Application of Seismic Interpretation Technology in the Effective Utilization of Low Permeability Reservoir

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Abstract. With the gradual deepening of oilfield exploitation degree, the accurate description the distribution characteristics of faults and the distribution law of reservoir sand body has become the core problem of efficient exploitation and enhancement of recovery ratio. In allusion to the geological characteristics of complex structure, fault development and large lateral variation of sand body in the low permeability reservoir, this paper utilizes advantages of seismic interpretation technology, comprehensive apply geology, earthquake and well logging data to accurately describe the structural shape of reservoir, fault distribution and reservoir sand body development characteristics, select the favorable sand body parts, deploy horizontal well locations, guide drilling of horizontal well, and provide strong technological support for effective use of low permeability reservoirs in the end.

Keywords: seismic interpretation technology, horizontal well, low permeability reservoir.

1. Introduction

The research area of this paper is located in the east wing of the Sanzhao depression in the central depression of the Songliao Basin. The development target layer is the Fuyu oil layer of the three and four members of the quantou formation of lower cretaceous, which belongs to the river-delta sedimentary system, the sandstone is mainly tight oil with less than 2mD and belongs to the ultra-low permeability tight sandstone reservoir. Due to the poor reservoir physical properties and the low degree of well control in the research area, it is difficult to establish an effective drive system by using conventional well network encryption. The reservoir in the research area has less longitudinal oil layers, stable main layer, and the larger thickness of the single layer, in allusion to these geologic characteristics, therefore, horizontal well encryption is adopted, and then the reservoir structure and sand body distribution need to be described in detail. The geology, earthquake and well logging are comprehensively applied and so on, structural features and fault occurrence are carried out, spatial distribution characteristics of reservoir sand bodies are described finely, sand body parts are selected, and horizontal well locations are arranged, and provide strong technological support for effective use of low permeability reservoirs.
2. Research Content
In allusion to the complex structure, fault development and rapid transverse change of reservoir in the research area, it is necessary to accurately predict the favorable development area of the reservoir and finely describe the distribution characteristics of sand bodies, the research work needs to comprehensively apply geology, earthquake and well logging data, etc. determine effective solution, the structural description prediction and reservoir identification of the low-permeability reservoir development zone are carried out.

2.1. Fine structure interpretation
In order to improve the accuracy of structure interpretation, in allusion to the characteristics of seismic data, the 3D seismic data as basis, make full use of the large amount of geological information carried by seismic data, combined with logging and geological data, fine structure interpretation of the reservoir are carried out.

2.1.1. Full 3D structure interpretation. The well logging data and the seismic geological calibration subsystem are applied to make single well synthetic records, according to the seismic section layer calibration results; under the constraint and control of well hierarchical data, seismic section as the horizontal tracking subject to carry out geological position tracking

In the process of fault interpretation, the 3D seismic data body as the fault interpretation body, according to the principle of “body positioning, section closure, 3D inspection”, “multiple sets of data body unite with interpretation fault technology” is adopted, fine interpretation is carried out for faults from different angles of plane, section and space. The fault description takes the position of coherence cube (Fig.1) [1], and the closure is explained manually by line, and the 3D visual inspection ensures the accuracy of the fault interpretation.

![Coherence cube section](Fig.1)

![Congruent display of multi-attribute section](Fig.2)
In the interpretation of seismic data, the multi-attribute transparent display technology is adopted, through registration displaying of coherence cube and seismic data section (Fig. 2), and the color transparency of the two sections is adjusted to achieve the required display effect, which makes the interpreter more intuitively and accurately explain the fault. 3D visual interpretation technology is used to carry out fault combination and inspection, it can intuitively reflect the spatial distribution characteristics and mutual connection relationship of faults, and can visually inspect and verify the rationality of fault interpretation.

2.1.2. Structural features. The overall shape of structure of the research area descends from east to west, and wide horst structure, the top buried depth of top surface high spot of the Fuyu oil layer is -1390m. The structure is basically the same from deep to shallow, it has good inheritance, the stratum incidence is about 2.0°, and the change is relatively slow. The fault development is normal fault, the fault plane distribution of T2 and below the T2 layers have a certain stripe, the third fault in the east development is near north-south echelon arrangement fault zone, and the south develops a near north-south fault and the near west-east fault with southern part development, the fault extension length is 0.3-3.1km, and the fault throw is 7-68m.

2.2. Reservoir earthquake prediction
At present, the technological means for earthquake prediction reservoir development are mainly seismic attributes and seismic inversion, the longitudinal resolution capability of seismic inversion is significantly higher than seismic attributes, but the inversion results have certain multiplicity, and the accuracy is controlled by the drilling density. The overall well control degree in this area is low, the seismic attributes are combined with seismic inversion, the seismic attributes qualitatively judge the sand body strike and scale, the inversion carries out the spatial distribution characteristics of reservoir quantitative prediction, implements the sandstone enrichment area, and guides the plan deployment.

2.2.1. Seismic multi-attribute analysis and optimization. The Fuyu oil layer is mainly lithological association characteristics of “mud contains sand” [2], from the perspective of seismic reflection characteristics; the sand body development section presents strong amplitude reflection characteristics on the seismic section, and the upper and lower mudstone sections present weak amplitude reflection. The seismic response characteristics of the sandstone and mudstone sections are significantly different, and are easily identified on the seismic section, and it provides favorable conditions for predicting seismic attributes.

In order to study and determine feature types of earthquake and sedimentary facies in different sections and their plane distribution law in this area, the seismic attributes are used to extract and analyze the selection functions, through extraction, analysis, comparison of amplitude, frequency, phase categories and other different seismic attributes, determine the mean square root amplitude attribute with the most obvious reservoir thickness change response as sensitive attribute, and become effective attributes for identifying the Fuyu oil layer group and the seismic phase in major reservoir.

When extracting attribute sections, based on the position fine calibration and tracking interpretation, according to the seismic wave group characteristics of the target layer, the well-seismic combination selects the proper time window to extract attribute, the accurate selection of the isochronous interface and the reasonable extension ensure that the extracted seismic attributes are sedimentary strata of the same geological period, the extracted attribute section can reflect the horizontal attribute information of the target section, that is to analyze the scale, direction and distribution range of the river channel reflected on the seismic attribute section, and carry out qualitative prediction of the favorable phase spread.

Through the actual seismic response research, the sandstone development of the main layer of Fu I7 layer is compared with the actual seismic response, it has strong peak amplitude reflection characteristics, the section and the attribute plan shows that the thicker the sandstone, The stronger the corresponding reflection peak amplitude [3]. According to the prediction results of seismic attributes, the sand bodies
are distributed in stripe. Through the correlation analysis between seismic attributes and geology, there is a good corresponding relationship between the mean square root amplitude attribute and the lithology; it can more accurately reflect the spatial distribution shape and distribution range of reservoir sand body space (Fig. 3), through comparison of verification well, 17 wells were counted on the river and at the side, 15 wells meet, coincidence rate is 88.2%.

**Fig.3** The seismic attribute section of mean square root in the Fu 17 layer

**Fig.4** Inversion and original seismic congruence section

**Fig.5** Isogram of sand body thickness of seismic inversion in Fu 17 layer
2.2.2. **Seismic inversion prediction.** Seismic inversion is an important method for seismic prospecting and discriminate oil and gas reservoirs, at present, reservoir prediction technology takes seismic wave impedance inversion as core, and it has become an important means to study reservoir distribution characteristics in reservoir description.

This research mainly used post-stack wave impedance inversion. Comprehensive use of earthquake, geology, well logging and so on, through physical analysis of seismic rock, the sensitive seismic elastic parameters of the reservoir are clearly reflected [4]. The appropriate seismic inversion parameters are selected through experiments, it can not only reflect the characteristics of seismic reflection data, but also better reflect the non-uniformity of reservoirs, quantitatively predict the 3D spatial distribution of sand body, and significantly improve the reservoir description accuracy.

From the perspective of inversion section, the effective frequency band of the inversion sandstone body is reasonably broadened. As can be seen from the overlapping section of the inversion section and the seismic section, the resolution of the inversion section is significantly higher than that of the conventional seismic section, the sharp point of the sand body is clear, and the thickness of the sand body is obvious (Fig.4). In particular, the inversion section is basically consistent with the distribution of sandstone and properties in the well. On the plane, inversion sandstone thickness isogram can reflect the natural reality of the geological body change shape; the inversion results have better transverse resolution capability, moreover, it also roughly reflects the distribution law and shape of sandstone (Fig. 5).

2.3. **Favorable sand body prediction in target layer**

According to the sandstone thickness of developed well and seismic reservoir prediction results in the research area, the reservoir development sections are concentrated, mainly developed in the Fu I oil layer group, the main layer is the Fu I7 layer, the other layers are poorly developed, and the sand body thickness is small, presents narrow stripe and intermittent stripe. For this reason, this seismic reservoir prediction is mainly Fu I7 layer, which belongs to the river sedimentation, the whole is distributed in the northeast-southwest direction in a wide stripe, and the sand body width is generally 0.2-2.4km, the sandstone thickness is 1.4-8.8m.

3. **Application Effects**

Through the research of reservoir fine seismic interpretation of low permeability reservoirs, the fine structure description is carried out, the favorable enrichment area of sand body is described, and the favorable target is selected to be drilled, and remarkable effects are obtained.

3.1. **Well pattern deployment**

The developed sandstone thickness and seismic reservoir prediction results in the research area are integrated; the target layer of the horizontal well is the I7 layer. Focus on improving the control degree of well pattern on sand body on and improving the injection and production relationship of sand body, well network deployment is carried out; three horizontal wells were deployed in the I7 layer with better plane development and larger thickness (Fig. 6).

According to the characteristic comparison of sandstone in adjacent well and seismic wave groups, the target layer is peak strong amplitude reflection characteristics, The distribution range of sand body was predicted by referring to root-mean-square amplitude attribute on the plane, the thickness difference of sand body development predicted by longitudinal inversion section in space, based on the principle of maximum control of sand body, according to the variation trend of the top micro-amplitude structure, fully consider sand deposit thickness, extension length, direction, continuity and other spatial development characteristics in the sand body of research block, trajectory design horizontal well is carried out (Table 1) [5].
3.2. Tracking while drilling

In order to ensure the smooth completion of horizontal well FA1, Combine LWD monitors and cuttings logging at the site, moreover, according to the target layer sandstone in the seismic wave impedance section and corresponding lineups axis stability and micro-amplitude change trend, the drilling trajectory of horizontal section is tracked, corrected and adjusted in real time, and guide the direction of the drilling trajectory. Finally, the horizontal section of this well is 1204m, and the sandstone drilling rate in the horizontal section reaches 94.5%.

Three horizontal wells are deployed in the research area, and finally achieve good results through tracking while drilling, the average sandstone drilling rate in the horizontal section reach 86.6%. According to the actual drilling trajectory curve after drilling, it can be clearly seen that the drilling trajectory is consistent with the predicted reservoir sandstone (Table 2); it proves that the seismic interpretation technology has strong guidance in the horizontal well drilling process and also verifies the accuracy and practicality of reservoir prediction (Fig. 7).

| Table 2 Statistical table of sandstone drilling of horizontal well after drilling |
|---|---|---|---|---|---|
| well number | target stratum | drilling depth of horizontal well (m) | horizontal section length (m) | sandstone length (m) | Sandstone drilling ratio (%) |
| FA1 | FuⅠ7 | 2847 | 1204 | 1138 | 94.5 |
| FA2 | FuⅠ7 | 2672 | 980 | 854 | 87.1 |
| FA3 | FuⅠ7 | 3130 | 842 | 658 | 78.2 |
| average | | 2883 | 1008 | 883 | 86.6 |
4. Conclusion

(1) The seismotectonic interpretation technology is adopted, combined with logging and geological data, the structural interpretation is carried out for reservoir, and describe the reservoir structure shape, fault occurrence and micro-amplitude change trend.

(2) The seismic multi-attribute analysis technology is used to extract and analyze seismic attributes, determine that the seismic attributes that have the most obvious response to reservoir sandstone thickness changes is sensitive attribute, predict lithology and favorable reservoirs, and describe the distribution range and distribution features of sand body.

(3) Through fine structure interpretation and reservoir prediction, the development condition of horizontal well target reservoir and surrounding faults are described finely, and the geological optimization design and tracking while drilling of horizontal wells are guided to ensure the effective implementation of horizontal wells.

(4) The overall well control degree in this area is low, the seismic attributes are combined with seismic inversion, the seismic attributes qualitatively judge the sand body trend and scale, and the inversion is used to quantitatively predict spatial distribution characteristics of sand body, and the sandstone enrichment area is implemented, and program deployment and horizontal well drilling are guided

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