The Characteristics and Tectonic Evolution of Deep Buried Structures in Manas in the Southern Margin of Junggar Basin

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Abstract. The Manas anticline belongs to the second tectonic belt in front of the southern margin of Junggar Basin. Due to the multi-stage tectonic compression activity of the Indian plate and the Eurasian plate since the Cenozoic era, the tectonic activity is frequent and the deep tectonic style is complex, so the deep tectonic style of the quasi-south has not been clearly understood. For the study of the deep concealed characteristics of Manas anticline structure, in this paper, we will use the theory of fault-related fold, the geometric analysis and the balanced section forward simulation to construct the detailed structural analysis and simulation of kinematics of structural deformation process of the type section of the Manas anticline based on wide line seismic profile. The study shows that the vertical and upward parts of the Manas anticline are fault-propagated folds and thrust nappe structures while the deep parts are mainly composed of complex structural triangular wedges, burst structures and secondary fold regulating faults. The deformation process is the early low-amplitude fault-turning fold, which is blocked at the front of thrust and forms complex triangular wedge and burst structure. In the late neogene, large thrust faults and fault-propagated folds were developed along the bottom of Anji Haihe formation under the action of strong thrust nappe in the piedmont.

Keywords: Southern Margin of Junggar Basin, Manas Anticline, Construction Style, Construction in Progress

1. Introduction

The Manas anticline is located in the middle section of the second row of the piedmont thrust belt on the southern margin of Junggar Basin, adjacent to the Horgos anticline in the west and the Tuguru anticline in the east. The three anticline belts are distributed as a whole in the shape of pin shape near EW (Figure 1). Since the Cenozoic era, under the impact of the collision between the Indian plate and the Eurasian continent and its continuous compression, the region has been strongly uplifted by the Qinghai-tibet plateau and transmitted by the distant tectonic compression. Although some research work has been done on the south structural anticline belt, some research results have been obtained¹⁻³. However, due to the poor quality of seismic reflection, the lack of understanding of the deformation characteristics of deep buried structures, the lack of clear understanding of the tectonic deformation
pattern and formation mechanism restricted the oil and gas exploration in this area. Especially in recent years, a number of oil and gas fields have been discovered in the southern margin of Junggar Basin with great potential for oil and gas exploration. Therefore, the study on the hidden features of deep structures in the anticline in the southern margin is of great help to deepen the understanding of regional geological tectonic activities in the southern margin and explore the oil and gas exploration potential in the southern margin.

Based on the typical wide-line seismic section passing the Manas anticline, this paper intends to conduct an in-depth study on the deep buried structures in this area by using fault-related fold analysis and balanced section forward modeling technology to clarify the deformation characteristics of the deep buried structures and their deformation mechanism.

**Figure 1. Regional Structural Diagram**

**2. Regional Geological Background**

There are three tectonic belts in the southern margin of Junggar. The homatutectonic belt is the second one in the piedmont and the Manas anticline is part of the Homatutectonic belt.

The strata involved in the structural deformation analysis from old to new include the bottom of Jurassic Badaowan formation J1b, Jurassic Xishanyao formation J2x, cretaceous Qingshuihe formation K1q, cretaceous Shengjinkou formation K1sh+, cretaceous Lianmuqin formation K1l, cretaceous Donggou formation K2d, paleogene Ziniquanzi formation E1-2z and paleogene Anji Haihe formation E2-3a.

There are two sets of main deciduous strata in the region. The mudstone of Anji Haihe formation and the bottom mudstone of Shengjinkou formation or the coal seam of Xishanyao formation are the deciduous planes respectively. The deciduous planes of Anji Haihe formation mainly control the structural deformation in the shallow part and form the fault spreading fold and thrust nappe system. Strata of Shengjinkou formation mainly controlled the tectonic deformation in the middle part, forming a variety of structural styles such as tectonic triangle wedge, burst structure and derived fold regulating fault.

**3. Establishment of the Manas Anticlinal Structure**

The typical seismic section in the middle of the Manas anticline is selected and the structural deformation characteristics of the Manas anticline are analyzed by means of dip Angle domain, reflection axis interruption and axial plane analysis of fault-related fold theory.

According to the difference in the dip Angle domain of the vertical upward reflector, the deep part of the Manas anticline can be divided into three structural triangular wedges and combinations of their derived fault systems (seen from Figure 2 and 3):

The determination of the bottom forward thrust fault: the J2x reflection layer showed obvious dislocation in the anticlinal front wing and the fault slope reflection wave group (see arrow in figure 2). According to the deformation of J2x reflection layer, the upper slip surface of the thrust fault turned into the K1s bottom reflection layer slip. The position of the sliding detachment can be inferred from the synclinal axial plane of the wing behind the J2x reflector (seen from the dotted line in Figure 2).
Reverse thrust fault: the geometric morphology of $E \sim K_2$ and lower $K_1 \sim J_2x$ reflector shows angle difference belonging to different structural dip Angle domain, indicating the existence of thrust fault between them. In addition, the termination of the reflected wave group in the north wing of the anticline core shows the characteristics of being cut by the fault and also indicates the position of the thrust fault slope.

The derivative fault of the thrust fault at the top of the triangular wedge: the $K_2 \sim E$ reflector at the anticlinal core is misaligned with the corresponding reflector at the front direction. There are several groups of cross section reflection waves with southern dip which terminate on the reverse thrust fault with triangular wedge. According to the above structural geometry model, the derived fault and the reverse thrust fault at the top of the triangular wedge constitute a burst structure (seen from Figure 2 and 3).

![Seismic reflection characteristics of seismic section in the middle section of Manas anticline.](image)

It can be seen that the geometry of Manas anticline is mainly controlled by the triangular wedge of deep structure. The forward thrust fault at the bottom of the triangular wedge originates from the nappe process of slippage (lower flat) - thrust (slope) - slippage (upper flat) along the coal seam at the bottom of $J_1b$, and the upper flat is located in the reflection layer at the bottom of $K_1q$. The reverse thrust fault originates from the process of blocking the slippage of the upper flat of the forward thrust fault. The upward reverse thrust and the Angle of cutting the stratum gradually decrease, and the fault cuts the $K \sim E$ reflecting layer. Both bottom and top thrust faults derive secondary recoil fault systems and form burst structures.

Based on the above analysis of the relationship between the tectonic style and the fault foundation, the author constructed the structural geometry model of Manas anticline (seen from Figure 3).
Figure 3. Structural interpretation of seismic section in the middle section of Manas anticline

Structural Deformation Mechanism of Manas Anticline.

Forward balanced geological section technique is a section technique which, by analyzing the regional tectonic background, selects the appropriate deformation mechanism for the interpretation section and restores all or part of the structural deformation to the reasonable undeformed state through geometry and kinematics principles. It is an important research achievement in the field of modern geoscience. In terms of structural geology, petroleum exploration and basin simulation application, geologists and exploration geologists at home and abroad have considered it as an important tool for model interpretation \[^{[5]}\]. Structural simulation technology is based on the theoretical model of fault-related folds. Through the dynamic simulation of tectonic deformation, it seeks the most reasonable structural interpretation scheme of seismic section, determines the geometric deformation process of tectonic dynamic movement and reproduces the history of tectonic evolution.

It can be seen from the simulated structural geometric evolution section (FIG. 4) that, first, the slip thrust fault in the deep started to move and thrust upward at Manas to cut the J~K\textsubscript{1}q stratum. Due to the obstruction of the front end of the fault, the reverse thrust fault was induced in the K\textsubscript{1}q stratum at the front end, forming a structural triangular wedge (FIG. 4-1). Since the initial position of the reverse thrust fault at the top of the triangular wedge cuts down to the K\textsubscript{2}s reflector, the K\textsubscript{1}q reflector is reversely thrust to the anticlinal core with the upward insertion of the triangular wedge (FIG. 4-2).
Figure 4. The modeling process of structural geometry of Manas anticline.

As the tectonic compression continues and the front is blocked, the new tectonic triangular wedge starts to form behind the early triangular wedge, which causes the tectonic superposition deformation of several triangular wedges. Because the initial shape of the reverse thrust fault at the top of the second triangular wedge is in the shape of a ladder, the thrust process causes secondary fold deformation in the hanging wall strata (seen from figure 4, 3 and 4).

Finally, the thrust nappe fault to the surface was thrust to the surface along the rear wing of the anticline during the bottom slip of E2-3a, forming the present multi-stage structural geometric superposition (seen from figure 4-5).

By comparing the final simulated section with the actual seismic section (see figure 5), the main structural characteristics inside the triangular wedge are close to the actual one, which verifies the rationality of the structural interpretation of the seismic section[6].

Figure 5. Comparison of the forward model results.

4. Conclusion

According to the structural geometry analysis of typical section of Manas anticline, it is concluded that the buried structure in deep Manas is mainly the vertical superposition of fault-turning fold and
compound structural triangular wedge and the shallow surface layer is the fault-relaying fold structure.

The tectonic deformation process of the Manas anticline is the upward thrust blocking of the thrust slip fault in the deep in the early stage. The thrust at the front of the fault at K1q formed a tectonic triangular wedge. Finally, the thrust nappe fault at the bottom of E2-3a thrusts from the rear wing of the Manas anticline to the surface.

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