Contact Stiffness in Gas-Bearing Shales Estimated from Velocity Measurements Under Pressure

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Abstract

Pore pressure has a direct influence on gas production from shale gas reservoirs. Based on the relation between pressure and seismic velocity in shale, many methods have been used to estimate pore pressure. The detailed mechanisms underlying pressure-velocity relation still remain to be understood. Grain contact models such as Hertz-Mindlin model and modified Digby model have been used to understand velocity variation with pressure in dry rocks. Winkler (1983) proposed a method to estimate the contact stiffness ratio directly from velocity measurement and compared the estimated ratio to the theoretical calculation from modified Digby model. Using velocity measurements under pressure in unconsolidated glass beads with a porosity of 38% and Berea sandstone with a porosity of 16%, he concluded that the contact stiffness ratio is insensitive to pressure but the estimated contact stiffness ratio from measurement is much higher than the theoretical calculation. We estimated the contact stiffness ratio from velocity measurements under pressure for 73 samples from gas-bearing shale reservoirs in Sichuan basin, China. The main mineral content of the shale samples is clay, quartz and calcite. The clay content ranges from 16% to 66%, quartz content ranges from 2% to 71% and calcite content ranges from 1% to 73%. Porosity varies from 1% to about 20%. Results show that both Vp/Vs ratio and contact stiffness ratio for a given sample are nearly constant even though Vp and Vs increase with pressure individually, confirming Winkler's results on unconsolidated glass beads and consolidated sandstone rock. For all the studied samples, Vp/Vs ratio varies from 1.5 to 1.9, depending on mineralogy composition. And contact stiffness ratio varies in general from 3 to 40. Similar to Winkler's

observation, the theoretical calculated contact stiffness ratio using the velocity-contact stiffness relations from the modified Digby model severely underestimated the value from velocity measurements. Based on the modified Digby model, the Vp/Vs ratio is limited to the range from 1.15 to 1.73. However, for some samples, the Vp/Vs ratio is greater than 1.73, resulting in negative estimated contact stiffness ratio which is unrealistic. Although Digby model gives reasonable estimation for the majority of studied samples, it needs to be improved for real practical application to estimate pore pressure from seismic velocity.

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