Dependencies of pore pressure and fracture distribution on elastic wave velocities for thermally cracked rocks : Implications for high Vp/Vs zone related to slow slip events along plate boundary

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Seismic studies have found that there are high Vp/Vs ratio regions in oceanic crusts at subducting oceanic plates (e.g., Cascadia (2.0-2.8) (Audet et al., 2009), Nankai trough (> 2.03) (Kodaira et al., 2004)), and the correlations between the location of high Vp/Vs and slow slip zone have been pointed out by several studies. Christensen (1984) indicated that high pore pressure may cause high Vp/Vs. It is also known that Vp/Vs also depends on porosity or pore structures (fracture distributions). However, the relationships between Vp/Vs, pore pressure, porosity and fracture distribution have no investigated in detail for rocks composing oceanic crusts.
This study reports the results of measurements of Vp and Vs (transmission method) at controlled confining and pore pressure and estimation of Vp/Vs ratio for thermally cracked dolerite and relation between Vp/Vs, pore pressure and fracture distributions. Confining pressure was constant (50 MPa) and pore pressure was decreased from 49 to 0.1 MPa and then increased to 49 MPa. We did measurement with an intact rock specimen (0.5% in porosity) and the rock specimens heated under 300, 500 and 700^{o}C for 24 hours (2.1%, 3.4% and 3.5% in porosity, respectively). Rock specimens heated under 500 and 700^{o}C were reddish in color, which suggested a possibility that not only cracking but also oxidizations of rock forming minerals might affect elastic velocities. Therefore, we operated elastic velocity measurements under atmospheric pressure with rock specimens heated under 500 and 700^{o}C at air (an oxygen concentration is around 21%) and at nitrogen conditions (an oxygen concentration is less than 0.5%), and revealed that the effect of oxidization on Vp/Vs is several times less than the effect of heating-temperature conditions.
In this experiments, for the intact rock specimen and specimen heated under 300^{o}C, Vp and Vs was almost constant at any pore pressure, and for specimen heated under 300^{o}C, Vp/Vs was 1.7 to 1.8, which is less than the high Vp/Vs ratio observed at oceanic crusts of subducting plates. On the other hand, for specimens thermally cracked under 500 and 700^{o}C, Vp/Vs increased as pore pressure was increased (effective pressure was decreased), and was more than 2 when pore pressure was over 40 MPa and 30 MPa, respectively. This results indicate that Vp/Vs is not over 2 unless porosity is larger enough (approximately 3% for the results in this study), even if pore pressure is higher.
We also observed fractures in the specimens by using a microscope, and measured fracture densities. The fracture densities for the specimens heated under 500 and 700^{o}C were larger than that of the intact rock specimen. There was no clear difference on the fracture density between the specimens heated under 500 and 700^{o}C, but microscope observations revealed that there was differences on fracture distributions such that fine net-like fracture distributions or networks of intra-mineral fractures were observed more for the specimen heated under 700^{o}C than that under 500^{o}C. These features on fracture distributions might affect elastic velocities. In general, high Vp/Vs near slow slip zones tends to be simply interpreted as high pore pressure, but it may also be influenced by porosity and features of fracture distributions.
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