A proposal for the automatic extraction of Vp/Vs from multi-component seismic data

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ABSTRACT

One of the most promising aspects of multicomponent analysis is that the elastic-wave properties of the rock, such as Vp/Vs ratio, can be extracted to enhance our geological interpretations. In this paper, a technique based on a global optimization is proposed to extract the Vp/Vs ratio automatically from P-P and P-S seismic data without picking horizons. This technique assumes that the similarity between P-P and P-S data (after converted into P-P two-way times) are maximized once the proper Vp/Vs values are found.

INTRODUCTION

Traditional P-wave seismic data contains elastic wave information through the amplitude versus offset (AVO) relationship. Careful processing is required to preserve the prestack amplitude of the data and advanced techniques are also needed to form a common-reflection-point gather for the analysis. Additional information about the background shear-wave velocity function is also very important. On the other hand, the upgoing waves of P-S data contain shear-wave velocity information, and together with the P-P data, the velocity ratio can be extracted. This can help determine the lithology of the subsurface. However, the velocity ratio is calculated from the P- and S-wave interval velocities of a layer. Normal time processing does not provides this information directly. Velocity analysis based on depth migration can be used to extract the background interval velocity information. Unfortunately, the time-consuming depth migration process makes it less attractive. However for flat layers, there is a simple relationship between interval velocity ratios and interval times of P-P and P-S stacked section. Hence, by stretching P-S stacked section and matching to the P-P stacked section, Vp/Vs ratios can be extracted. This method depends on the ability to identify the events on both P-P and P-S data. Events on the P-P stack can be identified by generating synthetic zero-offset P-wave seismogram from nearby wells. Lawton et al. (1992) describe a method, based on ray-tracing, to generate both P-P and P-S offset stacks to better match the processed stacked sections. If no full-waveform sonic logs are available, user has to supply the Vp/Vs ratio. Miller et al (1994) use forward modelling technique, based on the possible values of Vp/Vs ratios, to convert P-wave zero offset synthetic seismograms to a set of P-S zero-offset seismograms in order to match the P-S data locally. Alternatively, horizons are interpreted at the same time from both P-P and P-S data with a valid range of Vp/Vs ratios as constrains. Unfortunately all the above methods will suffer, in different degrees, from picking the wrong cycles due to the oscillatory nature of the seismic trace.

In this paper, the correlation technique is considered as a global optimization problem. If the proper Vp/Vs ratios as a function of time/depth are found, and the P-S data are converted into two-way P-P vertical time, the similarity (measured by cross-correlation) between P-P and P-S data will be maximized. A global optimization technique like the simulated annealing technique is required to distinguish between different local optima.

OPTIMIZATION PROCEDURES

In this technique, the major discontinuity of background Vp/Vs ratios in time are first sought rather than the subtle change in Vp/Vs ratios. Therefore at the beginning, only one function, representing the background, of Vp/Vs ratio is estimated for the whole line. P-P stack data are segmented into several pieces. Within each piece or segment, the Vp/Vs value is assumed to be constant, but can be different among segments. The function to be optimized is the cross-correlation value between P-P and P-S stack data after stretched and shifted according to the current Vp/Vs values. Other correlation attributes, like instantaneous amplitudes or phases, can be used too. Given a fixed number of segments, the program searches for the optimal individual segment-length in terms of the P-P times and the corresponding Vp/Vs ratios. Since there is a possibility of a statics shift between P-P and P-S data due to the processing, it may be wise to flatten both P-P and P-S data on a common horizon to define a single statics shift between two data sets. This time shift is then built into the cross-correlation function. Different trails are requiired to determine the number of segments to be used for the data set. Once this background Vp/Vs ratio is found, it can be allowed to change slightly at every CDP location to match both P-P and P-S stack data locally. The changes of Vp/Vs ratios across the line can then be obtained.

REFERENCES

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