

# UPSCALING IN ORTHORHOMBIC MEDIA

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Stack of homogeneous elastic arbitrary anisotropic layers in welded contact in long-wavelength limit is equivalent to elastic, anisotropic, homogeneous medium. First, Backus (1962) analytically showed that stack of homogeneous isotropic layers is equivalent to a homogeneous, transversely isotropic medium with a vertical axis of symmetry in a long-wavelength limit. This approach is widely used in industry nowadays for upscaling of well-log data to seismic wavelengths. After, Schoenberg and Muir (1989) extended the work of Backus and developed an analytical method to average the stack of homogeneous layers of arbitrary anisotropy in the long-wavelength limit. In this paper we apply this formalism to a stack of layers with orthorhombic (ORT) symmetry in order to study the behavior of surface seismic processing parameters. We focus on two models: stack composed of layers with orthorhombic symmetry including azimuthally rotated layers and a stack of vertically fractured layers with intrinsic vertically transversely isotropic (VTI) symmetry.

*Model 1.* Medium is composed of two different orthorhombic layers, the volume fraction of one of the layers is a model variable. One of the layers is azimuthally rotated at some angle. Azimuthally rotated orthorhombic medium has 13 non-zero elements in its stiffness matrix and, hence, the effective medium constituted of orthorhombic layers and azimuthally rotated orthorhombic layers exhibits monoclinic symmetry. It is nearly impossible to obtain any feasible analytical expressions for the medium of such complexity, therefore we numerically investigate whether obtained effective monoclinic medium can be approximated with some effective orthorhombic medium azimuthally rotated at some effective angle. We propose two different approaches to the solution of this problem: least-square minimization and eigenvector decomposition of the stiffness matrix (Cowin and Mehrabadi, 1987). Both approaches demonstrate the possibility of locating an unique effective azimuth for different values of volume fraction of one of the media, however output angles are different.

*Model 2.* Medium is composed of a VTI layer and a layer of the same VTI background embedding a set of vertical fractures. The volume fraction of pure VTI medium in composite is a model variable. Schoenberg and Helbig (1997) showed that the model composed of the set of vertical fractures (characterized by fracture weaknesses) embedded in VTI background exhibits orthorhombic symmetry and they also described the stiffness matrix of orthorhombic medium constructed this way. We analyze the dependence of important  $P$ -wave processing parameters (2 normal moveout velocities and 3 anellipticities) on VTI volume fraction and on fracture parameters. We also obtain weak anisotropy and weak fracture weaknesses approximation following Bakulin et al. (2000). We use a well log data example to study the applicability of this model, especially in application to full-azimuth surveys.

## References

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