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How does seismic anisotropy evolve as a function of mineralogical and textural changes across ductile shear zones? – an experimental and modelling approach

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Strain localization and the development of ductile shear zones in the middle and lower crust play major roles in lithosphere dynamics. Geophysical imaging of ductile shear zones is an issue for ore geology, for the understanding of the lithosphere rheology and of the faults behavior. Indeed, shear zones constitute the ductile roots of the faults of the upper crust; studying these structures can thus help to better understand the behavior of the seismogenic faults (e.g. Sibson, 1977).

In the absence of significant seismicity, methods using active source illumination cannot be used to image shear zones. However, by the way of metamorphic and metasomatic reactions, ductile strain localization is accompanied by mineralogical, textural and microstructural changes, that can produce seismic anisotropy. The propagation of teleseismic waves from distant earthquakes is sensitive to this anisotropy, and can be used to image the anisotropic crustal structures through which they propagate. Deep crustal seismic anisotropy has thus the potential to fundamentally advance our understanding of lithospheric structure and deformation processes.

Intrinsically anisotropic minerals, the development of preferential crystallographic orientations and layered textures, can produce seismic anisotropy within shear zones (e.g. Mainprice and Nicolas, 1989). However, these intrinsic properties of shear zones change from their margins to their mylonitic cores, that may imply changes in seismic anisotropy. Furthermore, developed shear zones acquire a more complex geometry than these "ideal" tabular strain zones. They form anastomosed networks, with a mylonitic matrix delimiting weakly deformed lenses showing more localized deformation, and in which preexisting textures can be eventually preserved. Thus, there are multiple potential contributions for the shear zones "final" anisotropy.
Although many geophysical studies aim to better image crustal anisotropic structures, it is also crucial to study outcropping fossil shear zones, in order to identify and estimate the different contributions to the final anisotropy. This study aims to bring a geological contribution to the understanding of geophysical signals. This approach begins with the study of the simplest case of an "ideal" shear zone, to determine how evolves the seismic anisotropy along a strain gradient.

The present study is based on natural samples from eclogitic shear zones developed in the Monte Mucrone metagranodiorite (Sesia zone, Western Alps). We consider homogeneously deformed samples, corresponding to various stages of deformation: undeformed protolith (with potential inherited magmatic textures), orthogneiss, mylonite and ultramylonite. Besides, a composite sample contains a cm-scale shear zone, representing the combination of the different contributions estimated with the homogeneous samples.

The seismic anisotropy of both homogeneous and composite samples will be (1) experimentally estimated, by P- and S- waves velocity measurements and (2) modelled using the program MTEX (Mainprice et al., 2011), and a microstructure-sensitive finite element orientation averaging using the ESP toolbox (Vel et al., 2016). The so calculated anisotropies are compared with the petrological features of each sample. The objective is to test the hypothesis that shear zones seismic anisotropy may reflect the lower strained margins of the zones (e.g. Almqvist et al., 2013; Tatham et al., 2008; Schulte-Pelkum and Mahan, 2011).