



Contribution ID: 697

Type: Oral 20 Minutes

Gassmann Equation for Nanoporous Media

Wednesday, 16 May 2018 10:26 (15 minutes)

Recent progress in extraction of unconventional hydrocarbon resources, in particular shale gas, has ignited the interest in the studies of fluid-saturated nanoporous media. Since many thermodynamic and mechanical properties of nanoscale solids and fluids differ from the analogous bulk materials, it is not obvious whether wave propagation in nanoporous media can be described using the same framework as in macroporous one. Prior to approaching media as complex as shales, it is necessary to get a thorough understanding of wave propagation in simpler nanoporous media, e.g. a widely studied Vycor glass.

Here we test the validity of classical Gassmann theory of wave propagations in saturated media [1]. We consider the literature data on longitudinal and shear ultrasonic velocities in nanoporous Vycor glass as a function of pressure of n-hexane and argon vapors respectively [2,3]. The quantitative testing of the Gassmann theory on Vycor glass requires the knowledge of the bulk modulus of the solid nonporous glass K_S , which is impossible to measure directly. We propose to estimate K_S from the so-called pore-load modulus obtained from measurements of the adsorption-induced deformation [4]. Furthermore, comparison of this estimate with the estimates from the elastic effective medium theory gives a recipe for estimating K_S when adsorption-induced deformation data are not available. The fluid modulus can be calculated according to Tait-Murnaghan equation at the solvation pressure in the pore [5]. Substitution of these parameters into Gassmann equation provides predictions consistent with measured data. Our findings set up a theoretical framework for investigation of fluid-saturated nanoporous media using ultrasound [6].

References

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Session Classification: Parallel 6-E

Track Classification: MS 1.12: Fluids in Nanoporous Media