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Research Advances

Amplitude Non-Sensitive Stratal Dispersion Shadow for Dim Spot Reservoir Delineation

ZHONG Wenli[1, 2], CHEN Xuehua[1, 3, *], LUO Xin[3], JIANG Wei[3] and YANG Wei[4]

1 *State Key Laboratory of Oil & Gas Reservoir Geology and Exploitation, Chengdu University of Technology, Chengdu 610059, Sichuan, China*
2 *College of Earth Sciences, Chengdu University of Technology, Chengdu 610059, Sichuan, China*
3 *Key Lab of Earth Exploration & Information Techniques of Ministry of Education, Chengdu University of Technology, Chengdu 610059, Sichuan, China*
4 *Research Institute of Exploration and Development, Northwest Oilfield Company, Sinopec, Urumqi 830011, Xinjiang, China*

Objective

Dim spots are those gas reservoirs located in relative deeper target strata in which seismic reflection energy remarkably goes down or disappear, and are thus quite difficult to recognize in comparison with the bright spots in conventional seismic interpretation due to their weak reflection amplitude. To pursue the amplitude non-sensitive indicators to brighten dim spot reservoirs, this work presents the stratal dispersion shadow (SDS) to reveal the hydrocarbon dim spots by measuring their dispersion anomalies instead of their reflection amplitude.

Methods

The inherent dispersion is dependent mainly on the permeability, pore geometry, fluid types and saturations of porous reservoirs with low acoustic impedance contrast. We derived a frequency-dependent AVO linear approximation that is a function of incident angles of seismic P-wave and frequency-dependent elastic moduli which depict dispersion variation rates. Next, we performed the inversion of elastic moduli dispersion on the seismic angle gathers by employing the frequency-dependent AVO inversion method. The dispersion combination factor developed by the crossplot between elastic moduli dispersion attribute at the characteristic frequency and well log is the most sensitive to hydrocarbon accumulation. Then, its anomalies, shown as the SDS at the bottom of the dim spot reservoir and underlying reflection interfaces, can be used as an indirect indicator of dim spot reservoirs.

Results

The method is applied to the seismic data from the TH oil field in northwestern China (Fig. 1).There is a distribution of carbonate reservoirs at the top strata in the target interval of the T74 Formation. However, since the reservoirs locate in the deeper strata (>6500m) and there are distributions of complex fractures and karst caves in different scales in the strata, the reflection events of reservoirs suffer from notable lateral discontinuities with quite weak reflection amplitude and lower dominant frequency. In Fig 1a, we can see the significantly diminished seismic reflection amplitude or energy of the carbonate reservoir shown as the dim spot (denoted by a cyan arrow). This leads to a huge challenge for gas reservoirs delineation on conventional seismic amplitude-dependent attributes and inversive parameters transformed from seismic data. We then performed the frequency-dependent AVO inversion on the seismic angle gathers and obtained the most sensitive dispersion combination factor produced by the dispersive Lamé elastic moduli of λ and μ at the characteristic frequency of 28Hz (Fig. 1b). Although the reflection energy of the gas reservoir (indicated by a cyan arrow) at the upper layers in the T74 Formation on the raw section passing through well TX7 (Fig. 1a) are quite weak, in Fig. 1b, a significant SDS (indicated by a black contour) related to the invisible hydrocarbon accumulation (indicated by a cyan arrow) at the top of the T74 Formation can be observed immediately beneath the reservoir on the dispersion combination factor section. In this field data example, the SDS is an indirect hydrocarbon indicator that delineates the upper carbonate reservoir. The hydrocarbon anomalies indicated by the

* Corresponding author. E-mail: chen_xuehua@163.com

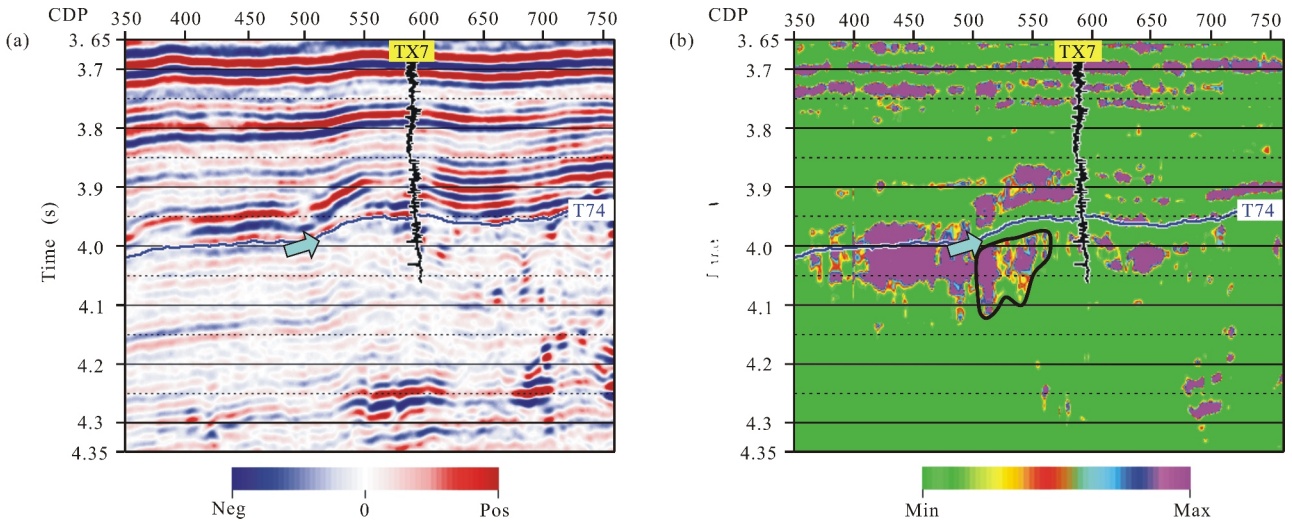

Fig. 1. (a), Stacked seismic section; (b), Dispersion combination factor section. Note that the reflections of the reservoir nearly diminish in Fig. 1a whereas a notable SDS is exhibited beneath the reservoir in Fig. 1b.

SDS correlate well with the known production of well TX7.

Conclusion

The SDS resulted from the presence of pore hydrocarbons can be measured in dim spot reservoirs and their underlying reflection interfaces. Despite the seismic reflection energy of dim spots goes down or nearly diminishes, the SDS still exhibit a notable anomalies. Since the dispersion is independent on the seismic reflection amplitude at the interfaces across the dim spots and their surrounding rocks, the SDS is an amplitude non-sensitive measurement which can be used as an indirect indicator to illuminate the subsurface dim spots and a potential hydrocarbon saturation indicator.

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