Application of High Resolution Reservoir Prediction Technology Based on Sequence Stratigraphic Framework Constraints

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Abstract. In Tazhong area of Tarim Basin, silurian oil and gas is abundant, the target interval is sand and mudstone thin interbedded, and the horizontal continuity is poor, so it is difficult to obtain accurate inversion results by conventional inversion methods. Taking silurian system in Tazhong 12 well area as an example, this study USES seismic data and well logging data to carry out fine stratigraphic division, and divides the Kalpentag formation into a third-order sequence, five quasi-sequence groups and ten quasi-sequences. In addition, the upper third sub-member above the target layer is further divided into ten six-level sequences. Based on this framework, the characteristics of reservoir seismic response were clarified through fine borehole calibration in the upper third sub-member, and the prestack geostatistical inversion was further carried out, and ten sets of sand bodies were identified vertically in the target section. Combining with the analysis of reservoir physical property and oil-gas property, two sets of favorable sand bodies are finally selected.

Keywords: Sequence stratigraphic framework · Prestack geostatistical inversion · Silurian · Reservoir prediction

1 The Introduction

1.1 A Subsection Sample

The Silurian in Tazhong area of Tarim Basin is rich in oil and gas, and the vertical distribution of oil and gas is controlled by caprock. The bitumen and heavy oil are distributed in Kepingtage Formation below the red mudstone member of the lower member of Tataertage Formation. At present, several oil reservoirs have been found in the Silurian Kepingtage Formation in Tazhong area, which is rich in oil and gas resources and has great exploration potential [1]. However, the contradiction between the large area of oil and gas exploration in the Silurian and the absence of large oil and gas fields has been the driving force for the exploration and research of the Silurian in the Tazhong Upline in the past decade [2]. Most researchers believe that reservoir is the main constraint factor [3–10].

Through previous studies, the sedimentary law of the Silurian Kepingtage Formation in Tazhong area has been systematically recognized, and it is considered that this layer

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system is a tidal flat sedimentary system with interaction of fine sandstone, siltstone and mudstone, and mainly develops sand bodies with great lateral changes, obvious sedimentary characteristics and vertical reciprocal superposition [11, 12].

In order to deeply study the distribution law of Tazhong Silurian reservoir, a lot of previous studies have been done on the establishment of sequence stratigraphic framework. Li Mingyun et al. divided the Silurian in Tazhong into 3 third-order sequences and 18 parasequence groups, and pointed out the distribution range of favorable reservoirs in the parasequence group [13]. Chen Fanghong et al. identified four logging sequence boundaries in the Silurian system, and divided them into three logging sequences through comprehensive analysis of logging information [14], and pointed out the superposition and transverse distribution of sedimentary facies. Xu Yin et al. divided the Kepingtage Formation into one sequence. The upper third sub-member and the upper second sub-member are transgressive system tracts, which can be further divided into five parasequences [15], and the hydrocarbon accumulation model under the control of sequence framework is proposed.

Sequence research is a macroscopic analysis of reservoir distribution law, but can not do detailed research and achieve quantitative prediction. Inversion is widely used as a kind of reservoir prediction method. However, the reservoir of the Silurian Kepingtage Formation in Tazhong is characterized by strong heterogeneity, thin thickness and poor physical properties, which brings great difficulties for reservoir inversion. Therefore, this paper proposes a high resolution reservoir prediction technique based on the constraints of sequence stratigraphic framework. This technique uses seismic data and well logging data to carry out fine division of sequence stratigraphy, to establish fine sequence stratigraphic framework for the target layer, and to construct geological framework model. Based on this constraint, the prestack geostatistical inversion is further carried out to achieve fine characterization of thin layers. In Tazhong 12 well area, this technology has achieved good application effect.

2 The Introduction Overview of the Study Area

Tazhong 12 well area is located in the Tazhong 10 structural belt of the north slope of the Tazhong uplift in the Tarim Basin (Fig. 1). The target bed is the upper third sub-member of Kepingtage Formation of Silurian, which is mainly interbedded sand and mudstone in tidal flat sedimentary environment. The sand body is buried deep and thin. The thickness range of single sand body is mainly 1–3 m, and the lateral connectivity distribution is not clear, which brings great difficulties to the prediction of reservoir distribution. Therefore, we need to use the high resolution reservoir inversion method to quantitatively predict the reservoir with the fine isochronous stratigraphic framework as the constraint.

3 Establishment of Sequence Stratigraphic Framework

3.1 Identification of Tertiary Sequence and System Domain Interface

In the Tazhong 12 well area, the bottom interface of the Silurian Kepingtage Formation overlaps the mudstone section of the Ordovician Sangtamu Formation from northwest to southeast, and the stratigraphic contact relationship shows an angular unconformity. The interface shows continuous strong reflection on the seismic profile, and the erosion response characteristics can be seen below the interface. The logging response characteristics from bottom to top change from flat and high natural gamma ray and low resistivity in mudstone section of Sangtamu Formation to serration-shaped block and low natural gamma ray and high resistivity in siltstone section of upper third sub-member of Kepingtage Formation.

On the top of Kepingtage Formation, there is a mutation of lithology and lithofacies. Under the interface, there is a relatively deep sedimentation sand flat in the tidal flat environment of the upper first sub-member of Kepingtage Formation, and above the interface, there is a relatively shallow thick mud flat in the Tataertage Formation. The interface is characterized by continuous moderate peak reflection. The logging curve shows a sudden change from serrated low natural gamma ray and high resistivity of sandstone with thin layer mudstone to micro-dentate high natural gamma ray and low resistivity of mudstone section.

In the middle of Kepingtage Formation, a set of grey mudstones with gradually decreasing sand content from bottom to top are developed, which reflects that the scope of transgression is expanding continuously and reaches the maximum flooding surface at the top of mudstones. The sandstones increase gradually above the flooding surface. It reflects the process from transgression to regression (see Fig. 1).

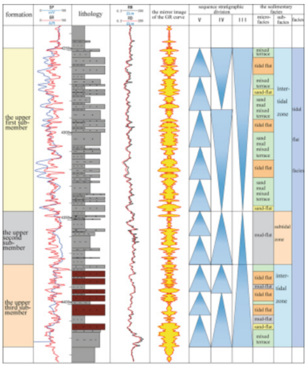

Fig. 1. Sequence stratigraphic division unit histogram of Kepingtage Formation in TZ 12 Well

3.2 Division and Correlation of Logging Sequence Stratigraphy

The Kepingtage Formation is divided into a third-order sequence, which consists of transgressive system tract and high-order system tract. In the tidal flat depositional system, the parasequence is characterized by a gradually finer grain size sequence. According to the logging lithology, sedimentary microfacies combination and logging curve variation characteristics, the Kepingtage Formation can be divided into 1 third-order sequence, 2 system tracts, 5 parasequence groups and 10 parasequences under the constraint of third-order sequence interface and combined with three sets of stable mudstone marker beds in the study area.

On the top of Kepingtage Formation, there is a mutation of lithology and lithofacies. Under the interface, there is a relatively deep sedimentation sand flat in the tidal flat environment of the upper first sub-member of Kepingtage Formation, and above the interface, there is a relatively shallow thick mud flat in the Tataertage Formation. The interface is characterized by continuous moderate peak reflection. The logging curve shows a sudden change from serrated low natural gamma ray and high resistivity of sandstone with thin layer mudstone to micro-dentate high natural gamma ray and low resistivity of mudstone section.

In this study, three quasi sequences were divided into the upper third sub-member above the target layer, but the corresponding three sand groups could not meet the constraints of a single sand body. Therefore, multi-well correlation was further carried out in the sand group to divide small layers. In the logging, the sedimentary cycle corresponding to the logging curve is used to divide the small layers, and the lateral phase change of the sand body is compared by using the equal proportion model. According to the logging information, a total of 10 sets of small layers were divided in the upper third sub-member, and fine closure correlation and framework are established in the whole area (see Fig. 2).

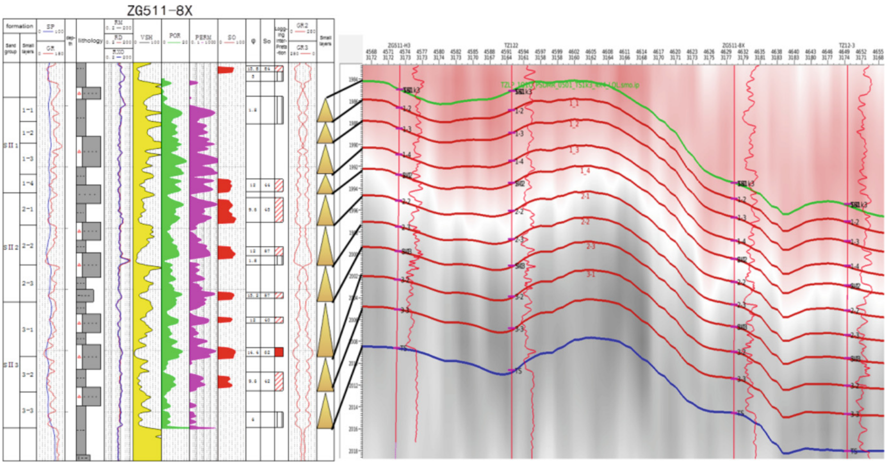

Fig. 2. Comparison of small layers and interwell through ZG511-8X well

4 High Resolution Reservoir Prediction

Under the constraints of sequence stratigraphic framework, pre-stack geostatistical inversion is carried out, and the distribution characteristics of sand body on VP/VS section are in good agreement with the GR curve on well.

In terms of the resolution ability of thin-bedded sandstone in a single well, taking ZG511-H3 and TZ122 Wells as examples, the minimum single-layer thickness of thin sand layer on the lithologic profile of time-depth conversion through well inversion is 1.2 m and 1.5 m, respectively. Compared with the natural gamma curve, the position and thickness of sand body are basically the same (see Fig. 3). It shows that geostatistical inversion can identify thin sandstone from thin interbed sand and mudstone.

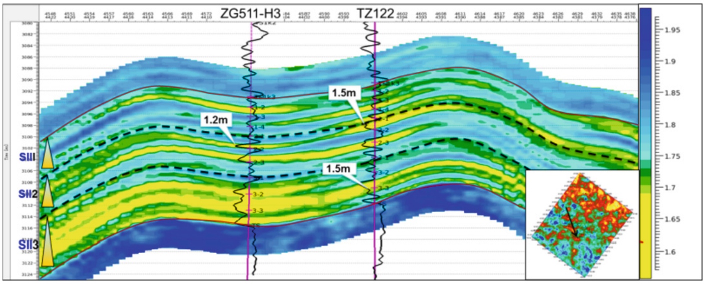

Fig. 3. VP/VS inversion profile of well ZG511-H3 and TZ122

In terms of pinch-out identification ability of thin-bedded sandstone, taking Wells ZG511-2 and ZG511-H4 as examples, the three sets of sandstone in the cross-well inversion lithologic profile are vertically superposed, gradually thinning from well ZG511-2 to well ZG511-H4, i.e. from northwest to Southeast to pinch-out. The morphology, structure and sedimentary rules of sandstone are clear and clear (see Fig. 4). The pinch-out position of the inversion impedance basically meets the need of characterizing the pinch-out point of sandstone.

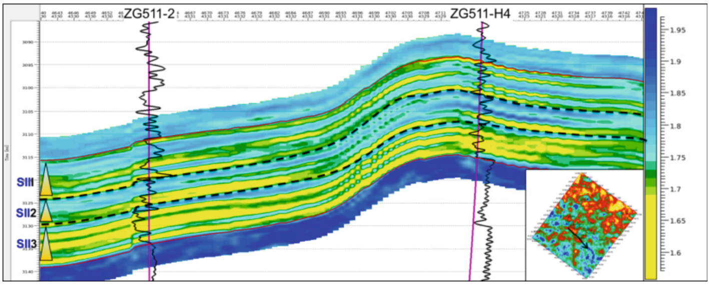

Fig. 4. VP/VS inversion profile of well ZG511-2 and ZG511-H4

In the northern area with low well control degree and the area with high well control degree in the reservoir area, well ZG7 and well ZG511-H4 were respectively selected for blind well verification comparison. The vertical distribution law of sand body retrieved by the former is consistent with the GR curve division result on the whole, while the accuracy of the inversion result of the latter is higher than that of the former (see Fig. 5).

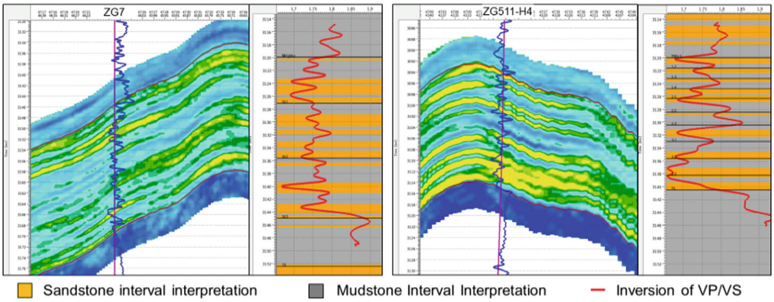

Fig. 5. Blind well verification of well ZG7 and well ZG511-H4

In terms of the prediction coincidence degree of thin-bedded sandstone, the sandstone body of the third sand set is thicker in the cross-well inversion lithology profile, and the upward sand body is gradually thinning and decreasing in number, which reflects that the bottom tidal channel of the upper third sub-member is more developed, and the upward regressive parasequence superposition style is presented. By comparison on the plane, the amplitude attribute extracted from the earthquake is basically consistent with the amplitude attribute in the inversion results, indicating that the information used in the inversion under the constraint of fine lattice is mainly from the earthquake, and the inversion results are relatively reliable (see Fig. 6).

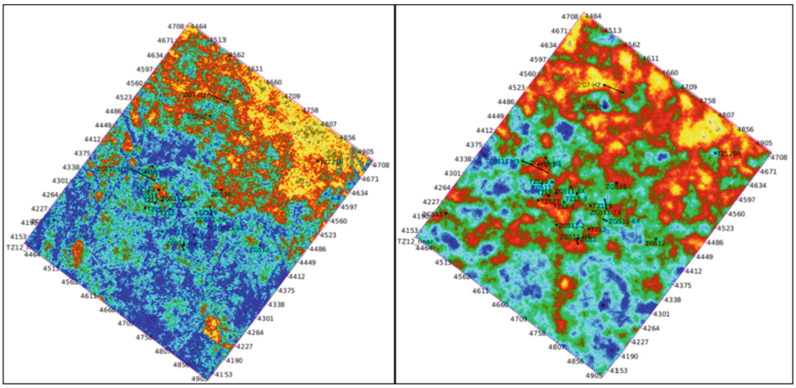

Fig. 6. Comparison of RMS amplitude plan and VP/VS inversion plan of upper third sub-member

According to the inversion results constrained by the fine stratigraphic framework, 10 sets of single sand bodies were identified in the upper third sub-member of the Silurian Kepingtage Formation in the Tazhong 12 well area. On the whole, tidal channel sand bodies extend from north to south and gradually thin and decrease from bottom to top, showing a regressive sedimentary sequence during transgression, and the spatial distribution of sand bodies is consistent with the sedimentary understanding.

Combined with logging information and physical property parameters, 3 sets of main small beds are selected from 10 sets of single sand bodies, which are mainly located in the thin sand beds with relatively high physical property and good oil and gas display in the middle and upper part of the upper third sub-member. Among them, the 2–3 sublayer of the SII2 sand set is located at the bottom of the Silurian, with an average thickness of about 5.87 m, an average sand body thickness of 2.43 m, an average porosity of the sand body of 10.71%, and a reservoir anastomosis rate of 84.2%. The overall reservoir is relatively developed with good physical properties (see Fig. 7). Sublayer 2-1 is located at the top of SII2 sand set, with an average thickness of about 5.13 m, an average sand body thickness of 1.98 m, an average porosity of 9.88% and a reservoir anisotropy rate of 94.7% (see Fig. 8). Sublayer 1-4 is located at the bottom of SII1 sand set, with an average thickness of 4.48 m and an average sand body thickness of 2.56 m. The average porosity of the sand body is 14.34%, and the physical property is good. The reservoir anisotropy rate is 84.2% (see Fig. 9).

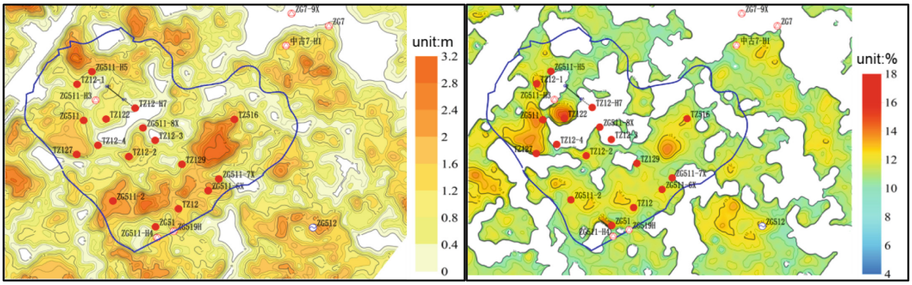

Fig. 7. Reservoir thickness map (left) and porosity map (right) of sublayer 2-3 of SII2 sand set in the upper third sub-member of Tazhong 12 Silurian

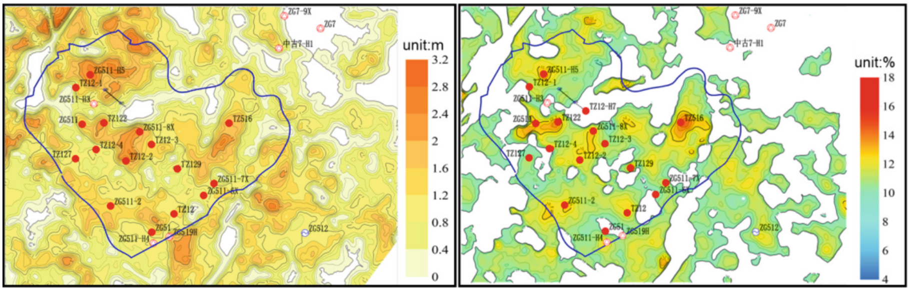

Fig. 8. Reservoir thickness map (left) and porosity map (right) of sublayer 2-1 of SII2 sand set in the upper third sub-member of Tazhong 12 Silurian

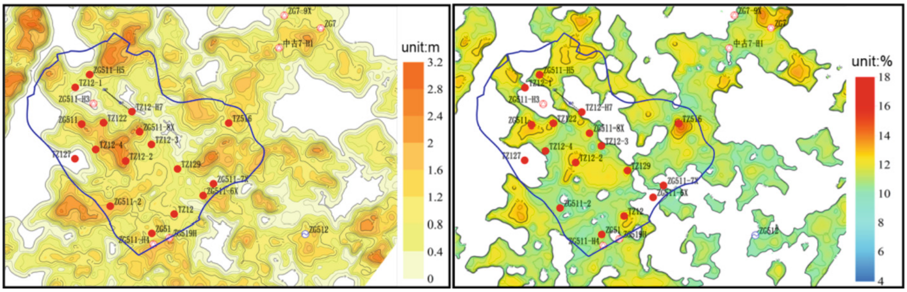

Fig. 9. Reservoir thickness map (left) and porosity map (right) of sublayer 1-4 of SII1 sand set in the upper third sub-member of Tazhong 12 Silurian

5 The Conclusion

(1) Based on lithologic characteristics and sedimentary microfacies combination types, the Kepingtage Formation can be divided into 1 third-order sequence, 2 system tracts, 5 parasequence groups and 10 parasequences. According to the well information, the three sand beds in the upper third sub-member are further divided into 10 small beds.

(2) When the sedimentary cycles of single sand bodies can be finely divided within the sequence stratigraphic framework, the high-resolution reservoir inversion method under the constraints of the sequence stratigraphic framework can effectively improve the resolution ability of single well thin-bedded sandstone, the identification ability of pinch-out points of thin-bedded sandstone and the prediction coincidence degree of thin-bedded sandstone in the cross-well section.

(3) According to the inversion results of 10 sublayers in upper third sub-member, combined with the logging interpretation results and physical property characteristics, three sublayers 1-4, 2-1 and 2-3 are selected as the favorable reservoir segments.

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