AVO Analysis of a Single Thinning Bed
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ABSTRACT

Synthetic seismograms are constructed with a Ricker wavelet of 50 Hz dominant frequency to represent a gradually thinning bed with equal magnitude and opposite polarity reflection coefficients in a homogeneous medium. A tuning thickness of λ/4 is observed for the PP data. AVO intercept and gradient crossplot analysis is studied for a shale embedded in sandstone and a sandstone embedded in a thick homogeneous shale unit. For a slow velocity thin layer above tuning thickness, the AVO crossplot results show a counter-clockwise rotation, indicating a negative correlation as the gradient decreases and the reflection coefficient magnitude increases. For the fast velocity thin layer, a clockwise rotation occurs in the AVO crossplot trend results as the bed thins. The gradient increases and the reflection coefficient magnitude decreases. Results below tuning thickness are less predictable, and could be misinterpreted as either a change in porosity or lithology.

INTRODUCTION

Thin bed reflection studies are important to evaluate resources in thin reservoirs, studying sedimentary processes, and surface resolution for structure mapping. Resolving and defining thin layers is difficult and challenging (Chang et al., 1996), and many approaches can be taken. Vertical seismic resolution is defined by Widess (1973) as the thickness equal to one eighth of the seismic predominant seismic wavelength. However, this threshold does not account for noise and wavelet broadening, so one quarter of the predominant wavelength is taken as an industry standard for thin bed vertical resolution. This vertical resolution threshold is also known as the tuning thickness, or tuning point, and is where maximum constructive amplitude occurs.

AVO analysis is useful in identifying lithology, predicting pore fluid content, and evaluating hydrocarbon potential. The AVO effect is dependent on the petrophysical properties Vp, Vs, and density p. Crossover plot analysis of AVO parameters such as a scatter plot of P-wave reflectivity (Intercept) and the AVO gradient defined by Shuey’s approximation of the Zoeppritz equations are useful in identifying linear trends in clusters of data for further analysis.

This study examines the case of thinning beds having equal magnitude and opposite polarity. Two geological models are investigated; a gradually thinning embedded lower velocity and density layer, and a gradually thinning embedded higher velocity and density layer in homogeneous media. Models of flat reflectors are created with a moderate acoustic contrast at the interfaces. AVO crossover analysis investigates the reflectivity behaviour of thinning beds with offset.

THEORY

The Zoeppritz equations describe how the energy of a plane wave partitions into transmitted and reflected waves at an elastic interface between two isotropic and homogeneous half-spaces, relative to the incident angle. Shuey (1985) simplified the Zoeppritz equations to give the P-wave reflectivity coefficient as a function of angle of incidence:

$$R_{PP} (\theta) = A + B \sin^{2} \theta + C (\tan^{2} \theta - \sin^{2} \theta)$$

(1)

where A represents the linearized zero-offset P-wave reflection coefficient, B is the AVO gradient which approximates reflection amplitudes at various offsets and depends on the sine of the angle of incidence squared, and C is the AVO curvature term which is dropped for angle of incidence greater than 30°. These coefficients are often used as AVO indicators for modeling studies (Castagna and Smith, 1994).

RESULTS

MODEL I

The reflection points follow a counter-clockwise rotational trend above tuning thickness, and amplitude decreases with offset. However, as the bed continues to thin below tuning, the results could lead to misleading interpretations.

MODEL II

An amplitude peak occurs on the top of the Sh-SS interface, and a trough on the bottom S-SS interface. As the sandstone bed thins, the Intercept-Gradient crossplot rotates clockwise. Amplitude decreases with minimum offsets.

CONCLUSIONS

Two cases of each a slow and fast velocity thin layer embedded in a homogeneous medium is modelled as a synthetic seismogram with equal magnitude but opposite polarity. Thin beds below tuning thickness cause limitations and complexities in the theoretical analysis of the Zoeppritz reflection coefficients and AVO crossplot analysis as the top and bottom interfaces of the thin layer converge. Variations in the AVO crossplot due to tuning thickness can be misinterpreted as either a change in porosity or lithology.

Future work includes exploring unequal polarity or strength models, and multiple beds. Also, by further investigating frequency and enhancing the spectral bandwidth of the seismic data, the theoretical limits of resolution can be improved and tuning thickness further decreased (Chopra et al., 2006). Using a 90 degree Ricker wavelet is proposed by Zeng (2009) to focus more on resolving the bed itself, rather than the interfaces to identify thickness.

REFERENCES


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