Fourth order sequence and its distribution characteristics determined by well-seismic combination in Wuercxun depression

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Abstract. Wuercxun depression is a secondary structural unit of Beier lake depression in Hailaer basin. It is located in the middle of the basin and has a high degree of exploration, with the gradual deepening of exploration degree, the previous studies on sequence division and sedimentary facies cannot meet the requirements of high-precision exploration. In this paper, the Nantun Formation is divided into three third-order sequences and eight fourth-order sequences through the study of high-resolution sequence stratigraphy in Wuercxun depression, in the study, firstly, multiple exploration wells with complete sequence development are selected in Wunan area of Wuercxun depression, because Wuercxun depression on the whole is characterized by complex structural features, multiple provenances, short provenances and rapid phase transformation, so we should try our best to make the distribution of preferred wells in all the fourth order structural zones, in order to facilitate the next step of stratigraphic correlation between the structural zones and the whole region. After that, the original sequence of all the selected wells is further subdivided according to the rock and electrical characteristics of single well, and a set of scheme for dividing the fourth-order sequence is determined. Finally, through the tracing of seismic horizon between exploration wells and the fine comparison of well and well seismic in the development area, the traceability and comparability of the newly divided fourth-order sequence are determined, and a set of reasonable fourth-order sequence division scheme in Wuercxun depression is finally determined, which effectively guides the geological oil and gas exploration deployment and lays a solid foundation.

1. Preface
Since 2002, the study of sequence stratigraphy in Wuercxun depression can be divided into three stages. The first stage: before 2005, taking Wuercxun - Beier depression as a whole, the sequence stratigraphy research was initially carried out, and the macroscopic distribution law of sedimentary facies was generally clarified; the second stage: from 2006 to 2010, the research and application of sequence stratigraphy were more and more during this period In the third stage: from 2011 to now, the research on the sedimentary subfacies under the framework of the third-order sequence and system tract has been carried out, and the macro distribution law of the sedimentary subfacies has been further clarified. In the third stage, from 2011 to now, the research on the sedimentary subfacies of the subdivision layer has been preliminarily carried out, and the Nantun Formation has been further subdivided into eight fourth-order sequences, and the characteristics and distribution rules of sedimentary subfacies under the fourth-order sequence framework have been basically clarified.
2. According to the characteristics of rock and electricity, the layered standard well is optimized, and the fourth-order sequence division scheme is determined by combining well and seismic data.

Based on the oil and gas exploration practice in Wunan area of Wuerxun depression, through the comparison of 169 exploration and evaluation wells and 347 development wells in Wuerxun Sag, the wells with sandstone development, obvious cycle, complete facies type, strong vertical separability, good well logging curve stratification and representative regional stratigraphic characteristics are selected as the standard wells for stratification (Fig. 1).

Within the framework of the current fourth-order sequence, after studying the cycle development characteristics and seismic waveform combination characteristics of eight fourth-order sequences in Nantun Formation of stratified standard well, it is found that Nantun Formation in Wuerxun Sag is divided into eight fourth-order sequences (Table 1).

| Original Stratigraphy (third order sequence) | New Stratigraphy (third order sequence) | New Stratigraphy (fourth order sequence) |
|---------------------------------------------|----------------------------------------|------------------------------------------|
| N2 SQN3                                     | N2-1                                   |                                          |
| N2 SQN2                                     | N2-2                                   |                                          |
| N1 SQN1                                     | N1-1                                   |                                          |
| N1 SQN1                                     | N1-2                                   |                                          |
|                                             | N1-3                                   |                                          |
|                                             | N1-4                                   |                                          |
|                                             | N1-5                                   |                                          |
3. Combined with the seismic reflection characteristics of the fourth-order sequence and the variation law of the characteristics above the well in the development area, the traceability of the fourth-order sequence is determined

It is the most basic but difficult work in seismic interpretation to demarcate seismic reflection layer by drilling layers. The synthetic records of 169 exploration and evaluation wells in the work area are calibrated repeatedly.

When making synthetic records, the main frequency of the target interval is 25-35Hz according to the frequency analysis of the seismic traces near the well. The actual wavelet and the Ricker wavelet of different frequencies are extracted from the seismic traces of the borehole side of the seismic section to make synthetic seismic records of several frequency bands, which are repeatedly compared with the seismic section. Before calibration, in order to improve the calibration accuracy, the acoustic time difference curves of 160 wells were corrected and standardized again, and good coincidence rate was obtained. 145 wells met the requirements, 15 wells did not, and the coincidence rate reached 90%.

Well seismic joint tracking of fourth-order sequence boundary is a comprehensive analysis process of "point line surface body" with the purpose of "three-dimensional closure". There are choices and choices, mutual verification of evidence, and repetition of eliminating false and retaining true. There are many contradictions between seismic data and drilling, logging, logging and other data. How to solve the contradictions reasonably requires not only fine technology, but also experience. No matter which order of sequence, well seismic joint tracking is the top priority of geological and seismic joint research. It is the foundation of stratigraphy, sedimentation, petroleum system, reservoir seal combination, reservoir prediction and so on.

The fourth-order sequences are traced through seismic profiles before the well pattern density is lowered. It is found that each fourth-order sequence has its own characteristics and can be distinguished from other sequences. It has a time span of 1-2 reflection axes in the trough area and 0.5-1 reflection axis in the slope area, which meets the necessary conditions for tracing on the profile (Fig. 2).

At the same time, the Nantun Formation can be divided into three third-order programs and eight fourth-order sequences according to the wavelet transform atlas and transform coefficient, which are consistent with the actual geological conditions of Nantun Formation in this area. Wavelet transform is
to transform logging data from one-dimensional depth domain to two-dimensional depth scale domain, and obtain a series of wavelet variation coefficient values corresponding to scale and depth. Different scales represent independent periodic cycles: the larger the scale, the longer the sedimentary period, the greater the thickness of corresponding stratigraphic cycle, which is a large-scale cycle, otherwise it is a small-scale cycle. Compared with using lithologic section and logging curve alone, the high-frequency sequence boundary divided by seismic time-frequency analysis and wavelet transform is clear, which conforms to the geological law and greatly reduces the interference of human factors.

At this time, the even well profile in the development zone can accurately track and reflect the change of the fourth-order sequence. Therefore, in the development zone with high well pattern density, through the selection of multiple source profile and cutting source profile, it is found that the fourth-order sequence tracking has similar electrical and lithologic characteristics in the Development Zone, which can be traced and compared completely.

4. Single layer or lithologic combination with stability, particularity and easy identification is selected as marker bed
The study shows that Hailaer basin has the characteristics of typical fault basin. In the early stage of fault depression, each fault depression is independent of each other and has poor connectivity with each other. Wuerxun depression, as the main fault depression in Hailaer basin, has the characteristics of north-south differentiation, juxtaposition of fault trough belt, different provenance in east-west direction and rapid phase transformation. The two sides of the uplift in Wuerxun depression and the two sides of the large fault in the same sag "lack of comparable events and wave groups", so it is very difficult to trace the event only from the seismic phase characteristics. Therefore, seeking for typical geological marker beds is the key to break through the problem.

5. Fourth order sequence correlation controlled by profile
Because of the complex structure, multi provenance, short provenance and fast phase transformation, the overall contrast design must be carried out in order to realize the accurate, fine and unified stratigraphic correlation in the whole area. On the profile, starting from standard well, combining well seismic with well by well, fine correlation is carried out one by one. After the completion of correlation, the third-order sequence boundary is closed step by step, and then the fourth-order sequence boundary is closed after the third-order sequence boundary is closed.

6. Distribution characteristics of fourth order sequence
In general (Fig. 3), the second member of the south is mainly distributed in the trough area and slope zone, partially eroded; the n2-1 trough area and slope zone are developed, and the eastern part of the structural transition zone is denuded; n2-2 is distributed in the whole area; N2-3 trough area and slope zone are eroded; n1-1 and n1-2 are mainly distributed in the trough area; n1-3 and n1-4 are distributed in the whole area; n1-5 trough area is distributed in the upper part of the slope zone. The structural transition zone is absent, and it is distributed in other areas.
Figure 3. Well-seismic profile through standard well in Wuerxun depression

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