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A combined geophysical, hydraulic and mechanical approach to study confining and pore pressure effects in sandstones

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Introduction

Mechanical and transport properties of rocks are pressure dependent and variably affected by the confining and pore pressures (Berryman, 1992). The concept of effective stress, which determines the stress state of the rock (based on the combined effects of pore and confining pressures) is central to the analysis of pressure-dependence of physical properties of rocks (Gurevich, 2004). Previous works show that different properties exhibit different stress-dependence (Berryman 1992, Gurevich 2004). Pressure-dependence of velocities has been widely studied, while our understanding of such pressure effects on other physical properties of rocks remains limited.

The aim of this work is twofold: i) we present an experimental work to analyse the pressure-dependence of physical properties of rocks, using a combined geophysical, hydraulic and mechanical approach; ii) we conduct the experiments on real and synthetic sandstones of similar composition and porosity to compare trends because synthetic rocks might be preferred in some rock physics experiments due to various reasons, and it is desirable to see how they compare to real rocks.

Methods

The tests were carried out using the experimental rig described in Falcon-Suarez et al. (2016). The rig is designed around a triaxial cell which allows confining (σ_c) and pore pressures (P_p) up to 65 MPa (two dual ISCO DX-100 pumping controllers), and allows simultaneous measurements of geophysical and hydromechanical parameters of rock samples during flooding. Four sandstones samples of ~2 cm length, 5 cm diameter with porosities between 22 and 27%, were selected for this experiment. The samples were subjected to a loading/unloading (hydrostatic) stress-path within the differential pressure ($P_{diff} = \sigma_c - P_p$) range 10-40 MPa. The path combines alternate variations of P_p while keeping P_{diff} constant, and variations in P_{diff} while keeping P_p constant (Figure 1). After pressure stabilization at the end of each step, electrical resistivity, P and S-wave velocities (V_p, V_s) and their respective inverse quality factors (Q_p^{-1}, Q_s^{-1}) were measured. Also, permeability (k), axial (ε_a) and radial strains (ε_r), and the computed volumetric strain ($\varepsilon_v = \varepsilon_a + 2\varepsilon_r$) were measured continuously during the tests.

Results

Figure 1 shows preliminary results of measurements on a synthetic sandstone sample. V_p, V_s and resistivity increase with increasing pressure, and the opposite is seen for Q_p^{-1}, Q_s^{-1}, strains (and related changes in porosity) and permeability.

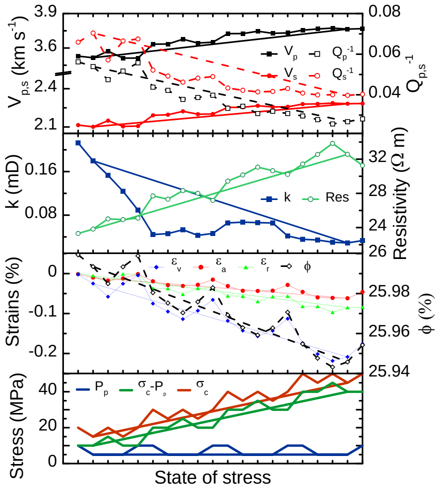

***Figure 1**. Measurements of hydraulic, mechanical and geophysical properties of synthetic sandstone*

Discussion and conclusions

The trends observed in this sample are as expected, but varying the stress-dependences of the different properties (Figure 1). Preliminary results from the other samples show evidences of different trends for the same properties from natural to synthetic sandstones. Overall, our comprehensive dataset will be developed and presented in more detail at the workshop, aiming at further analysing the effect of effective stress on the physical, mechanical, elastic and hydraulic properties of rocks, crucial for remote characterisation of pressure and saturation changes in reservoirs.

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