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Univeristy of Science and Technology AGH in Kraków

Faculty of geology, Geophysics and Environmental Preotection

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Title of the doctor al thesis: Spectral decomposition of a seismic signal: thin bed thickness estimation and analysis of attenuating zones

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Summary

The doctoral thesis describes frequency analysis of a seismic signal by the use of spectral decomposition. The analysis focused on two aspects. One which was application of spectral decomposition algorithms for thin bed thickness estimation, and the other – the analysis of attenuating zones. To complete these tasks synthetic 2D and 3D seismic data were used as well as real 3D seismic data.

Thin bed thickness estimation was performed with the application of fast Fourier windowed transform. The first model was a single layer model which was used to test the applicability of the algorithms in commercial geophysical software. The results occurred to be positive – the method enabled to estimate correctly temporal thickness of a single layer.

Next, according to the data from the well Lubocino-1, a multi-layered models indicating the Paleozoic strata interval were created. Layers that were the subject of the analysis are considered to be seismically thin but of significant shale gas potential. The seismogeological models were convolved with the elementary Ricker wavelets of different peak frequencies as well as wavelets extracted from a 3D seismic dataset – Lubocino 3D seismic survey. The models underwent spectral decomposition process with the use of three available algorithms. The decomposition algorithms based on Fast Fourier Transform (FFT), Continuous Wavelet Transform (CWT) and Complete Ensemble Empirical

Mode Decomposition (CEEMD). For the model data chosen seismic attributes were computed: dominant frequency and instantaneous frequency.

The aim of a/m procedures were to calibrate spectral decomposition parameters and to find an optimal set of seismic attributes that would be helpful for thin bed thickness estimation. The calibration of the decomposition parameters enabled to separate the best set for which the results were most promising. Parameters that were tested enclosed: window length for the FFT method, choice of the base wavelet for the CWT method, number of iterations, noise level and number of frequency slices for the CEEMD method. The chosen parameters were applied to the real 3D seismic data.

The focal conclusion of thin bed thickness estimation is that the quantitative estimation is only possible for the single layer model and it fails to succeed in more complex geological setting. Nevertheless, the qualitative thickness analysis with the use of spectral decomposition algorithms is possible and it gives good and reliable results. So as to seismic attributes instantaneous frequency is an attribute that is helpful for thin bed identification.

The attenuating zones analysis was performed according to the theoretical concept of a transition zone which is characterised by selective, dependent on frequency signal attenuation. The theory of a transition zone – Wolf ramp is introduced in the doctoral thesis. The transition zone is understood as a zone of linearly changing velocity with depth (density is assumed to be constant.).

For the transition zone modelling and numerical verification were undertaken in order to verify if its response would be visible in commercial geophysical software. Tests were successful. The possible Wolf ramp occurrence was linked to the lower Silurian deposits, the Pasłęk Formation which is defined in the well Lubocino-1. For the chosen interval the velocity curve manifests itself by the steady drop, that can be arbitrary classified as linear. The seismic response of this interval is considered to be insignificant which excludes the horizon from routine seismic interpretation. The seismic reflections that are linked to the Pasłęk Formation have low amplitude and dynamics but the interval may be a potential shale gas horizon. Hence finding an alternative way of its analysis is a matter of the paramount importance.

The synthetic seismograms analysis enabled to state that the amplitude of a seismic reflection from the interval of interest indeed depends on frequency. The amplitude increases for low frequency values (in order of 15-20 Hz).

First, to verify the applicability of the set of analyses, seismic inversion was performed. The inversion process was computed according to the well data from well Lubocino-1 and for synthetic data volume spectral decomposition were applied. The results of spectral decomposition were promising – the interval of interest manifested itself by an increase of amplitudes for lower frequencies. The application of spectral decomposition methods for real 3D seismic section gave good results which are consistent for all algorithms. The best results among them gave the CEEMD method. According to this results it was possible to interpret the top and the bed of a low-frequency anomaly and afterwards to compute the thickness map for the interval of interest within the Lubocono 3D seismic survey.

The application of instantaneous frequency enabled to interpret the additional seismic horizon which lays between two horizons that were not previously interpreted. These horizon were to thin for routine seismic interpretation due to their insignificant thicknesses. The additional seismic boundary between them is linked to the strong high frequency anomaly that was interpreted with the use of spectral decomposition and instantaneous frequency.

As a result the Pasłęk Formation was classified as an example of the transition zone. The analysis is concluded by the discussion about the possible source of a transition zones occurrence in the specific geological setting. It was possible to state an open question about causal or coincidental relationships that can be encountered for the interval of interest in the wells in the vicinity of the survey area: Kochanowo-1, Oplino-3 and Wysin-1. The velocity curves from these wells strengthened the hypothesis that the Pasłęk Formation is an example of a transition zone. The method of spectral decomposition helped to define such an interval for real 3D seismic survey.

Apart from the described experiments the doctoral thesis describes the theoretical discussion on methods of thin bed thickness estimation. The algorithms that are routinely used in industry are introduced and some problems linked to their application are presented. The separate chapter is dedicated to the wavelet stability verification, which is treated as a preparatory step for spectral analysis. In the dissertation the geological setting of the survey area is introduced. In this chapter its structural style and lithology of the chosen geological formations are described. The results are presented in figures along in the dissertation and attached as maps.