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Effect of soil texture on the propagation and attenuation of acoustic waves at saturated conditions

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The study of the propagation and dissipation of acoustic waves through a fluid-containing porous medium is crucial for the successful application of seismic methods to characterize subsurface hydrological properties. To gain a better understanding of changes in two important acoustic wave characteristics (speed and attenuation) due to the effect of soil texture and excitation frequency, a complex-valued dispersion relation obtained from the Biot theory of poroelasticity was solved numerically for eleven soil texture classes whose pore space is fully saturated by one of two very different fluids, air or water. Two modes of acoustic motion can be demonstrated to exist, the Biot fast and slow waves. Five lower excitation frequencies (100-500 Hz) were selected for numerical simulation, below which Darcy's law remains valid for describing fluid flow under wave perturbation.

Numerical results show that in the frequency range we examined, the predicted phase speed of the Biot fast wave takes the same value as the Biot reference speed. The variation in speed is not obvious in a water-filled system, but becomes more significant in an air-filled system. When the pore fluid is water, an inverse linear relation exists between the phase speed of the Biot fast wave and porosity. An important physical parameter controlling its attenuation coefficient is intrinsic permeability, which renders a positive impact. A statistical analysis indicates that the attenuation coefficient of the Biot slow wave linearly increases with an increase in intrinsic permeability. In an air-saturated system, the phase speed of the Biot slow wave is found to be quadratically proportional to intrinsic permeability, whereas the attenuation coefficient of the

Biot slow wave bears a quadratic relation with the inverse of intrinsic permeability. A study on the influence of pore fluid reveals that the Biot fast wave attenuates more in the water-saturated system than in the air-saturated system; an exception occurs in clay. A reverse trend is observed for the Biot slow wave.

As far as the effect of excitation frequency is concerned, the attenuation coefficient of the Biot fast wave is essentially proportional to the square of excitation frequency, whereas the phase speed and attenuation coefficient of the Biot slow wave are both proportional to the square root of excitation frequency. The phase speed of the Biot fast wave is frequency independent.