# Full Seismic Investigation means Multi-Component Seismic

*(Robert Garotta July 2015)*

The early seismic users aimed at time sections evocating geological structures, however the present user's ambitions are 3D blocks (X,Y,Z) displaying color coded values of the elastic parameters ($V_P$, $V_S$, ρ) and additional seismic attributes parameters related to rock physics, anisotropy, reservoir architecture.

This is the context of one-component P mode seismic, where only one component of the emerging wavefield is recorded.

In the one-component or P mode however we are faced with several problems like:
- seismic noise cancellation
- time to depth conversion
- elastic inversion.

The multicomponent seismic method has the advantage to be able to record not only the P mode, but also other wavefields such as shear waves. These include the PSV mode whose PS conversion occurs at the reflection point. This is the most convenient one since it includes an upgoing shear mode travel path.

## Seismic noise

In most cases, stacked data delivered by single component seismic in P mode exhibits reflectivity images whose signal to noise is satisfactory, but the signal precision of single (or small) fold data, necessary to perform AVA analysis is sometimes insufficient.

Multi-component seismic offers an additional tool to eliminate surface waves by considering the difference between their own polarized wave and the singlecomponent of the P mode signal equal to one.

## Time to depth conversion

Because of the underground anisotropy, the "velocity model building" remains a delicate and somewhat uncertain step of the time to depth conversion. If we consider the polar anisotropy concept of a vertical or tilted model, the NMO velocities ($V_{NMO}$) obtained from velocity analysis are linked to the normal incidence velocity ($V_{P0}$) and to (ε, δ) Thomsen's anisotropy parameters (see fig 1).

**Normal Moveout Velocities**

$$V_{PNMO} = V_{P0}\sqrt{1+2\delta}$$

$$V^2_{PSNMO} = V_{P0}V_{S0}\left(1+\frac{2(\sigma+\gamma_0\delta)}{1+\gamma_0}\right)$$

δ, ε,σ : Thomsen's parameters

$$\sigma = (\varepsilon - \delta)\,\gamma_0^2$$

Fig. 1

Within single component P mode seismic, residual moveout analysis gives the possibility to estimate ε but not δ, that is the depthing parameter, essential for depth conversion.

Within the PSV mode, multi-component seismic offers a relationships between $V_{PNMO}$, $V_{P0}$ and δ and then between $V_{PSNMO}$, $V_{PS0}$, δ and ε. The parameters δ and ε are considered correct when their values cancel the residual NMO on both P and PS modes on the same interface.

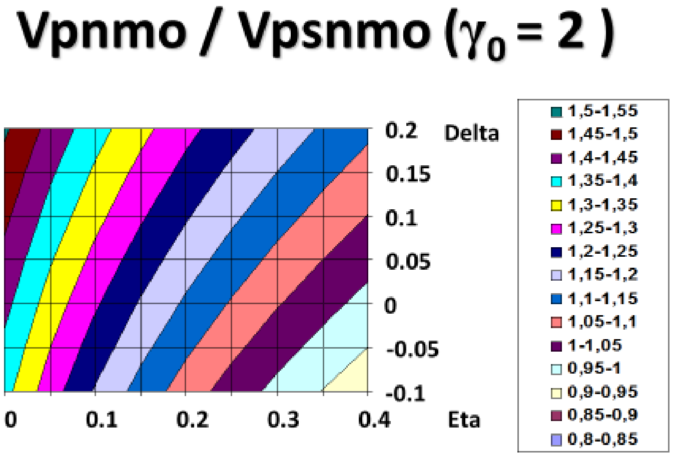

Fig. 2

Another possible way for the δ definition after the ε definition through P mode residual moveout is to proceed to $V_{PNMO}/V_{PSNMO}$ ratio (see fig 2). Finally, we should observe that the compatibility of P or PS depth images should be checked, this may lead to further adjustments of the depth models.

## Elastic inversion

Elastic inversion procedures concern the P mode AVA analysis. Strictly speaking, the definition of three elastic parameters ($V_P$, $V_S$, ρ) would require three AVA parameters. In practice, the Hpp wide angle AVA parameter is most often poorly defined because of the angle increasing effect of non-considered causes: anisotropy, overburden tectonics, differential absorption, etc. This is why additional non seismic constraints like Gardner's law are generally included in the process.

Elastic inversion reaches a higher precision when a first order PS AVA parameters (Gps) replaces the fourth order P mode parameter (Hpp) (see fig 3).

**VTI and AVA Parameters (Thomsen)**

$$\mathbf{R_{pp}(\theta_w) = R_{p0} + G_{pp}\sin^2\theta_w + H_{pp}\sin^2\theta_w\tan^2\theta_w}$$

$$\mathbf{R_{ps}(\theta_w) = \sin\theta_w\,(G_{ps} + H_{ps}\sin^2\theta_w)}$$

$$G_{pp} = 1/2\,[\Delta V_{p0}/V_{p0} - (2/\gamma_0)^2\,\Delta\mu/\mu + \Delta\delta]$$
$$H_{pp} = 1/2\,[\Delta V_{p0}/V_{p0} + \Delta\varepsilon]$$

$$G_{ps} = 1/2\,[\Delta\rho/\rho - (2/\gamma_0)\,\Delta\mu/\mu + (\gamma_0/1+\gamma_0)\,\Delta\delta]$$
$$H_{ps} = -\,1/2\,\gamma_0^2[\Delta\rho/2\rho - (2+\gamma_0)\,\Delta\mu_0/\mu_0] + (\gamma_0-1)\,\gamma_0\,\Delta\eta + 1/2\,[2\,\gamma_0^3+(\gamma_0-1)^2]/[2\,\gamma_0(\gamma_0^2-1)]\,\Delta\delta$$

$$\eta = (\varepsilon - \delta)\,/\,(1 + 2\delta)$$

Fig. 3

Polar anisotropy effects can be taken into account to refine the elastic inversion. Five AVA parameters instead of three must be considered; confidence on the accuracy of the wide angle parameters is required.

## Azimuthal anisotropy

To complete the list of the multi-component seismic benefits, we should also mention the description of azimuthally anisotropic materials. In this domain, the polarization of the shear propagation is the best tool since shear wave splitting effects are present on any single ray of the SV propagation.

## Conclusion

Multi-component seismic is the optimal way to approach the description of elastic domains. Its benefit is already present at the data denoising, this then confirms the precision of the depth imaging and for even more advanced investigations like elastic seismic inversion and azimuthal rock properties.