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Effect of fold structures on seismic anisotropy in continental crust

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Tectonic deformation and metamorphism in the middle and lower crust can produce and modify seismic anisotropy owing to the development of micro-scale fabrics including crystallographic preferred orientation and large-scale structures such as folds, domes, faults and shear zones. Although the impact of the microfabrics on seismic anisotropy is well known via petrophysical or thin-section-based measurements, there have been few studies on how the macro-scale structures affect seismic responses. In this study, we investigate the influence of types and limb angles of cylindrical fold structures on seismic anisotropy through tensor manipulation. To calculate the velocity of seismic waves propagating through the fold structures, the elastic stiffness tensor in the Christoffel equation is substituted by geological effective media (GEM) of the folds. Here the Voigt averaging method is used in computing the GEM stiffness analytically or numerically. In this case, the GEM (C*) is decomposed into the product of a structural geometry operator (SGO) and stiffness of a representative rock that makes up the fold (C^{rep}); C* = SGO × C^{rep}. SGO is an operator that reorients C^{rep} at each point of the fold with respect to a geographical reference frame and averages the reoriented stiffnesses. As an example of the representative rock stiffness, we take the stiffness tensor of the Haast schist of South Island, New Zealand (Okaya & Christensen, 2002), which has intrinsic P-wave anisotropy (AV_P) of 12.7% and S1-wave anisotropy (AV_{S1}) of 16.5%. While the rock is hexagonal in symmetry, the calculated GEM for the fold structures range between hexagonal to orthorhombic symmetry, depending on limb angle. The common types of folds are described via power or trigonometric functions: cuspate, chevron, sinusoidal, parabolic and box folds. Our results include the velocity behavior with respect to limb angle and incident angle on specific planes of the folds as well as the seismic anisotropy as a function of limb angle. The fold with sharper hinge represents the minimum seismic anisotropy at lower limb angle. For instance, chevron fold shows minimum AV_P (10.4%) and AV_{S1} (5.7%) at limb angle of 45°, whereas sinusoidal fold has minimum AV_P (9.2%) and AV_{S1} (4.9%) at 60° limb angle.

References:

Okaya, D. A. & Christensen, N. I. 2002. Anisotropic effects of non-axial seismic wave propagation in foliated crustal rocks. *Geophysical Research Letters*, **29**, doi:10.1029/2001GL014285.