Effect of pressure on 3D distribution of P-wave velocity and attenuation in antigorite serpentinite

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Introduction

Seismic velocity and attenuation anisotropy is an important property of many crustal and mantle rocks. The velocity anisotropy characterizes a directionally dependent propagation velocity of seismic waves, whereas attenuation anisotropy controls directionally dependent dissipation of seismic energy. The role of velocity and attenuation anisotropy in understanding the evolution of the Earth crust and upper mantle is becoming increasingly important, because the measured anisotropy has a structural origin. We present a detailed study on the pressure dependence of P-wave velocities and amplitudes on a spherical sample of antigorite serpentinite from Val Malenco, Northern Italy. Measurements were done at room temperature and hydrostatic pressures up to 400 MPa in a pressure vessel with oil as a pressure medium. The transducer/sample assembly allows simultaneous velocity and amplitude measurements on the spherical sample in 132 independent directions. Three significant directions of the foliated sample were selected to study changes of the directional dependence (anisotropy) of velocity, amplitude and Q-factor with increasing pressure. Remarkable differences are observed in the changes of velocity and attenuation anisotropy as pressure is increased.

Sample characteristic

The sample studied in this paper is a serpentinite from Val Malenco in Western Alps, Northern Italy. The serpentinite is an antigorite-rich rock exhibiting pronounced foliation and lineation with relics of primary olivine minerals. The sample has macroscopically visible foliation and lineation, which together with microcracks give rise to a significant anisotropy.

Methods

A device for generating ultrasonic pulses, traveltime measurement and data acquisition was used (Lokajiček and Svitek, 2015). The equipment allows for the ultrasonic measurements of spherical rock samples in 132 independent directions by using a pair of P-wave sensors (transmitter and receiver polarized along the radial direction). For the analysis of the 3D distribution of P-wave velocities and amplitudes we used an angular grid of 15°.

The inversion for viscoelastic media is based on the equations which are similar to those in elastic media except for being complex. Methods for determining viscoelastic parameters from measured velocities and amplitudes of waves were developed by Vavryčuk (2015) and Vavryčuk et al. (2017).

Results

The results shown in the picture represent 3D distribution of measured P-wave velocities, amplitudes, calculated radiation pattern and Q-factor on the surface of the sphere at two pressure levels (0.1 and 400 MPa).
It is obvious that the same effect of crack closure due to acting pressure causes different behaviour of individual variables. While directional dependence of velocity and radiation pattern with the rising pressure is stable, however with different spatial distribution, the symmetry of amplitudes is changed and Q-factor surprisingly rotates. We have selected three significant directions in relation to rock structure – LD (lineation), FN (foliation normal) and AD (amplitude minimum at 400 MPa). The pressure development in these directions and their mutual relation vary for individual variable.

![3D projection on spherical surface of measured velocities (a, e), amplitudes (b, f), calculated normalized radiation pattern (RP) (c, g) and ray Q-factors (d, h) at 0.1 and 400 MPa, respectively. The black dots represent points of measurement and the white letters mark selected directions. X, Y, Z coordinates show the orientation of the sample.](image)

**Conclusions**

Velocities and amplitudes react differently on the microcracks closure. In the direction normal to the foliation, the amplitudes form maximum, whereas velocity remains minimal even at high pressure. Amplitudes at 100 MPa start forming a symmetrical cone of low values in 45° to the foliation plane. While velocities do not change the symmetry as well as its orientation with increasing pressure, the amplitudes change the pattern with respect to the orientation of structure elements. Interestingly, the Q-factor keeps the pattern but rotates its symmetry with pressure.

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**References**


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