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Measurement of elastic wave velocities for oceanic crust-mantle rocks with a piston-cylinder type high-pressure apparatus

Satoshi SAITO[1]; Masahiro Ishikawa[2]; Makoto Arima[3]; Yoshiyuki Tatsumi[1]

[1] IFREE, JAMSTEC; [2] Graduate School of Environment and Information Sciences, Yokohama Nat. Univ.; [3] Geolo. Instit. Yokohama Natl. Univ.

The existence of 'Moho transition zone' in the oceanic crust-mantle boundary has been revealed by the results of Multi-Channel Seismic survey on oceanic region (eg. Kasahara et al., 2008). On the other hand, there is 'mantle-crust transition zone' in Oman Ophiolite, with variation of thickness (from meter to kilometer scale) and occurrence (eg. Uesugi et al., 2003). In order to evaluate the relationship between the 'Moho transition zone' and the 'mantle-crust transition zone', it is important to make a petrological structure model for the oceanic crust-mantle boundary based on elastic wave velocity measurement under high-temperature and high-pressure conditions for the rocks of the 'mantle-crust transition zone'. The experiments, however, should be performed under relatively high-pressure condition for understanding 'crack-free' elastic wave velocities of rock samples because microcracks remain within rock sample in low-pressure experiments and affect the velocity data. Therefore, we developed the system for elastic wave velocity measurement under oceanic lower crust - upper mantle condition (0.2-1.0GPa and 25-450 degree Celsius) with a piston-cylinder type high-pressure apparatus of 34 mm inner diameter in Yokohama National University.

Simultaneous P-wave velocity (Vp) and S-wave velocity (Vs) measurements were conducted with dual mode $LiNbO_3$ transducer. We monitored P- and S-wave travel times for tungsten rod which was mounted together with rock sample in cell assembly to know actual pressure of rock sample during experiments. The P- and S-wave travel times for tungsten rod showed liner relation with set pressure (0.2-1.0GPa) during our preliminary experiments.

We used gabbro sample collected from Wadi Bani Umar area in the Oman Ophiolite for experiment. The sample is homogeneous and isotopic rock consisting of plagioclase (#An=0.77-0.81, 58vol.%), clinopyroxene (#Mg=0.76-0.78, 23vol.%), orthopyroxene (#Mg=0.72-0.74, 8vol.%), olivine (#Mg=0.70-0.71, 8vol.%), serpentine (2vol.%) and magnetite (1vol.%). We measured elastic velocities at 0.05GPa intervals from 0.2GPa to 1.0GPa at room temperature during pressurization and subsequent depressurization. We also measured elastic velocities at 25 degree Celsius intervals from room temperature to 450 degree Celsius during heating and subsequent cooling at 1.0GPa and 0.6Gpa.

Vp and Vs increases rapidly from 0.2GPa to 0.4GPa, and gradually and linearly increased from 0.4GPa to 1.0GPa. This result is probably attributed to the closure of microcracks at high pressure. The measured Vp and Vs at 0.2GPa were 6.51km/s and 3.65km/s, respectively. To estimate 'crack free' elastic wave velocities, we extrapolated Vp and Vs values of high-pressure (0.6-1.0GPa) linearly to 0.2GPa, which resulted in 6.51km/s (Vp) and 3.65km/s (Vs). The estimated 'crack free' Vp and Vs were significantly higher than measured velocities. To estimate porosity during experiment, we calculated volumes of sample during experiments based on elastic constants obtained from experimental result. The calculated sample volume rapidly decrease with increasing pressure at low pressure and gradually and linearly decrease with increasing pressure at high-pressure. The linearly extrapolated sample volume at room pressure from high-pressure volumes was $1.798cm^3$, which is 2.49% smaller than the measured volume at room pressure ($1.802cm^3$). In the same way, we estimated that the sample at 0.2GPa contained 0.06vol.% of microcracks during experiment.

As we showed in this study, microcracks in rock sample strongly affect the elastic wave velocity data during experiment. We suggest that the high-pressure experiment with a piston-cylinder type apparatus is an effective to reveal 'crack-free' velocities of rock samples.