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Simplified and Constrained Gassmann's Equations

Gassmann's (1951) equations are predominant in the analysis of direct hydrocarbon indicators (DHI) such as amplitude 'bright spots', amplitude versus offset (AVO) as well as for time-lapse reservoir monitoring. These equations are commonly used to predict velocity changes resulting from different pore fluid saturations. However, the input parameters are often crudely estimated and the resulting estimates of fluid effects can be unrealistic. In rocks, parameters such as porosity, density, and velocity are not independent and values must be kept consistent. Misaligned depths or incorrect fluid saturations can cause substantial errors. We reformulate the relations in terms of a porosity-dependent normalized modulus Kn, and the fluid sensitivity in terms of a gain function G. More important, the simplified Gassmann's relations provide better physical insight into the significance of each parameter.

General Voigt-Reuss bounds and critical porosity limits constrain the Gassmann's equations and provide upper and lower bounds of the fluid saturation effect on bulk modulus. Empirical porosity-velocity trends add further constrains as well as simplifying applicable forms. The estimated moduli remain physical, calculations are more stable, and the results are more realistic.