# Seismic anisotropy beyond Thomsen. What for?

José Cláuver de Aguiar Junior (PETROBRAS)



## Abstract

Since many decades ago, seismic waves propagation through an acoustic or elastic medium is a solved problem. Thus, given a reliable representation of some piece of the earth (the model), one can simulate in a fairly accurate manner how seismic waves spread along it, i.e., one can perform seismic modelling. By the other side, in spite of the existence of a multitude of strategies, for the inverse problem we have to face the big challenges due to non-uniqueness.

A big difficulty in any kind of inversion is the number of parameters to estimate. For an anisotropic 3D elastic medium with random variation of properties in any direction, we should determine 21 components of the elastic tensor for each position in space, what is far from being solvable given some seismic reflection data recorded at surface.

To incorporate seismic anisotropy into seismic imaging we needed to perform a lot of simplifications, and this became feasible and usual only after the classical paper of Leon Thomsen (1986), which is well known worldwide.

In this work, I intend to discuss the validity of using anisotropic models more complicated than the polar symmetry adopted by Thomsen in that paper. Due to the augment in the number of parameters to estimate and the high level of uncertainty in these estimates, as a consequence of the restricted variety of measures we can do in seismic surveys, I don´t believe that we´ll increase accuracy of seismic images just by choosing a more complicated anisotropy model.

## Introduction

The incorporation of Thomsen´s VTI model into seismic imaging brought big improvements to pre-stack depth migration results, widely documented in thousand of papers and seismic processing reports. This revolution can be synthesized in two great benefits: residual moveout was drastically reduced (once we could consider the variation of velocity with incidence angle) and, the most critical for oil industry, depth estimates became to be much less uncertain (once we didn´t have anymore to neglect zero-incidence velocities in the benefit of NMO velocities).

During these twenty nine years since Thomsen´s classical work, many experts in seismic imaging could propose improvements of VTI model, as well as the adoption of more general symmetry models. However, up to now the seismic industry has adopted few of these suggestions.

The most successful ideas were TTI model (which is only a generalization of VTI model in order to consider the layer´s dip) and the segmentation of wide-azimuth field data in azimuth sectors (what allows the variation of velocities and anisotropic parameters with azimuth). These sophistications were well received because they could improve results without complicating significantly the model building. Our challenge still remained in estimating only three difficult parameters (velocity, delta and epsilon), once azimuth and dip of the layers, as well as source-receiver azimuth, are very easily determined. Attention must be paid in agreeing with the last phrase, that is true only when we deal with “weak anisotropy”, in the way that Thomsen (1986) defined it.

Why am I so reluctant with more complex anisotropy models as, for example, orthorhombic symmetry? The answer resides in the limitation of seismic measures in relation to the numbers of parameters to estimate. Talking specifically about P-waves, geophysicists do hard work to build reliable 3D models for velocities, delta and epsilon, and even in this scenario is well known that epsilon estimates are less accurate than those for delta, specially due to the lack of very long offsets.

## Conclusions

In my opinion, we run the risk of degrading our seismic imaging when we decide to work with more complicated anisotropic models. Having to estimate more parameters, and knowing that some of them can be “awkward combinations” of elastic parameters (borrowing Thomsen´s words) and, therefore, difficult to be understood in its physical meaning, our chance to control their variabilities are small.

In physics, everytime we choose to work with a more complicated model, we must be sure that benefits will surpass the difficulties we are introducing in parameter estimation methodology. In this case, I´m not sure.

## References

Karazincir, M., and Orumwense, R., 2014, Tilted orthorhombic velocity model building and imaging of Zamzama gas field with full-azimuth land data; The Leading Edge, **33**, 1024-1028.

Thomsen, L., 1986, Weak elastic anisotropy: Geophysics, **51**, 1954-1966.