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Application of Seismic Stratigraphic Slice Continuous Browsing Technology to Delicately Characterize River Sedimentary Microfacies

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Abstract: On the basis of understanding the regional tectonics characteristics and stratigraphic sedimentary characteristics of the study area, the sequence stratigraphic framework within the region is gradually studied by applying the principle of high-resolution sequence stratigraphy, and G4 oil formation is divided into three sets of sand formations, namely, G4 upper, G4 middle, and G4 lower sand formations, and divided into small layers in detail. Through comprehensive analysis of lithofacies, logging facies, and seismic facies, the sedimentary facies of the G4 oil formation are comprehensively analyzed. The main sedimentary facies type of the G4 oil formation is the delta front facies belt, and the most important sedimentary microfacies in the delta front facies belt are underwater distributary channel sedimentary microfacies. Using seismic sedimentology methods, make stratigraphic slices of each sub layer of the G4 oil formation, and use the rapid browsing method of stratigraphic slices to trace river sand in detail.

Keywords: Seismic Sedimentology; Stratigraphic Slicing; Sedimentary Microfacies; Delta Front; Channel Sand.

1. Introduction

Seismic sedimentology is currently an important method for studying the distribution of sedimentary facies. Initially, in 1979, Dahm and Graebner identified channel characteristics on seismic time amplitude slices [1]. In 1981, Brown first applied the seismic imaging method along layers [2]. In 1998, Zeng H proposed the concept of seismic sedimentology and discussed the production of stratigraphic slices [3]. In 2008, DongY et al. applied phase adjustment in seismic sedimentology analysis Frequency division interpretation and stratigraphic slicing technology [4]. In 2009, Zhu X and others applied spectral decomposition and stratigraphic slicing technology to identify delta lobes and underwater branch channel sand [5]. In 2020, Zhu X summarized and reflected on the current research status and development of seismic sedimentology [6]. After more than 20 years of research and development by many scholars, seismic sedimentology has now developed a basic and mature application principle and gradually formed a comprehensive research process, Mainly around the seismic work area, combined with the tectonic background and related research results, establish an isochronous stratigraphic framework in the target layer of the study area; Perform 90 ° phase rotation on 3D seismic data, optimize attributes for stratigraphic slicing, and identify and characterize channel sand on the stratigraphic slicing. These methods enable more sedimentary evolution characteristics within geological bodies to be clearly displayed on the plane, providing more favorable information for further understanding the ancient sedimentary evolution system, searching for favorable sand, and conducting oil and gas exploration.

2. Regional Geological Overview

Area A is a continental sedimentary basin. With the continuous increase of numerous scientific research achievements and oil and gas exploration achievements, a large amount of research data has been obtained at present. People have more and more understanding of various oil and gas bearing formations in different blocks. At the same time, they have obtained a large amount of formation information by interpreting seismic data. Area A has complete data, a total area of about 1200km2, and relatively high seismic frequencies, which are more conducive to seismic sedimentology research. The G4 oil layer group mainly corresponds to shallow water delta front facies sedimentation.

3. Processing of Seismic Data

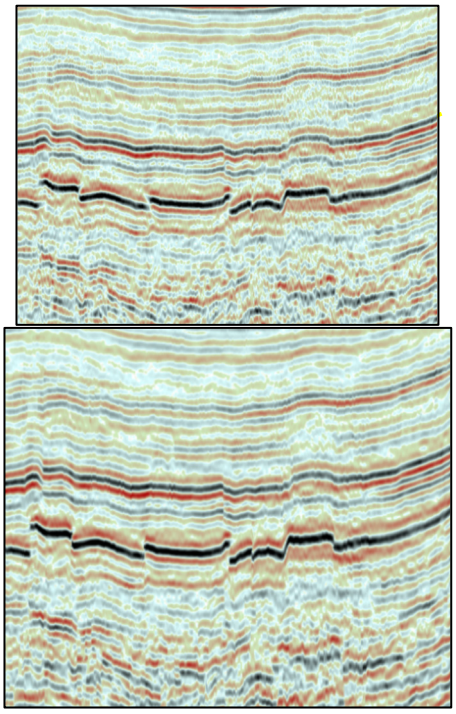


Fig 1. Changes in seismic reflection characteristics before and after frequency expansion processing of G4 oil layer

The research area focuses on the G4 oil layer as the research target layer. Based on seismic data, well data, and other information, a seismic work area is established. Seismic frequency extension technology is applied to broaden the main frequency of seismic data, making the seismic waveform clearer and the details more abundant, improving the overall seismic resolution, and achieving a higher recognition rate for thin sand layers. Perform a 90 ° phase rotation of 3D seismic data to correspond the logging curve with the seismic reflection interface, preparing for the production of isochronous stratigraphic slices. From the comparison before and after processing, it can be seen that the seismic reflection is more pronounced after processing (Fig. 1).

4. Sequence Stratigraphic Framework

After the establishment of the seismic work area, the sequence stratigraphy is divided under the guidance of the sequence stratigraphy theory, in combination with seismic well data, logging data, drilling core data and other data. The top and bottom of the target layer G4 oil reservoir group are identified in the seismic work area, and the G4 oil reservoir group is further divided into three medium-term cycles, namely, G4 upper, G4 middle, and G4 lower, and a total of 18 short-term cycles [7], G41-G418(Fig. 2). By combining well and seismic data, an isochronous stratigraphic framework is established for the entire area. Standard wells with multiple layers, relative concentration, obvious cycles, and vertical separability are selected, and the study area is compared with other typical wells for cycles. The G4 oil layer group is divided into three sets of sand formations and 18 small layers, with G4 corresponding to G4 top to G46, G4 corresponding to G47 to G413, and G4 corresponding to G414 to G4 bottom.

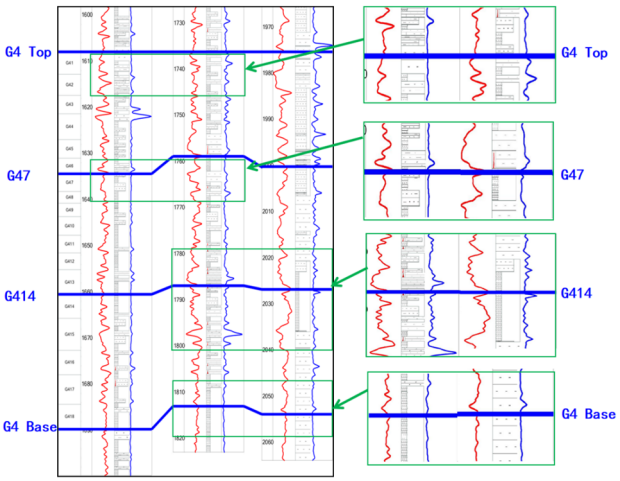


Fig 2. Stratigraphic framework of G4 oil layer in Area A

5. Seismic Slice Analysis

Since the development of seismic slicing, there are mainly three slicing methods: time slicing, layer slicing, and stratigraphic slicing (Fig. 3). Different slicing methods have different purposes and applications. In order to have a better correspondence between seismic slicing and seismic wavelet phase, 90 ° rotation should be carried out. For the identification of sedimentary microfacies, the stratigraphic slicing method should be applied. Stratigraphic slicing is based on well information and seismic interface analysis in seismic data, based on the division of the sequence stratigraphic framework, the two adjacent isochronous sedimentary interfaces accurately identified are the top and bottom. Interpolation is performed proportionally between these top and bottom, and the number of interpolated layers corresponds to the number of stratigraphic slices. Along these interpolations, seismic amplitude attributes are optimized through techniques such as layer flattening to create stratigraphic slices along the interpolated layers [8].

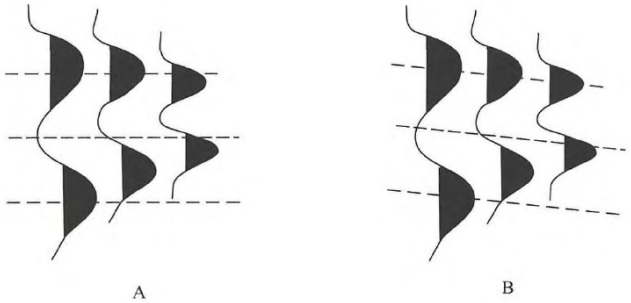


Fig 3. Comparison of Different Seismic Interface Slicing Methods (A. Time slice, B. Along layer slice, C. Stratigraphic slice, according to Zeng and Hentz, 2004; modified)

6. Stratigraphic Slice Analysis Method

Stratigraphic slice analysis first calibrates seismic facies by studying single well sedimentary facies, and establishes the relationship between single well sedimentary facies and seismic facies through various data analysis such as logging, logging, and core analysis; Then, on the basis of single well facies research, study the sedimentary facies of connected wells, match them with earthquakes, achieve the purpose of combining well and earthquake, accurately track isochronous marker layers, and finally use the top and bottom of the tracked two marker layers as the top and bottom to perform a large number of interpolation slices. If the number of slices is too small, it is difficult to reflect more detailed information within the small layer, and the number of slices is too large, as the interpolation between the top and bottom is proportional, It will inevitably increase the situation of river passage within the small layer. In order to depict the river channel sand in more detail, the number of slices must be sufficient, and the problem of river channel passage within a small layer can be determined through the comparison and browsing of continuous slices. By comparing the sand dynamics of continuous slices through extensive browsing, the overall integrity of the river channel can be better understood from a macro perspective, and the direction and branching evolution of the river channel can be judged, thus delicately depicting the river channel sand.

7. Verification Analysis of Lithofacies Logging Facies Seismic Facies

By using seismic sedimentology methods to trace and characterize channel sand, lithofacies logging facies seismic facies effectively verify and unify each other. The interpretation of sedimentary facies in the stratigraphic slices corresponds well with lithofacies logging facies seismic facies interpretation, thereby verifying the accuracy of sedimentary facies types and methods.

As shown in the seismic section of the Jin51 well in the research area, it is located at the edge of the distributary channel. The 1850th section of the seismic section corresponds to the G417 sub layer on the seismic section, and the logging curve of the G417 sub layer shows a combination of box and bell shapes; At the core of 1960.81m, it shows

parallel bedding argillaceous siltstone facies, see the interface. The lithofacies, logging facies, and seismic facies all indicate that the G417 sublayer is a narrow branch channel edge sediment, and the interpretation of sedimentary facies in its stratigraphic slices corresponds well with the interpretation of lithofacies, logging facies, and seismic facies (Fig. 4, Fig. 5).

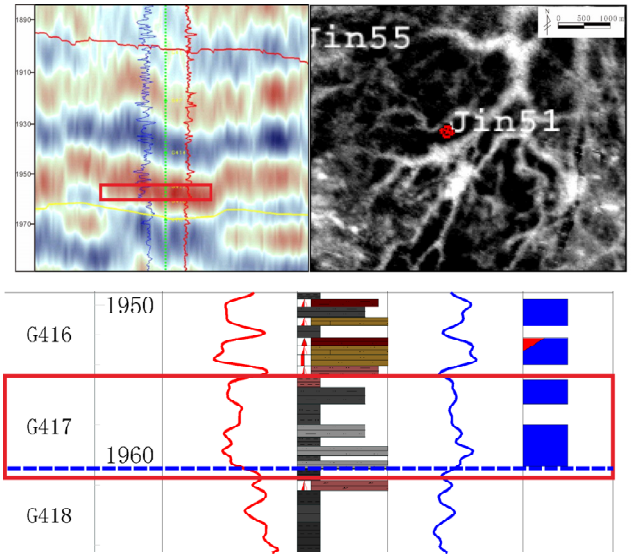


Fig 4. Analysis of Well Jin51 Seismic Combination in G417 Sub layer of G4 Oil Formation in Area A

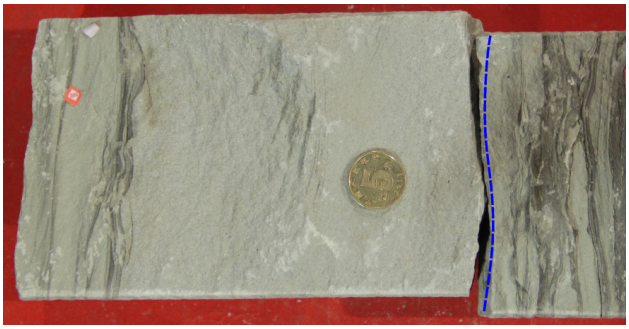


Fig 5. Core Photo of Jin51 Well in G417 Sub layer of G4 Oil Formation in Area A
(Well Jin51, 1960.81m, siltstone, developed scouring surface)

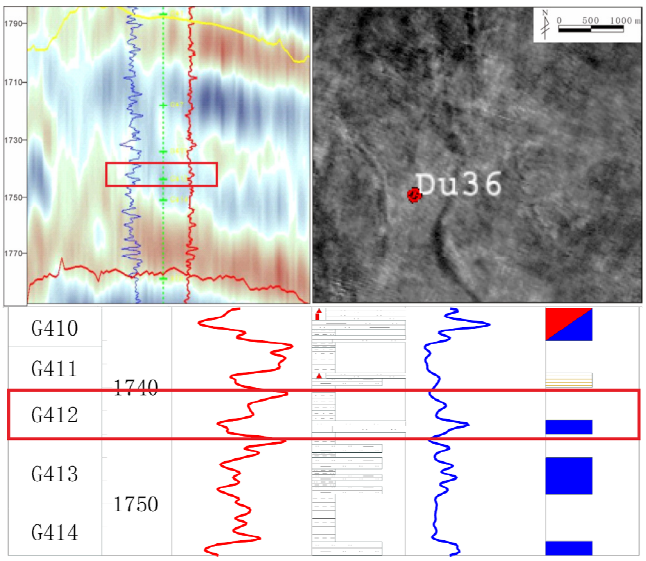


Fig 6. Seismic Analysis of Well Du36 in G412 Sub layer of G4 Oil Formation in Area A

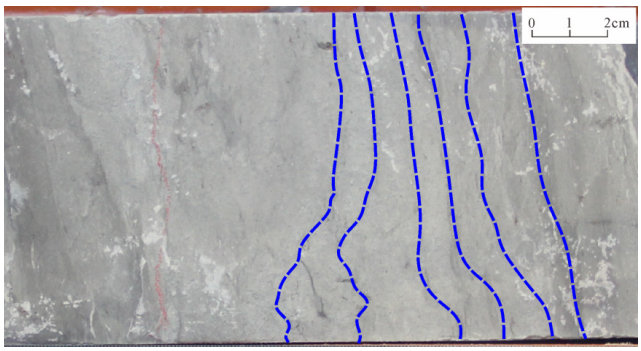


Fig 7. Core Photo of Du36 Well in G412 Sub layer of G4 Oil Formation in Area A
(Well Du36 1739.5~1743.5m, massive argillaceous siltstone and wavy bedding argillaceous siltstone)

For example, the seismic section of Well Du36 in the research area shows that it is far from the river channel. The 980th section of the seismic section corresponds to the G412 sub layer on the seismic section, which shows a clear finger shape on the logging curve of the G412 sub layer; The rock cores at 1739.5~1743.5m are massive muddy siltstone and wavy bedding argillaceous siltstone facies. The lithofacies, logging facies, and seismic facies all indicate that the G412 sublayer is composed of overflow sand and sheeted sand deposits. The interpretation of sedimentary facies in its stratigraphic slices corresponds well with the interpretation of lithofacies, logging facies, and seismic facies (Fig. 6, Fig. 7).

8. Tracing and Characterizing of Channel Sand in Stratigraphic Slices

After determining the seismic marker layer, a total of 2000 stratigraphic slices were made from the bottom of G4 to the top of G4. Each sub layer of G4 corresponds to more than a hundred slices, and the slicing effect is good, which can clearly reflect the morphology of the river channel. Through continuous browsing of more than a hundred slices in the corresponding sub layers, clear river channel responses were locked through a large number of continuous slices [9]. The morphological changes of the entire river channel were traced, and the sand in the sub layers was carefully depicted (Fig. 8).

The G415 small layer slicing has a clear effect, and the river channel morphology develops in a fan-shaped manner from north to south. Continuous slicing shows little change in the river channel morphology, and small fluctuations in the migration of the river channel can be observed. As the time units represented by the small layer are relatively short-term, the small changes in the adjacent vertical slices of the river channel are a manifestation of the vertical continuity of the river channel, quickly browsing through a large number of continuous slices solves the discontinuity reflected in the passage of single layer slices within a small layer

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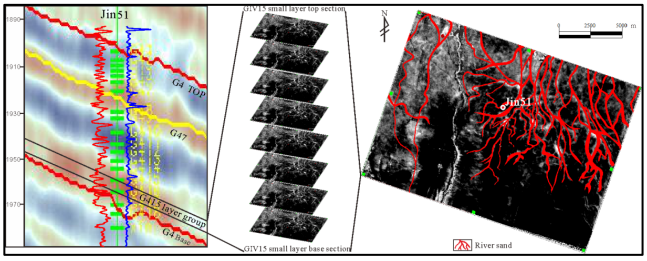


Fig 8. Schematic Diagram of Tracing and Characterizing Channel Sand in G415 Strata Slice of Area A

From the G412 small slice, it can be observed that the effect of stratigraphic slicing is not always able to display continuous and clear river channels. Often, in a single slice, the river channel reflection is intermittent and fuzzy. Although the approximate shape of the river can be recognized, the reflection of the overall continuity of the river channel is often incomplete. Therefore, further continuous recognition of the river channel is needed. Firstly, continuous and fast browsing of the small slice is carried out to lock in obvious river channels, If only slices with good single effect are used, although the single effect is good, the river channels often exhibit intermittent distribution, which often makes it difficult to accurately determine the true continuity between these intermittent river channels within the small layers; Then depict the intermittent river channels identified on the top and bottom slices of this sub layer; Finally, quickly browse between small layers to analyze the dynamics of the river channel, determine the actual continuity of the intermittent river channel, comprehensively explain the complete form of the river channel, track the river sand, and achieve the purpose of delineating the river sand in detail, According to the observation of the final morphology of the channel sand, it is shown that it is a underwater distributary channel at the end of the delta. From north to south, the channel gradually narrows and the branching of the channel increases [10] (Fig. 9).

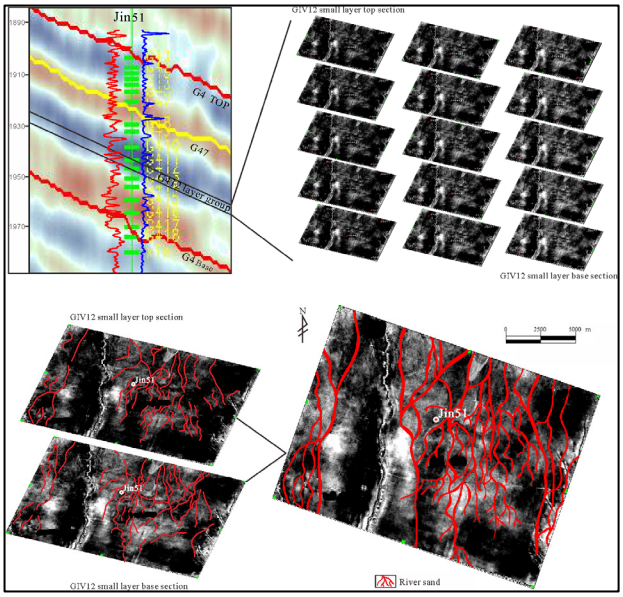


Fig 9. Schematic Diagram of Tracing and Characterizing Channel Sand in G412 Small Stratum Slice of Area A

9. Conclusion

The G4 oil formation in the research area can be divided into three sets of sand formations: G4 upper, G4 middle, and G4 lower. It can be further divided into 18 sub layers, G41-G418. By using seismic sedimentology methods, stratigraphic slices of each sub layer can be made to better correspond to the actual strata. Unified verification can be obtained in lithofacies, logging facies, and seismic facies. A large number of continuous stratigraphic slices can be browsed for each sub layer, effectively tracking river sand and comprehensively characterizing the range of river sand, Analyze the intermittent channel sand through a large number of stratigraphic slices, and finally obtain the complete morphology of the channel sand continuously.

References

[1] Dahm C G, Graebner R J.1979.Field development with three-dimension-al seismic methods in Gulf of Thailand-a case history.Offshore Tech-nology Conference,Paper 3657:2591−2595.

[2] Brown A R, Dahm C G,Graebner R J.A stratigraphic case history usingthree-dimensional seismic data in the Gulf of Thailand[J].Geophysical Prospecting,1981,29(3):327-349.

[3] Zeng Hongliu, Backus M M, Barrow K T,et al . Stratal slicing, Part I : Realistic 32Dseismic model[J]. Geophysics, 1998, 63 (2) :502−513 12 Zeng Hongliu, Henry S C,Riola J P. Stratal slicing, Part II : Real 32D seismic data [J]. Geophysics,1998,63 (2) : 514−521.

[4] Dong Yanlei, Zhu Xiaomin, Zeng Hongliu, et al. Study on seismic sedimentology of the Paleogene Shahejie Formation in the Qinan Sag of the Huanghua Depression [J] Journal of Sedimentology, 2008, 26 (2): 234-240.

[5] Zhu Xiaomin, Liu Changli, Zhang Yina, et al. Application of seismic sedimentology in the prediction of continental lake basin delta sand [J] Journal of Sedimentology, 2009, 27 (5): 915-921.

[6] Zhu Xiaomin, Dong Yanlei, Zeng Hongliu, et al. Research status and development thinking of seismic sedimentology in China [J]. Journal of Paleogeography, 2020, 22 (03): 397-411Zhu X, Zeng H, Li S, et al. Sedimentary characteristics and seismic geomorphologic responses of a shallow-water delta in the Qingshankou Formation from the Songliao Basin, China[J]. Marine and Petroleum Geology, 2017, 79: 131-148.

[7] Zeng H., Hentz T. F. High-frequency sequence stratigraphy from seismic sedimentology: Applied to Miocene, Vermilion Block 50, Tiger Shoal area, offshore Louisiana[J]. AAPG Bulletin, 2004, 88(2): 153–174.

[8] Sun Le, Qi Yu, Wang Bo, Fang Maojun, Li Hao, Fan Weipeng, Li Wenlan. Shallow water delta sand characterization and sedimentary evolution of the fourth member of the Kangning gas field [J]. China Offshore Oil and Gas, 2022, 34 (04): 132-143.

[9] Changkuan N I, Mingjun S U, Cheng Y, et al. Thin-interbedded reservoirs prediction based on seismic sedimentology[J]. Petroleum Exploration and Development, 2022, 49(4): 851-863.

[10] Olariu C. Terminal distributary channels and delta front architecture of river-dominated delta systems[J]. Journal of Sedimentary Research, 2006, 76(1-2):212-233.