Geophysical Research Abstracts,
Vol. 11, EGU2009-3862-1, 2009
EGU General Assembly 2009

Experimental verification of the physical nature of velocity-stress relationship for sandstones and shales

M. Pervukhina (1), B. Gurevich (2), D. N. Dewhurst (3), and A. F. Siggins (4)

(1) CSIRO Petroleum, Kensington, Australia (Marina.Pervukhina@csiro.au), (2) Department of Exploration Geophysics, Curtin University of Technology, and CSIRO Petroleum, Australia (B.Gurevich@curtin.edu.au), (3) CSIRO Petroleum, Kensington, Australia (David.Dewhurst@csiro.au), (4) CSIRO Petroleum, Clayton, Australia (Tony.Siggins@csiro.au)

Knowledge of stress dependency of elastic properties of rocks is important for a variety of geophysical applications ranging from pore pressure prediction in sedimentary crust and seismic monitoring of hydrocarbon production to constraining material properties in the mantle. It has been shown by many authors that stress dependency of compressional and shear velocity in many porous rocks can be well approximated by a combination of linear and exponential term. Recently, it was suggested Shapiro (2003) that such form may be explained by dual distribution of porosity (so-called stiff and soft porosity). The author obtained that change of pore microstructure due to the exponential decay of soft porosity is responsible for stress dependency of elastic moduli up to the stresses of about 100MPa and that isotropic elastic compressibility decreases exponentially with effective stress with the same exponent as soft porosity. However, this stress sensitivity theory is not widely accepted due to the lack of the experimental verifications. In this study simultaneous measurements of ultrasonic velocity and porosity for a suite of seven sandstone and ten shale samples in a high fidelity pressure cell are used to validate the theoretical predictions. It is shown that elastic compressibility vs. soft porosity correlations can with a good accuracy be approximated with a linear tread that imply that the closure of pores with similar compliances causes variation of elastic properties at the range of effective stresses up to 100MPa. The experimentally measured elastic compressibility or anisotropic compliances and soft porosity are approximated by exponential functions using a nonlinear fitting based on the Levenberg-Marquardt algorithm and show the same exponents. For sandstones, soft porosities predicted from the variations of elastic compressibility with stress are in a good agreement but slightly higher than the measured values. This fact can be explained with the difference between the static and dynamic elastic moduli which is not taken into account in Shapiro's theory. For shales an anisotropic extension of the stress sensitivity theory derived by Shapiro and Kaselow (2005) is used. Predicted soft porosities strongly underestimate measured ones in the case of shales and show that the approach should be modified. We have suggested estimating the soft porosity from the fitting coefficients of the approximation of the stress dependency of Gassmann estimated dry bulk moduli of shales. The dry moduli of shales imply that stiff pores are dry, while soft pores within clay are still filled with capillary and bound water. The soft porosity estimated from the fitting of the dry bulk moduli of shales is of the same order of magnitude, but somewhat lower, than measured. One of possible explanations of this small discrepancy is that we used the porosity estimated from isotropic bulk moduli while the shales are essentially anisotropic. Hence, Brown and Korringa anisotropic relations should be used instead of isotropic Gassmann relations to estimate elastic properties from saturated ones. Alternatively, this may be explained by the lack of pressure relaxation within the pore space at ultrasonic frequencies, especially at low effective stress.

References

Shapiro, S.A. (2003) Elastic piezosensitivity of porous and fractured rocks, Geophysics, 68(2), pp. 482–486.

Shapiro, S.A. and Kaselow, A. (2005) Porosity and elastic anisotropy of rocks under tectonic stress and pore-pressure changes, Geophysics, 70(5), pp. 27–38.