Combined X-ray microtomography and elastic wave velocity measurements of porous material at in situ high pressures

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Elastic wave velocity is ubiquitously used as seismic probes in a variety of geologic settings including subduction zones, and it is an integral tool for seismologists to understand not only the mineral constituents but also the conditions, such as porosity, pore structure and permeability in the subduction zones. Therefore, an important but complicated question considers what information about the porosity, pore structure and permeability can be gleaned from seismic probes. There are many theoretical models for the effect of porosity and/or pore geometry on elastic wave velocity, but coupling this theoretical framework with directly measured pore structures has not been experimentally tested. The complexity of natural rock samples and the observations involving many parameters such as mineral constituents, volume fraction of the constituents, grain size, lattice orientation, etc. make it difficult to isolate the effect of pore structure on elastic wave velocity.

In this study, we introduce a new approach, which combines in situ high pressure experimental observations on elastic wave velocity and X-ray microtomography measurements with lattice-Boltzmann analysis to understand the connection between elastic wave velocity and structural properties such as porosity and permeability. Combined X-ray microtomography and elastic wave velocity measurements were carried out in a 250-ton press with a rotation anvil apparatus at beamline 13-BM-D (GSECARS) of the Advanced Photon Source, USA. Experiment was conducted on a simple analog material, porous aluminum, in a Paris-Edinburgh-type high-pressure cell at pressure conditions between 0.14 and 1.36 GPa. Porosity was observed to have a strong inverse dependence on pressure up to ˜0.9 GPa, while permeability has an anisotropic dependence on pressure. Elastic wave velocity and Poisson's ratio all increase with pressure, with P-wave velocity agreeing well with the Hashin–Shtrikman upper bound under high porosity conditions. These results demonstrate a new methodology combining experimental tools of X-ray microtomography and elastic wave velocity measurements and analytical method to provide cross-property links between microscopic structure and macroscopic elastic wave velocities. Future investigations on more complex rock samples may have important implications for our understanding of the nature of subduction zones.

Keywords: X-ray microtomography, elastic wave velocity, high pressure

