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Measurement of 'pore-space-free' elastic velocities of crustal rocks of the Oman Ophiolite

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Elastic velocities of rocks measured at high pressures are important data for interpreting seismic velocity structures of oceanic crust. Christensen & Swewing (1981, JGR) performed elastic velocity measurements on the rocks in the northern section of the Oman ophiolite under pressure conditions of the oceanic crust to uppermost mantle levels (0.06-0.43GPa). It is well known from laboratory measurements, however, that elastic wave velocities obtained at relatively low pressures were effected by internal pore-spaces, and were different from the intrinsic values of the rocks. In this work, we performed elastic velocity measurements of the crustal rocks of the Oman ophiolite at 0.2-1.0 GPa, and determined the intrinsic 'pore-space-free' elastic velocities of the rocks. We also estimated the total porosity of the sample based on elastic data and evaluated the influence of pore-spaces in the Vp, Vs, Vp/Vs and Poisson's ratio of the rocks.

The rock sample studied is a fine-grained (<2 mm) homogeneous and isotropic olivine gabbro without recognizable foliation and lineation. It consists of plagioclase (63 vol.%), clinopyroxene (1 8 vol.%), orthopyroxene (12 vol.%), olivine (4 vol.%) with minor amounts of secondary serpentine (2 vol.%) and magnetite (1 vol.%). We prepared two cylindrical rock samples (14 mm in diameter and 12 mm in length) from the olivine gabbro for high pressure experiment. One is an 'uncracked sample' with few visible cracks. The other is a 'cracked sample' which was pre-heated to 500 degree celsius at 0.5 GPa and pre-pressurized up to 1.0 GPa before the velocity measurement. Petrographic observation suggests that the sample developed cracks after the pre-heating and the pre-pressurization. Both samples were dried in a vacuum-oven at 120 degree celsius for 24 hours before experiments.

The measured Vp, Vs, Vp/Vs and Poisson's ratio of the 'cracked sample' are systematically lower than those of the 'uncracked sample' in lower pressures (up to 0.6 GPa) and comparable in higher pressures (0.6-1.0 GPa). In the 'uncracked sample', the Vp, Vs, Vp/Vs and Poisson's ratio markedly increase up to 0.40 GPa, and gradually increase from 0.45 GPa to 1.00 GPa. The compressibility of the 'uncracked sample' is markedly higher than the theoretical 'pore-space-free' value up to 0.40 GPa, and is comparable to the theoretical value from 0.45 GPa to 1.00 GPa, which was calculated on the basis of the modal proportions and chemical compositions of its mineral constituents (Hacker & Abers, 2004, G-cubed). The data strongly suggest that the pore-spaces in the 'uncracked sample' closed completely at pressures higher than 0.45 GPa. On the basis of liner regression of data points at higher pressure (0.45-1.00 GPa) and by extrapolating to lower pressures, we evaluated the 'pore-space-free' intrinsic Vp, Vs, Vp/Vs and Poisson's ratio of the sample. They can be expressed as a liner function of pressure (P, in GPa);

Vp (km/s) = 7.004 + 0.096 x P,
Vs (km/s) = 3.827 + 0.007 x P,
Vp/Vs = 1.830 + 0.021 x P,
Poisson's ratio = 0.287 + 0.007 x P.

We evaluated the total porosity of the sample based on the compressibility changes of the studied samples as a function of pressure. We also evaluate the deviation in the elastic properties of the ' pore-space-bearing' samples from the 'pore-space-free' intrinsic values. The deviations exhibit a negative correlation with total porosity suggesting that the development of pore-spaces in crustal rocks will lower their Vp, Vs, Vp/Vs and Poisson's ratio.

As shown in this study, the internal pore-spaces are not completely closed in cases in the relatively low pressure experiments (< ca. 0.6 GPa) and influence on the elastic properties of the rocks. Therefore, the experiments in the wide range of pressure conditions (0.2-1.0 GPa) are required to determine the intrinsic 'pore-space-free' elastic properties of rocks and to evaluate the influence of pore-spaces on the elastic properties.

Keywords: Ophiolite, elastic velocities, pore-spaces