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GEOLOGY

Study on the relationship between multi-stage strike-slip mechanism and basin evolution in Fangzheng fault depression

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ABSTRACT

Fangzheng fault depression is controlled by the northern of the Tan-Lu fault zone. It undergoes multi-stage strike-slip, extrusion modification, and erosion of the thermal uplift, forming a tectonic pattern of uplifts connected with sags. Through the regional dynamic analysis, the study of the activity law of the western Pacific plate has clarified the formation and transformation of the regional tectonic stress field. Under the background of the multi-stage of the strike-slip mechanism in the northern part of the Tan-lu fault, the Fangzheng fault depression has a characteristic of the "left-lateral strike-slip pull-apart basin, right-lateral strike-slip extrusion transformation." According to the difference of the strike-slip, the Fangzheng fault depression has divided into two parts: the East fault depression and the West fault depression. The seismic data, seismic attribute analysis, and geological modeling techniques have applied to analyze the two fault depressions, the East fault depression has actively controlled by the strike-slip activity, and the structure is complex. The seismic data quality is poor; the structure of the West Fault Depression is the opposite and structural characteristics of asymmetrical difference strike-slip in the East and West fault depressions. Interpretation of seismic sections through a slippery background, the strike-slip attributes of the whole fault depression from south to north are segmented, and the strike-slip mechanism from east to west is different. Under the control of the multi-stage strike-slip mechanism, the Fangzheng fault depression is divided into six stages of strike-slip evolution, corresponding to the six different stages of the strike-slip control basin, the formation process of the asymmetric difference strike-slip fault basin is clarified, which provides a reference for the study of the strike-slip pull-apart basin with multi-stage structure.

Keywords: Fangzheng fault depression; Tan-Lu fault zone; Strike-slip pull-apart basin; Asymmetric difference strike-slip mechanism.

Estudio sobre la relación entre el mecanismo de deslizamiento por etapas y la evolución de la cuenca en la depresión por falla Fangzheng

RESUMEN

La depresión de la falla Fangzheng está controlada en el norte por la zona de falla Tan-Lu. Esta registra un deslizamiento de varias etapas, modificación de extrusión y erosión del levantamiento térmico, lo que forma un patrón tectónico de levantamientos conectados con hundimientos. A través del análisis dinámico regional, el estudio de la ley de actividad de la placa del Pacífico occidental ha aclarado la formación y transformación del campo de estrés tectónico regional. En virtud de los antecedentes de las múltiples etapas del mecanismo de deslizamiento en la parte norte de la falla Tan-lu, la depresión de la falla Fangzheng tiene una característica de "cuenca extraíble de deslizamiento lateral izquierda, transformación por extrusión de deslizamiento lateral derecha". Según la diferencia del deslizamiento, la depresión de la falla Fangzheng se ha dividido en dos partes: la depresión de la falla del Este y la depresión de la falla del Oeste. Se aplicaron los datos sísmicos, el análisis de atributos sísmicos y las técnicas de modelado geológico para analizar las dos depresiones de fallas. La depresión de fallas del Este ha sido controlada activamente por la actividad de deslizamiento y la estructura es compleja. La calidad de los datos sísmicos es pobre; la estructura de la depresión de la falla del oeste es la opuesta y las características estructurales de la diferencia asimétrica de deslizamiento en las depresiones de la falla del este y el oeste. La interpretación de las secciones sísmicas a través de un fondo resbaladizo, los atributos de deslizamiento de toda la depresión de falla del sur al norte están segmentados y el mecanismo de deslizamiento de este a oeste es diferente. Bajo el control del mecanismo de deslizamiento por etapas, la depresión de falla de Fangzheng se divide en seis etapas de evolución de deslizamiento, correspondientes a las seis etapas diferentes de la cuenca de control de deslizamiento. Se aclara el proceso de formación de la cuenca de falla asimétrica de la cuenca de falla de deslizamiento, que proporciona una referencia para el estudio de la cuenca extraíble de deslizamiento con estructura de múltiples etapas.

Palabras clave: Depresión de la falla Fangzheng; Zona de falla de Tan-Lu; Cuenca extraíble de deslizamiento; Mecanismo de diferencia asimétrica de deslizamiento.

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Introduction

Fangzheng fault depression is the basin with the most significant oil and gas potential in the peripheral basin of Daqing Oilfield. In recent years, some progress has been made in the study of tectonic characteristics (Yang et al., 2014; Chen, et al., 2015), tectonic evolution (Huang et al., 2003; Gao & Li, 197) and hydrocarbon potential. However, there are few pieces of research on the mechanism of the sliding control basin, which cannot correctly understand the formation process of the basin and restricts the progress of oil and gas exploration. In this paper, the evolution process of the Fangzheng fault depression under the strike-slip mechanism is discussed.

Regarding the strike-slip mechanism, the predecessors have studied more on the fault zone and reached a consensus on the strike-slip zone of the Tanlu fault zone (Xu and Zhu, 1994; Mercier et al., 2007). As a significant strike-slip fault system, the formation of the Tanlu fault zone, kinematics (Wang, 2006; Wang and Zhou, 2009; Tang et al., 2009; Tang et al., 2010) and tectonic evolution (Gilder et al., 1999; Zhu et al., 2009). It has recognized for the first time since the 1950s. These research results have mostly concentrated in the southern part of the Tanlu fault zone (Niu et al., 2000; Ge et al., 2009) and the Bohai Bay Basin (Hsiao et al., 2004; Tong et al., 2008; Li et al., 2013). However, the strike-slip mechanism in the northern part of the Tan-Lu fault zone has less studied (Chen & Nábelek, 1988), the sliding control basin in the northern section of the Tanlu fault zone is still unclear. For the Fangzheng fault depression, most of the former people analyzed the structural characteristics of the basin in the mode of stretching the basin (Ren et al., 1999) and did not consider the influence of strike-slip on the basin. In the background of strike-slip (Hu et al., 2010), combined with the change of regional stress field and the activity characteristics of the fault zone, the latest seismic interpretation data, seismic attribute analysis, and geological modeling techniques are used to analyze the strike-slip characteristics of Fangzheng fault depression. Through in-depth research, the author proposes an asymmetric difference strike-slip control mechanism.

Tectonic background and stress field change process

Fangzheng fault depression is located at the eastern end of the Central Asian orogenic belt and adjacent to the Pacific plate in the east (Fig. 1). It is the most complex area for the superposition and transformation of the Paleo-Asian Ocean and the Pacific Rim. From the Paleozoic to the early Mesozoic, the Central Asian-Mongolian Sea experienced many times of cracking and closure, and the basement formed. At the same time, the Mesozoic Late Triassic to Early Jurassic, the Pacific plate subduction began and entered the Pacific Rim structural domain and Era (Hilde et al., 1977). The positive northward subduction movement of the western Pacific plate since the early Cretaceous caused the left lateral of the Tanlu fault zone. Under the mechanism of the left-lateral strike-slip pull, the Fangzheng fault depression formed, and the NW direction of the Late Cretaceous Western Pacific plate subducted. Fangzheng fault depression right-lateral strike-slip extrusion, leading to Cretaceous strata uplift and erosion.

In the early Paleogene, the movement direction of the Pacific plate changed to NNW direction, the TanLu fault zone began to be left-lateral strike-slip, and the basin area has further expanded. In the late Paleogene, the movement direction of Pacific plate has changed to NWW direction, and the Tan-Lu fault zone was right-lateral strike-slip. The slippery feature is intensified. The post-arc expansion of the western Pacific plate since the Neogene has caused a lateral thrust force to the west, causing the Fangzheng fault depression and Tan-Lu fault zone, and even the eastern part of China to be in a near-East-west squeeze environment (Chen et al., 2015). Fangzheng fault depression under the action of right-lateral strike-slip compression and torsion, along with the northern heat uplift, the northern part of the fault depression is uplifted and denuded, and the stress field presents a three-dimensional state, forming the current tectonic pattern.

Fangzheng fault depression is a series of narrow and Cenozoic fault basin distributed in the northeast direction in the Tan-lu fault zone, which stratum develops from bottom to top:Cretaceous (K), Paleogene Paleocene Xin'ancun Formation (E_1x), Eocene Dalianhe Formation (E_2d), Oligocene

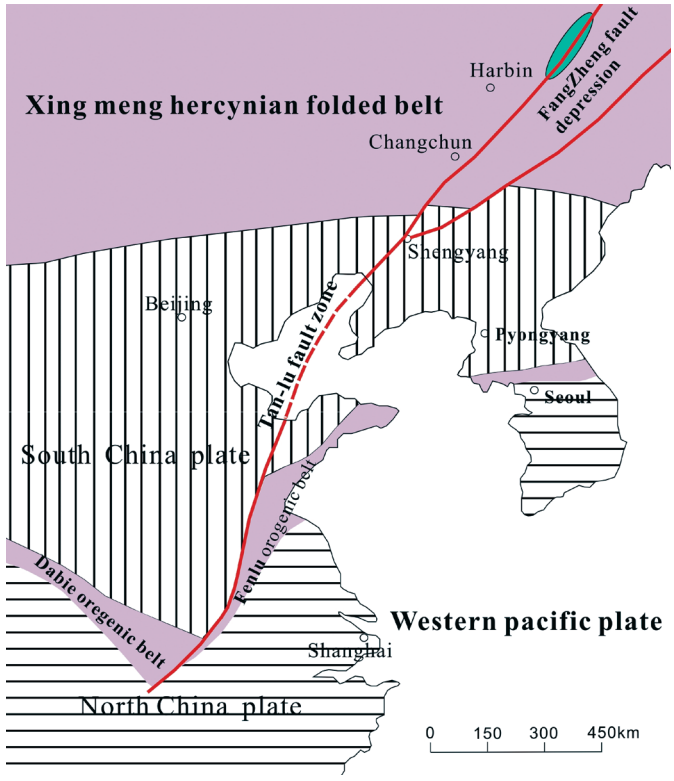


Figure 1. Fangzheng fault depression structure location

Baoquanling Formation (E_3b: E_3b1, E_3b_2, E_3b_3), Neogene Fujin Formation (Nf), and the Quaternary (Q) stratum, generally in the direction of the North East 40 °-50 °, the area is about 1460km^2.

Asymmetric difference strike-slip characteristics

The Fangzheng fault depression has mainly controlled by tectonic activities such as strike-slip and compression of the Tan-Lu fault zone and the thermal uplift caused by deep geological processes. It presents the characteristics of asymmetric strike-slip pull-apart basins under the superposition of multiple tectonic activities.

Fangzheng fault depression from south to north seismic profile shows different fault depression structures (Fig. 2). The southern structure is wast-faulting and east-overlapping (Fig. 2. A-A), the middle structure is double-faulting (Fig. 2. B-B, C-C), Northern structure is east-faulting and west-overlapping (Fig. 2. D-D). The entire fault depression structure presents an asymmetrical "warping" feature. This is entirely different from the extended fault basin. Therefore, the extended basin model was used to understand the Fangzheng fault depression is not comprehensive.

The fault depression has controlled by three faults (Fig. 2). FZ1 is the western strike-slip pull-apart fault boundary; FZ2 is the eastern strike-slip extrusion fault boundary; FZ3 is the middle strike-slip regulation fault. FZ1 and FZ3 control the Cretaceous basin; FZ1 and FZ2 control the Cenozoic basin. Hence, the fault depression has divided into the Western and Eastern fault depression by the FZ3 fault control. The internal fault structure of the West fault depression and the East fault depression is entirely different. The strata in the West fault depression are stable, the Cretaceous strata are developed, and the seismic data quality is good, the signal-to-noise ratio characteristic of the west fault depression is better than the east fault depression (Fig. 3a).

Conversely, the strata continuity of the East fault depression is weak, the later transformation is strong, the Cretaceous strata are not developed, and the seismic data quality is poor (Fig. 3a). Through the above analysis, it shows the segmentation of the strike-slip characteristics from the south to the north and the difference of the strike-slip mechanism from east to west. In particular, there are different strike-slip fault structures on both sides

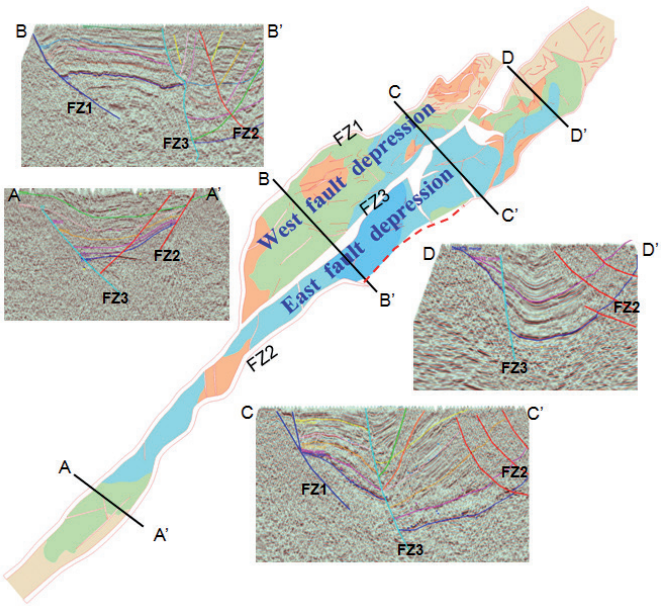


Figure 2. Fangzheng fault depression structure and seismic section.

of the FZ3 fault (Fig. 3b), which have the characteristics of asymmetric difference strike-slip fault basin.

Evolution of multi-stage strike-slip basin

Because of the asymmetric difference strike-slip control basin, since the strike-slip effect through the entire basin evolution process, it cannot have simply explained by the evolution model of the conventional fault basin, and the control and influence of the strike-slip activity on the fault depression must have considered. Since the formation of the Cretaceous, the Fangzheng fault depression has divided six evolution stages according to the different slipping periods (Fig.4). Including the evolution of the two stages slip-control basin in the Cretaceous, the evolution of the four stages slip-control basin in the Cenozoic, under the control of the six-stage strike-slip mechanism, experienced three stages of uplift and erosion, and the sedimentary subsidence center also experienced four migration process from south to north, and north to south.

Cretaceous slip-controlled basin evolution

(1)Early Cretaceous strike-slip pull-apart stage

Early Cretaceous, affected by the high-angle subduction of the western Pacific plate, the left- lateral strike-slip of the Jiayi fault in the north of the Tan-Lu fault zone, the rigid blocks on both sides of the strike-slip fault were separated, and the Fangzheng fault depression began to form. An Early Cretaceous fault basin (Western fault depression, Figure 5) near the northwest-south-eastward distribution was created on the pre-Mesozoic granite or metamorphic rock basement.

(2)The end of early Cretaceous to late Cretaceous strike-slip extrusion stage

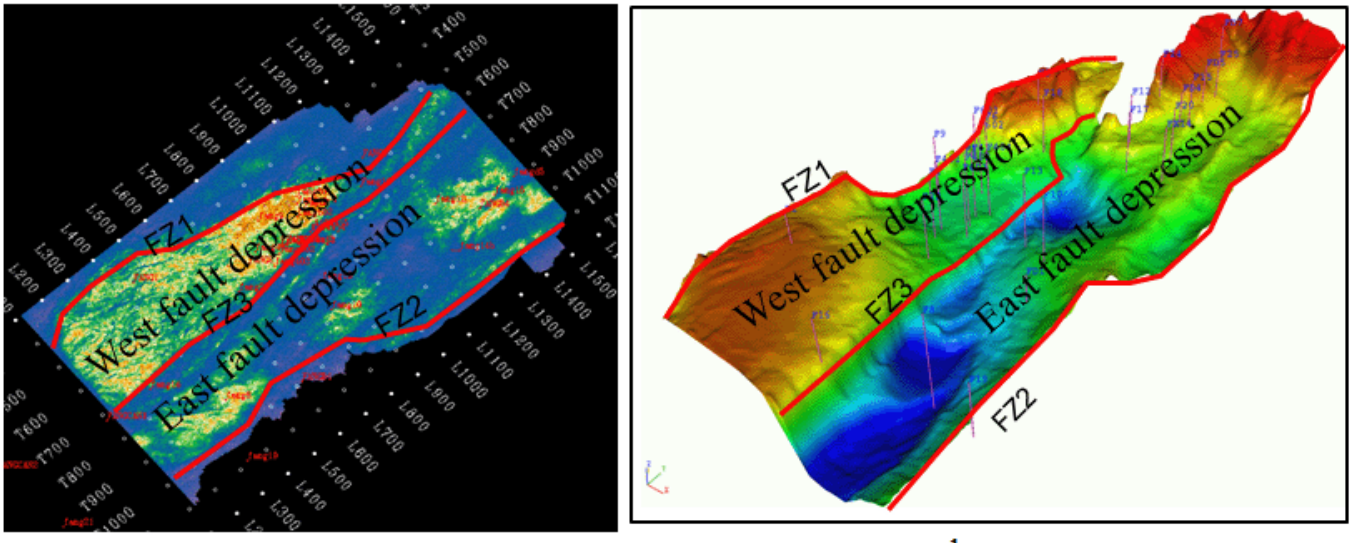
As the direction of the western Pacific plate changed from the north to the northwest, the northeastern part of China gradually entered the extrusion environment at the end of the Early Cretaceous, and the fold uplift suffered erosion of Fangzheng fault depression. The Cretaceous residual strata have developed in the southern part of the fault depression. The Cretaceous weathering crust revealed by the northern drilling confirmed the uplift.

Cenozoic slip-controlled basin evolution

In the early Paleogene, the movement direction of the western Pacific plate changed to the north-northwest, and the Fangzheng fault depression was again left-lateral strike-slip. At this time, the FZ2 fault began to become the eastern boundary fault of the Fangzheng fault depression, and as the fault deepened, the magma and the volcanic activity promoted the extension of the lithosphere, which caused the Fangzheng fault depression to enter the Paleogene main basin period, and formed the East fault depression (Fig. 5) between FZ2 and FZ3. The East Fault Depression and the West Fault Depression constitute a Cenozoic fault basin (Fangzheng fault depression).

(1) Paleocene-Eocene strike-slip pull-apart stage

The Fangzheng fault depression began to pull-apart in the north-south direction. Because the tensile stress direction is oblique to the northeast trend of the Fangzheng fault depression, this oblique pull-apart has characterized by a left- lateral torsion in the Fangzheng fault depression. Under the action



a

a: 1200-2000ms signal-to-noise image of 3D seismic work area

b

b: Comparison of geological modeling between the East Depression and the West Depression

Figure 3. 1200-2000ms signal-to-noise ratio image of the 3D seismic work area.

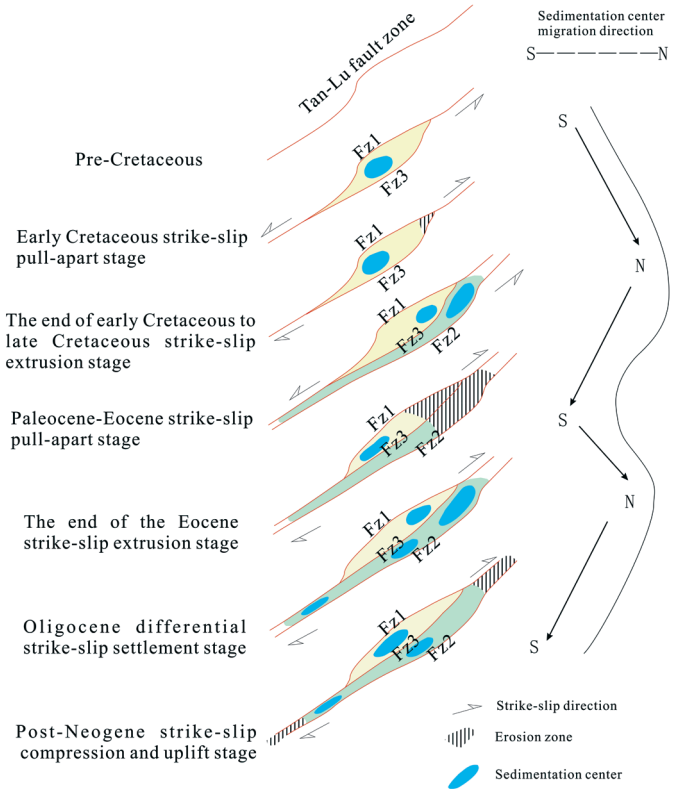


Figure 4. Evolution mode of the multi-stage strike-slip basin in Fangzheng fault depression

of left- lateral torsional stress, the fault FZ1 in the northwestern margin and the fault FZ2 in the southeastern margin are strongly active, but the FZ3 activity is weak, at this time, the structural of the Fangzheng fault depression has a double fault, and the structural pattern of the sag-uplift fault depression is initially formed.

(2) At the end of the Eocene, the strike-slip extrusion stage

At the end of the Eocene, the Fangzheng fault depression extrusion in the right- lateral background, the overall depression of the fault depression, the basin ascends as a whole, the northern part of the basin rises higher, and the south is relatively low. The Xin'ancun Formation (E1x) and the Dalianhe Formation (E2d) were strongly denuded, in particular, the Dalianhe Formation (E2d) has been eroded in the northern part of the fault depression.. As a result, the remnants of the Xin'ancun Formation (E1x) are also relatively thin.

(3) Oligocene-Neogene differential strike-slip settlement stage

During the Oligocene, as the western Pacific plate turned into high-angle subduction in the northwest direction, FZ3 began to move strongly, and the settlement of the west fault depression was small. The East fault depression received huge thick sediment under the control of FZ3, and the Fangzhengr fault depression began to enter the differential settlement stage. Affected by the paleo-geomorphology the Baoquanling Formation (E3b: E_3b_1, E_3b_2, E_3b_3) was overtaken from the north to the south.

(4) Post-Neogene strike-slip compression and uplift stage

The Fangzheng fault depression is affected by the regional right-lateral strike-slip compression stress, and the tectonic inversion occurs. The north and south sides of the fault depression are strongly uplifted and most eroded. The northern boundary forms a thrust-napped structure under the compressive stress, which is leading to the blurring of the north boundary fault. Eventually, the tectonic pattern of the asymmetry difference between the east fault depression and the west fault depression was formed (Fig. 5).

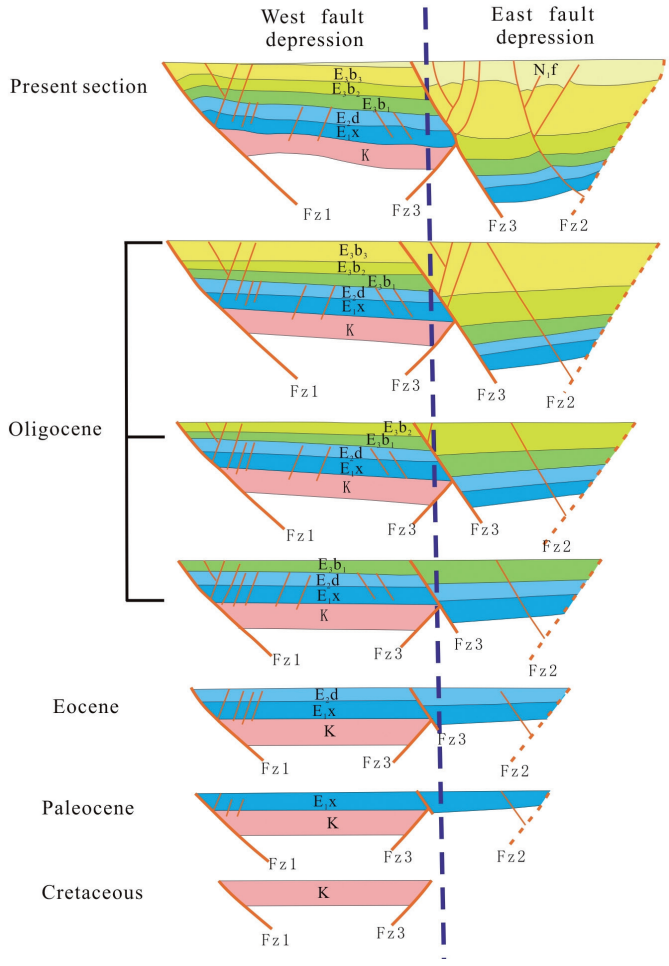


Figure 5. Comparison of geological modeling between the East Depression and the West Depression

Conclusions

The strike-slip effect through the evolution process of Fangzheng fault depression. The formation and transformation of the basin have closely related to the strike-slip effect. Therefore, it cannot have explained merely by the evolution model of the conventional fault basin. It must have applied because of evident regional stress transformation. The evolution of the slip mechanism is used to analyze the evolution process of the Fangzheng fault depression.

The strike-slip characteristics of the Fangzheng fault depression are segmented from south to north, and the strike-slip mechanism is different from east to west, especially the different strike-slip structures on both sides of the FZ3 fault, and the characteristics of the asymmetric difference strike-slip fault basin.

By the research of asymmetric difference strike-slip control basin, according to the different strike-slip mechanism, there are six evolution stages in the Fangzheng fault depression. Early Cretaceous strike-slip pull-apart stage; Early Cretaceous to late Cretaceous strike-slip extrusion stage; Paleocene-Eocene strike-slip pull-apart stage. At the end of the Eocene the strike-slip extrusion stage, Oligocene differential strike-slip settlement stage, the trend of the strike-slip compression and uplift since the Neogene, corresponding to the six different strike-slip control basin backgrounds.

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