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Comparison of Fracture Prediction Methods for Fracture-cavity Type Carbonate Reservoir

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Abstract

This is a case study for fracture prediction, using seismic data from Tahe oilfield Tarim Basin, Southwest China. The target layer of the study area is mainly composed of carbonate karst caves. Coherent, curvature, ant tracking and AVAZ inversion are used to predict fracture features in order to evaluate the applicability of different fracture prediction methods. Fracture prediction results show that coherent and curvature are unable to carry out prediction of fractures, while ant track and AVAZ inversion have the ability of fracture prediction. Compared with fractures of imaging logging, fracture density predicted by AVAZ inversion is more accurate than ant track. Methods based on post stack seismic are not applicable in fracture-cavity type carbonate reservoirs, and AVAZ provides a better way to predict carbonate reservoir fractures.

Keywords: Karst caves, Fracture, AVAZ Tahe.

1. Introduction

The Ordovician carbonate reservoirs of Tahe area have the characteristics of deeply buried, strong heterogeneity and complex reservoir connectivity which seriously restricts the efficient development of oil. In view of this special reservoir, a new research model of fracture-cavity type carbonate reservoir called fracture-cave unit was proposed [1]. A fracture-cave unit is a reservoir consisted of mainly caves connected by one or several fractures with a boundary of low permeable limestone or closed fault. As a result, it is essential to characterize the fracture correctly in order to evaluate the connectivity of fracture-cavity reservoirs.

This paper is an attempt to evaluate the applicability of common used methods of fracture predication such as coherent, variance, ant tracking and P-wave anisotropy and propose a suitable method for fracture-cavity type carbonate reservoir.

2. Methods

In this paper, the predication of fractures is carried out from two different seismic type, isotropic post stack seismic and anisotropic pre-stack azimuth gathers based on the offset vector tile (OVT) processing [2]. Coherence [3], variance and ant tracking attributes are used as the methods of post stack seismic fracture prediction [4], while amplitude versus offset and azimuth (AVAz) inversion is chosen as the method of anisotropic pre-stack azimuth gathers [5].

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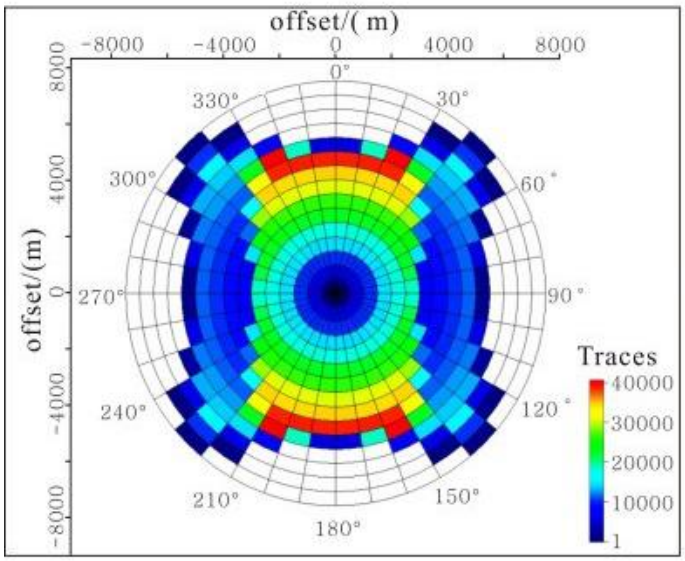
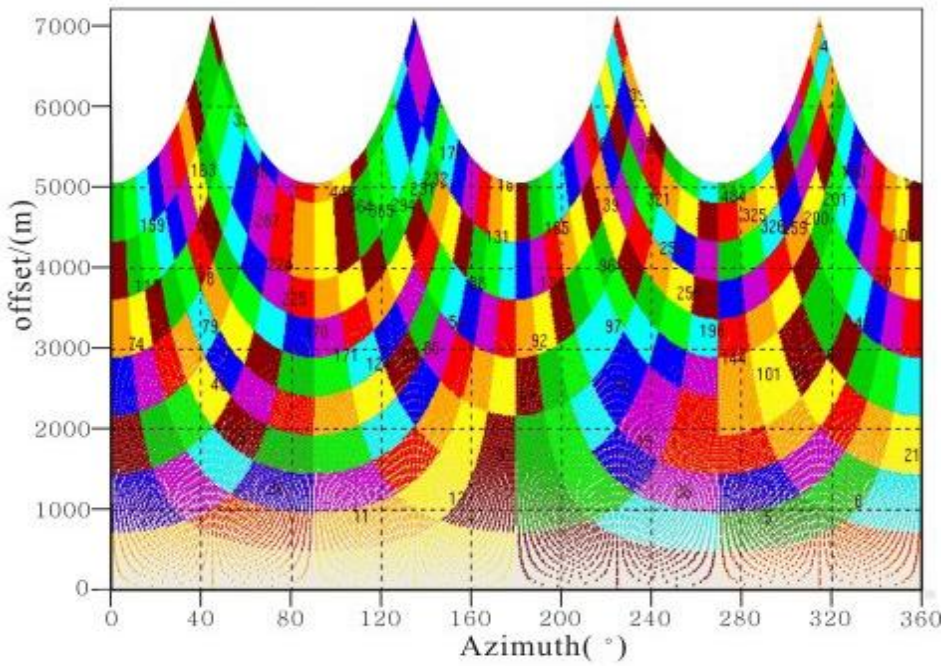
The known information of fractures comes from imaging logging interpretation, distribution characteristics of fracture density and fracture azimuth are chosen as the fracture prediction accuracy comparison standard. This technology includes four steps: (1) synthetic seismogram calibration; (2) seismic horizon interpretation; (3) attribute extraction or AVAz inversion; (4) comparison of fractures predicated by different methods. To make certain of the rationality of comparison maps of attributes or inversion are extracted with the same time windows based on fracture development section calibrated by synthetic seismogram.



(a)

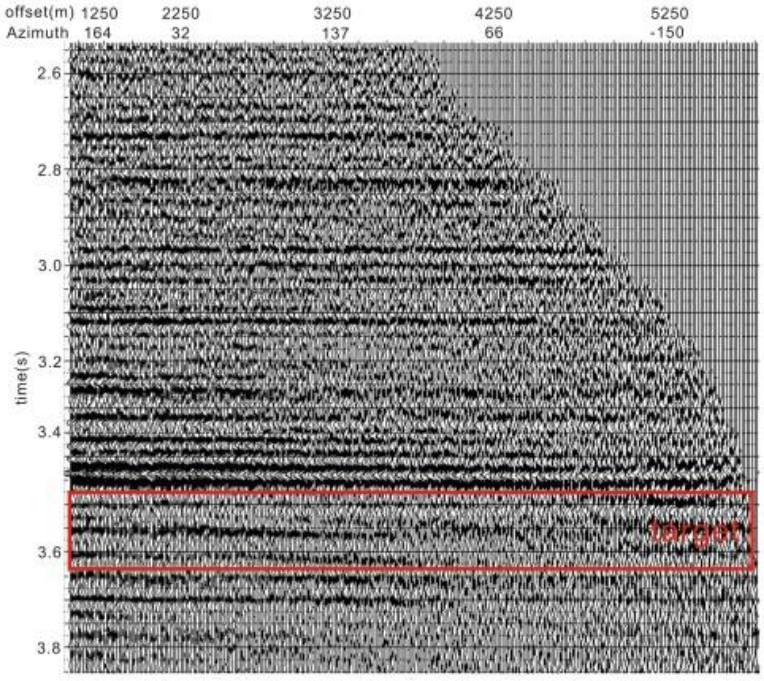


(b)

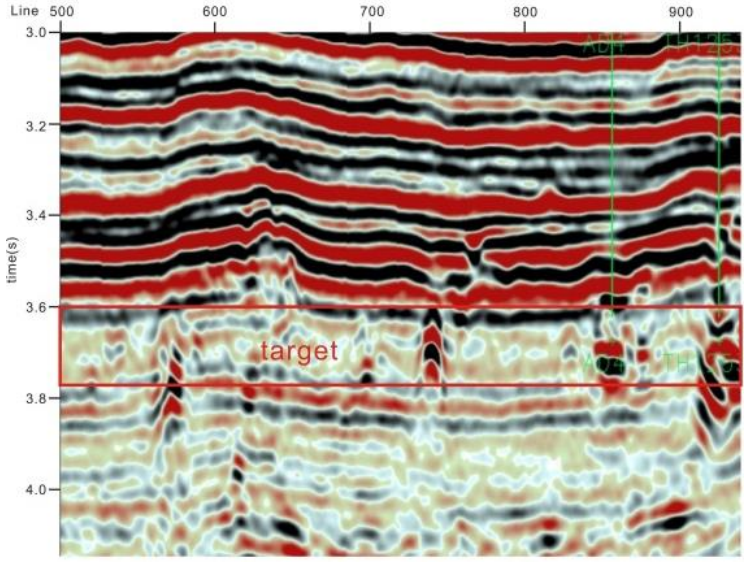
Fig. 1. The distribution of offsets and bin attributes. (a) The distribution of offsets. (b) OVT vector slice division.

3. Case study

Here we apply those methods on the full azimuth seismic data from Tahe oilfield in Tarim basin of north-west China. Tahe oilfield is a large Ordovician fracture-cavity type carbonate heavy oil reservoir, caves are the main reservoir space and fractures are the main connection channel, with a buried depth over 6000m. The study was based mainly on anisotropic pre-stack azimuth gathers, post stack seismic data, well logs and imaging logging interpretation data. Seismic acquisition uses 15 meter spacing, with a folds of 294 and full-azimuth (Fig.1). Dominant frequency of post stack seismic is approximately 25Hz, and the frequency bandwidth is 8-60Hz. The time depth of karst caves located at 3.6s~3.8s, with a higher signal to noise ratio (SNR) in caves position, lower SNR beyond caves (Fig.2).



(a)



(b)

Fig. 2. Seismic section features. (a) anisotropic pre-stack azimuth gathers. (b) post stack seismicprofile.

Based on the result of synthetic seismogram calibration and horizon interpretation, a time window of 10ms is chosen to extract post stack attributes and pre-stack inversion result. Fig.3 shows the fracture prediction results of different methods composited with faults. It's clearly that coherence (Fig.3a) and variance (Fig.3b) attribute mainly reflects the characteristics of faults and edges of caves, fractures are hardly recognized, while ant tracking (Fig.3c) and AVAz inversion (Fig.3d) shows more information about fractures. Four wells of imaging logging interpretation results are used in comparison (A04, A08, A10 and A13 four wells). The result of AVAz inversion shows high fracture density at all the four well spot, which represents high fracture density with a coincidence rate of 100%, while ant tracking attributes map shows only three well spots (A04, A08 and A10) drop in the fracture zone with a coincidence rate of 75%. Based on the prediction result, ant tracking shows A23 and A10 are connected and AVAz inversion shows A04, A10 and A11 are connected.

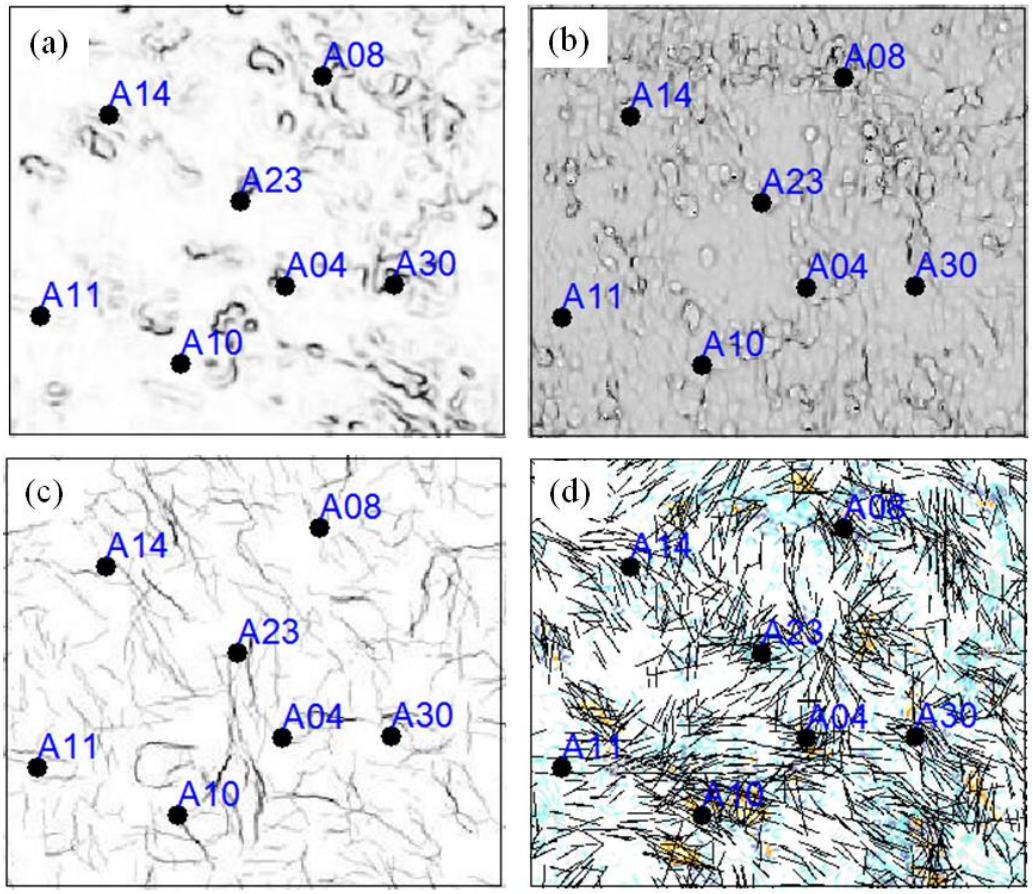


Fig.3. Fracture prediction result by different methods. (a) coherence characterizes of the target layer. (b) Curvature characterizes of target layer. (c) ant tracking characterizes of the target layer. (d) fractures predicted by AVAZ inversion, the black stick represents the fractures, the direction of the stick represents the azimuth of the fracture and the length represents the size of fracture.

Fig.4 shows the azimuth of fractures extracted from two wells, imaging logging presents the accurate azimuth of the fractures. Obviously AVAz inversion shows a higher coincidence with the imaging logging result.

Seven wells are drilled in the study area and all the wells are in production after fracturing. Common evaluation methods of reservoir connectivity usually use well testing, production performance or pressure

analysis [6], while fracturing changed the original connectivity. Conventional methods can not accurately characterize the connectivity between wells. The properties of crude oil in the connected reservoirs tend to be the same under the mixing action, so in this paper we use crude oil distillation range (distillation capacity of crude oil at different temperatures) and trace elements to evaluate reservoir connectivity. Fig.5 shows the composition characteristics of crude oil. Fig.5 (a) shows that A04, A10, A11 have the same characteristics of distillation range and A23, A30 have the same distillation range characteristics, while when it comes to trace elements ratio A23 and A30 are quite different in both Pb/Co ratio and Mn/Co ratio. The two crude oil composition characteristics indicate that A04, A10 and A11 are connected with each other, while the rest wells are not connected, which is consistent with the interpretation from AVAz inversion.

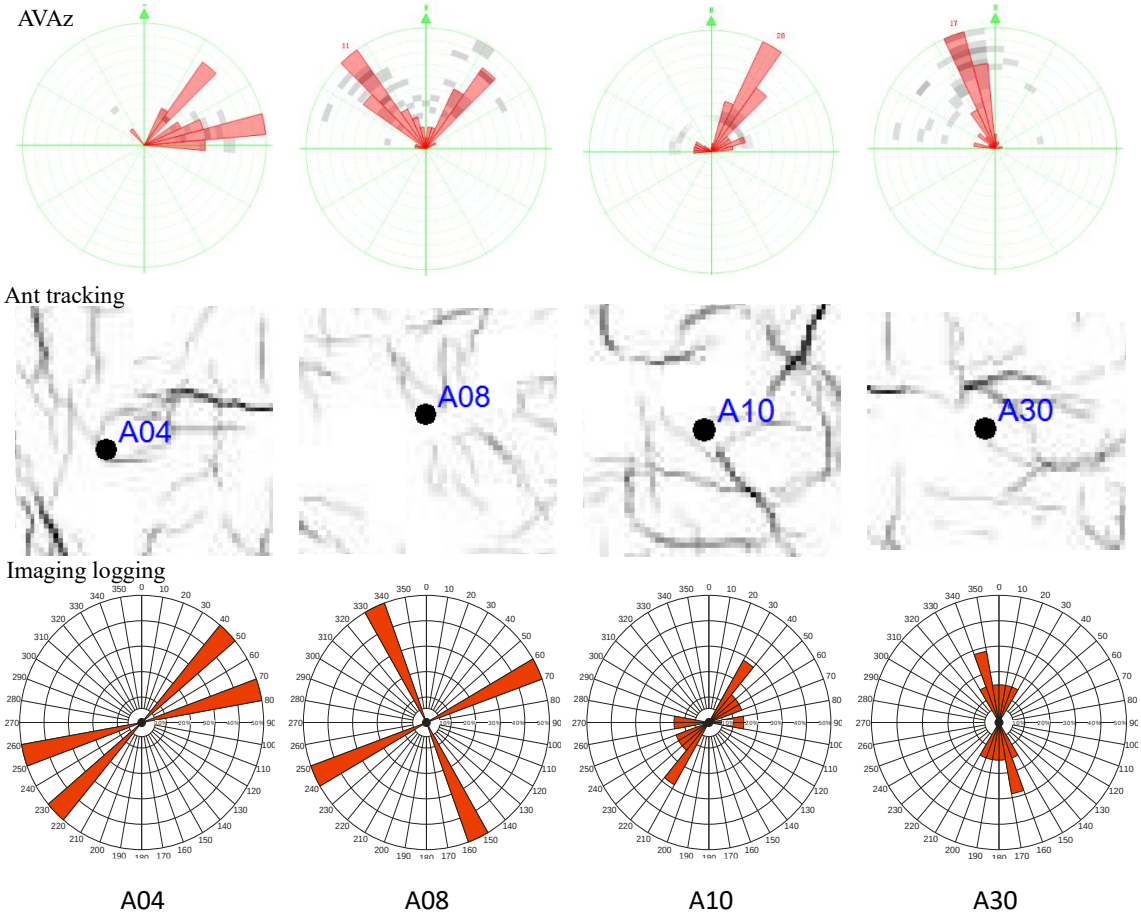


Fig.4 Fracture azimuth prediction result comparison of different methods.

Former research shows azimuthal anisotropy caused by fractures presents changes in travel time, amplitude and velocity with azimuth (Lynn et al, 1995; Lynn et al., 1998). Those differences can be reserved during progressing considered anisotropy. While conventional post stack progressing is based on isotropic theory, during which all the anisotropic information are lost. There are many kinds of fractures developed in carbonate reservoirs such as digenetic fractures, dissolution fractures and contracted fractures et.al have no relationship with structural features Fracture prediction methods based on post stack seismic are more about identifying small faults and large-scale fractures , when it comes to micro-fractures, the scale is far

smaller than the seismic resolution, and anisotropy methods are much more applicable in the prediction of fractures in fracture-cavity type carbonate reservoirs.

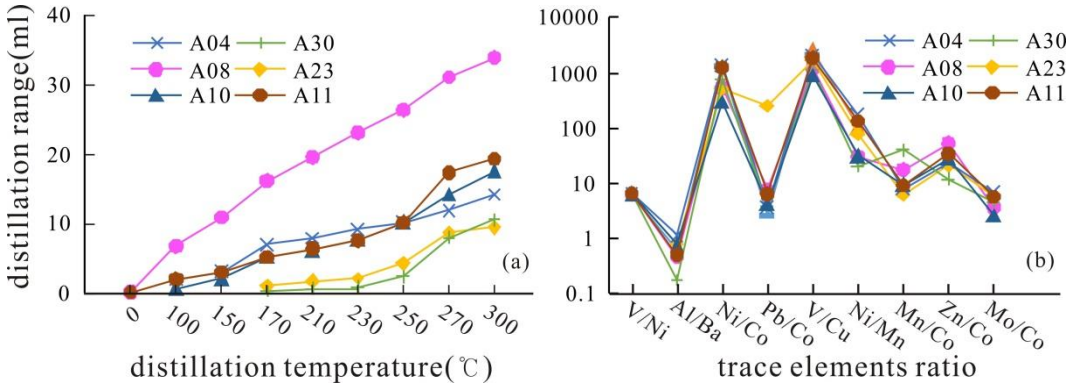


Fig.5. Composition charact3eristics of crude oil from different wells.

4. Conclusions

Take A block of Tarim Basin, China as an example, coherence, curvature, ant track and AVAZ inversion were used to predicted the fracture features, compared with fractures distinguished by imaging logging the following conclusions are drawn. Attributes extracted based on isotropic post stack seismic data such as coherence and curvature are capable of identifying faults and edges of caves, but with on fracture identifying capability. When it comes to fractures AVAz inversion has better identifying ability. Carbonate reservoirs with fractures such as Tahe oilfield anisotropy methods are much more applicable in the prediction of fractures in fracture-cavity type carbonate reservoirs.

References

[1] Zhang Ximing, Zhu Jianguo, Li Zongyu, et.al. Ordovician Carbonate Fractured-vuggy Reservoir in Tahe Oilfield, Tarim Basin: Characteristics and Subdivision of Fracture-vug Units. Marine Origin Petroleum Geology, 2007,12(1):21-25.

[2] Vermeer G J O. Creating image gathers in the absence of proper common-offset gathers. Exploration Geophysics, 1998, 29: 636-642

[3] Marfurt K J, Sudhakar V, Gersztenkorn A, et al. Coherency calculations in the presence of structural dip. Geophysics . 1999.

[4] Wang Yong, Chen Xueguo, Yue Lei,et al. Application of multiple post- stack seismic attributes in the prediction of carboniferous fracture in west Hashan. Progress in Geophysics, 2014, 29(4):1772-1779.

[5] Ruger. Variation of P-wave reflectivity with offset and azimuth in anisotropic media. Geophysics,1998, 63(3):935~947.

[6] Kang Zhihong, Chen Lin, Lu Xinbian, et al. Fluid dynamic connectivity of karst carbonate reservoir with fracture & cave system in Tahe Oilfield. Earth Science Frontiers, 2012, 19(2):110-120.

[7] Lynn H. B., and Beckham, W. P-wave azimuthal variations in attenuation, amplitude, and velocity in 3D field data: Implications for mapping horizontal permeability anisotropy: 68th Ann. Internat. Mtg., Soc. Expl. Geophys., Expanded Abstracts, 1998: 193-196.

[8] Lynn H. B., C. R., Simon, K. M., and Van Dok, R. The effects of azimuthal anisotropy in p-wave 3-D seismic: 65th Ann. Internat. Mtg., Soc. Expl. Geophys., Expanded Abstracts, 1995: 723-730.