VSP data processing based on 1D-3D model of medium.

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Summary

The conceptual VSP-oriented 1D-3D model is presented as convenient base of VSP processing and interpretation. The results of processing confirm the efficiency of technology in various applications.

Introduction

Except for solving the traditional VSP problems: correlation of reflection events on the surface to log data, estimation of one-dimensional model of medium and acoustic impedances in the well and below the bottom, imaging of nearborehole space [1,2,4], the major target is reconstruction of 3D model which corresponds to 3C wavefields recorded on the VSP profile. Components of the successful decision of this problem are:

- VSP data processing, based on application of 1D-3D models of medium, with iterative correction of the model [3],
- representation concept development of model itself and algorithms of the decision of direct and return dynamic problems.

The features of the decision of the first problem for key stages of VSP data processing is described and illustrated.

Generation of 1D-3D model

Model estimation process begins with an estimation of one-dimensional model on first breaks hodograph of zero offset shot point (SP) VSP data. The model (layers boundaries are to be chosen previously) is found by optimization method with the given accuracy of a deviation of theoretical hodograph times, designed on model, from real hodograph. The distance both depth of a source and a well bore geometry (deviation survey data) is taken into account. The achievable size of a difference of theoretical and real hodograph times, as a rule, does not exceed one ms.

Three-dimensional (3D) model of medium used in VSP data processing for offset shot point is estimated on the base of the received one-dimensional model of medium. Initial one-dimensional model is extended by additional two parameters - angle and azimuth of boundaries dip. As a result of introduction of these parameters spatial medium is divided into blocks (bodies) limited by planes. Pinching-out may be modeled. Thus 3D model with flat differently-inclined borders (in specific case, with flat-parallel) and parameters of layers (velocities, densities and depths of layers boundaries) one-dimensional model is optimized for several first breaks hodographs offset VSP data with far SP. At an estimation of medium model on the far SP data the SP space location (distance, depth, azimuth) and geometry of a well bore (directional survey data) is taken into account. Elliptical anisotropy is also calculated in optimization process. If hodographs of shear waves (SV or SH) are known, the estimations of velocities and anisotropy of shear waves may be estimated in the same way.

Velocity wave separation

The use of correct 1D-3D model gives rise to better estimates of time shifts and polarization and better wave separation.

Two versions of technology of waves selection procedure are applied.

In first, on the given model of medium, for the given type of a wave (downgoing compressional or shear, reflected compressional or shear, converted transmitted or reflected) and point, specified in a field of VSP traces, hodograph is generated and the estimations of wave polarization of given wave type is calculated. Designed hodograph is visualized in a field of traces. Then in given window the shape of wave is determined and subtracted from each trace. For 3C data polarization from model is used for better selection.

In the second approach dynamic corrections and turning into optimal component is applied to wavefields before selection. This technology is convenient for selection of offset VSP data , where the strong variability of the wave hodographs shape is observed.

Estimation of acoustic impedances

For zero offset VSP separated waves after spike deconvolution in optimal component are dynamically corrected to the depth of reflecting horizons in the well. This provides correct corridor stack for dipping horizons. Due to inphase stacking wise spectrum (up to 150-200Hz) is usually achieved in primary reflections. Primary reflections are then dynamically inverted with optimization procedure. The low frequency content is extracted from model and mixed to primary reflections to provide true values of acoustic impedances.

Imaging for offset VSP

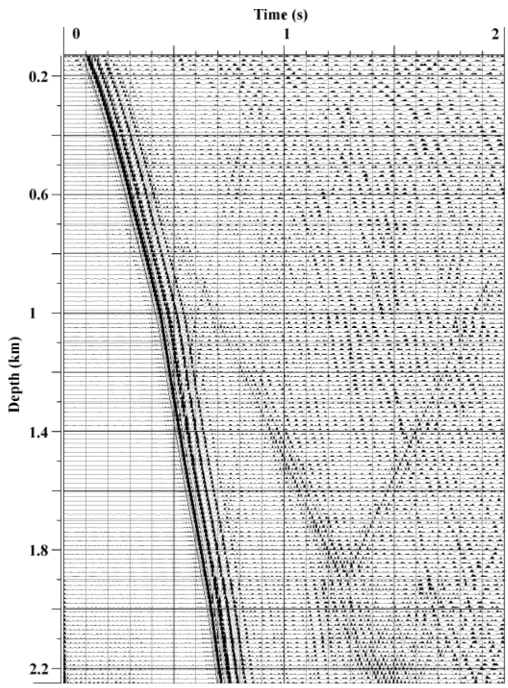
It is obvious, that the quality and reliability of the received image after VSP data processing in scale of depths essentially depends on reliability and accuracy of 3D model. Taking into account of all ray factors while imaging in depth scale provides representative amplitudes and high quality of images.

The same ray tracing procedure is used to obtain images from PS upgoing and downgoing waves.

Processing examples

In a fig. 1 and fig. 2 the example of VSP data processing of near SP with use 1D-3D model is given. It is obvious good similarity of the received curve acoustic impedances of VSP and acoustic logging curve.

(a)



(b)

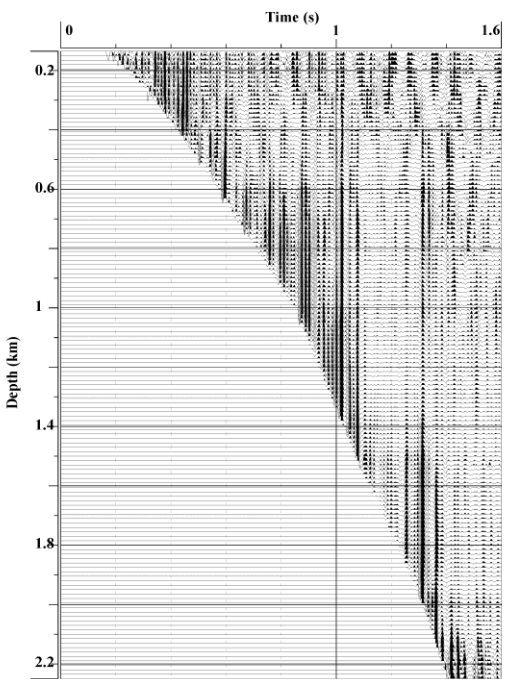


Fig 1. Results of VSP data processing of near SP: (a) the initial VSP data, (b) the field of upgoing waves after deconvolution moved out to a vertical.

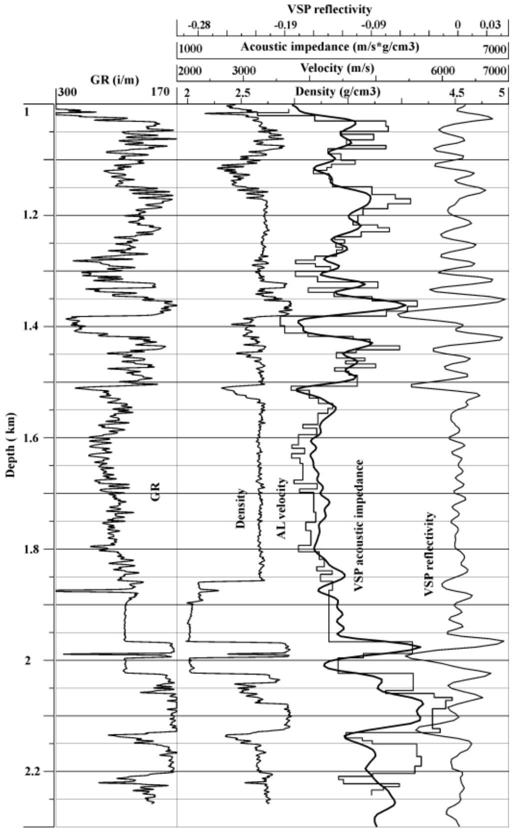


Fig. 2. Estimation of an acoustic impedance on a trace of the primary reflected waves received on the data in a fig. 1b, and comparison it with the acoustic logging and geophysical well logging data.

In fig. 3a and fig. 3b the P and PS are depicted. In this example PS image may be treated as more informative then P image in upper part of section.

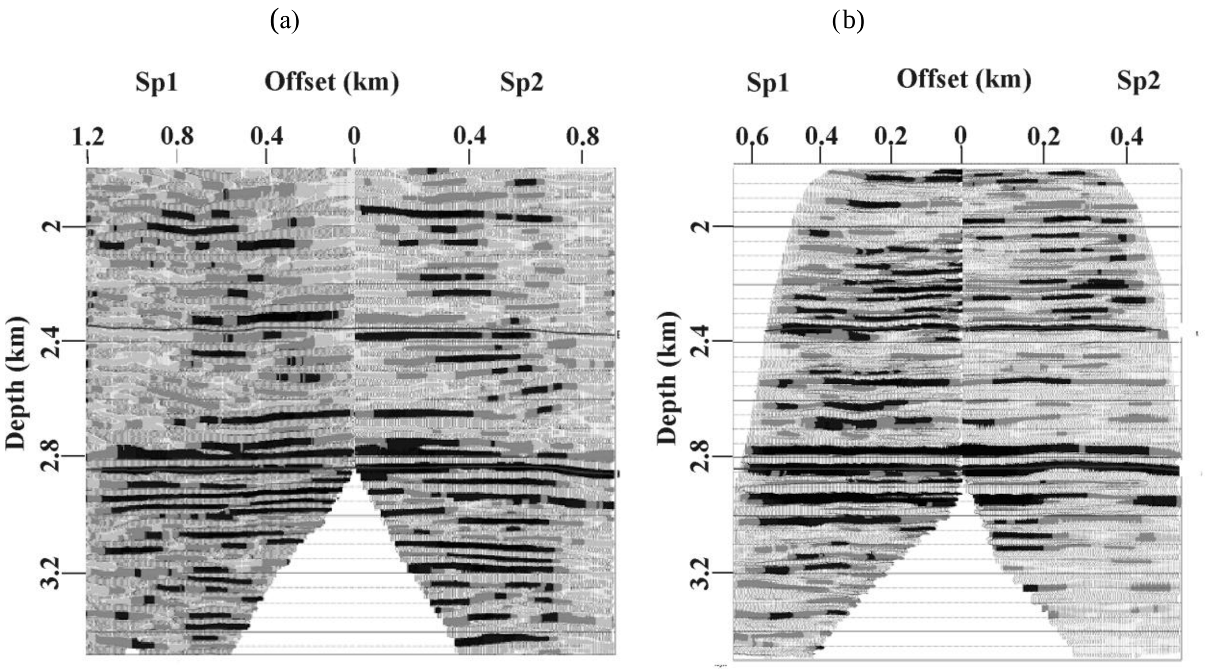


Fig. 3. The images of medium in scale of depths for compressional (a) and shear converted waves (b).

Conclusion

The estimation and application of the reliable 1D-3D models of medium at VSP data processing gave rise to more detail images in true amplitudes. The wide class of models for nearborehole space may be correctly formed and taken into account while processing and imaging of 3C data.

References

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