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Distribution Position Prediction Method of Fault-Caprock Oil and Gas Migration and Accumulation Configuration Pattern

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Abstract: This study aims to investigate the patterns of oil and gas dispersal within the fault-caprock configurations in an oil-gas-rich basin. Using the results of the mechanism and spatial distribution research of fault-caprock oil and gas migration and accumulation configuration patterns, a predictive method has been developed for determining the distribution of fault-caprock fluid migration and accumulation configuration patterns. This method involves superpositing source rock faults, mudstone and fault rock seals within fault-caprock configurations. The application of this method is demonstrated through the prediction of the distribution of fault-caprock fluid migration and accumulation configuration patterns within the lower sub-member of the 1st member of the Shahejie Formation ($E_3s_1^L$) in the Qikou Sag, Bohai Bay Basin. The Dazhangtuo fault and regional mudstone caprocks within the middle sub-member of the 1st member of the Shahejie Formation ($E_3s_1^M$) are involved. The results of this study demonstrate that the fault-caprock sealing of petroleum and natural gas by mudstone and fault-related lithological seals in the configuration pattern of the Dazhangtuo Fault and regional mudstone caprocks in $E_3s_1^M$ is primarily distributed in the western part of the basin, with localized occurrences in the eastern areas. This configuration pattern is optimal for the accumulation of petroleum and natural gas reservoirs in the $E_3s_1^L$. The fault-caprock configuration pattern that seals oil and gas by mudstone is primarily located in the western portion, making it relatively favorable for the accumulation of oil and gas reservoirs in the $E_3s_1^L$. However, the fault-caprock configuration pattern of sealing oil and gas by fault-related lithological is constrained to two specific localized areas in the eastern portion, which is not conducive to the occurrence of oil-gas convergence in the $E_3s_1^L$. The location of detected oil and gas within the $E_3s_1^L$ at the present Dazhangtuo fault is consistent with the predicted pattern of oil and gas accumulation and their distribution locations using this method. This demonstrates the viability of forecasting using this approach to predict the location of fault-caprock migration and the accumulation oil and gas configuration pattern.

Keywords: caprocks; configuration pattern; distribution location; fault; oil-gas migration; prediction method

1 INTRODUCTION

Petroleum and natural gas exploration practices have revealed that oil and gas tend to accumulate primarily along oil source faults within petroliferous basins. These faults serve as conduits connecting source beds and reserve stratas that were active during the formation of oil and gas [1-5]. However, not all segments of these faults contain accumulated petroleum and natural gas. The pattern and location of fluid's migration and accumulation along the fault are primarily influenced by the fault-caprock configuration pattern, in addition to trapping mechanisms and reservoir quality. This refers to the connection between the oil source fault and the regional mudstone caprock. Favorable fault-caprock configurations and accumulation locations facilitate the massive aggregation and entrapment of fluid, while unfavorable configurations impede significant accumulation [6-10]. Therefore, accurately predicting the distribution of fluid's migration and accumulation configuration patterns along fault-caprock is crucial for understanding the oil and gas distribution within fault-caprock configurations and providing guidance for petroleum and natural gas exploration. Previous studies on fault-caprock configurations have primarily focused on their sealing capacity and the potential for fluid's leakage. These studies have utilized the concept of juxtaposition thickness, which is calculated by subtracting the fault throw from the caprock thickness. The minimum thickness of juxtaposition required for fault-caprock seals to effectively retain oil and gas has also been investigated. These studies examine the effectiveness of fault-caprock configurations in sealing or leaking oil and gas by comparing the juxtaposition thickness to the minimum required thickness for effective sealing [11-16]. It is believed that fault-caprock configurations can effectively seal oil and gas when the thickness of the juxtaposition equals or exceeds the minimum thickness required for sealing in that particular configuration. On the other hand, fault-caprock configurations are considered to be leaking fluid when the thickness of the juxtaposition is less numerically compared to the minimum required thickness. Furthermore, the distribution of juxtaposition thickness within fault-caprock configurations has been utilized to study the sealing and leaking segments along these configurations [17-22]. Segments where the thickness of the juxtaposition equals or exceeds the minimum thickness required for sealing are considered sealing portions. Or otherwise, segments with a juxtaposition thickness below the minimum required thickness are considered as regions where the fault-caprock configuration is leaking. Despite this, there has been limited research on fault-caprock movement and concentration of oil and gas deposits configurations. Some studies have only focused on the segments of oil source faults that conduct petroleum and natural gas, as well as the sealing portions of regional caprocks within fault-caprock configurations related to the movement and concentration of oil and gas deposits [23-28]. Furthermore, these studies only consider the mudstone sealing regions of regional caprocks during the oil and gas accumulation period, potentially increasing the risk level of oil and gas exploration work. The studies do not consider the present-day fault rock sealing segments, let alone the patterns and distribution of oil and gas migration and accumulation within fault-caprock configurations. This potential uncertainty arising from this situation will inevitably lead to prediction errors in the effective fluid distribution pattern within this type of structure, making it difficult to accurately represent underground conditions. Based on the above research, it is of great significance to predict the transfer paths and final aggregation distribution positions of oil and natural gas under the control of such construction patterns. This study briefly describes the importance of the configuration form of fractured cap transport and accumulation of oil and gas, then introduces the establishment and application of prediction methods, and finally verifies the effectiveness of the methods through examples, and discusses their potential applications in oil and gas exploration. This study aims to provide a new prediction method for oil and gas exploration by deeply analyzing the distribution patterns of oil and gas configurations in fractured cap rocks, thereby improving exploration efficiency, reducing risks, and providing scientific basis for the sustainable development of oil and gas resources.

2 GEOLOGICAL SETTING

The research area of this study is the Dazhangtuo Fault in the Qikou Depression of the Bohai Bay Basin. The method described above is used to predict the configuration patterns of reservoir fluid migration and accumulation, as well as the distribution positions along the Dazhangtuo Fault and the middle sub-member of the 1st member of the Shahejie Formation ($E_3s_1^M$) regional mudstone caprock within the lower sub-member of the 1st member of the Shahejie Formation ($E_3s_1^L$). The predicted results are then compared with the oil and gas distributions currently discovered along the Dazhangtuo Fault within $E_3s_1^L$ to analyze their relationship. This analysis verifies the feasibility of using this method to predict patterns and locations of fault-caprock reservoir fluid migration and accumulation configuration. The Dazhangtuo Fault is a northeast-trending normal fault located in the northern Qikou Sag, spanning approximately 21.3 km in length. It dips to the southeast at an angle of 55° - 62°. It cuts through strata from the base of the sag to close to the surface, displaying long-term characteristics of faults as shown in Fig. 1. Drilling in the northern Qikou Sag has revealed that the stratigraphic sequence from bottom to top consists of the Paleogene Kongdian Formation (E_2k), Shahejie Formation (E_3s), and Dongying Formation (E_3d), Neogene Guantao Formation (N_1g), Minghuazhen Formation (N_2m), and a small amount of Quaternary (Q) deposits. Currently, oil and gas discovered along the Dazhangtuo Fault are mainly found in $E_3s_1^L$ and are primarily sourced from the underlying 3rd member of the Shahejie Formation (E_3s_3) source rocks. The caprock is composed of regional mudstones from the $E3s1^M$ submember. The Dazhangtuo Fault intersects the underlying E_3s_3 mudstones and $E_3s_1^L$, and was active during the late deposition of N_2m. It is highly probable that this fault is responsible for the oil charging of $E_3s_1^L$.

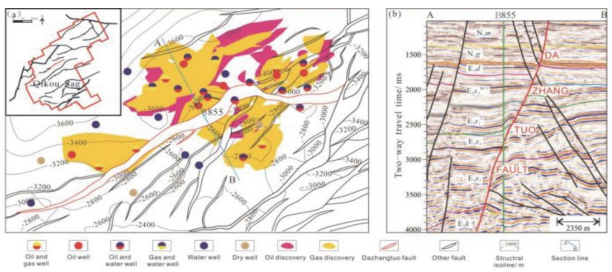

Figure 1 Relationship between the Dazhangtuo fault and oil and gas distribution in $E_3s_1^L$

Fig. 1 shows that the oil and gas discovered along the Dazhangtuo Fault within $E_3s_1^L$ are essentially scattered in the middle and eastern segments. The configuration patterns and locations of reservoir fluids migration and accumulation along the Dazhangtuo Fault and the $E_3s_1^M$ regional mudstone caprock within $E_3s_1^L$ primarily influence the trapping mechanisms and reservoir quality in this area. Therefore, to accurately predict the distribution position of these configuration patterns is crucial for determining the distribution patterns of reservoir fluids along the Dazhangtuo Fault within $E_3s_1^L$ and guiding further exploration.

3 METHODOLOGY

3.1 The pattern and Distribution of Fault-Caprock Migration and Accumulation of Oil and Gas Configurations

Substantial research [29-35] has demonstrated that the configuration of oil source faults and regional mudstone caprocks has the potential to enhance the accumulation of reservoir fluids. Specially, reservoir fluids migration derived from source faults is hindered by the overlying regional mudstone caprock, both during the period of reservoir fluids accumulation and in the present day. Such entrapment beneath the regional mudstone caprock allows for the accumulation of oil and gas, as illustrated in Fig. 2. The distribution of conduit zones for oil source faults, the distribution of mudstone and fault rock sealing portions of the fault-caprock configuration, along with the interconnection of these three factors, lead to the development of three distinct reservoir fluids migration and accumulation patterns in fault-caprock configuration. The first pattern is the configuration of fault-caprock migration-mudstone and fault rock sealing petroleum and natural gas. The reservoir fluids migrate through source fault and are sealed by the combination of mudstone and fault rock, which is beneficial for the accumulation within the fault-caprock configuration. The second pattern is the configuration of the fault-caprock migration-mudstone sealing oil and gas. In this configuration, oil and gas migrated from the oil source fault, sealed solely by mudstone, which is less conducive to the accumulation of reservoir fluids compared to a configuration sealed by both fault rock and mudstone. The third pattern of fault-caprock configuration of reservoir fluids migration and sealing is the fault-rock sealing configuration. In this particular configuration, the oil and gas migrated from the oil source fault and were sealed exclusively by fault rocks. The absence of a caprock that would seal the fault makes this configuration unfavorable for the accumulation of oil and gas.

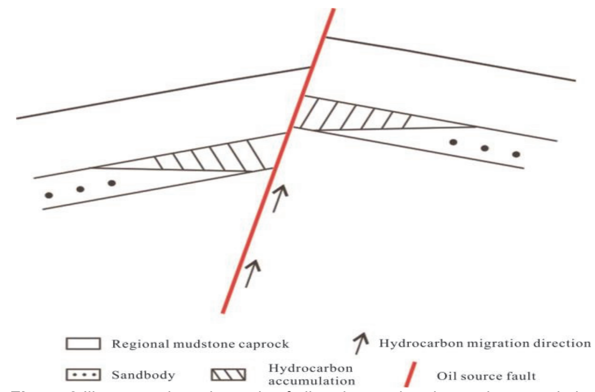

Figure 2 Illustrates the schematic of oil and gas migration and accumulation mechanism within the fault-caprock configuration

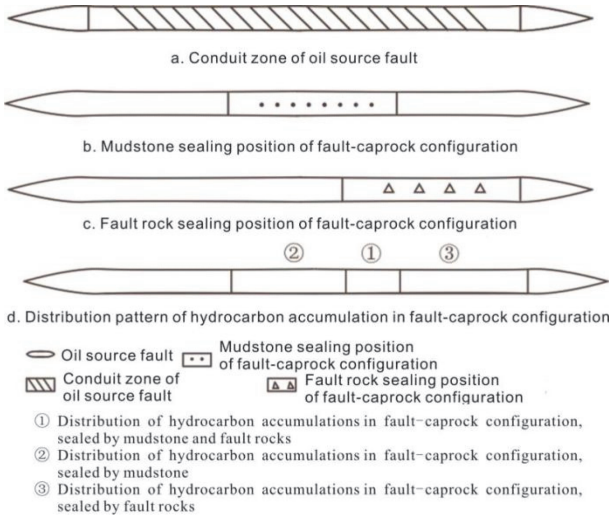

Figure 3 Illustrates the schematic depicting the patterns distribution of fault-caprock configuration migration and accumulation of oil and gas

3.2 Methods for Predicting the Distribution Position of Fault-Caprock Configurations Migration and Accumulation of Oil and Gas

To predict the distribution of fault-caprock configuration accumulation of oil and gas accurately, it is essential to identify the locations of oil source fault conducting oil and gas, mudstone sealing portions of fault-caprock configurations, and fault rock sealing portions of fault-caprock configurations. By adding the above three factors, the distribution of oil and gas positions in the reservoir under the control of fault caprock can be obtained, as shown in Fig. 3.

3.2.1 Methods for Determining the Location of Oil Source Fault Conducting Oil and Gas

Due to the limitation of limited data during the exploration phase, it is necessary to use three-dimensional seismic data to determine the current fault distance within the reservoir of oil source faults that can conduct reservoir fluids. According to the ancient fault distance recovery method [36], the ancient fault distance within the reservoir during the effective fluid accumulation period can be restored. Dividing the distance of ancient faults by the duration of fault activity can obtain the rate of ancient fault activity during the period of fluid accumulation. The method can be used to determine the minimum fracture activity rate required for fault conducting oil and gas in the research region [36]. The area where the activity rate of ancient faults in source rocks is equal to or greater than the minimum activity rate required for transporting fluid faults is called the fault oil and gas transmission area, as shown in Fig. 4a.

3.2.2 Method for Determining the Sealing Position of Mudstone in Fault-Caprock Configuration

To identify suitable areas for the sealing position of mudstone in fault-caprock configuration, it is necessary to analyze seismic and drilling data. This analysis will help to determine the fault distance of source faults within the regional mudstone caprock and the thickness of the faulted regional mudstone caprock. Using the paleo-fault distance restoration method [36] and the paleo-thickness restoration methods of strata [37, 38], it is possible to restore the paleo-fault distance of source faults within the regional mudstone caprock and the paleo-thickness of the regional mudstone caprock that were faulted by faults during the period of fluid accumulation. By subtracting the thickness of the former from that of the latter, we can determine the paleo-juxtaposition thickness of the fault-caprock configuration during the period of oil and gas accumulation. Using the method [39], we can determine the maximum juxtaposition thickness required for the segmented growth of faults within the mudstone cap rock in the study area to connect the upper and lower strata. The source faults within the regional mudstone caprock, which do not show vertical connectivity, are not considered conduits for oil and gas migration through the caprock. By identifying the locations where the fault juxtaposition thickness exceeds or equals the maximum thickness required for the segmented growth and vertical connectivity of faults within the regional mudstone caprock, we can determine the locations where the fault-caprock configuration effectively seals the oil and gas, as shown in Fig. 4b. To determine the locations where fault rock seals within the fault-caprock configuration, seismic and drilling data are essential. The data provide information about the fault distance of the source faults within the regional mudstone caprock, the thickness of the strata juxtaposed by these faults, and the mudstone content within them. The data provide crucial information for characterizing the geometry and properties of the fault-related caprock, which is necessary for assessing its sealing capability. The calculation of the fault rock mudstone content of the source fault within the regional mudstone caprock can be performed using Eq. (1). By determining the burial depth, dip angle, the period of fault stop activity of the source fault within the regional mudstone caprock, and the period of compaction diagnosis of the surrounding rock at the same burial depth as the fault rock, Eq. (2) can then be used to obtain the depth of fault compaction. By substituting the two values into the empirical relationship between the measured displacement pressure and the compaction depth and shale content of the surrounding rock in the study area, we can calculate the displacement pressure of the source fault rock in different positions, as shown in Fig. 4c.

3.2.3 Method for Identifying Fault Rock Sealing Areas within Fault-Caprock Configurations

Using drilling data, the depth of the underlying reservoir can be obtained. Using natural gamma logging data and the method [40] for obtaining shale content, it is possible to determine the shale content of the underlying reservoir formation. Based on the empirical relationship between the actual displacement pressure measured by the reservoir in the study area and factors such as depth and mud content, the displacement pressure of rocks in each part of the underlying reservoir can be determined, as shown in Fig. 4c. Taking the displacement pressure of the fault in the regional-mudstone caprock of the source fault, which exceeds or equals the displacement pressure of the underlying reservoir rock, the fault rock sealing positions within the fault-caprock configuration can be obtained, as shown in Fig. 4c.

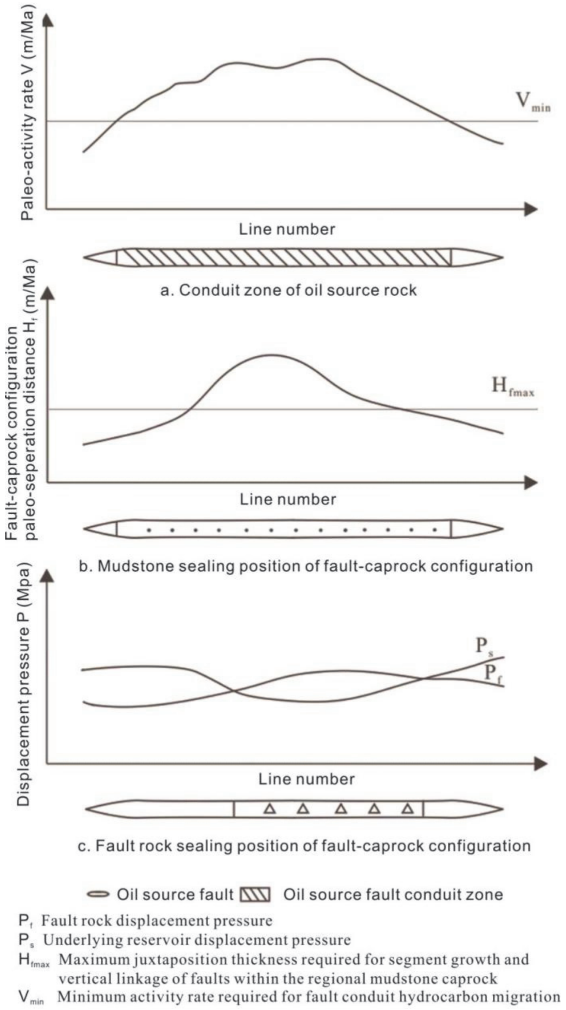

Figure 4 Identification of source fault conduit zones, mudstone, and fault rock sealing positions within the fault-caprock configuration

$$R_f = \frac{\sum_{i=1}^{n} H_i R_i}{L} \quad (1)$$

In the formula: R_f is the shale content of the fault, expressed as a percentage (%); H_i represents the thickness of the i-th layer of rock cut by the fault, measured in meters (m); R_i represents the mud content of the *i*-th layer of rock cut by the fault, expressed as a percentage (%); L denotes the vertical fault distance of the fault, measured in meters (m). The variable i represents the *i*-th layer of rock cut by the fault, while n represents the total number of layers cut by the fault.

$$Z_f = \frac{T_0}{T} \cdot \frac{Z}{\cos\theta} \quad (2)$$

In the formula: Z_f represents the compaction burial depth of the fault rock, measured in meters (m); T_0 denotes the period when the fault stopped being activity, measured in millions of years (Ma); T represents the period of the compaction lithification for the wall rocks at the same burial depth as the fault rock, also measured in Ma; Z indicates the burial depth of the fault rock in meters (m). Lastly, θ represents the dip angle of the fault.

4 RESULTS AND DISCUSSION

4.1 Source Rock Faults Conduction Parts

Using 3D seismic data, the present-day fault distance of the Dazhangtuo Fault within $E_3s_1^L$ is determined. Additionally, the paleo-fault distance of the Dazhangtuo Fault within $E_3s_1^L$ during the middle-late depositional stage of N_2m, when oil and gas were generated and accumulated, has been determined. This restoration is based on the paleo-fault distance restoration method [39]. By dividing the restored fault distance by the activity time of the fault, the paleo-activity rate of the Dazhangtuo Fault within $E_3s_1^L$ can be determined. With a minimum activity rate of around 4 m/Ma required for a fault to conduct the transmission of migrated oil and gas from the Qikou sag, as shown in Fig. 5, material movements pathways along the Dazhangtuo Fault within $E_3s_1^L$ are identified, as shown in Fig. 6. Fig. 6 reveals that, except for the eastern and western ends and certain local central areas, the majority of the Dazhangtuo Fault within $E_3s_1^L$ functions as oil and gas migration pathways.

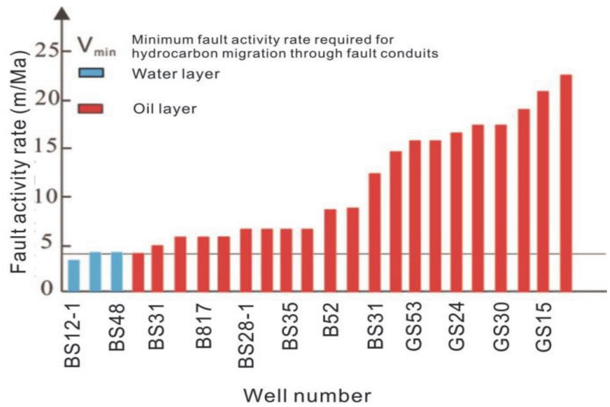

Figure 5 Determining the minimum activity rate required for fault conduit migration in the Qikou sag

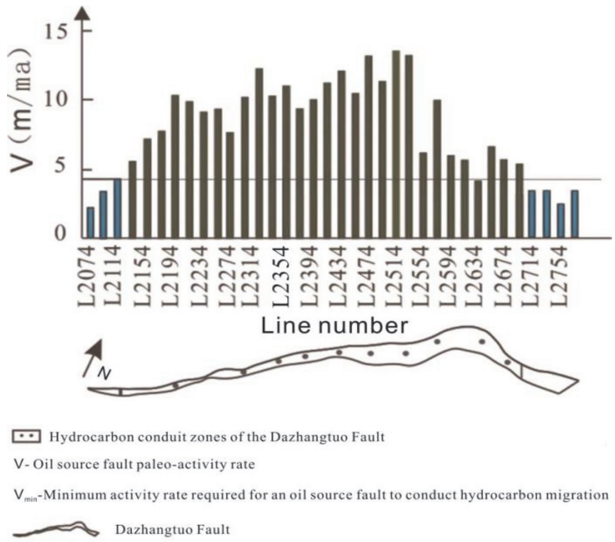

Figure 6 Identification of the oil and gas migration pathway of the Dazhangtuo Fault in $E_3s_1^L$

4.2 Mudstone Sealing Positions within the Regional Mudstone Caprock

Using 3D seismic and logging data, it is possible to determine the fault distance of the Dazhangtuo Fault within the region-specific mudstone caprock in $E_3s_1^M$, as well as the thickness of the fault formed in the regional mudstone cap rock. Additionally, the restored fault distance of the Dazhangtuo Fault within the region-specific mudstone caprock in $E_3s_1^M$ and the restored paleo-thickness of the regional mudstone caprock cut by the fault in $E_3s_1^M$ can be determined using the paleo-fault distance restoration method [39, 40] and the paleo-thickness restoration method [41-43]. By subtracting the thickness of the region-specific mudstone caprock from the paleo-fault distance of the Dazhangtuo Fault, the thickness of the paleo-juxtaposition thickness of the configuration of Dazhangtuo fault and regional mudstone caprock in the $E_3s_1^M$ is determined. Based on the maximum juxtaposition thickness required for the segmented growth and vertical alignment of faults within the region-specific mudstone caprock in $E_3s_1^M$ of the Qikou sag, as shown in Fig. 7, the mudstone sealing positions within the configuration of the Dazhangtuo Fault and the regional mudstone caprock in $E_3s_1^M$ are identified, as displayed in Fig. 8. As can be seen from Fig. 8, except for two local areas in the east, the remaining areas represent mudstone sealing positions within the configuration of the Dazhangtuo Fault and the region-specific mudstone caprock in $E_3s_1^M$.

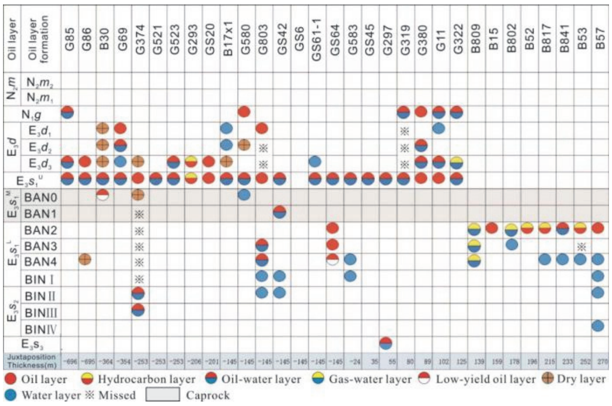

Figure 7 Determination of the maximum juxtaposition thickness required for segmented growth and vertical connection of faults within the regional mudstone caprock in $E_3s_1^M$ of Qikou Sag

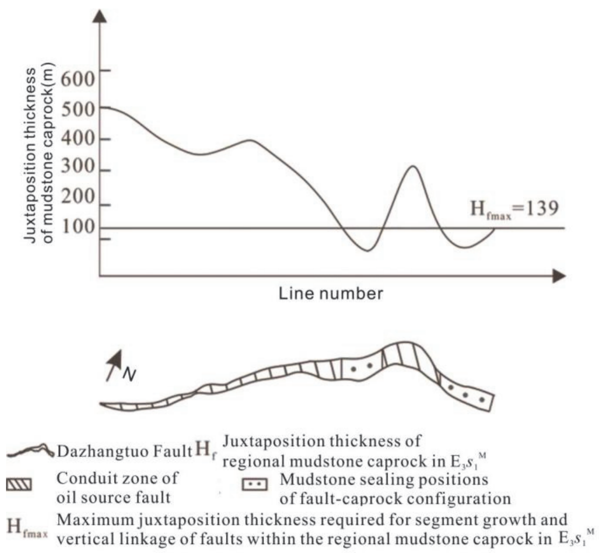

Figure 8 Identification of mudstone sealing zones within the configuration of the Dazhangtuo fault and the regional mudstone caprock in E_3s_1

4.3 Fault Rock Sealing Positions within the Regional Mudstone Caprock Configuration

Using 3D seismic and high quality drilling data, we can determine the fault distance, thickness, and shale content of the strata faulted by the Dazhangtuo Fault within. The mud content of the fault rock of the Dazhangtuo Fault within $E_3s_1^L$ is calculated using Eq. (1). Through the factors of the Dazhangtuo Fault within $E_3s_1^L$ such as burial depth, dip angle, cessation time of activity, and compaction lithification time of the wall rocks with equivalent burial depth as the fault rock, the compaction burial depth of the fault rock is obtained by Eq. (2). By substituting these parameters into Eq. (3), we can calculate the displacement pressure of the fault area of the Dazhangtuo Fault at different locations of the $E_3s_1^L$. This is illustrated in Fig. 9.

$$P_c = 0.28\left(\frac{Z_c R_c}{100}\right)^{1.415} \quad (3)$$

In the formula: P_C represents the displacement pressure of the caprock in the Qikou sag, measured in MPa; Z_C refers to the depth of the caprock in the sag, measured in meters; R_C represents the mud content of the caprock in the sag, expressed as a percentage (%). Using well logging data, the burial depth of the reservoir rocks in $E_3s_1^L$ can be determined. Additionally, the mud content of the reservoir rocks in $E_3s_1^L$ can be obtained using natural gamma logging data, based on the method for calculating mud content of rocks [43]. By substituting the above two parameters into Eq. (4), the displacement pressure of the reservoir of the Dazhangtuo Fault in different parts of $E_3s_1^L$ can be obtained, as shown in Fig. 9.

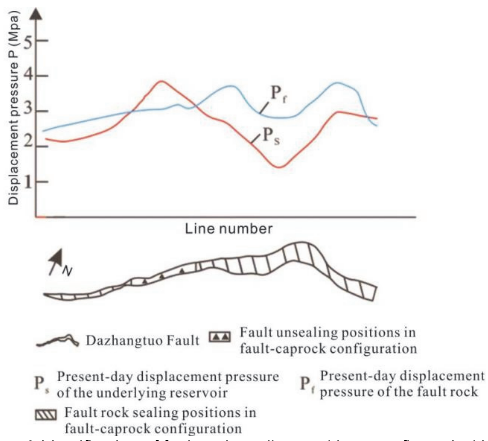

Figure 9 Identification of fault rock sealing positions configured with the Dazhangtuo Fault and the regional mudstone caprock in $E_3s_1^M$

$$P_s = 0.197\left(\frac{Z_s R_s}{100}\right)^{1.352} \quad (4)$$

In the formula: P_S represents the displacement pressure of the reservoir strata in the Qikou sag, measured in MPa; Z_S refers to the depth of the reservoir rocks in the Qikou sag, measured in meters; R_S represents the mud content of the reservoir in the Qikou sag, expressed as a percentage (%). Based on the determined locations where the displacement pressure of the fault along the Dazhangtuo

Fault within the region-specific mudstone caprock in $E_3s_1^M$ is greater than or equal to the displacement pressure of the reservoir strata in $E_3s_1^L$, the fault rock sealing positions configured with the Dazhangtuo Fault and the regional mudstone caprock in $E_3s_1^M$ can be identified, as shown in Fig. 9. As can be seen from Fig. 9, except for the middle-western sections where the fault rock fails to seal when configured with the Dazhangtuo Fault and the regional mudstone caprock in $E_3s_1^M$, the rest are fault rock sealing positions configured with the Dazhangtuo Fault and the regional mudstone caprock in $E_3s_1^M$.

4.4 Result Verification

By overlapping the identified migration pathways along the Dazhangtuo fault within $E_3s_1^L$, the positions where the mudstone and fault rock act as sealed part within the configuration of the Dazhangtuo Fault and the region-specific mudstone caprock in $E_3s_1^M$, the distribution pattern of reservoir fluids accumulation within $E_3s_1^L$, which is configured by the Dazhangtuo Fault and the regional mudstone caprock in $E_3s_1^M$, can be obtained using this method, as shown in Fig. 10.

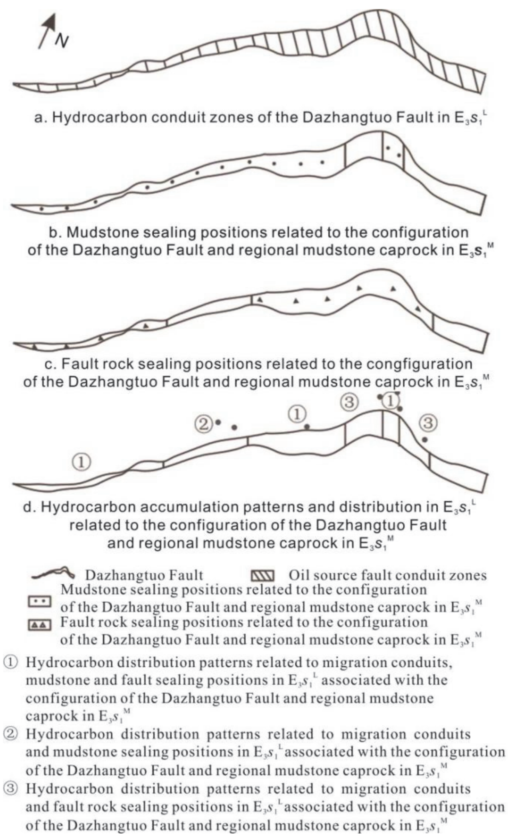

Figure 10 Relationship between the oil and gas distribution and the configuration of reservoir fluids migration and accumulation in $E_3s_1^L$ of the Dazhangtuo Fault and the region-specific mudstone caprock in $E_3s_1^M$

As shown in Fig. 10, the migration of mudstone and fault rock sealing of reservoir fluids accumulation pattern configured with the Dazhangtuo Fault and the regional mudstone caprock in $E_3s_1^M$ is generally found in the western and middle-eastern areas within $E_3s_1^L$. The migration-mudstone sealing pattern for oil and gas accumulation is mainly distributed in the middle-western area, whereas the migration fault rock sealing pattern for reservoir fluids accumulation pattern is only locally distributed in the middle-eastern area. It can be seen from Fig. 10 that the oil and gas discovered along the Dazhangtuo Fault within $E_3s_1^L$ are primarily located in the central and eastern area. The distribution mainly occurs in the reservoir fluids accumulation configuration of the mudstone-conduction and fault sealing pattern in $E_3s_1^L$, which formed by the Dazhagntuo fault and the region-specific mudstone caprock of $E_3s_1^M$. The next is the configuration of the migration-mudstone sealing pattern, which has led to the discovery of less reservoir fluids. The configuration of the migration-fault rock sealing pattern has the lowest amount of discovered fossil energy. This is because only in areas where the Dazhangtuo fault and the regional mudstone caprock of $E_3s_1^M$ form the configuration of migration-mudstone and fault rock sealing pattern in $E_3s_1^L$, it is conducive to the congregation of fossil energy, leading to relatively more discovered fossil energy through drilling. Next is the configurations of migration-mudstone sealing pattern areas, where relatively less fossil energy has been discovered. The configurations of migration-fault rock sealing pattern areas are the least favorable, as they have the minimum quantity of discovered petroleum and natural gas from drilling. Moreover, due to the compression effect of faults, reverse faults increase the sealing of fault rocks, which helps to preserve oil and gas. So when discussing issues related to the migration and accumulation of oil and gas in oil and gas basins, the main consideration should be reverse faults.

5 CONCLUSIONS

(1) There are mainly three types of fault-caprock configurations for reservoir fluids accumulation. The first type is the migration-mudstone and fault rock sealing pattern, which is favorable for the accumulation of reservoir fluids within the fault-caprock configuration. The second type is the migration-mudstone sealing pattern, which is relatively favorable for the accumulation of reservoir fluids within the fault-caprock configuration. The third type is the migration-fault rock sealing pattern, which is unfavorable for reservoir fluids accumulation within the fault-caprock configuration.

(2) A method for predicting the distribution of fault-caprock oil and gas accumulation configuration patterns is established by overlapping the migration pathways of source faults, fault-caprock configured mudstone sealing positions, fault-caprock configured mudstone seals, and fault-caprock configured fault rock seals. Field applications have demonstrated the feasibility of this method in predicting the distribution of fault-caprock oil and gas accumulation configurations.

(3) In the Qikou sag of the Bohai Bay Basin, the migration-mudstone and fault rock sealing pattern, configured with the Dazhangtuo Fault and the regional mudstone caprock in $E_3s_1^M$, is primarily found in the eastern areas of $E_3s_1^L$. This distribution is favorable for the accumulation of oil and gas within $E_3s_1^L$. The migration-fault rock sealing pattern is only locally distributed in the central and eastern areas, which is unfavorable for the accumulation of oil and gas within $E_3s_1^L$. This matches the current discovered distribution of oil and gas along the Dazhangtuo Fault within $E_3s_1^L$.

This method is primarily used to predict the distribution of fault-related oil and gas accumulation patterns in normal fault rock petroliferous basins.

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