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Research on Fracture Prediction Method of Carbonate Reservoir: A Case Study of a Block, Tarim Basin, China

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Abstract
The fracture-cavity type carbonate reservoir has the characteristics of complex porosity system and the prediction of small scale fractures is difficult. Fracture-cavity type carbonate reservoirs of A block in Tarim Basin, China is taken as an example, coherent, curvature, ant tracking and AVAZ inversion is used to predict fracture features in order to evaluate the applicability of different fracture prediction methods. Fracture prediction results shows that coherent and curvature 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, and the direction of fractures of AVAZ inversion is complete agreed with imaging logging, while the directions of ant track is discrepancy. Methods based on post stack seismic are not applicable in fracture-cavity type carbonate reservoirs, and AVAZ provides a better way to predict fractures.

Keywords: fracture-cavity type carbonate reservoir; fracture prediction; post stack seismic; AVAZ inversion.

1. Introduction

The fracture-cavity type carbonate reservoir has the characteristics of strong heterogeneity and complex porosity system. 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 the smallest reservoir development unit the fracture-cave unit shares the same pressure system and hardly exchanged any fluids with outside [2]. There are several methods for dividing fracture-cave units, such as inter-well production interference analysis, fluid differential analysis, reservoir pressure trend analysis and inter-well interference test et al. All those methods are based on wells, connectivity of caves beyond wells remains unpredictable. Fractures and faults are the main channel for the connectivity of caves determine the size of the fracture-cave unit, while accurate prediction of fracture remains tricky.

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

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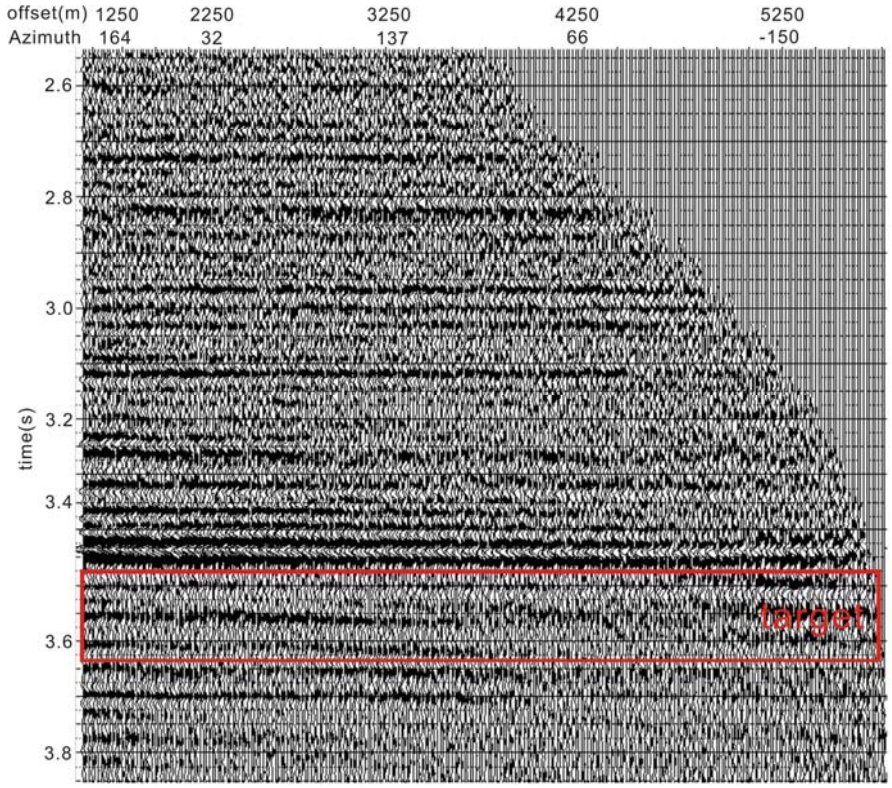
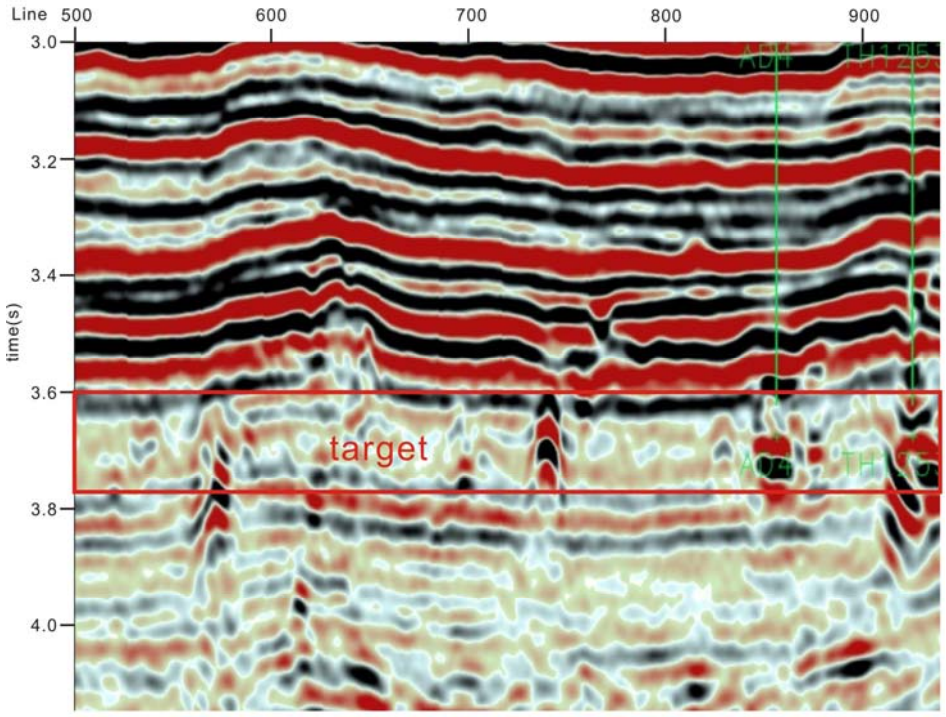


(a)



(b)

Fig. 1. Seismic section features

(a. anisotropic pre-stack azimuth gathers; b. post stack seismic)

2. Methodology

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 [3]. Coherence, curvature 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].

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.

3. A Case Study of Tahe Oilfield

A block is a large Ordovician fracture-cavity type carbonate heavy oil reservoir, with caves as the main reservoir space and fractures as the main connection channel, which located at northern Tarim Basin, Xinjiang province, China. 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. Dominant frequency of post stack seismic is approximately 25Hz, and the frequency bandwidth is 8-60Hz. The time depth of caves located at 3.6s~3.8s, with a higher signal to noise ratio (SNR) in caves position, lower SNR beyond caves (Fig.1).

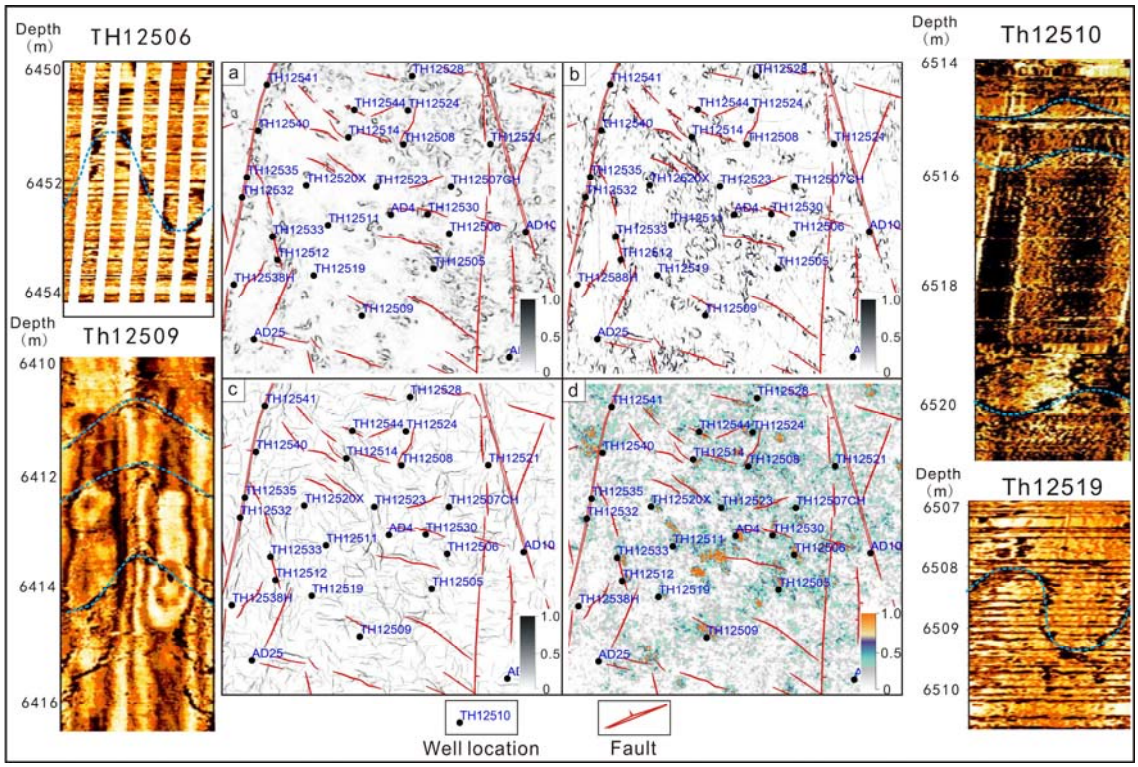


Fig.2. Map of fracture prediction composited with faults

(a. Coherence; b. Curvature; c. ant tracking; d. AVAz inversion)

Based on the result of synthetic seismogram calibration and horizon interpretation, a time window of 5ms is chosen to extract post stack attributes and pre-stack inversion result. Fig.2 shows the fracture prediction results of different methods composited with faults. It's clearly that coherence (Fig.2a) and curvature (Fig.2b) attribute mainly reflects the characteristics of faults and edges of caves, fractures are hardly be recognized. While ant tracking (Fig.2c) and AVAz inversion (Fig.2d) shows more information about fractures. Four imaging logging interpretation results are used in comparison. The result of AVAz inversion shows high values of anisotropic gradient at the four well spot, which represents high fracture density with a coincidence rate of 100%, while ant tracking attribute map shows only three well spots (TH12506, TH12510 and Th12519) drop in the fracture zone with a coincidence rate of 75%.

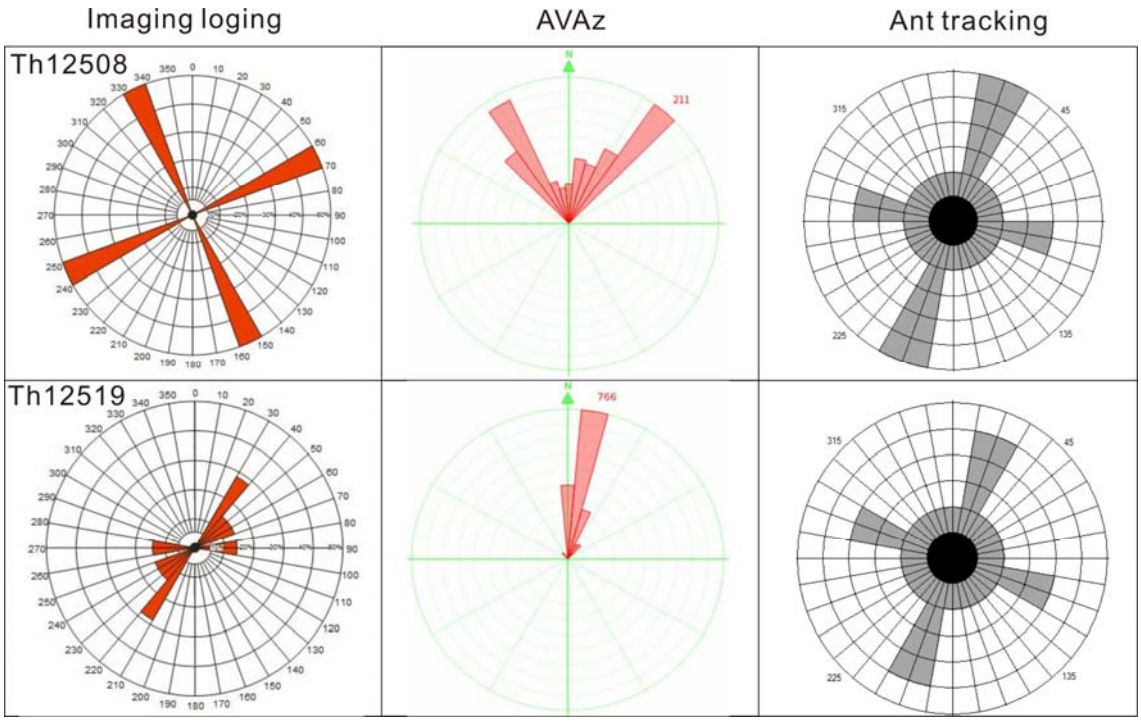


Fig.3. Prediction of fracture azimuth

Fig.3 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.

Former research shows azimuthal anisotropy caused by fractures presents changes in travel time, amplitude and velocity with azimuth [6,7]. Those difference 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 diagenetic 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.

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.Large-scale fractures and small faults can be identified well by ant tracking but the directions of fractures can't be predicted, when it comes to micro-fractures AVAz inversion has better identifying ability.Carbonate reservoirs with various micro-fractures such as A field anisotropy methods are much more applicable in the prediction of fractures in fracture-cavity type carbonate reservoirs.

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