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Quantitative Fracture Prediction Method in Yingmaili Area, Tarim Basin

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Abstract

In recent years, Ordovician carbonate reservoir is an important layer for oil and gas exploration and development in Yingmaili area, Tarim Basin. The prediction of fractures in carbonate rocks is of great significance to the exploration and development of oil and gas. Fractures, pores and vugs are the main migration channels and reservoir spaces of oil and gas, and their existence is one of the necessary conditions for hydrocarbon accumulation in carbonate rocks; The prediction of carbonate fractures has always been the focus and difficulty in this area. At present, the technologies of multi-component seismic exploration, such as S-wave exploration, P-S converted wave, multi-component seismic, multi-directional VSP, P-wave AVAZ. In this paper, based on the characteristics of fracture development of Paleozoic carbonate reservoir in Tabei, as well as well logging and the characteristics of pre-stack azimuth seismic data in Yingmaili area, it puts forward a seismic method of pre-stack anisotropy analysis to identify the spatial distribution characteristics of carbonate reservoir, which provides a basis for fracture prediction and reservoir connectivity research.

Keywords: Carbonate Rock, Fracture, Anisotropy Analysis.

1. Introduction

The Paleozoic carbonate reservoirs in Tarim Basin have various types of reservoir space, with obvious differences in size and grade. According to the shape and size, the reservoir space can be divided into three categories: vug, pore, fracture. According to the different spatial combination characteristics of the three categories, the reservoirs can be divided into four types: vug, pore, pore-fracture, fracture [1]. Fracture is not only an important channel for oil and gas migration, but also a favorable place for oil and gas accumulation; It is not only an important factor for connecting multiple fracture-vug bodies and dividing them into groups as well as deploying development plan, but also an important basis for the orientation and trajectory design of horizontal wells during drilling deployment. How to effectively predict the distribution and development of underground fractures is of great significance for seismic prediction of carbonate reservoirs. In Yingmaili area, North Tarim Basin, 3D seismic data are acquired with wide azimuth, and the ratio of horizontal to vertical is about 0.6. According to the principle of pre-stack P-wave AVAZ technology, it is suitable to predict fractures by the method of pre-stack P-wave AVAZ anisotropy analysis.

2. Concept of Fractures

In a broad sense, "rock fracture" includes all kinds of fault deformation with different size and origin in the crust. This includes both huge faults and microscopic cracks. In the study of reservoir rocks, fractures only refer to the faults along the extension direction without obvious relative displacement. Fractures can

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exist in all kinds of rocks, which have a significant impact on carbonate reservoirs. After the formation of fractures, they may become channels for all kinds of fluids. All kinds of fillings are often seen in fractures. For example, Calcite, dolomite, anhydrite and authigenic quartz are the most common fillings in fractures of carbonate reservoirs. In addition, asphalt, mud also can be seen. According to the filling degree, it can be divided into filled fracture, half-filled fracture and unfilled fracture (open fracture).

The open degree of fracture is less than 100um, which is indicated by the actual condition of underground fracture. According to the research of Smikhov (1974), the most common fractures in the deep underground are less than 50um in opening, and they are considered as important channels for oil and gas migration. This kind of fracture is called micro fracture. The visible cracks in the outcrops, tunnels and cores are called large cracks, which are mostly developed from micro cracks. Dissolution also occurs along various fractures. Generally, solution fracture is still classified as fracture, because the seepage state of fluid in it is roughly the same as fracture.

According to the distribution law and prediction research experience of carbonate fractures in Tabei area, the influence of fractures on reservoir connectivity and fluid is understood, and the spatial distribution characteristics of fractures with different scales need to be described by using seismic data and various methods. The small-scale fractures developed in yingmai-1 well block are bin (25m) level fractures, which are mainly identified by pre-stack azimuthal fracture prediction technology. According to the principle, we can can detect HTI or similar HTI type fractures by using pre-stack seismic data to extract seismic attributes, such as amplitude, velocity, frequency, attenuation, etc.

3. Principle of pre-stack seismic AVZS analysis method

At present, the developed exploration technologies for fractured reservoirs include S-wave exploration, P-S converted wave, multi-component seismic, multi-directional VSP, P-wave AVAZ, etc. The most effective method is shear wave splitting. However, the cost of S-wave acquisition and processing is very high, and the risk of oilfield investment is high, so it can not be a common technology. Multi-component seismic, multi-directional VSP, P-S converted wave technology has good effect, but either the exploration cost is high, or it is an unconventional seismic acquisition project, which is difficult to be widely used in China recently. Therefore, AVAZ technology is currently the most widely used.

The relative degree of fracture development can be deduced by using the characteristics of wide azimuth of 3D seismic data and extracting seismic P waves of different azimuth. This method is effective for open fractures of high dip. AVAZ (or AVOZ)- The amplitude of 3D seismic data varies with offset and azimuth.

The study shows that the spatial attenuation of fracture field is related to the variation of seismic frequency. The attenuation along the fracture strike direction is slow with offset, while the attenuation along the vertical fracture strike direction is fast with offset. The larger the fracture density is, the faster the attenuation is. According to Thomsen's research, the direction with smaller AVO gradient is the direction of fracture strike, and the direction with the largest AVO gradient is the normal direction of fracture, and the difference itself is proportional to the density of fracture, so the density of fracture can be calibrated. Gray et al. Described the AVAZ analysis method and showed that the relationship between AVO and azimuth (i.e. AVO gradient) reflects the change of rock hardness. Ramos et al. Show that the propagation of P-wave perpendicular to fracture zone will have obvious travel time delay and attenuation, and the reflection intensity and frequency will decrease. The results of petrophysical model experiments by He zhenhua and others show that the propagation velocity of seismic P-wave along the direction perpendicular to the fracture is less than that along the direction parallel to the fracture. The dynamic characteristics of

seismic wave such as amplitude, dominant frequency and attenuation are more sensitive to the change of fracture characteristics than kinematic characteristics such as velocity.

The above theoretical research shows that it is feasible to detect fractured reservoirs by extracting azimuth seismic attributes such as amplitude, velocity, dominant frequency and attenuation from pre-stack seismic data, and it has greater advantages than the fracture detection technology based on post stack seismic data. In Yingmaili area of northern Tarim, according to the distribution characteristics of azimuth and offset of seismic data in this area, the range of 300-5500m offset is selected and divided into five azimuth angles, which are 16 degrees, 51 degrees, 90 degrees, 129 degrees and 164 degrees, as shown in Figure 1.

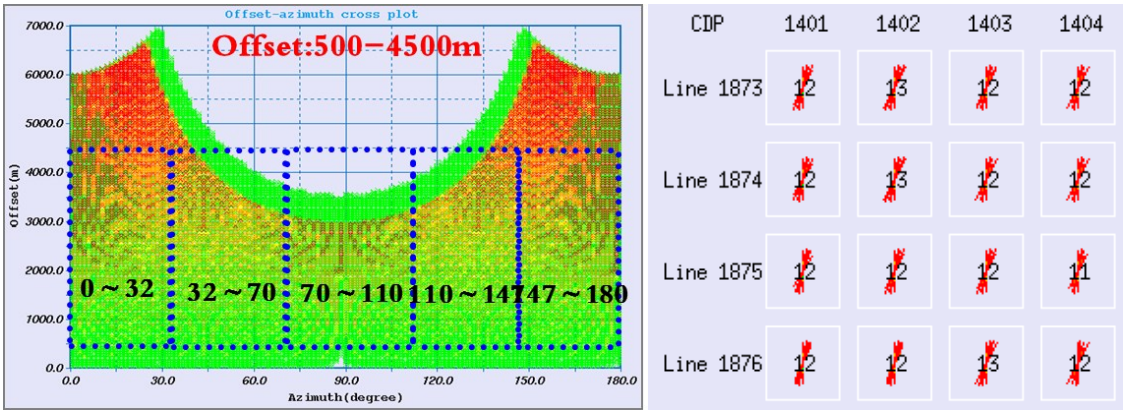

Fig. 1 azimuth division scheme of pre-stack gathers

According to the fracture development characteristics of carbonate reservoir, the azimuthal amplitude attribute, frequency attribute, attenuation attribute and energy attribute of each azimuthal superimposed gathers are compared and analyzed, and the relative development density and direction of fractures are predicted by optimizing the attributes. For each CDP point of the reservoir, the time window statistical attribute values of the above azimuthal angles are used for ellipse fitting, and three characteristic values are calculated. The length of the major axis, the length of the minor axis and the angle between the major axis and the minor axis of the ellipse. Then the oblateness of ellipse (major axis / minor axis) is obtained; according to the response relationship of selected seismic attributes to fracture orientation and the results in forward modeling, how the included angle indicates fracture direction is determined. Ellipticity usually indicates the distribution of fracture density; In the 3D area of yingmai-1 well, through drilling and logging fracture development characteristics, calibration and analysis with seismic prediction results, the azimuth amplitude attribute is optimized to predict the spatial distribution of small-scale fractures.

4. Application effect of pre-stack seismic AVAZ technology in fracture prediction in this area

The prediction results of pre-stack fractures of Ordovician carbonate rocks in Yingmaili 3D area show that the areas with well-developed fractures in Yijianfang Formation-Yingshan formation are the anticline area of Yingmai 1 well, the slope area of Yinggu 7 well, and the peripheral area of buried hill of Yingmai 4 well, which are mainly distributed in the higher structural parts and near strike slip faults. The buried hill area of Yingmai 4 well is exposed for a long time, and the dissolution is developed. The fractures are mostly dissolution fractures, and the structural fractures are not developed. The fracture development characteristics of Yingmai 1 anticline area are as follows: the fractures are not developed to the south of the

NW secondary fault (around Yingmai 101 well), and the fractures are relatively developed to the north of the fault. Yingmai 1 well is located at the edge of the fracture development zone, and Yingmai 102 well has relatively developed fractures, which is consistent with the results of FMI logging interpretation;

In YG7 slope area, fractures are developed around Yinggu7 well, but not at well point; Yingmai10 well has developed fractures. The profile is in good agreement with the drilling leakage, which is in line with the regional geological understanding, as shown in Figure 2.

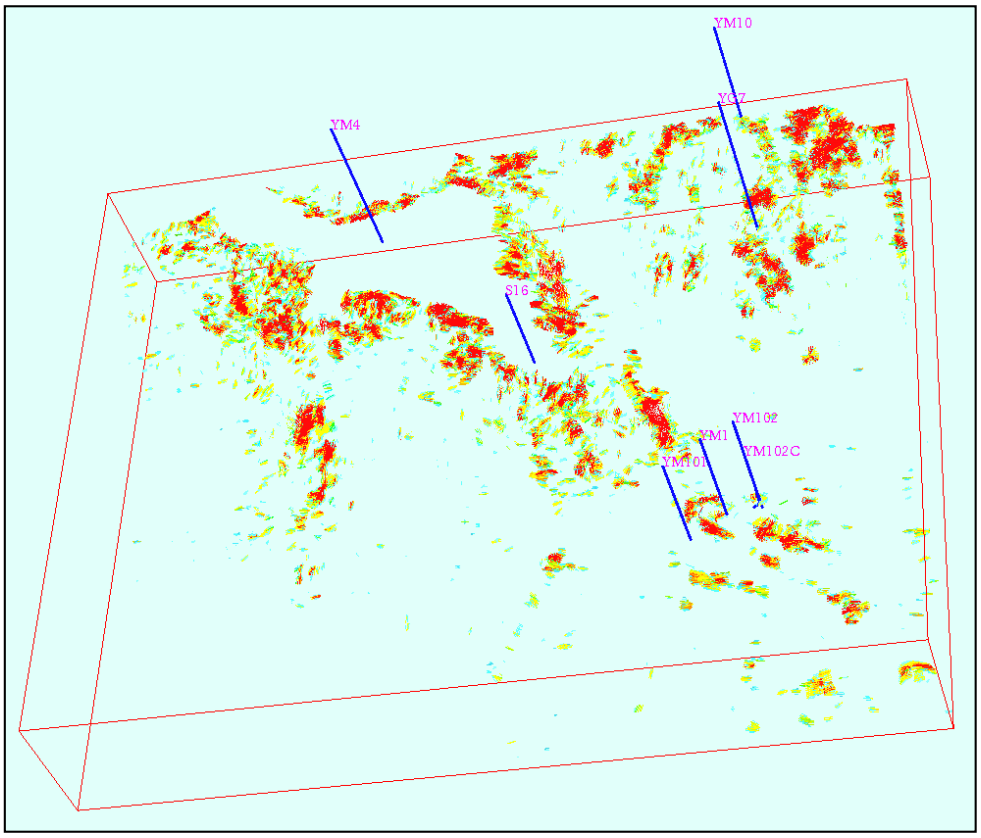

Figure 2 fracture prediction plan 120m downward from top of Ordovician Yijianfang Formation in 3D area of Well YM 1

5. Prediction of effective fractures in carbonate rocks

According to the well logging interpretation results drilled in Yingmaili 3D area, i.e. fracture porosity and predicted relative fracture development density, the intersection analysis is carried out, as shown in Fig. 3 and Fig. 4, and the threshold value of effective fracture development is determined.

According to the above intersection analysis, the effective fracture threshold values are: Class I: logging fracture porosity is greater than 0.1%, fracture relative density is greater than 1.07; Class II: logging fracture porosity is 0.04% - 0.1%, fracture relative density is greater than 1.04-1.07; Class III: logging fracture porosity is less than 0.04%, fracture relative density is less than 1.04.

By determining the level of relative density of fractures, on the relative density profile of fracture development, through the comparative analysis of single well fracture density and drilling leakage, the leakage volume of Yingmai 102 Well Yingshan formation is 437.6m3, the relative density of fractures at the leakage part of the read profile is 1.49, and the relative density development of fractures is consistent with that on the well, as shown in Figure 5.

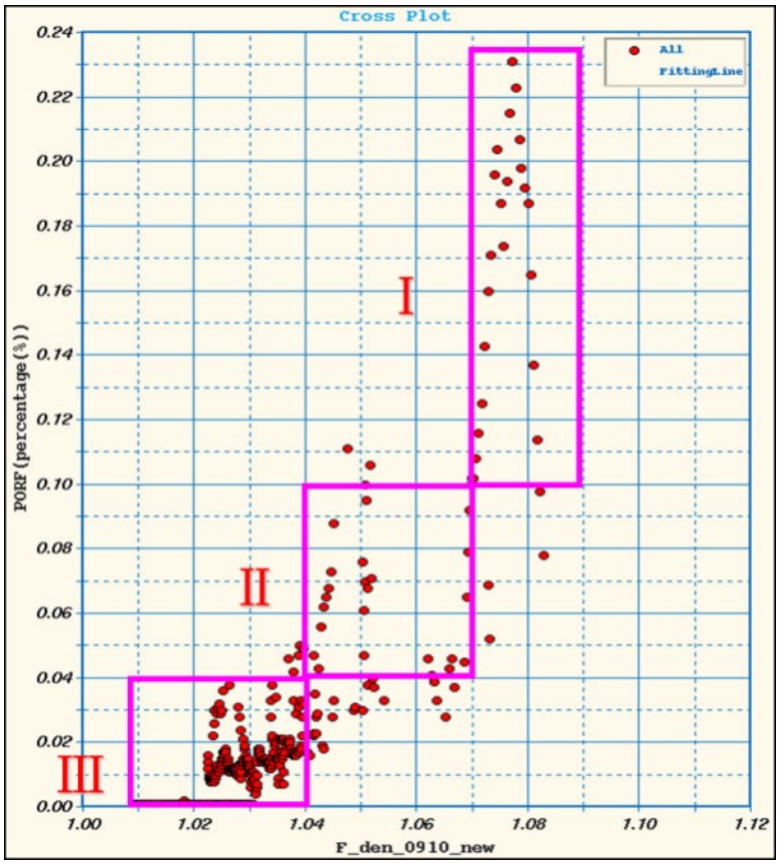

Figure 3 intersection analysis and threshold definition

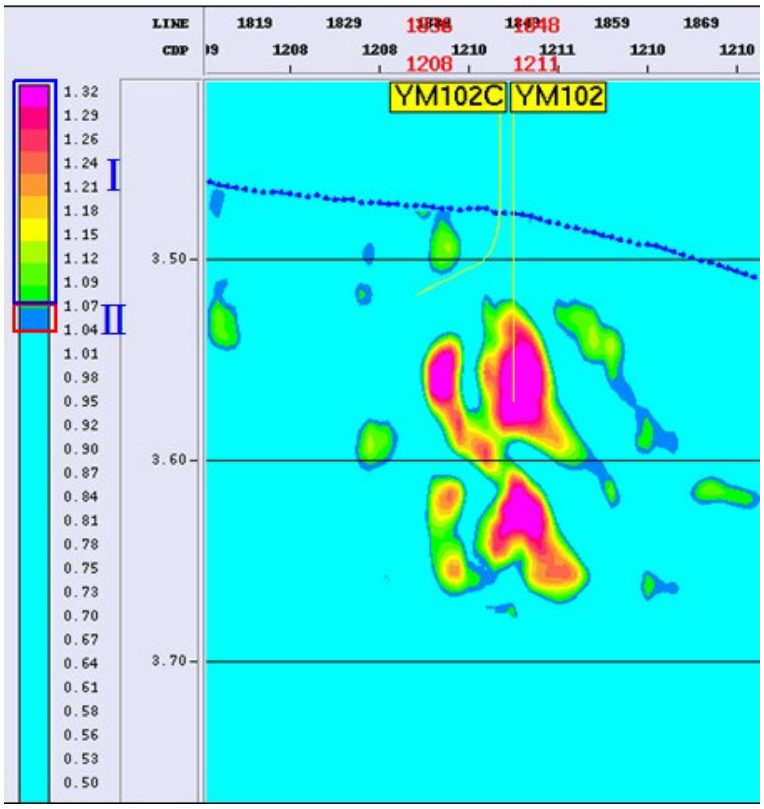

Fig. 4 fracture density profile of well YM 102-102c

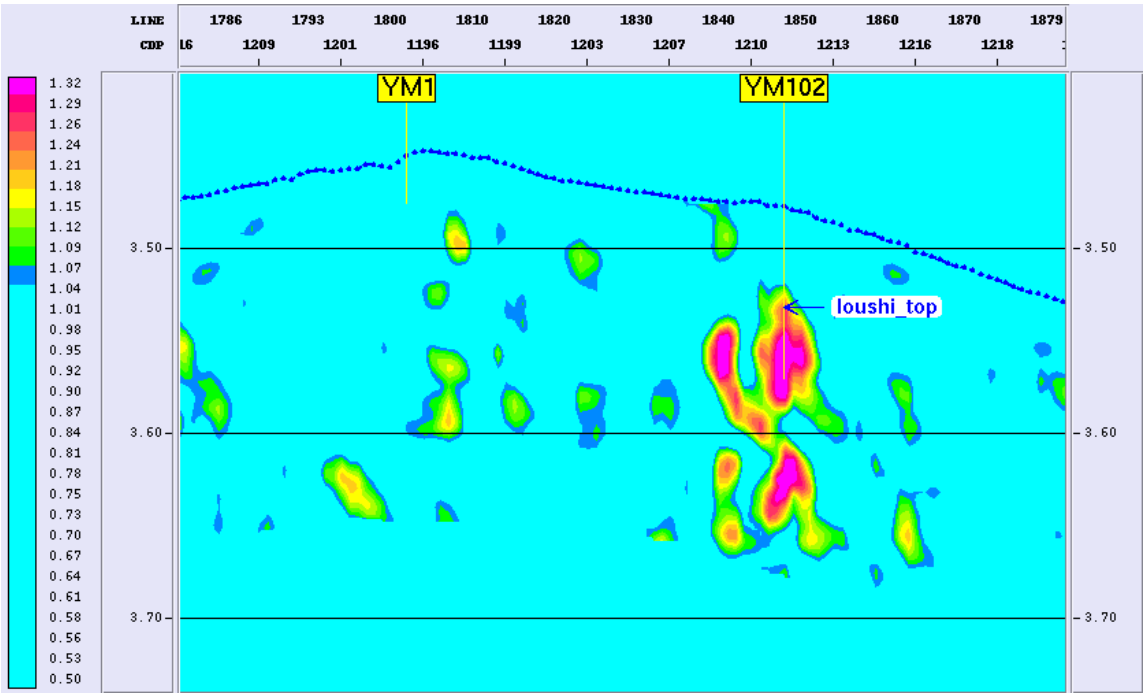

Figure 5 fracture relative density profile of Well YM 1-YM 102

To sum up, according to the characteristics of seismic data in Yingmai 1 Well 3D area, the application of pre-stack azimuthal analysis method has good prediction effect on carbonate fracture in this area, which is in line with the geological law of carbonate fracture development in this area. In addition, the effectiveness analysis of fractures can reasonably guide the connectivity analysis of carbonate fractured reservoirs.

6. Conclusions and suggestions

Based on the above prediction results of plane distribution and strike of fractures in Yingmaili area of Tabei, the prediction of effective fractures in carbonate rocks by pre-stack seismic AVAZ method has obtained the following conclusions.

(1) Based on the pre-stack seismic AVAZ analysis technology, the identification of fractures has good lateral resolution. For the prediction of fracture strike, the identification effect is good, which is consistent with the interpretation results of drilled FMIS.

(2) The development of high angle fractures in plane is mainly in the high part of local structure of carbonate strata, where the tectonic activity is frequent. The development of structural fractures is in line with the geological understanding of the distribution of carbonate fractures in this area.

(3) The prediction and division of effective fractures play an important role in the connectivity research and horizontal well trajectory deployment of fractured carbonate reservoirs.

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