Influence of water saturation and pore structure in rocks on elastic wave velocities

*Takuya Horikawa[1], Ryosuke Umezawa[1], Makoto Katsura[1], Satoru Nakashima[1]

1. Department of Earth and Space Science, Graduate School of Science, Osaka University

It is widely known that velocities (V_P,V_S) and attenuation of elastic waves through a rock depend on the permeability and pore fluid. The most simplified method to examine the dependence is to change the water/air ratio of pore fluids (water saturation S_w). Various studies have reported viscoelastic effects of unsaturated rocks on V_P. However, the relationship between S_w and V_P has not been understood quantitatively. In this study, we have measured V_P (100 kHz - 700 kHz), V_S (100 kHz) and strain changes during evaporative drying of three Berea sandstones with different pore size distributions (porosity: 22.6, 19.1, 11.6 %; permeability: 170, 230, 5 mD; hereafter described as Berea A, Berea B, Berea C, respectively).
The V_P values decrease between ca.0.2<S_w<1.0 with frequency dependences. The meniscus size at a specific water saturation can be estimated from pores size distribution data by applying the capillary flow concept. The permeability as a function of S_w is calculated by the modified Katz and Thompson model (Nishiyama and Yokoyama, 2014) under the assumption that the wave induced water flow in an unsaturated rock occurs through the water-filled pores. The obtained frequency dependent S_w-V_P relationships are discussed by taking into account of the permeability for two theoretical models describing the viscoelasticity of unsaturated rocks: Global flow model (Biot, 1956) and Patchy saturation model (White, 1975). The theoretical predictions from these extended models showed that the S_w-V_P relations could be understood quantitatively by combining the viscoelastic effects of these models. On the other hand, V_S increases drastically for S_w<c.a. 0.2 associated with the drying shrinkage observed by the strain change measurements.
These results suggest that the frequency dependence of S_w-V_P relationships could be interpreted by using the extended Global flow and Patchy saturation model considering the dependence of pore water distribution on water saturation S_w.

Keywords: Elastic wave velocities, Water saturation, Pore size distribution, Sandstone

