Analysis of Sedimentary Development and Distribution Characteristics of Raoyang Sag Based on Sedimentary Organic Facies

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Abstract: Raoyang Sag is the most important oil and gas sag in Jizhong depression. Combining sedimentary facies with Source rock soluble organic matter molecular markers and some oil and gas geochemical parameters, the types of sedimentary organic facies are divided, and the single well sedimentary organic facies and planar sedimentary organic facies are characterized, revealing the spatial distribution characteristics of sedimentary organic facies. Experimental results show that the Lower Es3 Subsection, Upper Es3 Subsection and Es1 Subsection 3 Source Rock are developed vertically. The sedimentary organic phase in the Source rock section of the main mantle area is dominated by B and C phases, and the A-B phase is occasionally seen. The development of the source rock of the Paleogene is controlled by the sedimentary facies and sequence. The Source rock develops in the shallow lake-semi-deep lake sedimentary environment. The Lower Es3 Subsection and Upper Es3 Subsection quality Source rock are both in the lake intrusion system and in the high-level system domain. Es1 Subsection quality Source rock is mainly developed in the lake invasion system, medium source rock is concentrated in the high system domain.

1. Introduction

Raoyang Sag is located in the middle of Jizhong depression and is the main oil-rich depression in Jizhong depression. Raoyang Sag oil and gas drilling began in 1963, and Renqiu Oilfield was discovered in 1975. By the end of 2013, 977 wells of various types of exploration wells had been completed, 467 industrial oil flow wells were obtained, and 11 industrial oil strata were discovered, and proven geological reserves were obtained. 69180.66 × 104t, the proven recoverable reserves are 20,314.29 × 104t, and the accumulated proved reserves are 89, 494.95 × 104t [1]. Studies have shown that the high-quality source rock in the depression is the main reason for the large exploration potential of the oil-rich basin, which lays a solid foundation for the accumulation of oil and gas. In recent years, based on the new theory and new technology of Source rock research at home and abroad, combined with the latest research results of North China Oilfield, North China Oilfield has established a technical method for the evaluation of Source rock under the sequence grid, and the main oil-rich depression in Jizhong exploration area. Source rock of different abundances has carried out a more detailed portrayal, and proposed a new viewpoint of “high-quality source rock control oil, medium and low abundance source rock gas”, breaking through the traditional dark mudstone and mature Source rock hydrocarbon concept [2]. However, many issues such as the sedimentary organic phase and Source rock distribution characteristics of Source Rock, the source rock evaluation and the classification criteria of high-quality Source rock, and the contribution to oil and gas have yet to be further studied.

This study takes Raoyang Sag as an example, focusing on the sedimentary environment, sedimentary organic facies, distribution characteristics of high-quality Source rock layers, geology, organic geochemistry, geophysics, sequence stratigraphy, seismic sedimentology, Sedimentology is

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a technical means to clarify the sedimentary environment of Source rock as a whole, to define different types of Source rock classification criteria, and to predict the spatial distribution characteristics of different types of Source rock. It provides a basis for the evaluation of oil and gas exploration targets, provides ideas for the evaluation of hydrocarbon generation sag, and guides the fine oil and gas exploration work.

2. Analysis of Raoyang Sag sedimentary system

The Lower Es3 Subsection, Upper Es3 Subsection and Es1 Subsection of the Raoyang Sag Source Rock layer are mainly composed of the river channel subfaces and the flood plain subfaces of the meandering river facies and the braided river facies, and the large-area floodplain subfaces in the western gentle slope zone. Local development of the river subphase. The subfaces of the river are mainly gray, brown-red sandstone, and often form a positive spiral profile with purple-red, brown-red mudstone and thin gray mudstone (Fig. 1). Its structure and composition have low maturity. The natural potential curve is bell-shaped or box-shaped, with a combination of medium-high and negative-negative anomalies. The seismic section shows parallel-sub-parallel or pre-product structure, often developing block-like bedding and trough-like interlaced bedding. And wavy cross-layering and the like. The sub-facies lithology of the flood plain is dominated by purple-red and variegated mudstones, with gray or brown-red medium sandstone, fine sandstone and siltstone. Sorting the grinding circle difference, the natural potential curve is approximately linear or micro-toothed, and the seismic section shows a parallel-sub-parallel structure, often with sand-grained interlaced bedding and lenticular bedding.

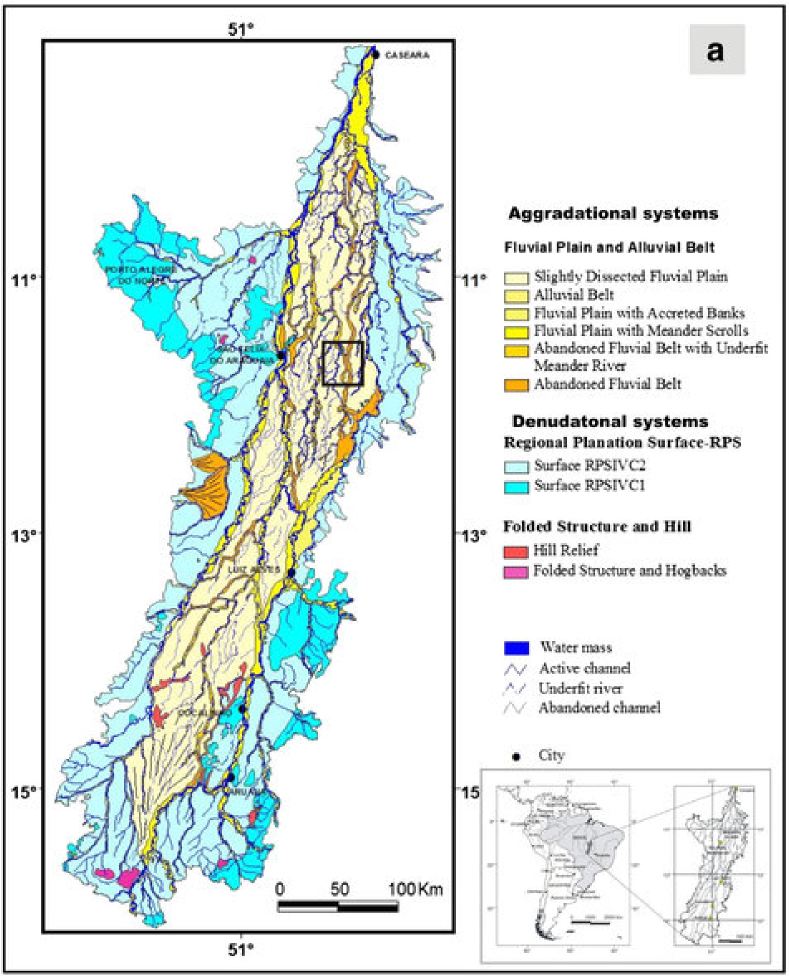

Figure 1. Rhythm characteristics of phase sequence of river-like river and meandering river.

2.1 Source analysis

The spatial distribution of the sedimentary facies includes both the profile distribution and the planar spread of the deposition system. By restoring paleo-water depth and sedimentary system analysis, combined with seismic and well logging data, and based on provenance analysis, the spatial distribution of sedimentary phase of Raoyang Sag Lower Es3 Subsection, Upper Es3 Subsection and Es1 Subsection was comprehensively analyzed [3].

(1) Characteristics of glutamate percentage. Generally, the percentage of glutamate in the direction of the source has a tendency to decrease. The closer to the source area, the higher the percentage of glutamate; the farther away from the source area, the lower the percentage of glutamate. By statistically collecting the percentage of glutamate in the logging data and plotting the contour map of the percentage of glutamate, the direction of the archaeological source can be judged. The main source direction of Raoyang Sag is western provenance and eastern provenance, followed by southwestern and northern provenances. During the continuous evolution of the depression, the source direction does not change much. During the Lower Es3 Subsection period, the source of the material was mainly the Gaoyang low bulge in the west and the Xian County bulge in the east. During the Upper Es3 Subsection period, the source of material originated mainly from the east and west, and the low-lying sag of the southwestern direction was a secondary source. During the Es1 Subsection period, the source of the material was mainly the Gaoyang low bulge in the west, the Xian County bulge in the east and the Maxi area in the northeast. The Shenze low bulge in the southwest was a secondary source.

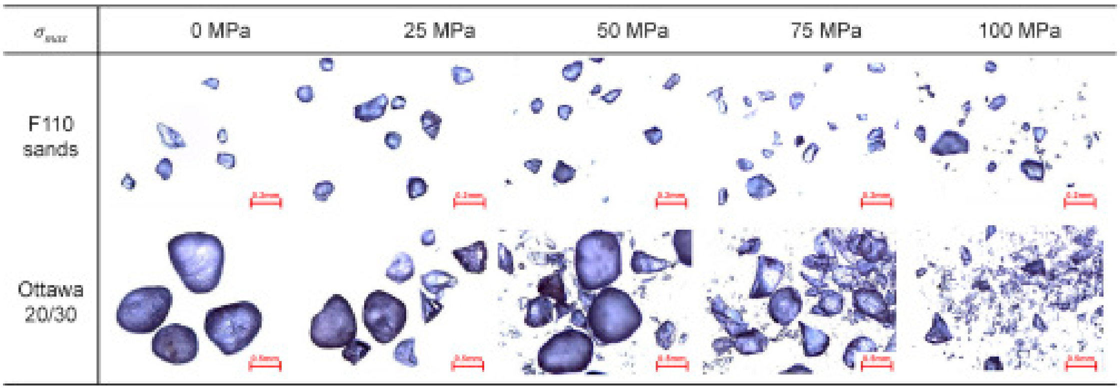

Figure 2. Raoyang Sag Lower Es3 Subsection gluten content percentage isobath.

(2) Combination of heavy minerals and their distribution. Deposition areas for the supply of detrital material from the same parent rock may form different sediments due to different natural geographical conditions or different transport distances, but the heavy mineral combinations they contain are generally the same; but over time or structure The influence of the movement, the rock exposed in the parent rock area has changed, and the heavy mineral combination has also changed. According to this principle, the source and recovery of heavy minerals in the horizontal direction are used to trace the source and recovery mother. Rock. Therefore, this study uses the ZTR method to determine the direction of the source. ZTR stands for the proportion of zircon, tourmaline and rutile in stable transparent heavy minerals. The farther away from the source region, the higher the stability coefficient, the larger the ZTR, and the smaller the ZTR. Due to the limitation of heavy mineral data, heavy mineral analysis of the Sha 3 and Shahe sections could not be completed separately. Therefore, the heavy mineral data of the key wells in the Sha 3 and Sha section were counted separately (Table 1) and heavy minerals were analyzed.

Table 1. Statistical Table of Heavy Minerals of Some Wells in the Section of Shahe and Shahe Sections of Raoyang Sag

Layer	Hashtag	Depth	ZTR	Layer	Hashtag	Depth	ZTR
Sha 1 member	Jian 6	3116.86	0.1523	Sha 1 member	Huang 2	3223	0.135
	Liu 93	3527.91	0.1855		Liu 3	3405	0.198
	Liu 435	3571.34	0.2136		Liu 85	3075	0.1533
	Liu 439	3472.93	0.1734		Liu 425	3263	0.3813
	Ning 26	3131.64	0.1309		Ma 8	1517.2	0.1415
	Ning 30	3229.98	0.1319		Ma 16	1779.2	0.1604
	Ning 32	3556.6	0.1339		Ma 19	1827	0.1492
	Ning 41	3496.57	0.1451		Ning 4	2681	0.256
	Ning 43	3216.23	0.2052		Ning 21	3090	0.0791
	Ning 50	3510	0.2072		Ning 23	3514.43	0.125
	Ning 201	3540.84	0.147		Ning 37	3320.91	0.1748
	Ning 623	3329.74	0.1399		Ren 96	3528	0.1896
	Ren 102	4421.89	0.218		Ren 807	2718	0.1743
	Ren 108	2665	0.2138		Yan shen 1	3322	0.239
	Ren 110	3211.4	0.2312	Sha 3 member	Liu 496	3705.94	0.4321
	Xi Liu 2	3345.89	0.1884		Liu 498	3499.55	0.4384
	Xi Liu 6	3381.15	0.1922		Liu Gu 2	4031.91	0.2099
	Xi Liu 8	2775.55	0.1411		Ning 41	3723.89	0.1491
	Chu 5	2698	0.1179		Ning 301	4421.47	0.1918
	Chu 16	3356.71	0.1387		Ning Gu 4	4672.52	0.1811
	Gao 3	2483	0.0541		Ning Gu 5	4761.93	0.1329

2.2 Sedimentary facies distribution

(1) Lateral distribution characteristics of sedimentary facies. Well Ren 96 and well Xi9 are located in the south of the depression. They cut Ren Xiwa Cave from north to South and then along the Southeast direction. Well Ren 96, well Ren 97, well Ren 65, well Ren 91, well Xi63, well Xi41 and well Xi 9 pass through. From the Lianjing section, it can be seen that the Es1 Subsection depression mainly developed semi-deep lake deposits. When the Es1 Subsection entered the upper sub-member of Shahejie Formation, the depression turned into shallow lake deposits, and braided river delta front deposits appeared on both sides of the section. Es1 Subsection lacustrine transgression system tract is characterized by semi-deep lakes in most areas, shallow lakes in well Xi9 near Maxi fault, mainly oil shale and dark mudstone; high-level system tract, lake water recession, semi-deep lake area reduction, Renxi Watershed (Ren 96 to Ren 97) and Maxi Watershed (West 41) developed. Semi-deep lake, other areas from semi-deep lake to shallow lake environment. The low-level tract system tract in the upper Sha-1 member has abundant provenances in the West and the Masi area, and the lake basin area has been reduced. Braided River delta front sub-facies developed in the East and west of Well Ren-96; transgressive system tract, Lake Basin expansion, lake water area increased, part of braided river delta deposits turned to shallow lake sub-facies; high-level system tract, lake water receded. The delta front advances forward, and the shallow lake subfaces on the lake basin margin turns to the front deposits.

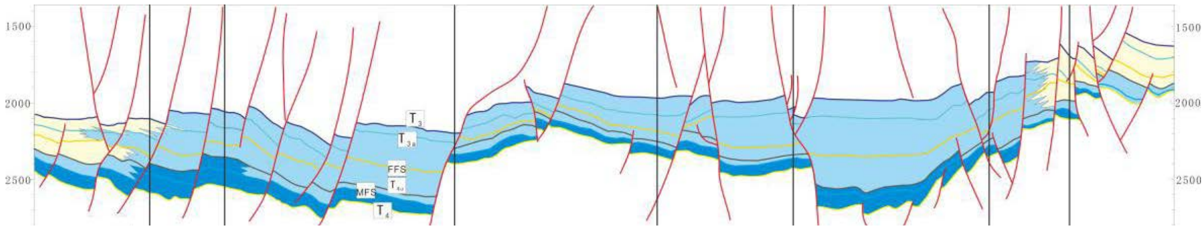

Figure 3. Sectional view of the sedimentary facies of the well in the 96th well of Xijing-Xi 9 well in Raoyang Sag.

(2) Deposition phase plane spread characteristics. The Lower Es3 Subsection period inherited the sedimentary background of the Kongdian-Sha 4 section, the distribution range became larger, the climate changed to warm and humid, and it was in the deep subsidence period of the fault depression. The depression quickly subsided and the space could be increased. The source is mainly the Gaoyang low bulge in the west and the Xian County bulge in the east. The deep sag in the southwest is a secondary source. The Songxian slope belt in the western part of the depression was denuded, most of which did not accept sedimentation. The braided river delta subfaces developed near the center of the basin, the shallow lake was developed in most of the basin center, and the semi-deep lake-deep lake facies developed in the Maxi area. The fan-delta plain is developed in the steep slope of the eastern part of the depression, and the fan delta front is advanced to the lake basin. During this period, there was no floodplain of the river phase.

3. Source rock identification and deposition of organic phase distribution

The logging curve responds well to the sedimentary strata, and its response to the difference in fluid physical properties between the source rock layer TOC and the filled pores is the basis for the evaluation of Source rock. Generally, the higher the organic carbon content of the Source rock layer, the greater the abnormality of the log curve, and the TOC can be solved according to the abnormal value. Natural gamma logging, resistivity logging, sonic time logging, and density logging can all identify Source rock, but with its limitations, the outliers measured by natural gamma logging may be caused by the fracture distribution; The abnormal value measured by logging may be caused by mud intrusion; the abnormal value measured by sonic time difference logging may be due to factors such as mineral composition, clay content, particle compaction, etc.; the abnormal value measured by density logging may be heavy mineral. Enriched by.

This study uses the $\Delta \log R$ method proposed by Passkey et al. to calculate TOC [4]. The method is applicable to the source rock evaluation of carbonate rock and clastic rock. The principle is to overlap the acoustic wave time difference and resistivity log in the fine non-oil rock, and establish a quantitative interpretation formula of organic carbon content according to the abnormal amplitude value. Thus, the Source rock content is obtained. The specific methods are as follows: 1. The acoustic wave time difference uses the arithmetic coordinates, the resistivity curve uses the arithmetic logarithmic coordinates, and the sound time difference of each two logarithmic resistivity scales is $-10\mu s/ft$; 2. Determine the baseline, and the two curves are at the non-Source rock For stacking, select the section with the highest degree of overlap as the baseline; 3. Determine the R baseline value and the Δt baseline value, and calculate the TOC value by the formula. The specific calculation process is as follows:

$$\Delta \log R = \lg\left(R / R_{Baseline}\right) + K\left(\Delta t - \Delta t_{Baseline}\right) \quad (1)$$

Where: $\Delta \log R$ is the value of the measured curve spacing on the logarithmic resistivity coordinates; R is the measured resistivity, $\Omega \bullet m$; Δt is the measured sound wave propagation time difference, $10\mu s/ft$; R is the baseline resistivity of the non-Source rock baseline, $\Omega \bullet m$; Δt baseline For the non-Source rock baseline, the acoustic wave propagation time difference, $10\mu s/ft$; K value is 0.02, depending on the $-50\mu s/ft$ ratio of each resistivity scale; it is clear that the baseline determination is disturbed by human factors and is difficult to determine. Optimized according to the improvement provided by the literature [5]. In the same well calculation, the maturity takes the same value, and the empirical formula becomes:

$$TOC = H \times \Delta \log R \tag{2}$$

Where: H is the coefficient. Substituting the $\Delta \log R$ calculation formula into the improved empirical formula, the simplification is available:

$$TOC = H \times \log R + 0.02H \times \Delta t - H\left(\log R_{Baseline} + 0.02\Delta t_{Baseline}\right) \tag{3}$$

Considering the complicated underground conditions and large area of the work area, this study needs to remove non-Source rock layers such as conglomerate, glutamate, sandstone, siltstone and fine sandstone to reduce the error caused by non-Source rock. For the same well, the source rock changes in different intervals are quite different, and different formulas need to be used for calculation. For the different reclamation areas, wells with well-measured points such as Ma 99, Yangyan 1 well, Chu 21 well, Liuugu 2 well and Qiang 22 well were selected and fitted to the Renxi-Maxi area. The calculation formulas of five areas including Hejian-Shuning area, Liuchu area, Liuxi-Dawangzhuang area and Wuqiang area. Since the Raoyang Sag Yangyan 1 well is the key sampling well of this study, the data is abundant and the dark mudstone is developed. Therefore, the Yangyang 1 well is taken as an example for explanation. Using the above method, build a calculation model:

$$\begin{aligned} &Sand\ three: TOC = 2.43 \times \lg R - 0.006\Delta t - 1.14 \\ &Sand\ one: TOC = 2.59 \times \lg R + 0.06\Delta t - 5.83 \end{aligned} \tag{4}$$

In order to verify the fitting of the established evaluation model to the measured values, the relationship between the measured values and the calculated values is plotted. See Figure 4. The results show that the correlation between the calculated values of the evaluation model and the measured values can reach 0.908. Very good. In the geochemical profile of the Yangshen 1 well, it can be seen that the degree of fitting is very high, among which the measured TOC of the high quality Source rock (TOC ≥ 2.0%) and medium Source rock (1.0% ≤ TOC < 2.0%) The logging curve is box-shaped, indicating that the deposition environment is stable during this period [6].

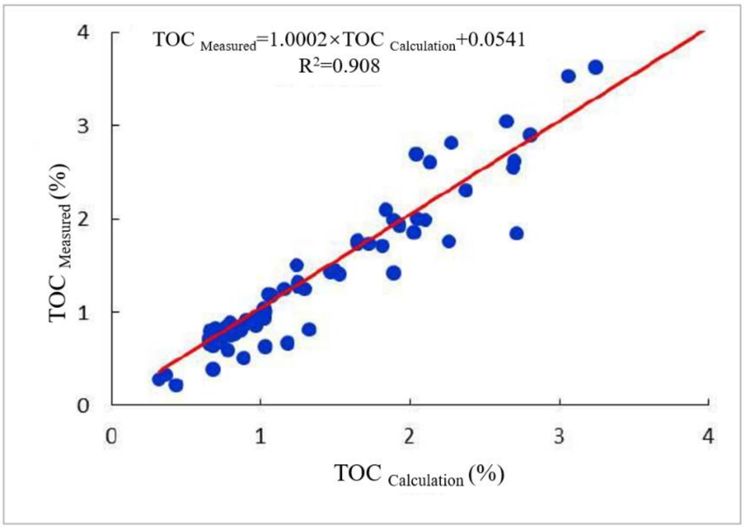

Figure 4. Raoyang Sag Yang Yan 1 Well calculation formula test.

4. Source rock developmental distribution

Studies have shown that the organic abundance and type of Raoyang Sag Lower Es3 Subsection, Upper Es3 Subsection, and Es1 Subsection mudstones have reached the standard of effective Source rock, which is the main hydrocarbon generation interval of the depression. Lower Es3 Subsection Raoyang Sag has a relatively small sedimentary range, and the shallow lake-semi-deep lake sedimentary environment is developed in some areas. The study shows that the Source rock in this period is mainly located in the Masi area. Due to the limited research data, the Lower Es3 Subsection Source rock plane cannot be completely drawn. Distribution. The focus of this study is on the Upper Es3 Subsection and the Es1 Subsection.

The analysis of the seismic phase of the main source rock layer and the analysis of the seismic sections of the main source indicate that the seismic responses of the Es1 Subsection and the Upper Es3 Subsection are both strong reflection axes, and the frequency and amplitude have certain changes. Therefore, the amplitude attribute can be extracted. Several amplitude-related seismic attributes of the 3D seismic data in the study area were extracted, and the attribute profile was compared with the corresponding lithology section. It was found that the root means square amplitude best reflected the lithological change and stratification. The root mean square amplitude seismic attributes of the Es1 Subsection and the Upper Es3 Subsection quality Source rock are extracted respectively to determine the distribution range of the high-quality Source rock. As shown below (Figure 5). The more red and yellow the color, the stronger the amplitude. However, not all ranges of strong amplitude represent the range of high-quality Source rock development, and it is necessary to combine sedimentary phase synthesis analysis. The medium Source rock's response to earthquakes is not as good as that of the high-quality Source rock, so it is difficult to extract the range of medium source rock from seismic attributes. However, it is impossible to develop only high-quality Source rock in a sub-segment. On a single well, there may be a medium source rock near the high-quality Source rock. Therefore, the medium source rock has a development range similar to that of the high-quality Source rock, and its range is larger than that of the premium Source rock. The development range of medium source rock can be reasonably estimated in combination with the development range of high-quality Source rock.

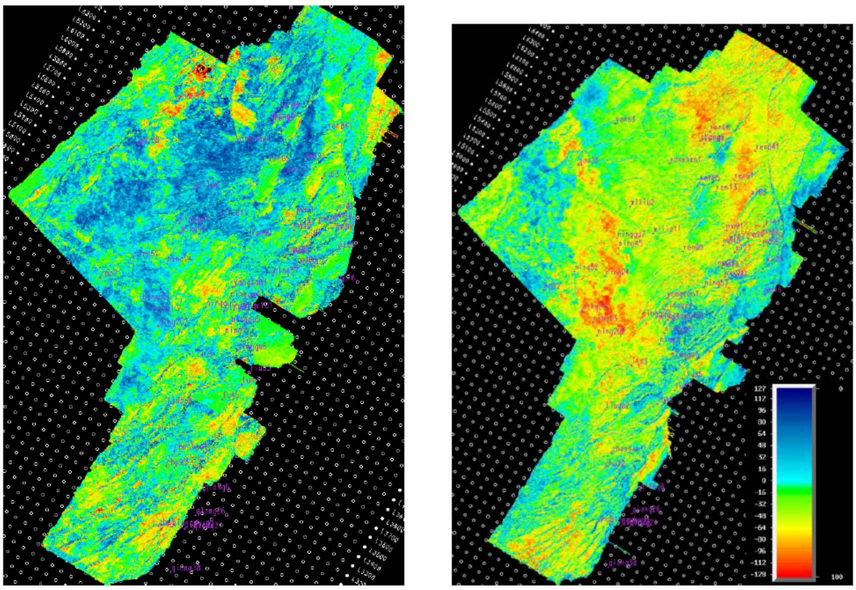

Figure 5. Raoyang Sag Upper Es3 Subsection RMS Plane Distribution (left) and Es1 Subsection RMS Plane Distribution (right).

Raoyang Sag Source rock is mainly developed in the shallow lake and semi-deep lake sedimentary environment. The Lower Es3 Subsection, Upper Es3 Subsection, and Es1 Subsection are mainly composed of thick layer of high-quality Source rock [7]. The sedimentary facies are affected by the elevation of the lake plane. The Es1 Subsection high quality Source rock is mainly developed in the lake intrusion system, and the medium source rock is mainly developed in the high system domain. The Lower Es3 Subsection and Upper Es3 Subsection quality Source rock are involved in both the lake intrusion system and the high-level system domain, and the medium source rock is concentrated in the high-level system domain. In addition to being controlled by the environmental water depth, the development of high-quality Source rock is also affected by the nature of the water in the lake basin: Es1 Subsection is shallow, but it is salt water and strong reducing environment, which is conducive to the development of Source rock; Upper Es3 Subsection is deeper. It is a brackish water and a weak reducing environment, which is also conducive to the development of Source rock. Therefore, the sedimentary facies and sequences control the spatial distribution of the Source rock.

5. Conclusion

This paper focuses on the sedimentary facies developed by Source rock, and analyzes the spatial distribution of sedimentary facies of Raoyang Sag Lower Es3 Subsection, Upper Es3 Subsection and Es1 Subsection by restoring paleo-depth and analyzing sedimentary systems, combining seismic, well logging and provenance analysis. Geological and geochemical analysis of key wells to identify Source rock at each level. Establish a logging response model and calculate the single well Source rock thickness. Studies have shown that the sedimentary facies and sequences control the spatial distribution of Source rock. Source rock is mainly developed in the shallow lake-semi-deep lake environment. The Lower Es3 Subsection and Upper Es3 Subsection quality Source rock are developed in both the lake invasion system and the high system domain. The Es1 Subsection high quality Source rock is mainly developed in the lake invasion system domain, and the medium Source rock is concentrated in the high system domain.

References

[1] Stassen, I, De, VD, & Ameloot, R. Vapor-phase deposition and modification of metal-organic frameworks: state-of-the-art and future directions. Chemistry, 47(48) (2016) 14452- 14460.

[2] Alema, F, Ledyaev, O, Miller, R., Beletsky, V, Osinsky, A, & Schoenfeld, WV Pulsed-metal organic chemical vapor deposition (pmocvd) for growth of single-phase wurtzite mgxzn1 -xo epitaxial film with high mg content (x=0.51) Mrs Advances, 1(4) (2016) 299-304.

[3] Park, SH, Lee, HS, Ahn, HS, & Yang, M. Crystal phase control of ε-ga2o3 fabricated using by metal-organic chemical vapor deposition. Journal of the Korean Physical Society, 74(5) (2019) 502-507.

[4] Ji Youliang, Du Jinhu, Zhao Xianzheng, Zhang Yiming, and Zhang Ruifeng. Tertiary sequence types and developmental patterns under Raoyang Sag. Journal of Sedimentology, 25(1) (2007) 1-9.

[5] Wang Quan, Jin Fengming, Wang Suqing, Qiao Xiaoxia, Si Jiwei, & Li Qing. Control factors and accumulation model of lithologic reservoirs in Raoyang Sag. Xinjiang Petroleum Geology, 29(5) (2008)595-598.

[6] Ji Youliang, Du Jinhu, Zhao Xianzheng, Zhang Yiming, and Zhang Ruifeng. Jizhong depressionRaoyang Sag Paleogene sequence stratigraphy and evolution model. Journal of Palaeogeography, 8(3) (2006) 397-406.