Joint pressure and temperature effects on seismic properties of gneisses and amphibolite

Mohsen Bazargan[1], Bjarne Sven Guestav Almqvist[1], Hem Motra[2], Christoph Hieronymus[1], and Sandra Piazolo[3]

[1]Uppsala University
[2]Christian-Albrechts-University of Kiel
[3]University of Leeds

November 23, 2022

Abstract

Pressure and temperature change simultaneously in the Earth's crust from surface to depth. Joint pressure and temperature changes influence many different physical properties. There are many studies on samples at elevated pressure, where the influence of open cracks, fractures, voids and pores have been studied. Applying confining pressure has a direct influence on crack closure, and this influence on dynamic properties (density and elastic modulus, bulk, shear and young's) of rocks above 200 MPa is assumed linear with the linear increase in wave speed. This is because it is generally assumed that most cracks are closed above 200 MPa, which in nature would correspond to a depth of ˜7-8 km. However, from the KTB deep drilling well in Germany, it is known that fluid-filled fractures and pores can remain open until 8 to 9 km depth. Applying temperature can affect the dynamic properties of rock by thermal expansion, possibly reopening cracks that were closed at pressures >200 MPa, and thermally expanding grains. This influence is also assumed to be linear at a temperature below partial melting, and in the absence of phase transitions. A similar effect has been observed by a number of research groups during laboratory experiments and calculating seismic velocity results under 600 MPa confining pressure and 600°C temperature. In this work, an effort has been made to mathematically investigate the influence of temperature and pressure on the seismic properties (velocity of pressure and shear waves, density and Poisson's ratio) of crystalline rocks, measured during laboratory experiments. Elastic wave speeds, moduli and density are increasing as a function of pressure and decreasing as a function of temperature. However, these pressure and temperature-related changes are shown to be nonlinear from room conditions up to 600°C and 600 MPa. In this presentation, we focus on non-linear changes mainly in the high-pressure portion of the velocity as a function of pressure (>200 MPa). When confining pressure is applied, measured P- and S- waves show an increase in velocity and decrease in anisotropy. However, the effect of temperature on measured P- and S- waves show a decrease in velocity and increases in anisotropy. These changes are not very different from linear, but it is not possible to fit velocity as a function of pressure or temperature with linear mathematical functions. The implications of non-linear relationships between pressure, temperature and elastic wave speeds are discussed in this presentation.

Title

Joint pressure and temperature effects on seismic properties of gneisses and amphibolite

Authors

Mohsen Bazargan, Bjarne Sven Guestav Almqvist, Hem Motra, Christoph Hieronymus, Sandra Piazolo

Abstract

Pressure and temperature change simultaneously in the Earth's crust from surface to depth. Joint pressure and temperature changes influence many different physical properties. There are many studies on samples at elevated pressure, where the influence of open cracks, fractures, voids and pores have been studied. Applying confining pressure has a direct influence on crack closure, and this influence on dynamic properties (density and elastic modulus, bulk, shear and young's) of rocks above 200 MPa is assumed linear with the linear increase in wave speed. This is because it is generally assumed that most cracks are closed above 200 MPa, which in nature would correspond to a depth of ~7-8 km. However, from the KTB deep drilling well in Germany, it is known that fluid-filled fractures and pores can remain open until 8 to 9 km depth. Applying temperature can affect the dynamic properties of rock by thermal expansion, possibly reopening cracks that were closed at pressures >200 MPa, and thermally expanding grains. This influence is also assumed to be linear at a temperature below partial melting, and in the absence of phase transitions. A similar effect has been observed by a number of research groups during laboratory experiments and calculating seismic velocity results under 600 MPa confining pressure and 600ºC temperature. In this work, an effort has been made to mathematically investigate the influence of temperature and pressure on the seismic properties (velocity of pressure and shear waves, density and Poisson's ratio) of crystalline rocks, measured during laboratory experiments. Elastic wave speeds, moduli and density are increasing as a function of pressure and decreasing as a function of temperature. However, these pressure and temperature-related changes are shown to be nonlinear from room conditions up to 600ºC and 600 MPa. In this presentation, we focus on non-linear changes mainly in the high-pressure portion of the velocity as a function of pressure (>200 MPa). When confining pressure is applied, measured P- and S- waves show an increase in velocity and decrease in anisotropy. However, the effect of temperature on measured P- and S- waves show a decrease in velocity and increases in anisotropy. These changes are not very different from linear, but it is not possible to fit velocity as a function of pressure or temperature with linear mathematical functions. The implications of non-linear relationships between pressure, temperature and elastic wave speeds are discussed in this presentation.