Introduction

Even though offset-VSP image is not so large, these results are very important, especially in situations when surface seismic cannot be acquired or its results cannot solve geological task. The knowledge of velocity model not even along well but at offset is key for building of VSP-CDP image. And the task is more difficult in situations of lateral variations of the media properties. The quality of obtained image is in a straight dependence on quality of reference model. And it is the main reason to obtain adequate reference model for offset-VSP processing.

There are good recommended algorithms based on solving of back propagation seismic problem by optimization method to solve the problem of velocity model determination. The common drawback of these methods is in a necessity of ray propagation through the unknown media. The main idea of method suggested in this paper is in reverse extrapolation of time-field of primary downing wave in the media based on first break hodograph and velocity model defined along the well with the specific dip for all layers of the model.

Then back propagation seismic problem is solved based on extrapolated time-field and resulting wave field is stacked to primary reflectivity trace. In these calculations dip of layers is variable. Then one must make interpretation of obtained scope of reflectivity traces, using the following rule: largest amplitude in trace corresponds to the true layer dip at a given depth. After that discovered values can be stacked in one trace which is to correspond to the multi-dipped layer model.

Mathematical statement

Let us assume model of the media to be dip-layered, and denote V_i –layer velocities, h_i – layer depth $\varphi(h)$ -dip of layer at depth *h* and $\theta(h)$ - azimuth of layer at depth *h (fig.1).*

Problem of time-field extrapolation in three-dimensional area using only one survey line is very hard and not correct. Thus it is expedient to simplify this problem to 2D case. To do this let us realize the following coordinate transformation. We rotate plane π (layers border) on φ and θ to be parallel to XOY plane (geographic coordinate system) with origin in point *O* denoting well mouth. Then we define new coordinate system $\{x, y, z\}$ and its relation to old system as $(x, y, z)^T = A(\varphi, \theta)(X, Y, Z)^T$. As for chosen model of the medium its properties are constant inside each single layer it is possible to apply the following transformation preserving shot-receiver distance. An image of a borehole must be constructed in the ξOz plane which contains point S (SP) and Oz axis. (рис. 2, 3). In this case the image of a borehole is curve $\{\xi(z), z \in [0, h]\}$, were $\xi(z) = \sqrt{x_0^2 + y_0^2} - \sqrt{(x(z) - x_0)^2 + (y(z) - y_0)^2}$, were (x_0, y_0) denotes coordinate of shot point.

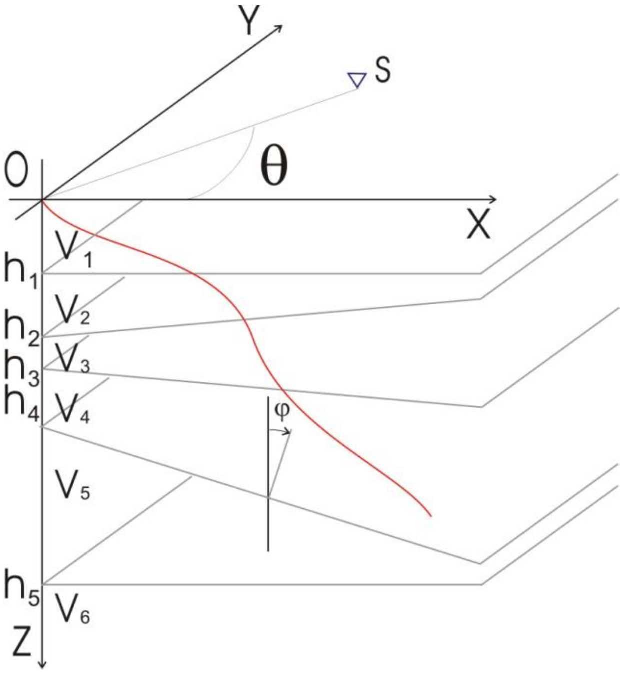

Fig1. Three dimensional model of media

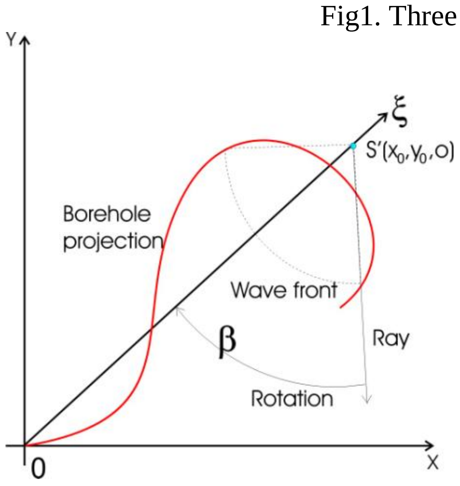

Fig.2 Projection of rays and borehole at plane xOy

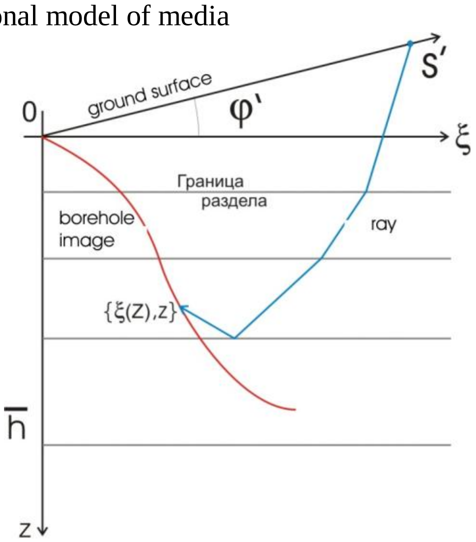

Fig.3 Projection of borehole image at plane $\xi O z$

After reduction of problem to two dimensional model with flat parallel boundaries we can calculate field of reflected waves $\mathbf{u}_{\varphi,\theta}(z,t)$ in well, for comparison with recorded wave field $\mathbf{u}(z,t)$ with intention to minimize by φ and θ ,and fixed h residual functional $J(\varphi,\theta,h)=\int_{t(h)-\delta}^{t(h)+\delta}\int_{h-\Delta}^{h+\Delta}||\mathbf{u}_{\varphi,\theta}(z,t)-\mathbf{u}(z,t)||^2_{R^3}\,dz\,dt$. Simplifying this functional we have

$$J(h,\varphi,\theta)=\int_{t_-}^{t_+}\int_{h_-}^{h}\left\|\mathbf{u}\right\|^2_{\mathbf{R}^3}\,\mathrm{d}\xi\,\mathrm{d}t+\int_{t_-}^{t_+}\int_{h_-}^{h}\left\|\mathbf{u}_{\varphi\theta}\right\|^2_{\mathbf{R}^3}\,\mathrm{d}\xi\,\mathrm{d}t-2\int_{t_-}^{t_+}\int_{h_-}^{h}\left(\mathbf{u},\mathbf{u}_{\varphi\theta}\right)_{\mathbf{R}^3}\mathrm{d}\xi\,\mathrm{d}t=$$

$$=I(h)-2\int_{t_-}^{t_+}\int_{h_-}^{h}\left(\mathbf{u},\mathbf{u}_{\varphi\theta}\right)_{\mathbf{R}^3}\mathrm{d}\xi\,\mathrm{d}t=I(h)-2K(h,\varphi,\theta).$$

By reason of features of $I(h)$ it hardly depends on φ and θ, and hence the problem can be presented as maximization of function $K(h,\theta,\varphi)$. As a result, we have both functions

$\varphi(h)$ and $\theta(h)$, determining needed angles of model, and function $K(\varphi,\theta,h)=\int_{t(h)-\delta}^{t(h)+\delta}\int_{h-\Delta}^{h}(\mathbf{u}_{\varphi(h),\theta(h)}(z,t),\mathbf{u}(z,t))_{R^3}\,dz\,dt$ which means the measure of a presence of seismic boundary at depth h with dip φ and azimuth θ [1,2,3].

Results

The proposed method has been repeatedly employed on modeled and real-field data and its efficiency has been proved (fig. 4, 5, 6).

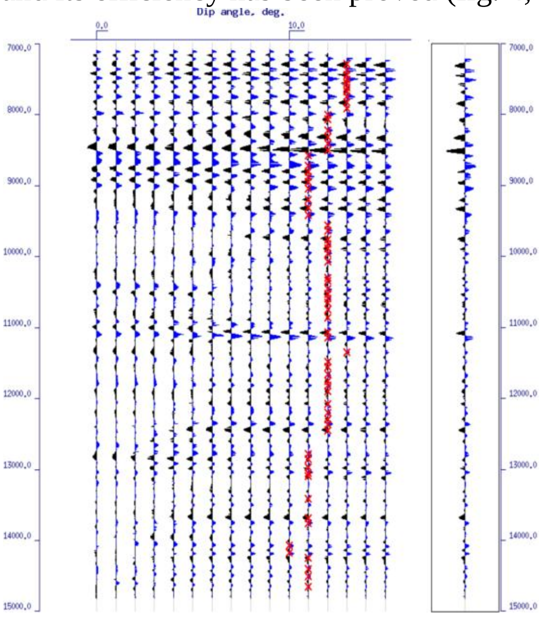

Fig. 4 A scope of reflectivity traces for different angles and fixed azimuth of layered model.

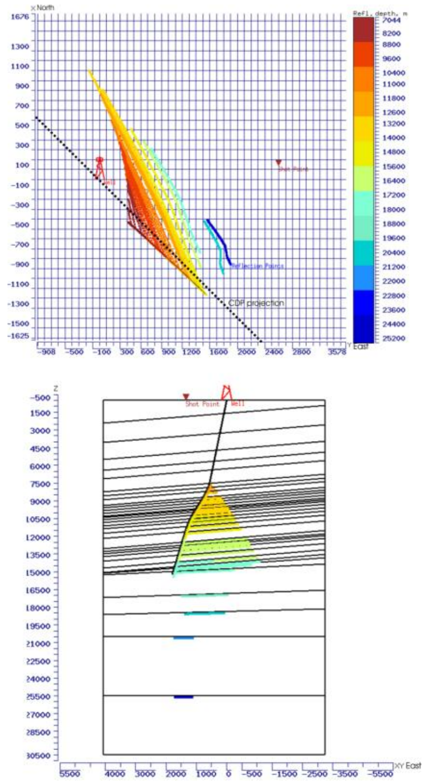

Fig. 5 Multi-dipped layered model constructed by DIPSCAN method.

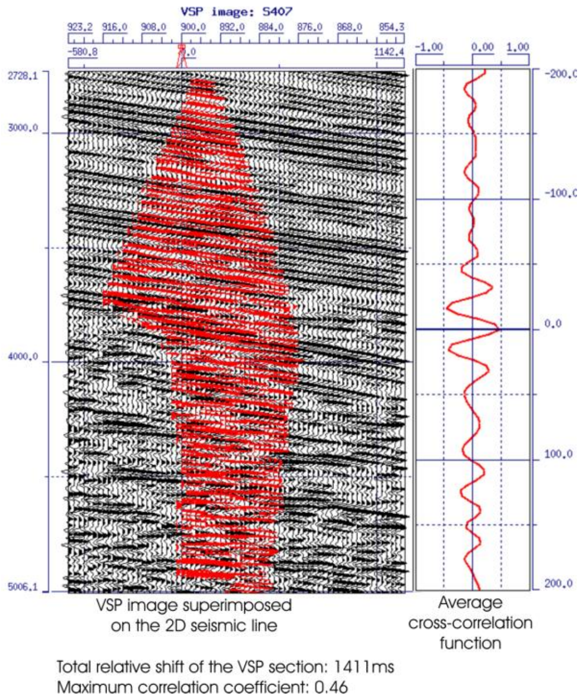

Fig. 6 VSP image of the media superimposed with CDP image.

References

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