

Application of Microstructural Studies in the Development of Complicated Fault-block

Xia Bo*

PetroChina Liaohe Oilfield Company, Panjin, Liaoning 124010 China

*Corresponding author e-mail: 269772460@qq.com

Abstract. The geological conditions of the Liaohe oilfield are complex and the fracture system is developed. It is particularly important to study the tectonic characteristics of development blocks in the process of oil and gas resources and geothermal resources development. How to effectively identify microstructures becomes the key to capacity building and rolling stock increase during the development of old areas. By carrying out microstructural research, the research idea of microstructural description for complex fault blocks is proposed, and the fracture system is finely carved through different fault distance faults with hierarchical and methodological interpretation, and the velocity field establishment method is preferably selected, combined with the inclination guide body to finely carve the micro-amplitude tectonic morphology, which can effectively carve microstructures and provide reliable geological foundation support for the development of oil and gas resources and geothermal resources in complicated fault-blocks.

Keywords: Microstructure; Low-sequence Faulting; Velocity Field; Geothermal; Inclination Guide Body.

1. Introduction

Fracture activity is the main form of tectonic movement in the Liaohe Depression and is characterized by a large number of faults, large scale and mainly tense positive faults. Multi-phase and multi-group faults intersect each other in plan and cut each other in profile, controlling the tectonic pattern and evolution of the depression. As oil field development continues to progress, large fracture systems and tectonic fault blocks are better recognized, and further understanding and carving of microstructures becomes an important potential point and breakthrough in the development of hydrocarbon and geothermal resources. The identification and study of microstructure is important for finding the remaining oil in the reservoir and clarifying the oil-water relationship in each block of the reservoir, rationalizing the injection and extraction well network design, avoiding the injection and extraction conflicts between wells, increasing the recovery of crude oil, or improving the injection and extraction correspondence in geothermal development.

2. Definition and classification of microstructure

2.1 Definition of microstructure

The concept of microstructure was introduced by Xingguo Li in 1987, and the reservoir microstructure refers to the small localized structure of the reservoir itself with microscopic undulations in the total field context, which can also be called micro amplitude structure [1]. Microstructure is a tectonic unit that has been modified several times by multiple tectonic movements, so that the local structure (three levels) can be independently formed into oil and gas reservoirs after being cut by many small faults [2, 3].

2.2 Classification of microstructures

Microstructures mainly include positive microstructures, negative microstructures and oblique microstructures according to the undulating changes and morphology of the top surface of the structure.

(1) Positive microstructure: The part of the reservoir top surface that is relatively convex, including micro-high point, micro-backlash, micro-nose structure and micro-break-nose structure, etc.

(2) Negative microstructure: The top surface of the reservoir is relatively depressed, including micro-lows, micro-slopes, micro-grooves, micro-grooves, etc.

(3) Oblique microstructure: The inclined part of the reservoir, often located between positive and negative micro-amplitude structures, can also exist alone, including micro-slope and micro-terrace [4].

For oil and gas field development, positive microstructure is the focus of research.

3. Identification and portrayal of microstructures

In complex fault block areas, where tectonic movements are active and the deposition and spatial spreading of reservoirs vary in blocks, the formation of microstructural traps is mostly controlled by fracture systems in such areas. Therefore, the identification and characterization of microstructures are mainly divided into two main aspects: the identification of low-grade small fault and the characterization of micro-amplitude morphology of traps and closures. These two aspects are two indispensable aspects for the description of complex fracture block microstructure, one is to finely delineate the fracture structure grid, and the other is to finely describe the morphological features of the top surface of the structure.

3.1 Identification of low-grade faults

Low-order faults refer to those derived from high-order faults (first, second, third, fourth, and fifth-order faults in oil fields), which are usually referred to as fourth and fifth-order faults and below, and are small faults that are difficult to identify by conventional geophysical methods and have strong concealment [5, 6]. There are many methods for identifying low-order faults, ranging from profile identification to planar identification to single well fault calibration and fault convergence check for tectonic modeling [7]. In this study, by interpreting the faults in different levels and methods for different fault distances, we can not only carve the fracture system more accurately, but also reduce the workload and improve the efficiency of fault interpretation. For faults with a fault distance above 10m, the fault is carved by a combination of special profile display profile interpretation combined with coherent body plane identification, and for faults with a fault distance between 5-10m that are more hidden and difficult to identify by conventional methods, the fault is interpreted by a combination of profile interpretation such as instantaneous phase attributes and fault enhancement processing combined with ant body plane tracing. On the basis of seismic fault interpretation, use the completed wells to carry out fine stratigraphic comparison under the control of the marker layer, implement single well breakpoints, calibrate the seismic interpreted fault surface with the single well breakpoints through the 3D fault model, ensure the spatial convergence between the fault surface and the single well breakpoints, and use the single well breakpoints to correct the fault plane position after the breakpoint position is unified with the fault surface(Figure 1).

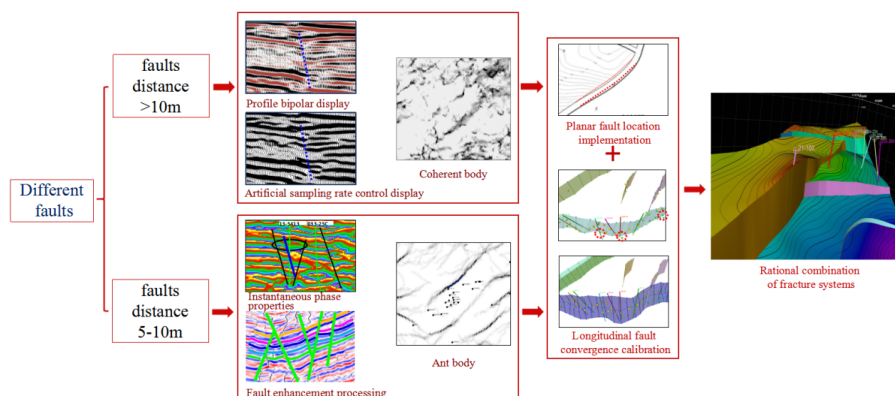


Figure 1. Flowchart for fine carving of low-order level faults

3.2 Closed micro-amplitude morphological portrayal

3.2.1 Initial plane model building

The micro-amplitude morphology inscription is based on the results of layer tracing interpretation in the 3D seismic fine interpretation work, and firstly, the area where the micro-amplitude morphology needs to be finely inscribed is encrypted for interpretation. At present, we are able to achieve 6.25*6.25m interpreted surface elements using high-precision small surface element seismic data, and we are able to obtain the dimensional information in the time domain through 3D interpretation. Through the whole-area velocity analysis, the velocity construction method is preferred to establish a reasonable velocity field, reduce the time-depth conversion error, convert the depth domain level information into depth level information, and then construct the depth domain level into a map to get the initial plane model (Figure 2).

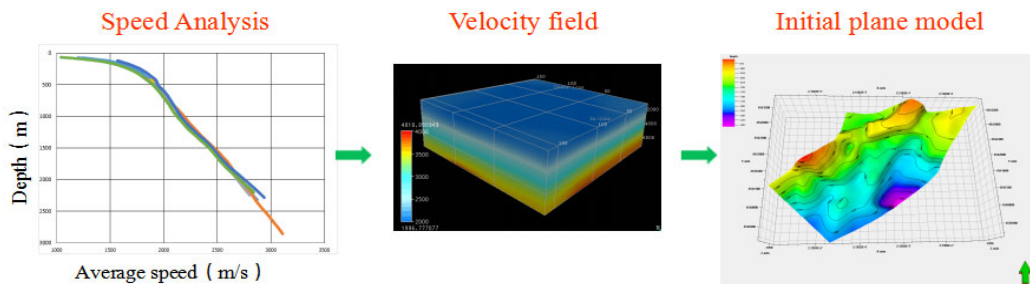


Figure 2. Initial plane model building process

3.2.2 Inclination plane distribution inscription

In order to further reduce the impact of errors generated in the conversion process of time domain and depth domain on the portrayal of micro-amplitude tectonic morphology, the laminae are extracted under the control of the tilting guide by the time domain laminae information. The tilting guide is a guide that scans and calculates the tilt and azimuth of each sampling point of the seismic body using the three-dimensional Fourier transform technology to generate the tilt and azimuth information of each sample point. The dip plane distribution of the destination level is obtained under the control of the laminae (Figure 3).

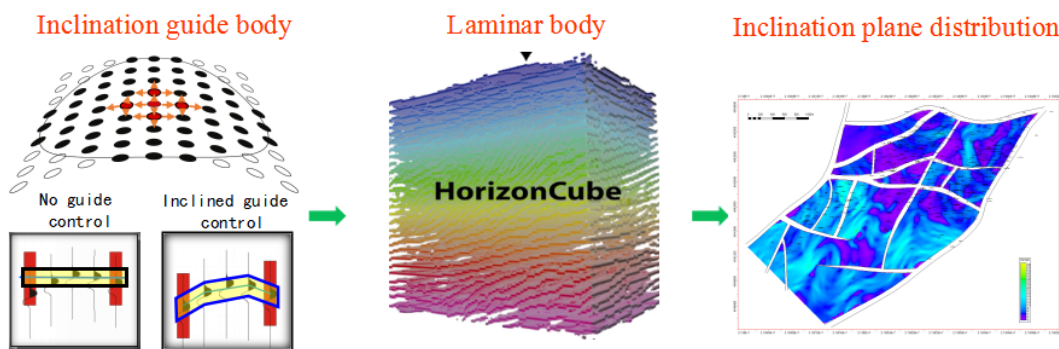


Figure 3. Inclination plane distribution inscription process

3.2.3 Microstructure plan

On the basis of the initial plane model, combined with the dip plane distribution inscription, the initial plane is refined differentially under the constraint of the dip plane, and finally the microstructure plane diagram is obtained (Figure 4). Through the analysis of the error of the old and new structures, the mapping error of the new structure map obtained by using the inclination control refinement mapping method is less than 4 meters, and the mapping accuracy is significantly improved compared with the conventional method (Table 1).

Table 1. Comparison of old and new structural errors at the top boundary of the Lotus oil formation in block Q12

Name of well	Lotus top depth(m)	Original construction drawing error(m)	New construction drawing error(m)
Q12-1	1001	-6.0	-2.0
Q12-2	1132	-8.0	-3.5
Q12-3	1125	-7.0	-3.0
Q12-4	1065	-6.0	-1.5
Q12-5	1117	+3.0	+2.0
Q12-6	1133	-8.0	-2.5

3.3 Application Effect

Microstructural mapping has been widely used in the development of complex fault blocks in the Liaohe Oilfield, the most typical one being block Q12, which is tectonically located in the up-dip part of the southern section of the Huanshu upper terrace on the western slope of the Liaohe Depression. There are many oil-bearing formations in Lotus, Dalinghe, Xinglongtai and Tantaio formations in the work area, with variable geological conditions, complex oil-water relationships and low levels of well control. The block was put into development in 1991, lasting 29 years, and has experienced four stages: rolling development, basic well network throughput, up return to Xinglongtai, and low efficiency throughput. Before carrying out microstructural research, the daily oil production of single wells was low, reservoir pressure was low, and the degree of recovery was only 26.8%, so it is urgent to deepen geological understanding, improve the block capacity effect, and increase the degree of reserve utilization.

Through microstructural fine delineation study, 17 faults were implemented in the block, and 13 traps were interpreted, of which the smallest trap was 0.12km² and the largest 1.16km², with the trap amplitude ranging from 20 to 150m. Finally, 2 rolling wells (Figure 4) were successfully deployed in the micro-amplitude tectonic highs of the block and 44 development wells. After the rolling well was completed, the oil formation drilling encounter was consistent with the prediction, and the proven reserves were successfully reported to be nearly one million tons. As the development wells came into production one after another, the daily oil production of the block rose from 14t to 112t, and the production achieved a leap forward. The success of microstructure fine delineation in the development of this block also finds a new breakthrough direction for the development of the same type of complex fault block reservoir.

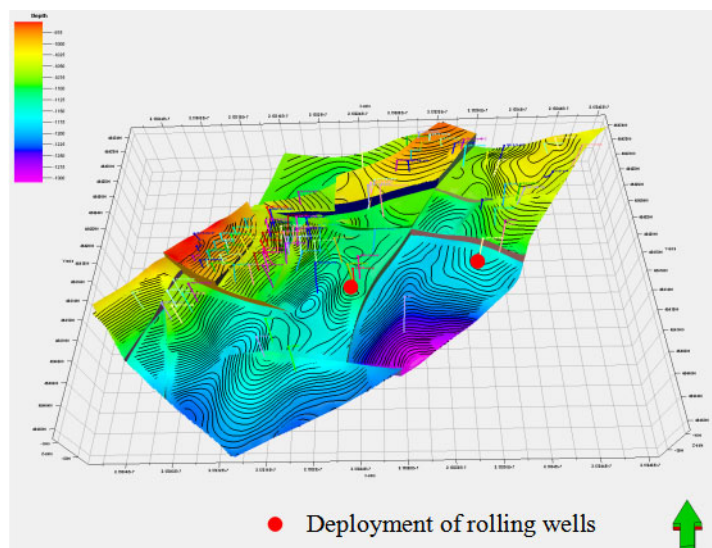


Figure 4. Schematic diagram of rolling well locations for the Lotus formation deployment in block Q12

4. Conclusion

The Liaohe oilfield is tectonically fragmented and the fracture system is developed. As the development of the oilfield enters the middle and late stages, the study of internal and marginal microstructures in complex fault block areas gradually becomes the focus and breakthrough of geological research. The key to microstructural work is the identification of small faults at low sequence level and the micro-amplitude morphology of traps. It has been proved that the microstructure fine delineation can find the remaining oil-rich area of the reservoir, and provide new research potential points for the development of old area capacity construction and rolling reserve increase. At the same time, microstructural research is of great practical significance in the development of oil reservoirs and geothermal heat to clarify the relationship between oil and water in each block, to design a reasonable injection and extraction well network, and to avoid the contradiction between injection and extraction wells.

Acknowledgements

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