Elastic anisotropies of deformed crustal rocks in the Alps

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The crust within collisional orogens is very heterogeneous, in composition as well as in type and intensity of deformation, leading to highly variable physical properties at small scales. This causes difficulties for seismic investigations of tectonic structures at depth since the diverse and partially strong upper crustal anisotropy might overprint the signal of deeper anisotropic structures in the mantle. We characterized the range of elastic anisotropies of deformed crustal rocks in the Alps according to the crystallographic preferred orientation (CPO) of their constituent mineral phases.

In the Lago di Cignana area of the Italian Western Alps, we sampled eclogites, blueschists and greenschists of oceanic origin (Zermatt-Saas-Zone). From the lower crustal and mantle rocks of the Ivrea Zone near Finero metagabbros and marbles were collected. The Adula Nappe in the central Alps, which was intensely deformed during the Alpine orogeny, was sampled for rocks from a typical deformed upper continental crust within the Alps. The two major rock types, orthogneisses and paragneisses and small lenses of eclogites, amphibolites and marbles were sampled.

CPOs of minerals in the samples were measured using time-of-flight neutron diffraction. Combined with single crystal elastic anisotropies these were used to model seismic properties of the rocks.

Similarities can be found within the mafic samples. The eclogite and amphibolite lenses within the continental crust, the eclogites and blueschists of oceanic origin, as well as the metagabbros of the lower crust exhibit highest P-wave velocity (VP) in lineation direction. An exception within the mafic samples is the greenschist, which shows a distribution of high VP within the foliation plane. P-wave anisotropy (AVP) of the metagabbros and eclogites is generally low with about 1.5%. The greenschist, blueschist and amphibolite samples show higher AVP of 2-4.5%. Marble also yields highest VP in lineation direction and high AVP of 8%. It can be distinguished from all other samples in the set by its high VP/VS ratio of 1.8. The felsic rocks of the continental crust show high variability. Those with high mica contents also show VP maxima in the foliation plane. They can be distinguished from greenschists, which show an average VP of 7.30 km/s, by their generally lower average VP of 6.18 - 6.81 km/s.

To approximate an average for upper crustal rocks units, we picked common CPO types of rock forming minerals within gneiss samples of the Adula Nappe representing the most common lithology. These data were used to determine an average elastic anisotropy of a typical crustal rock within the Alps yielding 4 %. This value is an approximation, which can be used for seismic models at a lithospheric scale. At a crustal or smaller scale, however, local variations in lithology and deformation as displayed by the range of elastic anisotropies within the sample set need to be considered. In addition, larger-scale structural anisotropies such as layering, intrusions and brittle faults have to be included in any crustal or smaller scale seismic model.