Geophysical Research Abstracts,
Vol. 11, EGU2009-3893, 2009
EGU General Assembly 2009

Direct laboratory observation of fluid distribution and its influence on acoustic properties of patchy saturated rocks

M. Lebedev (1), B. Clennell (2), M. Pervukhina (2), V. Shulakova (2), T. Mueller (2), B. Gurevich (1,2)
(1) Curtin University of Technology, Perth, Australia (m.lebedev@curtin.edu.au), (2) CSIRO-Petroleum, Perth, Australia

Porous rocks in hydrocarbon reservoirs are often saturated with a mixture of two or more fluids. Interpretation of exploration seismograms requires understanding of the relationship between distribution of the fluids patches and acoustic properties of rocks. The sizes of patches as well as their distribution affect significantly the seismic response. If the size of the fluid patch is smaller than the diffusion wavelength then pressure equilibration is achieved and the bulk modulus of the rock saturated with a mixture is defined by the Gassmann equations (Gassmann, 1951) with the saturation-weighted average of the fluid bulk modulus given by Wood's law (Wood, 1955, Mavko et al., 1998). If the fluid patch size is much larger than the diffusion wavelength then there is no pressure communication between different patches. In this case, fluid-flow effects can be neglected and the overall rock may be considered equivalent to an elastic composite material consisting of homogeneous parts whose properties are given by Gassmann theory with Hill's equation for the bulk modulus (Hill, 1963, Mavko et al., 1998). At intermediate values of fluid saturation the velocity-saturation relationship is significantly affected by the fluid patch distribution. In order to get an improved understanding of factors influencing the patch distribution and the resulting seismic wave response we performed simultaneous measurements of P-wave velocities and rock sample CT imaging. The CT imaging allows us to map the fluid distribution inside rock sample during saturation (water imbibition). We compare the experimental results with theoretical predictions.

In this paper we will present results of simultaneous measurements of longitudinal wave velocities and imaging mapping of fluid distribution inside rock sample during sample saturation. We will report results of two kinds of experiments: "dynamic" and "quasi static" saturation. In both experiments Casino Cores Otway Basin sandstone, Australia core samples (38 mm in diameter, approximately 60 mm long) were dried in oven under reduced pressure. In dynamic saturation experiments, samples were jacketed in the experimental cell, made from transparent for X-radiation material (PMMA). Distillate water was injected into the sample from the one side. Fluid distribution in such "dynamic" experiment: both spatial and time dependant was measured using X-ray Computer Tomograph (CT) with resolution 0.2 x 0.2 x 1 mm3. Velocities (Vp, and Vs) at ultrasonic frequency of 1 MHz, were measured in the direction perpendicular to initial direction of the fluid flow injection. Sample saturation was estimated from the CT results. In "quasi static" experiments samples were saturated during long period of time (over 2 weeks) to achieve uniform distribution of liquid inside the sample. Saturation was determined by measurement of the weight of water fraction. All experiments were performed at laboratory environments at temperature 25 C.

Ultrasonic velocities and fluid saturations were measured simultaneously during water injection into sandstone core samples. The experimental results obtained on low-permeability samples show that at low saturation values the velocity-saturation dependence can be described by the Gassmann-Wood relationship. However, with increasing saturation a sharp increase of P-wave velocity is observed, eventually approaching the Gassmann-Hill relationship. We connect the characteristics of the transition behavior of the velocity-saturation relationships to the increasing size of the patches inside the rock sample. In particular, we show that for relatively large fluid injection rate this transition occurs at smaller degrees of saturation as compared with high injection rate. We model the experimental data using the so-called White model (Toms 2007) that assumes fluid patch distribution as a periodic assemblage of concentric spheres. We can observe reasonable agreement between experimental results and theoretical predictions of White's model. The results illustrate the non-unique relationships between saturation and velocity in sandstones dependent on texture and fluid displacement history: fuller understanding of these phenomena is needed for accurate assessment of time lapse seismic measurements, be they for oil and gas recovery or for CO2 disposal purposes.

Gassmann, F., 1951, Elastic waves through a packing of spheres. Geophysics 16, 673-685;

Mavko, G., T. Mukerji, and J. Dvorkin, 1998, The Rock Physics Handbook: Tools for seismic analysis in porous media: Cambridge University Press.

Wood, A. W., 1955, A Textbook of Sound, The MacMillan Co., New York, 360 pp.

Hill, R., 1963, Elastic properties of reinforced solids: some theoretical principles. J. Mech. Phys. Solids, 11, 357-372.

Hill, R., 1952, The elastic behavior of crystalline aggregates. Proc. Physical Soc., London, A65, 349-354.

J. Toms, T.M. Mueller, B. Gurevich, 2007 Seismic attenuation in porous rocks with random patchy saturation. Geophysical Prospecting, 55, 671–678.