Influence of pore size distribution on elastic wave velocities during evaporative drying

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Elastic wave velocities (V_P,V_S) in porous rocks are known to be sensitive to the water saturation (S), the size and shape of pores, the distribution of fluids in pores, and the incident wave frequency. Various studies have tried to understand these dependences on the basis of Biot's theory (Biot, 1956). The method for accurately predicting the quantitative relationship between S and V_P, V_S for the entire range of S (from S = 1 (saturated) to S = 0 (dry)) still remains to be fully elucidated. In this study, we measured the changes of V_P and V_S during drying for two Berea sandstones (permeabilities: 300 mD, 20 mD; hereafter described as Berea300 and Berea20, respectively) and Shirahama sandstone (permeability: <0.6 mD). P-wave and S-wave frequencies used in the measurements were 200 kHz and 100 kHz, respectively. The measured pore size distributions (aperture radius) showed that the predominant pore radii were ~5-100 μm for Berea300, ~1-10 μm for Berea20, and less than 0.4 μm for Shirahama. The change of V_P with S for Berea300 can be classified into the following 4 stages: [(1) S=1→0.5: decrease of V_P; (2) S=0.5→0.3: increase of V_P; (3) S=0.3→0.1: decrease of V_P; (4) S=0.1→0: increase of V_P]. The change of V_S with S for Berea300 can be separated to 2 stages: [(1) S=1→0.15: gradual increase of V_S; (2) S=0.15→0: rapid increase of V_S]. For Berea20, the V_P change trend appeared to correspond to part of stage 1 plus the entire range of stages 2, 3, 4 observed in Berea300, and the V_S change trend was approximately equal to that in Berea300. For Sirahama, the V_p change trend seemed to be equivalent to the stages 3 and 4 in Berea300, whereas V_S decreased first and then increased, unlike in the case of Berea sandstones. When the drying proceeds, it is known that water is lost first in the larger pores, and later in the smaller ones (Nishiyama et al., 2012). Therefore, the size of pores containing water at a given S can be determined on the basis of the pore size distribution of each rock. By incorporating the information of pore size distribution and the frequency dependence of bulk modulus into previously reported models, we tried to precisely predict the change of V_P and V_S during drying.

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

