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A Review of Thin Layer Methods

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Abstract: The thickness, lateral connectivity and boundary position of the thin layer are increasingly becoming the focus of lithologic seismic exploration, but the recent progress on thin layer have less systematic summary. Therefore, four aspects of thin layer research relating to research subject, forward modeling method, time-frequency analysis method, thickness prediction method are summarized. The following conclusions show that spectrum variation regularity of reflected wave is the key to thin layer analysis. A quantitative relationship between the peak frequency or notches frequency and thin layer thickness has already established. Wave equation forward modeling can reflect the dynamic characteristics of seismic wave in the propagation process, so the simulated wave field information is more rich and real. Analytical tools of reflected wave field are from time domain, frequency domain analysis to the time-frequency analysis and temporal characteristics of the reflected wave spectrum are took more attention. Thus wave field characteristics of thin layer are gradually evolved from a simple qualitative analysis to quantitative prediction direction.

Keywords: Thin layer, Quantitative prediction, Forward modeling, Time-frequency analysis, Wave equation.

INTRODUCTION

Widess defined the thin layer is the thickness which is less than 1/8 of main wavelength of formation [1]. Neidell *et al.* defined as the 1/4 wavelength of the main thin "tuning thickness."[2]. Indeed, consider the impact of noise and wavelets, usually 1/4 wavelength corresponding to the primary layer thickness as the actual seismic resolution limit, in this sense, refers to a thin layer of its two-way travel time is less than the thickness of the incident tuning thickness (1/4 wavelength) and on conventional seismic stratigraphy indistinguishable.

Although thin geological structure is simple, but it is thin interbedded important geological basic research wedge-shaped body, lens, river sand, etc. Therefore, in-depth understanding of a thin layer of the seismic response characteristics, particularly its time-frequency domain response features, correct identification and interpretation of the above geological significance [3-9].

Years of exploration and practice has shown that thin research and research more difficult compared to the thick layer, because the occurrence of seismic reflection thin layer interfere with each other, so that a thin layer of seismic reflections from the various aspects of the change in the intensity and other characteristics of the waveform and have a thick layer different characteristics. In theory, due to the resolution of seismic data by itself, a thin layer of research also have significant limitations and uncertainties, the actual seismic data, a limited number of all kinds of interference and is caused by seismic acquisition and processing factors signal distortion. In addition, the thin layer can accurately extract seismic attributes and the quantitative relationship between these properties and the thickness of thin layers also major factors affect the prediction accuracy [10].

Many domestic and foreign scholars from different angles, using different means of thin-layer analysis a lot of research, made a lot of new knowledge, new achievements, which TLC study played an important role in promoting. But so far, still it does not have a system of elaborate literature research progress by TLC. Therefore, the author of a large number of thin literature of the sort, from the study, forward modeling method, time-frequency analysis method, a thin layer of thickness quantitative prediction method which gives an overview of the four angles of a thin layer of research, hoping to follow TLC study has certain significance.

SUBJECTS

Source

Seismic trace can be seen as the source wavelet and reflection coefficient phase formation convolution process. Because the underground geological structure is determined, so the reflectance spectrum is determined, but really the main factor to influence and control the spectrum of the reflected wave is the source wavelet spectrum, its frequency and the band width determines the size of the reflected wave frequency spectrum and bandwidth. Voogd and Rooijen deduced by the theory: a thin layer having a reflection source in the form of a wavelet of the first derivative, source pulse shape, particularly the shape of the amplitude spectrum and the spectral bandwidth of the reflection wavelet response curve has an important influence. Proposed a thin layer of basic principles identified: in solving a problem, if the wavelet resolution falls we call "not ideal" range, we can try to increase the spectral bandwidth, in order to distinguish the two interfaces, if seismogram the frequency cannot achieve this goal, we can turn to reduce the frequency, so that the study of the formation to become "thin" [11].

Sunlu Ping *et al.* [12-13] by means of three-thin dual interface model discussed the impact of the type of wavelets, wavelets and wavelet phase peak frequency and peak frequency of a thin layer thickness relation. He used Ricker wave, damped cosine wavelet, wavelet damped sine stretched thin wedge, respectively, relative to the convolution model making synthetic seismic trace, through a comparative study found that: different sub-wave seismic response waveform obtained very different. Under zero-phase and 90 degree phase and 180 degrees phase wavelet of the peak frequency and the thickness of the curve is completely coincide (Fig. 1), indicating that the same sub-wave type of situation does not affect the phase tuning earthquake caused peak TLC frequency characteristics. With the reduction in thickness, the higher the peak frequency wavelet, seismic response of a thin layer of "upscaling" phenomenon reflects the more obvious (Fig. 2), indicating that the seismic waves have a higher frequency, the more favorable interpretation layer [14]. This shows that the source wavelet in the wave type, peak frequency, spectral width and other characteristics of seismic response characteristics on the thin layer is relatively large, while the phase characteristics less affected.

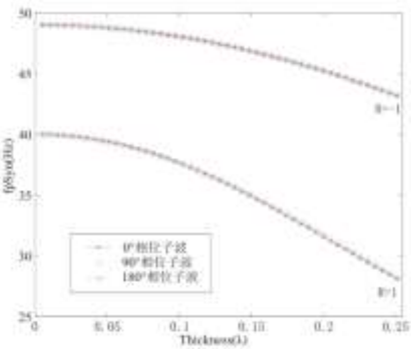


Fig-1: Relationship between peak frequency and

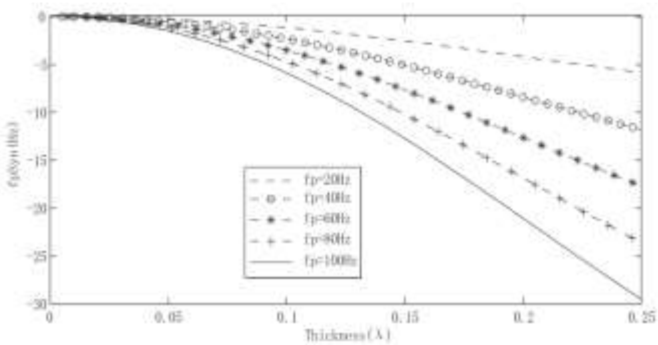


Fig-2: Relationship between Increment and the thickness of the synthetic track thickness of the peak frequency

Reflectance spectrum

In addition to the source, the reflection coefficient and polarity, size, spacing, composition relationship reflection wavelet spectrum is currently a critical study of thin. Voogd by calculating (the thickness of the thin layer; a thin layer of wavelength) and a function of the reflection coefficient, and the obtained thin layer thickness is approximately linear response, and the response of its thin calculated approximate linear a difference of 10% of the value, referred to as the linear limit, may result in different reflection coefficients of the linear limit is influential [11], it provides a reference for future generations from the angle of reflection coefficients for sheet. By summarizing the results of previous studies can be drawn: the polarity and magnitude of the reflection coefficient determines the form of the amplitude spectrum; polarity affects the reflection coefficient of the spectral peak frequency, phase shift, zero amplitude values, etc.; determines the size of the reflection coefficient the strength of its spectral energy [15-17]; and when the top and bottom of a thin layer of the reflection coefficient is not the same polarity, changes of the time and frequency domain characteristic parameters are very different, generally speaking, when the reflection coefficient a thin layer having a polarity opposite upscaling decline in the role of having the same polarity increases down effect [18]; when the spacing of the reflection coefficient is small, synthetic seismogram can not reflect the size of each individual and the reflection coefficient polarity and other characteristics, but rather reflect the reflection coefficients; TLC factors increase or decrease the tuning frequency caused by the thin layer of top portfolio at the end of the reflection coefficient for thin, tuning effect of different combinations of the reflection coefficient caused by frequency the variation is different [14]. These conclusions have important guiding significance for the future of thin research.

In the reflection coefficient spectra of the thin layer, there is an important issue worthy of discussion, whether the incident wave normal incidence. Wangen Hua in the derivation of a plurality of thin vertical angles of incidence in any conditions, longitudinal shear wave reflection coefficient on reflectance spectrum theory, based on a simplified single thin layer of normal incidence spectrum formula, derived from his course of can be drawn: when assuming that the incident wave is normal incidence, the formula to calculate this time TLC reflectance spectra only the speed and density of about [19]. When any incident angle, reflection coefficient spectrum is not only the speed and density, but also with Poisson's ratio, the angle of incidence, transmission angle and so on. It follows that when we calculate the reflection characteristics of the thin layer thickness on reflectance spectrum and the relationship between the formula and the study should also consider the thin layer of normal incidence of the incident wave are satisfied.

FORWARD MODELING METHOD

Convolution model law

Convolution model convolution method in the production of synthetic recording seismic waves and the reflection coefficient of the geological body interface or, to put this forward model called the convolution model.

Early research by many scholars abroad are utilizing the convolution model of thin conduct forward studies [20], for example, Okaya and Widess classic series is the use of seismic convolution model. The most important feature of this method is described kinematic characteristics of seismic wave propagation, and calculation speed, the propagation time of the resulting seismic waves more accurate. But there are obvious shortcomings, Du Shi Tong pointed out that many phenomena such as seismic data implied thin tuning effect amplitude waveform amplitude changes along the horizon, a large number of layers reflecting its internal reflection interface crossover phenomena cannot be used seismic convolution model to explain and difficult to use traditional geological-geophysical model will be explained. In recent years, observed in a large number of high-resolution seismic data in complex phenomena fall into this category.

In short, the convolution model ignores the seismic waves geometric diffusion effect and a phase change in the communication process, but also susceptible to the formation medium complexity and acquisition system, and cannot fully simulate seismic wave's underground medium propagation.

Wave equation

Due to lack of convolution model itself, seismogram after the simulation is difficult to reflect the real situation of the wave field. Using wave equation forward modeling of seismic wave fields recorded information after the simulation rich, the kinematic and kinetic characteristics of seismic waves can be maintained, as the initial source wavelet can be used to simulate wave propagation in underground media field to achieve a pulse point, thereby obtained consistent with the actual seismic recording analog recording. Zhou Li *et al.* designing different hydrocarbon thin layer of sand body model for the wave equation forward modeling, has been CRP gather records extracted object layer reflection amplitude, calculated based on the incident wave amplitude reflection coefficient to obtain a thin seismic AVO forward curve, AVO analysis of clastic reservoirs in Tahe Oilfield with different fluids, find out the correspondence between the hydrocarbon potential and AVO attributes of the actual geological conditions, to guide the seismic section containing fluid forecasting. This shows that more practical forward modeling based on wave equation. Currently based thin wave equation forward modeling literature is not much, but its unique advantages will become thin forward modeling study in a new direction.

FREQUENCY ANALYSIS MEANS

Fourier, short-time Fourier and wavelet transform

Early research is characterized by a thin layer of frequency domain Fourier domain expanded. Yao Jianyang by Fourier transform in the frequency domain of the reflectance spectrum and the relationship between the thickness and seismic stratigraphy and stratigraphic thickness spectrum relationship were discussed, and the amount of produced formation thickness strike plate stratigraphic thickness. But Fourier transform is a unitary transformation can only understand the signals in the time domain and frequency domain global characteristics, cannot give the signal spectrum transient characteristics. To solve this problem, Gabor proposed a short window Fourier transform (STFT), the basic idea: using the window function signal interception, assuming the signal within the window is smooth, then the signal within the window Fourier transform to determine the frequency of the time, and then move along the window function signal to obtain a frequency signal changing with time. This analysis method is also applied in a thin layer of research, however, due to the short-time Fourier transform using a fixed analysis window, it is difficult to adapt to non-stationary seismic signal, so that the instantaneous frequency spectrum obtained there are some errors, and the uniqueness of its window function defines a resolution of the uniqueness.

In the late 1980s in France and geophysicists J. Morlet theoretical physicist A. Grossmam wavelet transform theoretically establishes a framework for the system, the introduction of wavelet transform scale factor. The advantage is to overcome the shortcomings of single-resolution analysis of the short-time Fourier transform, and it is only the most relevant searches and signal number of atomic items of the strong centralized information. The disadvantage is that once the basic wavelet function is selected, you must use it to analyze the entire signal all of the data, which makes thin wavelet transform frequency analysis application is limited.

Generalized S transform

Stockwell with Morlet wavelet based on the inheritance and development of short-term thinking localized Fourier transform and wavelet transform, using Harmonic and Gaussian function as a basic product of the wavelet transform first proposed S. S transform basic transfer function form fixed, limited In practical applications. Therefore, many scholars basic S basic wavelet transform or window function was improved, and the generalized S transform. It has many advantages:

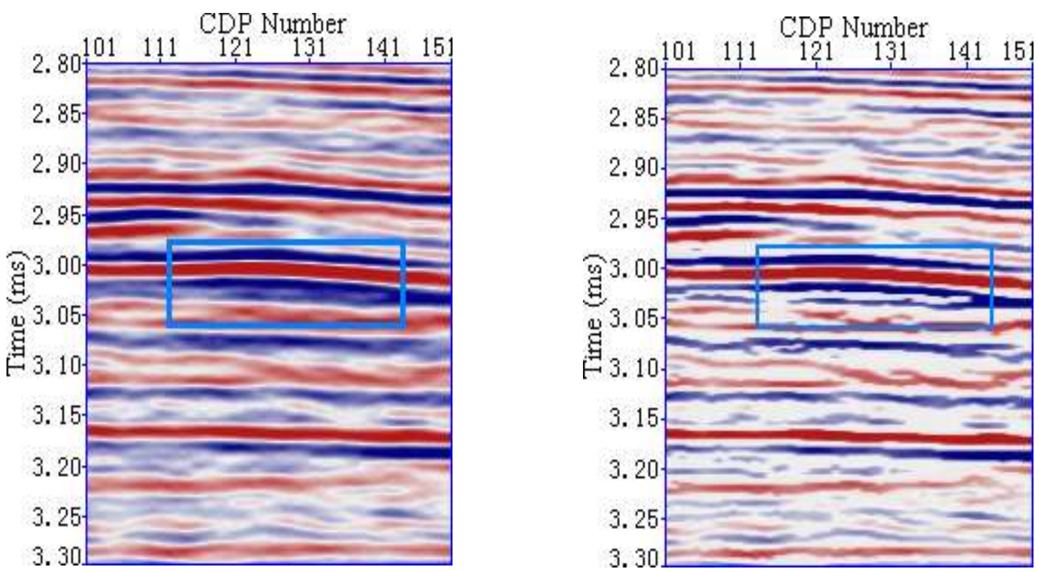
(1) generalized S transform can effectively overcome the short-time Fourier transform window function selected fixed frequency resolution of problems, its window function adaptively inversely proportional to the frequency change (i. e scale), and fully meet the non-seismic signals smooth requirements;

(2) as a generalized S transform time-frequency analysis method combines the advantages of short-time Fourier transform and wavelet transform, it is possible to obtain better time-frequency analysis taking into account the effect of temporal resolution and frequency resolution, can take the actual seismic data suitable wavelet function is calculated;

(3) The use of generalized S transform to extract single-frequency profile can clearly depict the top and bottom of a thin layer of the interface, with a high resolving power, geological thin recognition provides a new method and thinking.

Xiong Xiaojun *et al.* using the information generalized S transform high-frequency information indicating a thin top and bottom of the interface, the development of high-resolution cross-sectional transform based generalized S. Fig. 3 (a) is a period of a western oil fields stacked section, Fig. 3(b) is a high-resolution cross-sectional view of the generalized S transform. Compare these two cross-sectional views, Fig. 3(b) broadening the main frequency seismic records, effectively increasing the resolution. Fig. 3 (a) of the box, due to the low frequency seismic waves appears tuning phenomenon phase axis, but in Fig. 3 (b) of the box, due to increased seismic wave frequency and phase axis is very clear.

Although generalized S transform has many advantages, but with the single frequency extraction section will increase the frequency of false geological thin layer of workers will cause exploration judgment was error, so the use of generalized S transform while in practical applications but also with other comprehensive analysis of geological data, will achieve better results.



(a)The seismic profile; **(b) The high resolution profile**

Fig. 3 High resolution maps of real data

SUMMARY AND OUTLOOK

TLC study after several decades of development and improvement, made a series of studies. Object of study and reflection coefficients from the source to the spectrum of the reflected wave spectrum analysis development, and establish a reflected wave peak frequency or frequencies quantitative relationship between depression and thin thickness; forward modeling from the convolution model commonly used equations to simulate the development direction of volatility so that the seismic wave field information richer, more real; analytical tools from Fourier transform frequency analysis method when the direction of the generalized S transform and matching pursuit, etc., when the combination of frequency from a simple time domain and frequency domain analysis of the development, focus transient characteristics of the reflected wave spectrum; progressive development from simple qualitative analysis to quantitative prediction direction. The study of high-precision sheet thickness qualitative identification and quantitative prediction laid an important theoretical basis.

While previous research on thin layer has made some progress, but there are still many problems to be solved. The key to improving the ability to identify a thin layer is to improve the sub-bandwidth wave, so a high-resolution thin layer technology has been the subject of research. In addition, thin-based thin interbedded will be a focus of future research period. Thin interbedded sedimentary type is mainly under the actual geological conditions, single-layer thickness of the seismic reflection not only of the thin interbedded within the group, but also on the number of layers in the group, the group was difference between the layers and the reflection wavelet and frequency attenuation coefficient related, but there are different thicknesses and interlayers combination of relationship, therefore, thin interbedded identification and quantitative estimation of the difficulty will be even greater, longer-term fundamental research needs, will be a major breakthrough.

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