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Estimating Effective Moveout Parameters and Traveltime Model in an Orthorhombic Media

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ABSTRACT

The equation of hyperbolic normal moveout (NMO) as a function of the exact NMO velocity loses accuracy where the media is anisotropic or heterogeneous. Elliptical anisotropy is the only media where the reflection moveout is hyperbolic. The accuracy of velocity analysis is highly dependent on NMO equation which have to be rewrite for anisotropic medium. This study aims to estimate effective moveout parameters for each receiver depth in an orthorhombic media with one set of fractures, by fitting the best nonhyperbolic moveout surface on the first breaks multiplied by two. Traveltime was also modeled using the calculated effective moveout parameters and the modified reflection moveout equation for the orthorhombic media. The results indicated that the values of moveout parameters were larger in one direction and there were no dipping reflector in the studied area.

Keywords: nonhyperbolic reflection moveout, moveout parameters, residual moveout, orthorhombic media.

INTRODUCTION

Reflection moveout in a planar anisotropy is nonhyperbolic. Deviation from hyperbola in presence of the anisotropy leads to estimation of moveout parameters, ŋ and V_{nmo}. Alkhalifah (1995) studied the velocity analysis using reflection moveout in transversely isotropic (TI) media and indicated that nonhyperbolic moveout can be used for parameter estimation. He noted that the accuracy of estimations is sensitive to deviations from hyperbolic. He estimated $ŋ_{eff}$ for any offset and showed that the method is useful in estimating variations of $ŋ_{eff}$ (Alkhalifah and Tsvankin, 1995). In his method parameters are estimated for each receiver interval and have to be averaged from the depth of receivers to the surface. Grechka (1999) derived the general Dix-type equation and modeled normal moveout in an heterogeneous anisotropic media to average V_{nmo} from the receiver locations to shot locations (Grechka et al., 1999). Al-Dajani (1998) used the equation of Tsvankin and Thomsen (1994) and showed that the traveltime in an orthorhombic media can be written in terms of azimuthally varying NMO velocity ($V_{nmo}(\alpha)$) as well as azimuthally varying eta ($\eta(\alpha)$)(Al-dajani *et al.*, 1998). Bakulin (2000) indicated that the parameter ŋ can be calculated only if dipping events or nonhyperbolic moveout is available. In this way, three possible ŋ can be calculated for an orthorhombic media.

Tsvankin (2012) in his book gave an analytic description of nonhyperbolic moveout in horizontally layered anisotropic models and VTI media. He demonstrated that adding higher-order terms to the quadratic Taylor series leads to deviation from hyperbolic moveout (Tsvankin, 2012). Tamimi (2015) estimated effective moveout parameters at geophone depths using nonhyperbolic reflection moveout equations for an orthorhombic media while implementing moveout-based anisotropic spreading correction (MASC) method for geometry corrections (Tamimi, 2015).

This study gives estimations of azimuthally varying NMO velocities ($V_{nmo}(\alpha)$) and azimuthally varying anellipticity coefficients ŋ(α) in an orthorhombic media with one set of fractures. These parameters are estimated by fitting the best nonhyperbolic surface to first break traveltime multiplied by two. Finally the traveltime model is constructed based on the most effective moveout parameters and the least difference with real traveltime data.

Methodology

Traveltime T which is extracted from the first break data multiplied by two can be replaced by nonhyperbolic moveout equation. Wave signatures including reflection moveout and amplitude variation with offset (AVO) are affected by the presence of anisotropy (Tamimi, 2015). Here the modified Al-Dajani equation for an orthorhombic media is being used which can be written based on $V_{nmo}(\alpha)$ (Tsvankin and Grechka, 2011) and ŋ(α) (Pech and Tsvankin, 2004).

$$T^2(x,\alpha) = T_0^2 + \frac{x^2}{V_{nmo}^2(\alpha)} - \frac{2\eta(\alpha)x^4}{V_{nmo}^2(\alpha)\left[T_0^2 V_{nmo}^2(\alpha) + (1+2\eta(\alpha))x^2\right]} \qquad (1)$$

$V_{nmo}(\alpha)$ and ŋ(α) are calculated using the equations below:

$$V_{nmo}^2(\alpha) = \frac{(V_{nmo}^{(1)})^2(V_{nmo}^{(2)})^2}{(V_{nmo}^{(1)})^2\, cos^2(\alpha-\alpha_0)+(V_{nmo}^{(2)})^2 sin^2(\alpha-\alpha_0)} \qquad (2)$$

$$\eta(\alpha) = \eta^{(1)} sin^2(\alpha-\alpha_0) - \eta^{(3)} sin^2(\alpha-\alpha_0) cos^2(\alpha-\alpha_0) + \eta^{(2)} cos^2(\alpha-\alpha_0) \qquad (3)$$

Where, $V_{nmo}^{(1),(2)}$ and $\eta^{(1),(2),(3)}$ are the normal moveout (NMO) velocities and anellipticity parameters in the symmetry planes of orthorhombic media respectively. α_0 is the azimuth of the $[x_1, x_3]$ symmetry plane of the orthorhombic medium.

Data in this study are from picked first break traveltimes of five three-component geophones from a walkaway vertical seismic profiling in one of the offshore Iranian fields. Two acquisition lines and five geophones are used to model traveltime data by nonhyperbolic reflection moveout. Figure (1) shows the estimated moveout parameters at each receiver locations.

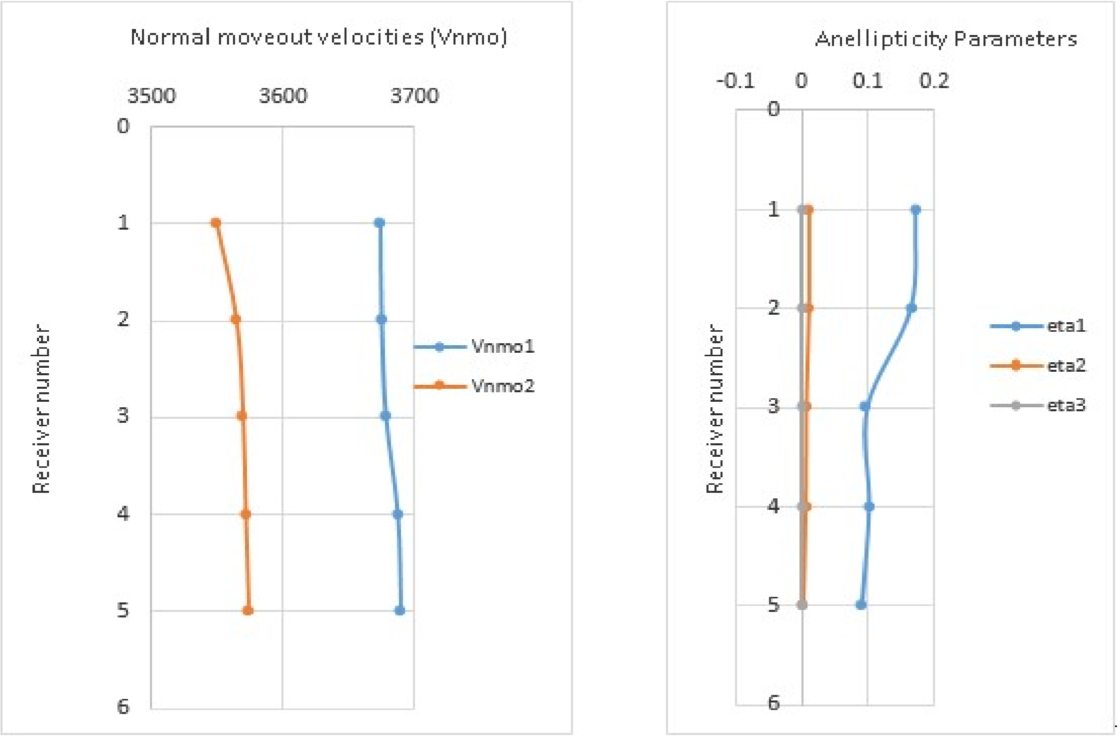

Figure 1: Estimations of anellipticity parameters and normal moveout velocities at each receiver locations.

As it is depicted in figure (1), effective parameters are estimated by fitting the nonhyperbolic surface. $\eta^{(3)}$ is almost zero in all receiver locations indicating no dipping reflector in the area. $\eta^{(1)}$ lies in a direction in line with the only fracture set in the area. So the values of $\eta^{(1)}$ are much more than the same parameter in other direction ($\eta^{(2)}$). All values of anellipticity parameters decrease with depth indicating a decrease in anisotropy. Increasing trends are recorded for both normal moveout velocities in two directions. However, the normal moveout velocities in direction (1) are much more than the direction (2) due to the dominant direction of fractures in the area.

Substituting effective moveout parameters in equation (1) leads to traveltime models for each receiver location. As there are two perpendicular acquisition lines, traveltimes in half of each line are modeled. In figure (2) the well is located at crossline where the coordinate is (0,0) and acquisition lines are 4000 meters on each side.

Traveltimes were modeled based on the minimum residual moveout which was calculated using the optimum moveout parameters. As effective moveout parameters were used for each receiver interval, the general Dix-type equation was used to calculate the average η and V_{nmo} from the receiver depth to the earth surface. There were no significant differences in models between five receivers due to the close distance of three-component receivers within ASI tool (15 meters).

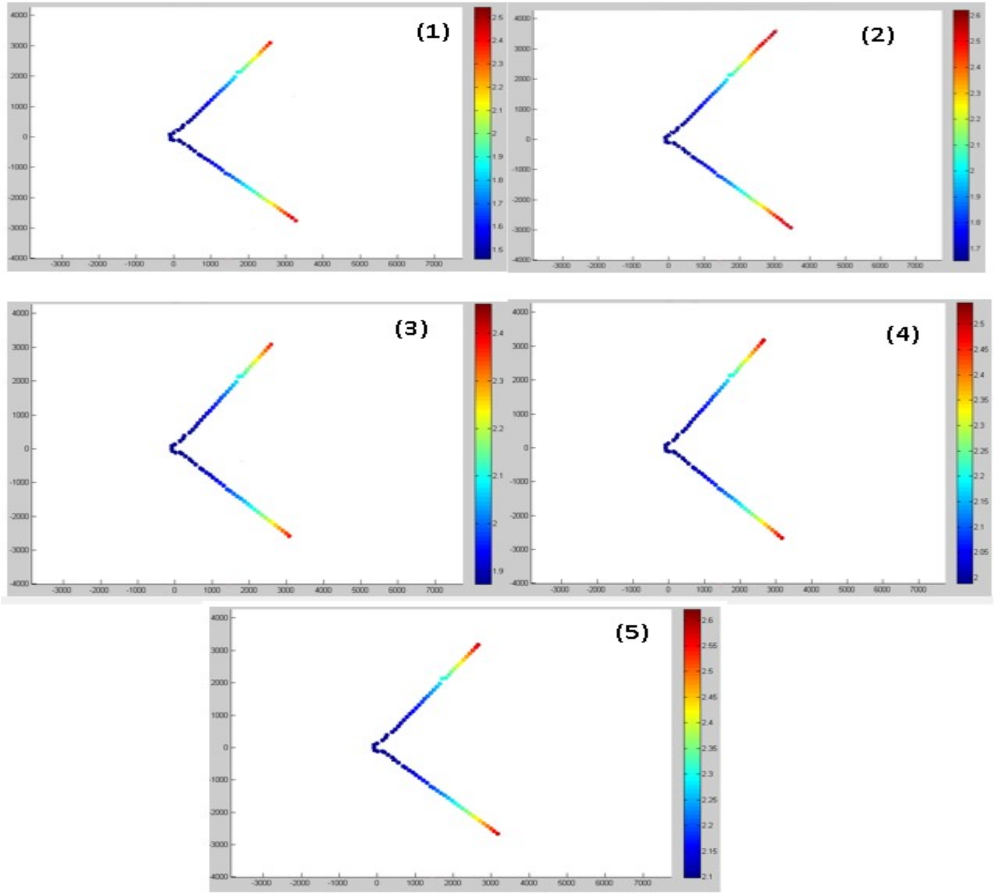

Figure 2: Traveltime model at each receiver location. X and Y axis are the acquisition coordinate and the color bar shows the values of modeled traveltime

CONCLUSION(S)

Increasing the accuracy of NMO equation requires the anisotropy to be included in the equation. As the anisotropy effects are reflected in eta and normal moveout velocity, these two parameters were determined for the anisotropic media. $\eta^{(3)}$ was calculated to be zero suggesting that no dipping reflector is present in the area. $\eta^{(1)}$ and $V_{nmo}^{(1)}$ were much more than $\eta^{(2)}$ and $V_{nmo}^{(2)}$ for the entire receiver tool denoting that the dominant direction of anisotropy is in line with the first acquisition direction. The effective moveout parameters were then used to model traveltimes based on the minimum differences between real and model traveltime data.

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