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Development of laboratory-rock physics relations to estimate velocity-amplitude of seismic waves in reservoir conditions

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Extended Abstract

Summary

Water and Gas injection are two major enhanced oil recovery methods in Iran. Gas (e.g. CO_2) injection, is one of the most applicable methods of enhancing oil recovery in oil fields. In order to study the behaviour of seismic attributes, the compatibility of the prediction made by Gassman theory and Greenberg-Castagna equations in the situation of CO_2 saturated environment is investigated using lab data. It should be noted that the mentioned equations are based on some assumptions that are not always represent the real situation, thus, some incompatibility is anticipated. Therefore, their predictions are liable to be incompatible with real world wave behaviour. In this research, CO_2 in dissolved phase is injected into pressurized sandstone samples in laboratory scale, and elastic waves are utilized in order to investigate the injection process. The variation of the propagation velocity of seismic waves and their amplitudes are studied versus variation of effective parameters e.g. confining pressure (close to reservoir pressure), pore pressure (close to reservoir pressure), transmission wave frequency, and CO_2 density and phase. We have also used the collected laboratory data for wave propagation at supercritical saturation state to investigate the compatibility of the prediction made by Gassman theory and Greenberg-Castagna equations. Based on the results of various laboratory experiments, we can conclude that some of the developed equations are useful for estimation of velocity and amplitude of seismic waves. Verifications confirm that compatibility of the developed equations with laboratory results are more than 90 percent, and thus, the developed equations can be preferred to other related popular equations.

Introduction

Rock physics has an effective role in the estimation of petrophysical and reservoir parameters e.g. porosity, permeability, rock type, saturation, pore pressure, and fracture density using seismic attributes. As a result, various seismic attributes such as velocity, frequency and phase are used in order to estimate the above-mentioned petrophysical and reservoir parameters (Dodds et al. 2007, Adam 2006, Ruiping et al. 2006, Avseth 2005, Gray et al. 2002). In recent decades, various empirical relations are also developed for this purpose (pennebake 1968, Eaton 1972, Reynolds 1970, Domenico 1977, Castagna et al. 1985, Greenberg and Castagna 1992, Castagna et al. 1993, Krzikalla and Muller 2007, Toms et al. 2007, Lebedev et al. 2009, Han et al. 2010, Han et al. 2014, Liu et al. 2010, Eftekharifar and Han 2011). Gassman theory and Greenberg-Castagna equations are widely utilized as basic rock physics equations in world oil fields. However, these equations are based on some unreal hypotheses which cause their results to be not fully compatible with real situations, for example these hypotheses do not consider the distribution of fluids, and also, do not pay attention to the real situation of the rock and fluids; e.g. pore size, pore shape, fracture density, fracture aperture, heterogeneity, the fabric of matrix, pore pressure, confining pressure, fluid type, saturation, fluid distribution, viscosity, compressibility index, etc. Therefore, these equations need reform, especially when rock type, fluid type and reservoir situation varies. In this paper, based on laboratory experiments, some empirical rock physics equations are developed that are more compatible with reservoir conditions, and present a new approach for estimation of velocity and amplitude of seismic waves.

Methodology and Approaches

In this research, a core holder has been designed in which measuring and controlling the confining, radial, axial and pore pressures have been feasible. Two transducers are put around the caps of core holder, in order to send and receive seismic waves. Transducers are in contact with plugs. The studied plugs having various grain sizes are taken from Berea sandstone formation in southwest of Australia. Three different CO_2 densities or concentrations are injected and dissolved into plugs saturated with distilled water. In the next stage, elastic waves having different frequencies are passed plugs under various pressure/density situations, and consequently, velocities of the waves are recorded. Based on these laboratory experiments, some equations are developed using multi-regression method that are more compatible with reservoir conditions

Results and Conclusions

In this paper, some novel equations, based on laboratory experiments, have been developed that not only are accurate but also are generalized. These equations or relations present a new approach in estimation of the velocity and amplitude of seismic waves. Based on the results, the authors of this paper prefer to give some practical recommendations as follow:

- All laboratory tests have been carried out in room temperature, and thus, the authors suggest that a similar research to be repeated in the reservoir temperature, and new equations to be developed.
- In the current research, just two seismic attributes (velocity and amplitude) are studied. The authors suggest that other seismic attributes are also investigated in future studies.
- The majority of Iranian oil fields are carbonate reservoirs while this research has been carried out on sandstone. Thus, the authors suggest that similar studies have been carried out on carbonate plugs.
- Repeating laboratory tests with reflected waves will help to approach more real results.
- In all laboratory tests, the authors have investigated the effect of pressure growth on the tests. It will be useful that other researchers investigate the effect of pressure drop on the results.