ISSN: 2688-8645

The Influence of Synsedimentary Faults on the Restoration of the Original Basin

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Abstract

The restoration of the original basin is a core geological task for reconstructing the original appearance of sedimentary basins, revealing the evolution laws of basins, and guiding the exploration of oil, gas and other mineral resources. As a tectonic phenomenon that occurs simultaneously with sedimentation during the evolution of sedimentary basins, syn-sedimentary faults directly control the boundary morphology of the basin, the migration of sedimentary centers, the distribution of strata thickness and the paleogeomorphic features. They are key controlling factors that cannot be ignored in the process of original basin restoration. This paper systematically reviews the relevant research results of syn-sedimentary faults and original basin restoration, elaborates on the geological overview of typical regions, summarizes the current research status at home and abroad and the commonly used research methods, and focuses on discussing the classification of syn-sedimentary faults, the methods of paleogeomorphic restoration under the control of syn-sedimentary faults, as well as the specific impacts of syn-sedimentary faults on the boundaries of the original basin, sedimentary filling and tectonic patterns. Finally, it summarizes the existing deficiencies in current research and looks forward to future research directions, providing theoretical references and technical support for subsequent original basin restoration research and mineral resource exploration.

Keywords

Qikou Depression; The Transition Period of the Fault Depression; Tectonic Evolution; Sedimentary System; Original Appearance.

1. Introduction

Depositional basins are the main storage carriers of strategic mineral resources such as oil, gas, and coal. The restoration of the original basin is the core content of basin analysis, and its core objective is to remove the influence of later tectonic modifications and reconstruct the original boundaries, ancient landforms, sedimentary centers, and filling characteristics of the basin during the sedimentary period, thereby revealing the formation and evolution mechanism of the basin and the distribution laws of resources. During the basin evolution process, synchronous deposition faults (also known as growth faults) are widely developed, and their activities run through the entire process of basin sedimentation, occurring simultaneously with the accumulation of sediments. They not only directly shape the macroscopic structural pattern of the basin but also affect the spatial distribution of stratum thickness and lithofacies combination characteristics by controlling the transportation and accumulation process of sediments. [1-2]

As oil and gas exploration advances towards deeper and more complex basins, traditional methods of original basin restoration often fail to accurately reconstruct the original appearance of the basin due to the neglect of the dynamic influence of synchronous deposition faults, resulting in deviations in resource prediction and exploration deployment. Therefore, in-depth research on the influence of synchronous deposition faults on original basin restoration, clarifying the activity patterns of synchronous deposition faults and their intrinsic relationship with original basin restoration, and improving the original basin restoration techniques considering the influence of synchronous deposition faults, have important theoretical significance and practical application value. In recent years, scholars at home and abroad have conducted a large number of studies on the identification of synchronous deposition faults, the analysis of their activity characteristics, and original basin restoration methods, achieving fruitful results. However, there are still many controversies and deficiencies in the original basin restoration of complex fault zones (such as the reformation zone of strike-slip faults), the quantitative characterization of the activity intensity of synchronous deposition faults, and their dynamic influence on the evolution of the original basin. Based on the existing research results, this paper conducts a systematic review of the influence of synchronous deposition faults on original basin restoration, providing a reference for subsequent research.

2. Regional Geology Overview

Episodic faults are widely developed in various sedimentary basins. The characteristics of episodic faults and their impacts on the original basins vary significantly in basins with different tectonic backgrounds. This paper selects typical sedimentary basins at home and abroad as research references, and combines the regional tectonic evolution background to sort out the correlation characteristics between episodic faults and the development of the original basins, providing regional geological basis for subsequent research. [3-5]

Domestically, the Ordos Basin, as an important energy base in China, is a typical area for studying episodic faults and the recovery of the original basin. This basin spans parts of Shaanxi, Gansu, Ningxia, Inner Mongolia, and Shanxi, covering an area of approximately 370,000 square kilometers. Geologically, it belongs to a secondary tectonic unit of the North China Plate. It is a large-scale multi-cycle sedimentary basin with stable subsidence, significant flexure migration, and obvious torsion. It is surrounded by mountains such as the Yinshan, Qinling, and Liangpan Mountains. The basin has undergone an evolution process from marine sedimentation to terrestrial sedimentation. The Jurassic Zhiluo-An period is a key stage of basin evolution. Episodic faults are widely developed during this period, mainly in the form of extensional faults, controlling the distribution of the basin's sedimentary boundaries and sedimentary centers. Later, due to tectonic modifications such as the Yanshan Movement and the Himalayan Movement, some episodic faults stopped activity, and the strata suffered varying degrees of erosion, posing a significant challenge to the recovery of the original basin. In addition, the Bohai Bay Basin, the Youjiang Basin, and the Sanjiang Basin Group are also typical areas with the development of episodic faults in China. The early Tertiary subsidence of the Bohai Bay Basin is mainly related to the extensional action of episodic faults, and the intensity of fault activity is linearly related to the sedimentation volume, sedimentation rate, and facies filling characteristics. In the evolution process of the Youjiang Basin, episodic faults control the formation and filling characteristics of sequence boundaries. In the early Cretaceous of the Sanjiang Basin Group, episodic faults promoted the formation and evolution of a unified lake basin.

Internationally, the Gulf of Mexico Basin, the Nigerian Delta Basin, and the North Sea Basin all have a large number of episodic faults. The Gulf of Mexico Basin has mainly extensional episodic faults, and fault activity interacts with salt tectonic movements, controlling the sedimentation filling and hydrocarbon accumulation of the basin. The growth index of episodic faults in the Nigerian Delta Basin can reach 1 to 2.5, and their activity directly controls the migration of the sedimentary center and the distribution of reservoir facies. In the North Sea Basin, episodic faults mainly form in an extensional tectonic background, controlling the original boundaries and stratigraphic thickness distribution of the basin. Later, due to inversion tectonic modifications, the complexity of the recovery of the original basin increases. The geological profiles of these typical areas indicate that the development characteristics of episodic faults are closely related to the regional tectonic background and the evolution stage of the basin, and their impact on the recovery of the original basin is universal and has differences.

3. Current State of Research in China and Abroad

3.1. Current State of Research in China

The research on syn-sedimentary faults and the recovery of the original basin started earlier abroad. In the 1960s, scholars began to pay attention to the activity characteristics of syn-sedimentary faults and their influence on basin sedimentation, and proposed the basic concepts and identification markers of syn-sedimentary faults. From the 1980s to the 1990s, with the development of seismic exploration technology, scholars conducted in-depth studies on the activity patterns of syn-sedimentary faults through methods such as seismic profile interpretation and stratigraphic thickness analysis, established the filling patterns of the basin under the control of syn-sedimentary faults, proposed basic methods such as the equilibrium profile method and backstripping method for the recovery of the original basin, and applied them to the recovery studies of typical areas such as the Gulf of Mexico Basin and the North Sea Basin, initially revealing the control effect of syn-sedimentary faults on the boundaries and sedimentary centers of the original basin. [7-8]

Since the 21st century, foreign research has gradually developed towards a more refined and quantitative direction. Scholars have utilized numerical simulation technology, isotope dating technology, etc., to quantitatively characterize the activity intensity and duration of syn-sedimentary faults, and explored the coupling relationship between syn-sedimentary faults and paleogeomorphology, sedimentary systems. For example, using detrital zircon U-Pb dating technology to analyze the source direction and combining with paleoflow data, the original basin morphology controlled by syn-sedimentary faults was restored; through software such as Flex-Decomp and Stretch, combined with the backstripping method and equilibrium profile technology, the dynamic simulation of the evolution process of the original basin in an extensional basin was realized, further improving the technical method system for the recovery of the original basin. At the same time, foreign scholars have emphasized the integration of multiple disciplines, combining theoretical knowledge from disciplines such as structural geology, sedimentology, and geophysics, and conducting research on the recovery of the original basin in complex fault zones (such as the modified zone of strike-slip faults), proposing methods for restoring the original sedimentary appearance of the original basin in strike-slip modified basins, providing new ideas for the recovery of complex areas, but further research on the dynamic coupling mechanism between syn-sedimentary fault activities and the evolution of the original basin still needs to be deepened.

3.2. Current State of Research in Abroad

The research on co-sedimentary faults and original basins began in China in the 1980s. Initially, it mainly drew on foreign research methods and combined with the geological characteristics of typical basins in China (such as the Bohai Bay Basin and the Ordos Basin) to conduct preliminary studies on the identification of co-sedimentary faults and the recovery of original basins, with a focus on the influence of co-sedimentary faults on the thickness of strata and sedimentary facies. From the 1990s to the early 21st century, with the continuous deepening of domestic oil and gas exploration, scholars conducted targeted research on the characteristics of co-sedimentary faults in different types of basins, established identification markers and methods for recovering original basins suitable for the geological background of China, such as using drilling and logging data, outcrop observation combined with seismic interpretation to identify the growth index and activity duration of co-sedimentary faults; combining heavy mineral analysis, geochemical analysis, etc., to restore the source direction and paleogeomorphic features controlled by co-sedimentary faults, and improving the application of the balanced section method and back stripping method in domestic basins, achieving significant results in the restoration of the original basins in the Zhiluo-An period in the Ordos Basin and the faulting period in the Bohai Bay Basin.

In recent years, domestic research has focused on the influence of co-sedimentary faults on the recovery of original basins in complex tectonic settings (such as superimposed basins, strike-slip fault belts), using high-precision seismic exploration technology, numerical simulation technology, GIS technology, etc., to achieve quantitative characterization of the activity characteristics of co-sedimentary faults and the refined research on the recovery of original basins. For example, for strike-slip modified basins, a "determine basin type - analyze stratum sedimentary relationship - source analysis - original appearance restoration" four-step method was proposed. Through the combination of paleoflow analysis and zircon U-Pb dating, the original boundaries and shapes of the original basins were determined. In the research of the Ordos Basin, various methods such as cyclical comparison method, rock and mineral identification, geochemical analysis were comprehensively used to improve the accuracy of stratum division, providing a reliable basis for the recovery of the original basins. At the same time, domestic scholars also paid attention to the correlation between co-sedimentary faults and hydrocarbon accumulation, discussed the influence of the evolution of the original basin controlled by co-sedimentary faults on hydrocarbon generation, migration, and accumulation, providing theoretical support for hydrocarbon exploration. However, compared with foreign countries, domestic research still has shortcomings: First, the quantitative characterization methods for the intensity of co-sedimentary fault activity are not yet perfect, making it difficult to accurately reflect the dynamic relationship between fault activity and the evolution of the original basin; second, in complex superimposed basins, the study of the superimposed influence of multiple periods of co-sedimentary faults is insufficient, and the accuracy of the recovery of the original basin needs to be improved; third, the methods for the restoration of paleogeomorphology controlled by co-sedimentary faults still need to be further innovated, especially in areas with strong later erosion and modification, the reconstruction of paleogeomorphology is more difficult. [9-12]

4. Research Technique

The study on the influence of synchronous sedimentary faults on the recovery of the original basin requires the integration of theories from various disciplines such as structural geology, sedimentology, and geophysics, and the application of multiple research methods in combination to achieve the identification, quantitative characterization of the activity features of synchronous sedimentary faults, as well as the accurate restoration of the original basin morphology, paleogeomorphology, and sediment filling. Currently, the commonly used research methods can be classified into the following categories.

4.1. Method for Identifying Synchronous Faults and Analyzing Their Activity Characteristics

The identification of synchronous faults is the basis for studying their impact on the restoration of the original basin. Common methods include outcrop observation, drilling logging data analysis, and seismic profile interpretation. The outcrop observation method mainly involves field geological surveys to observe the changes in stratum thickness, lithofacies abrupt changes, fault polish marks, traction structures, etc., to identify synchronous faults. For example, by observing the thickness difference of strata on both sides of the fault and the abrupt change of sedimentary facies, the activity intensity and duration of synchronous faults can be determined. In the Jianshe area, through field outcrop observation, a rolling anticlinal structure developed on the descending plate of the kaphic extension normal fault was discovered, providing direct evidence for the identification of synchronous faults. The drilling logging data analysis method determines the activity layer and duration of synchronous faults by analyzing the thickness, lithology, and lithoelectric combination characteristics of the drilled strata, combined with paleontological fossil combinations and isotope chronology methods. For example, the growth index (the ratio of the thickness of the descending plate of the fault to the thickness of the adjacent strata at the same period) is used to quantitatively characterize the activity intensity of synchronous faults. The growth index of synchronous faults in the Jiyang Depression and Dongying Depression Basin is generally 1.2 to 2.0. The seismic profile interpretation method is currently the most commonly used method for identifying synchronous faults. By analyzing the superimposition, sub-superimposition, and truncation phenomena of strata in the seismic profile, combined with the geometric morphology of faults, the distribution range, extension direction, and activity characteristics of synchronous faults can be identified. At the same time, seismic attribute analysis technology can be used to further refine the identification accuracy of synchronous faults, especially for deep and concealed synchronous faults. [13-14]

4.2. The Basic Method for Restoring the Original Condition

The core of basin restoration lies in removing the influence of later tectonic modifications and reconstructing the original appearance of the basin during the sedimentation period. Common basic methods include the balanced section method, back stripping method, and sedimentary center analysis method. The balanced section method is based on the principle of volume conservation of strata, and by inverting the current tectonic section, it restores the original tectonic morphology of the basin during the sedimentation period. It is applicable to extensional basins with developed co-sedimentary faults and thrust basins for the restoration of the original basin. The 2D Move software is currently a widely used two-dimensional balanced section restoration tool. It adopts algorithms such as single shear without folding and oblique shear, which can effectively restore the stratum deformation caused by fault activity. The back stripping method (also known as stratum erosion back stripping method) strips the later sedimentary strata and eroded strata layer by layer, combined with stratum compaction correction and paleo-water depth correction, to restore the original sedimentary thickness and paleogeomorphic morphology of the basin at different evolutionary stages. Among them, the two-dimensional flexural equilibrium back stripping is more in line with the real geological situation than the one-dimensional Airy equilibrium back stripping. The Flex-Decomp software can obtain the lithospheric stretching factor through repeated iterative back stripping and forward simulation, improving the accuracy of the original basin restoration. This method is widely used in the restoration of the original basin in the later stage of extensional basin rifting. The sedimentary center analysis method determines the sedimentary center of the basin during the sedimentation period by analyzing the spatial distribution of stratum thickness and lithofacies combination characteristics. Combined with the distribution of co-sedimentary faults, it restores the boundary and morphology of the original basin. For example, by compiling stratum thickness, sandstone thickness, and sandstone percentage content maps, combined with regional cross-well sections, the migration law of the sedimentary center can be clearly defined, providing a basis for the restoration of the original basin.[15-16]

5. Discussion

5.1. Type of Co-precipitating Fractures

The classification of synchronous faults needs to be combined with their tectonic background, activity characteristics, geometric shape, and their control over the original basin. Currently, scholars at home and abroad have not yet formed a unified classification standard. Based on the existing research results, the synchronous faults can be classified from the following four dimensions. Different types of synchronous faults have significant differences in their impact on the restoration of the original basin.

According to the tectonic background, they can be classified as extensional synchronous faults, compressive synchronous faults, and strike-slip synchronous faults. Extensional synchronous faults are mainly developed in an extensional tectonic background and are the most common type. They often present as normal faults, and the fault activity causes the basin to sink, controlling the original boundary and sedimentation center of the basin. For example, the synchronous faults in the Ordos Basin and Bohai Bay Basin belong to this type. The activity intensity of extensional faults is positively correlated with the sedimentation rate, and the thickness of the subsiding layer is significantly greater than that of the ascending layer, directly affecting the sedimentation range and filling characteristics of the original basin. Compressive synchronous faults develop in a compressive tectonic background and often present as reverse faults. During the activity process, the strata are folded and uplifted, causing the basin to shrink and the sedimentation center to shift. This has a relatively strong effect on the morphology of the original basin and is common in foreland basins. Strike-slip synchronous faults develop in a strike-slip tectonic background. The fault activity is mainly horizontal displacement, accompanied by vertical movement, causing the basin to be cut and misaligned, resulting in discontinuous sedimentary facies and increasing the difficulty of the restoration of the original basin. For example, the synchronous faults in the strike-slip modified basin, the misalignment distance directly affects the reconstruction of the original basin's original morphology. [17-19]

According to the activity intensity, they can be classified as strong activity type, medium activity type, and weak activity type synchronous faults. Strong activity synchronous faults have a long activity duration, a large slip distance, and a growth index generally greater than 2.0. They have a significant control effect on the original basin and can directly determine the boundary morphology and sedimentation center distribution of the original basin, even causing the division and evolution direction of the basin to change. For example, the strong activity synchronous faults in the Nigerian Delta Basin control the distribution of reservoir facies and oil and gas accumulation. Medium activity synchronous faults have a medium activity duration and a moderate slip distance, with a growth index between 1.2 and 2.0. They mainly affect the sedimentary pattern within the original basin, causing local differences in stratum thickness and sedimentary facies changes. For example, most synchronous faults in the Jiyang Depression and Dongying Depression belong to this type. Weak activity synchronous faults have a short activity duration and a small slip distance, with a growth index less than 1.2. They have a relatively small impact on the original basin and mainly manifest as slight deformation of local strata, causing relatively less interference to the restoration of the original basin, and are mostly developed in secondary structural units within the basin.

According to the geometric shape, they can be classified as chisel-shaped, slope-shaped, and planar synchronous faults. Chisel-shaped and slope-shaped synchronous faults are prone to cause layer inversion, forming synchronous anticlines or reverse secondary faults. For example, the chisel-shaped concave fault in the Zhanci area, the upper plate develops a rolling anticline structure, directly affecting the distribution of local sedimentary facies. Planar synchronous faults are prone to form traction structures or synchronous secondary faults, having a relatively

ISSN: 2688-8645

uniform impact on stratum thickness, and having a relatively weak effect on the morphology of the original basin. They are commonly seen in the gentle areas within the basin.

According to the control effect, they can be classified as boundary synchronous faults and basin interior synchronous faults. Boundary synchronous faults are the main controlling faults of the basin, controlling the boundary range and evolution direction of the original basin. They have a large activity intensity and a long extension distance. For example, the edge synchronous faults in the Ordos Basin control the overall morphology and sedimentation filling of the basin. Basin interior synchronous faults are secondary faults within the basin, mainly controlling the migration of the sedimentation center and the thickness difference of the strata. Their activity intensity is relatively weak, with a short extension distance, and have a significant impact on the local morphology of the original basin. For example, the secondary synchronous faults within the Ordos Basin cause the differentiation of local sedimentary facies and changes in stratum thickness.

5.2. The Basic Method for Restoring the Original Condition

The core of basin restoration lies in removing the influence of post-construction modifications and reconstructing the original appearance of the basin during the sedimentation period. Common basic methods include the balanced section method, back stripping method, and sedimentary center analysis method. The balanced section method is based on the principle of volume conservation of strata, and by inverting the current structural section, it restores the original structural form of the basin during the sedimentation period. It is applicable to extensional basins with developed co-sedimentary faults and thrust basins for the restoration of the original basin. The 2D Move software is currently a widely used two-dimensional balanced section restoration tool. It uses algorithms such as single shear without folding and oblique shear, which can effectively restore the stratum deformation caused by fault activity. The back stripping method (also known as stratum erosion back stripping method) strips the later sedimentary strata and eroded strata layer by layer, combined with stratum compaction correction and paleo-water depth correction, to restore the original sedimentary thickness and paleogeomorphic morphology of the basin at different evolutionary stages. Among them, the two-dimensional flexural equilibrium back stripping is more in line with the real geological situation than the one-dimensional Airy equilibrium back stripping. The Flex-Decomp software can obtain the lithospheric stretching factor through repeated iterative back stripping and forward simulation, improving the accuracy of the original basin restoration. This method is widely used in the restoration of the original basin in the later stage of extensional basin rifting. The sedimentary center analysis method determines the sedimentary center of the basin during the sedimentation period by analyzing the spatial distribution of stratum thickness and lithofacies combination characteristics. Combined with the distribution of co-sedimentary faults, it restores the boundary and morphology of the original basin. For example, by compiling stratum thickness, sandstone thickness, and sandstone percentage content maps, combined with regional cross-well sections, the migration law of the sedimentary center can be clearly defined, providing a basis for the restoration of the original basin. [20]

5.3. Fine-grained Research Method

With the continuous deepening of research, refined and quantitative methods have gradually been applied to the study of the influence of co-sedimentary faults on the recovery of the original basin. These methods mainly include numerical simulation, isotope dating, and GIS technology. The numerical simulation method establishes a coupled model of co-sedimentary fault activity and basin sediment filling to simulate the process of co-sedimentary fault activity, the migration pattern of the sediment center, and quantitatively analyze the impact of co-sedimentary faults on the evolution of the original basin. Commonly used simulation software includes BasinMod, PetroMod, etc. It can be combined with the McKenzie post-breakup thermal

ISSN: 2688-8645

subsidence model to calculate the thermal uplift and optimize the results of the original basin recovery. The isotope dating method (such as zircon U-Pb dating, argon-argon dating) determines the activity period of co-sedimentary faults by measuring the isotope ages of rocks and strata in the co-sedimentary fault zone. Combined with the detrital zircon U-Pb dating analysis of the source area direction, it provides chronological basis for the recovery of the original basin boundary. The zircon LA-ICP-MS dating technology can precisely determine the age spectrum of zircons, match potential source areas, and clearly show the transportation path of detrital materials. It is widely used in the recovery of original basins in strike-slip modified basins and is calibrated during the testing process using standard samples such as 91500 and GJ1 to ensure data accuracy. GIS technology processes spatial visualization of stratum thickness, fault distribution, and lithological data, and draws various geological maps to intuitively display the spatial relationship between co-sedimentary faults and the morphology and paleogeomorphology of the original basin, assisting in the refined research of the recovery of the original basin and improving the accuracy and efficiency of the recovery.

6. Conclusion

Episodic faults, as a key tectonic phenomenon that occurs synchronously with sedimentation during the evolution of sedimentary basins, play a crucial role in the restoration of the original basin. Their activity characteristics (types, intensities, and timeframes) directly influence the boundary morphology, paleogeomorphic features, sediment filling, and structural patterns of the original basin. These are essential factors to be considered in the process of restoring the original basin. This paper presents a systematic review of the influence of episodic faults on the restoration of the original basin and concludes the following:

1. Episodic faults come in various types, classified by tectonic background as extensional, compressional, and strike-slip; by activity intensity as strong, moderate, and weak; by geometric shape as spoon-shaped, slope-shaped, and planar; and by control type as boundary-type and basin-intrusive-type. Different types of episodic faults have significant differences in their impact on the restoration of the original basin. Among them, boundary-type, strong-activity-type, and extensional-type episodic faults have the most significant control over the original basin, making them the core research objects in the restoration process.

2. Episodic faults are the main shaper of paleogeomorphology. Their activity causes differences in uplift and subsidence on both sides of the faults, forming landforms such as uplifts and depressions, which control the undulation and evolution speed of paleogeomorphology. By combining stratigraphic thickness analysis, sedimentary facies analysis, and numerical simulation methods, the detailed restoration of paleogeomorphology under the control of episodic faults can be achieved. At the same time, it is necessary to eliminate the interference of later tectonic modification and erosion, improving the restoration accuracy. The application of techniques such as detrital zircon dating and paleoflow analysis further enhances the accuracy of paleogeomorphological restoration.

3. The influence of episodic faults on the original basin mainly manifests in three aspects: controlling the range and shape of the original basin's boundaries, determining the expansion and contraction of the original basin; controlling the sediment filling characteristics of the original basin, affecting the direction of material sources, the migration of sediment centers, and the distribution of stratum thickness, shaping the spatial differentiation of sedimentary facies; shaping the macroscopic structural pattern of the original basin, forming structural styles such as fault depressions and fault-upslands, and refining secondary sedimentary units. It also controls the distribution laws of mineral resources such as oil and gas.

4. Currently, domestic and international research on the influence of episodic faults on the restoration of the original basin has achieved fruitful results, establishing a series of

identification, analysis, and restoration methods. However, there are still deficiencies: the quantitative characterization methods for the activity intensity of episodic faults are not yet perfect, making it difficult to accurately reflect the dynamic coupling relationship between fault activity and the evolution of the original basin; in complex superimposed basins and strike-slip modified basins, the study of the superimposed influence of multiple episodic faults is insufficient, and the accuracy of the restoration of the original basin needs to be improved; the restoration methods for paleogeomorphology under the control of episodic faults still need innovation, especially in areas with intense later tectonic modification, the reconstruction of paleogeomorphology is more difficult, and there is a lack of efficient and precise technical means.

5. Future research should focus on the following directions: First, improve the quantitative characterization methods for the activity intensity of episodic faults, combining numerical simulation, isotope dating, and other technologies to achieve dynamic coupling simulation of fault activity and the evolution of the original basin, improving the quantification level of original basin restoration; Second, strengthen the study of the superimposed influence of multiple episodic faults in complex tectonic backgrounds (superimposed basins, strike-slip fault zones), establish a restoration method system suitable for complex areas, such as optimizing the four-step method for restoring the original basin in strike-slip modified basins, to improve the restoration accuracy in complex areas; Third, innovate paleogeomorphological restoration techniques, combining high-precision seismic exploration and artificial intelligence technologies, improving the restoration accuracy of paleogeomorphology in areas with intense later tectonic modification, reducing the uncertainty in the original basin restoration process; Fourth, strengthen the research on the combination of the influence of episodic faults on the restoration of the original basin and mineral resource exploration. Through precise restoration of the original basin, guide the exploration and deployment of oil, coal, and other mineral resources, improving the efficiency and success rate of resource exploration, and providing strong guarantees for national energy security.

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