# Analysis Method of Activity Intensity of Ultra Deep Strike-Slip Fault Fractured Zone in Tarim Basin

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**Abstract.** The Ordovician ultra-deep tight limestone strata in the Tarim Basin develop strike-slip faults, which are buried at a depth of 6000–12000 m. Around the strike-slip faults are the fracture area that controls the reservoir development, hydrocarbon migration, and accumulation. Therefore, the strike-slip fracture zone is the primary target for oilfield reserves growth and productivity construction. The activity intensity of the fracture zone is closely related to the scale of reservoir development and hydrocarbon charging. It is the crux element of efficient exploration and development strategies for heterogeneous carbonate reservoirs. This paper proposes a method to evaluate the activity intensity of the fracture zone. The first step is to increase the resolution of seismic data for fractured fracture zones by multiple filtering. Then enhance the fracture features in the seismic data. The last step is extracting the cumulative time or depth amplitude thickness attributes that reflect the fractured zone based on geological knowledge. We have designed a parameter table and applied this method in the Tabei area. The parameter includes the segment length, longitudinal thickness, and transverse width of the fracture area around the strike-slip fault. The table represents the activity intensity of fracture zones and perfectly matches the drilling and testing conditions. The method can effectively guide the formulation of reservoir development strategies and promote to other oilfields.

**Keywords:** Strike-Slip fracture zone · Activity intensity · Amplitude thickness · Ultra-deep tight limestone strata · Tarim Basin

## 1 Introduction

The carbonate oil and gas reservoirs contain around 38% of the total reserves in the Tarim Basin, which has good prospects for exploration. The Ordovician fracture-cavity carbonate reservoir in the Halahatang area is a favorable direction for oil and gas migration and has rich resources, but the deep burial (around 7000 m) and strong heterogeneity make the exploitation difficult [1]. Previous experience on the development of carbonate reservoirs demonstrates that quality and connectivity are the main factors restricting their petroliferous properties and stable production. These two factors are significantly


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affected by later deformation and fault development [2]. The faults improve the carbonate reservoirs in two aspects. First, the large-scale faults are the channel for fluid migration, which not only allows the downwards thermal fluids to upwell and improve the storage space but also increases the depth of epigenetic karst upwards to promote the development of weathered crust karst reservoirs. Second, the fault activities cause a series of fractures to develop that enlarge and connect the storage space to form high-quality carbonate reservoirs [3]. Therefore, the study of faults is particularly important.

## 2 Background

The study area locates on the southern margin of the Halahatang Uplift in the Tabei Uplift of the Tarim Basin. Affected by tectonic movement, there are many large-scale strike-slip faults in the area (Fig. 1). Years of exploration and development experience indicated that the drilling success rate, the proportion of high-efficiency wells are closely related to the fractures' development. Especially in the past two years, the discovery of wells that produced above 100-ton and even 1,000-ton of oil has confirmed the perspective that large-scale strike-slip controls the distribution and enrichment of carbonate reservoirs. The main target of evaluating oil and gas reservoirs is thus changed to the strike-slip fracture zone and effectively supported the construction of 30 million tons of Tarim Oilfield and the rapid production of Fuman Oilfield.

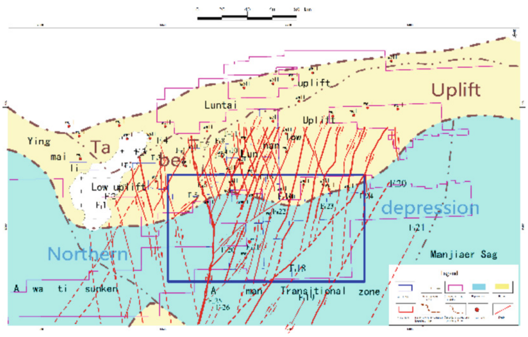



**Fig. 1.** Location map of the study area

## 3 Research Methods and Principle

### 3.1 Principle of Amplitude Thickness

Previous exploration and development have confirmed that the stronger the vertical activity of the strip-slip faults, the better the connectivity between resource and reservoirs. However, conventional attributes can reflect geological discontinuities in the horizontal direction, but cannot represent the strength of the fault's vertical activity. The detection of vertical fault activity was manual, which had a strong uncertainty. Therefore, we introduced the amplitude thickness attribute to represent the vertical activity strength. The method has two steps: first defining a threshold for any attribute, and second vertically accumulating where the value has reached the threshold (Fig. 2). The result displays a larger value along the faults that have higher vertical activity strength. When conducting amplitude thickness attribute from the target layer downwards, the possibility of strip-slip faults connects the resource with the reservoirs increasing with the value.

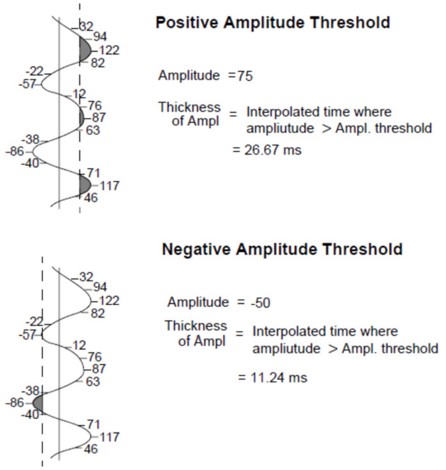



**Fig. 2.** Principle of amplitude thickness attribute

## 3.2 Principle of Amplitude Difference

The different geophysical properties of underground geological anomalies would change the speed of seismic waves. When seismic waves pass through the anomalies and reflect back, the reflected energy will be different from the surrounding rock. The difference manifested in the seismic data is the seismic amplitude variety. We analyze the changes through the amplitude difference attribute and calculate the amplitude by or the RMS amplitude. A0 is the amplitude value corresponding to the center point, Ai is the amplitude value corresponding to any point; τi is the inclination time difference of any point relative to the center point (Fig. 3) [4]. The amplitude change can reflect the discontinuous of reservoirs or strata, and describe the changes in geological characteristics.

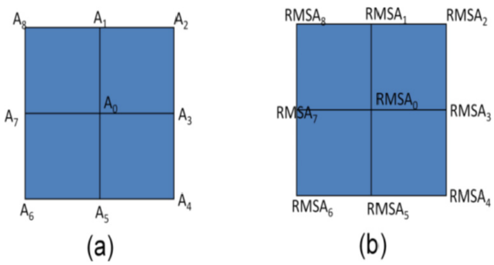
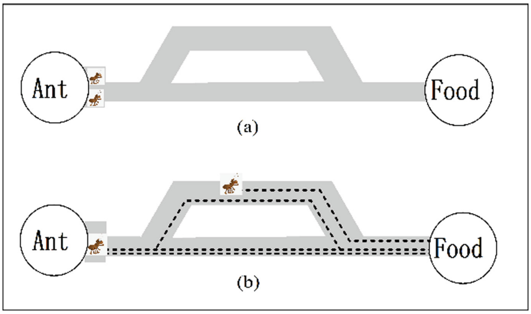



**Fig. 3.** Calculation method of amplitude difference (a) and RMS amplitude difference (b)

### 3.3 Ant Tracking Principle

Italian scholar M.Dorigo proposed an ant colony algorithm, also known as ant algorithm in 1992. The ant algorithm is a bionic evolutionary algorithm inspired by the path selection behavior of ants in the foraging process [5]. He observed the process of ant foraging and found that the ants always find the optimal path to the food, and if the path is blocked, they can quickly bypass the obstacles and find another path. This is because ants can exchange information and cooperation between colonies. Ant will release a pheromone during the walking that evaporates over time, and they also can perceive the strength of it. When more ants choose a path, the hormone will be enhanced, which attracts even more ants to choose the path. Thus forming a positive feedback process (4). The ant tracking method mimics this behavior to detect the development of the fault.




## 4 Application Analysis of Fracture Strength

### 4.1 Fracture Width Calibration

Researchers agree that the width of the fracture zone increases with the intensity of strike-slip fault activity [6]. Therefore, the width of the carbonate strike-slip fault fracture zone can intuitively reflect the strength of the fault activity. The fracture zone is described through a combination calibration of amplitude value, amplitude difference, coherence attribute, and inversion impedance. Figure (5) indicates that these attributes are capable to reflect the boundary of the entire fractured zone. Comparing the attributes with the well abnormal fluid loss on the edge of the fracture zone and high yield oil at 7395 m, the width of the F1 fault fracture zone is about 180 m (Fig. 4).

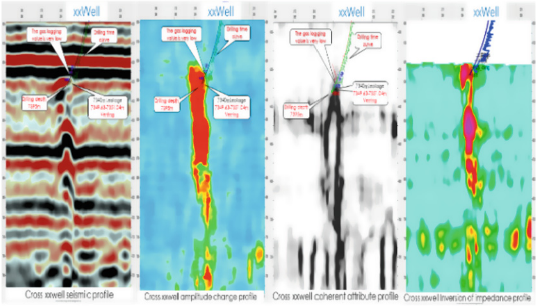



**Fig. 4** Well Calibration of amplitude value, amplitude difference, coherence attribute value and inversion impedance attribute

### 4.2 Longitudinal Extension of Fault

The previous detection of the vertical extension of fault is the manual observation from the seismic profile (Fig. 5), which lacks accuracy and efficiency. Additionally, this method only works in a limited area and is impossible to apply to the entire basin.

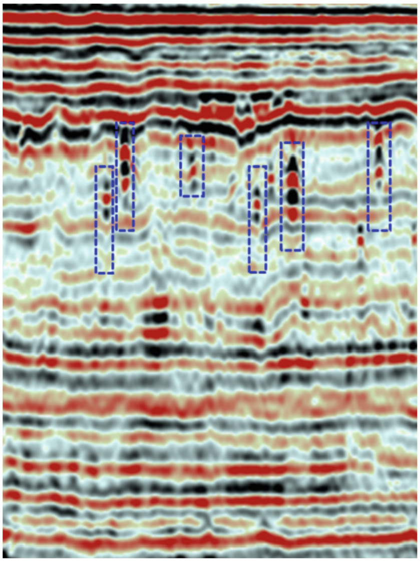


**Fig. 5.** Seismic profile

In the research, we used the amplitude thickness attribute to determine the vertical strength among the area. Take the F-X fault in the northern part of Halahatang Oilfield as an example, the fault feature is visible from the conventional coherent properties, but most of the wells along the fault zone had low productivity. However, the amplitude thickness attributes map indicates a weak vertical activity of this fault, which explained the reason for the low production in this block (Fig. 6).

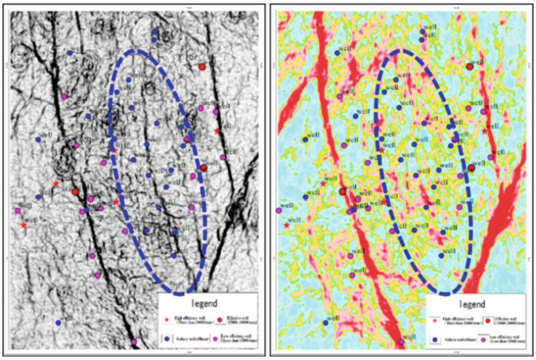



**Fig. 6.** Coherence map (left) and amplitude attribute map (right) of the F-X fualt

### 4.3 Fault Longitudinal Segmentation Analysis

The longitudinal segmentation of faults is always hard to define. We found that the ant tracking result has a good correlation with oil and gas enrichment, which can represent the vertical segmentation. The vertical segmentation of the stirp-slip fault controls the enrichment of the carbonate reservoir. The strip-slip fault that vertically cut through multi-layer and has no segment connects the reservoir with the source and makes it rich in oil and gas reserves. The fault penetrates downwards that disconnects from the upper strata would decrease the oil and gas enrichment. The worst phenomenon is the fault has no connection with the resource and leads to a failed well (Fig. 7).

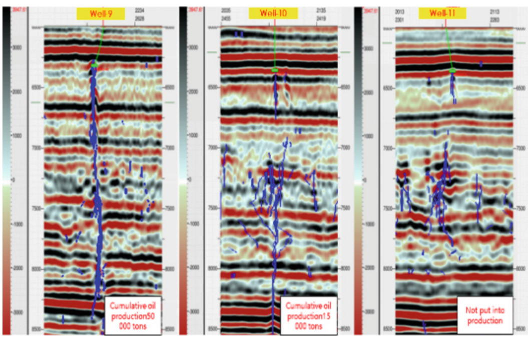



**Fig. 7.** Ant tracking and seismic overlay

## 5 Conclusion

1. Exploration and development practice shows that the strike-slip fault in the north of the Tarim Baisn can effectively connect the source rock in the Cambrian Yuertusi Formation. Oil and gas migrate and accumulate vertically along the fault zone to form Ordovian carbonate fault-cavity reservoirs. The source-connectivity of faults a major factor for oil and gas accumulation and enrichment, which requires further research to promote the discovery of fault-controlled reservoirs and new areas exploration.
2. This study applied the amplitude thickness, amplitude difference, and ant tracking properties to represent the activity intensity of the strip-slip fault fracture zone and achieved a satisfying effect.

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