down or laterally, are favorable oil and gas accumulation facies belt with favorable reservoir forming conditions.

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