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Stress dependant permeabilities of sandstones: anisotropic response and end effects

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This study focuses on the forecast of the changes of porosity and permeability of reservoir rocks submitted to anisotropic stress conditions representative of the field conditions. The significant deformations that reservoirs undergo during fluid pressure changes not only affect well performance through well integrity and near-wellbore flow changes, but often through widespread changes in the flow properties of the reservoir. A better understanding of the reservoir response to production requires the identification of the physical phenomena directly responsible for the production and recovery rates. Mechanical effects are of great importance during reservoir exploitation because the stresses variations induce sensible changes of the transport properties. In most cases, the production is function essentially of the horizontal permeability . In order to predict its evolution, we need not only to perform flow experiments on rock samples with stress conditions representative of an anisotropic stresses field, but we also need to perform the flow experiments with the correct geometry. Therefore, it is important to measure the permeability in at least two directions, along and transverse to the principal direction of stresses.

While classical permeability measurements are performed in the direction of the principal stress axis, the triaxial cell designed at IFP, not only allows the measurement of permeabilities in three orthogonal directions, but also allows to get rid off piston end effects. Since complex geometrical conditions are involved in our flow set-up, Darcy's law cannot be used directly , and numerical tools are needed to interpret the experimental data. The determination of the permeability (for isotropic microstructure) or the permeability tensor (for anisotropic microstructure) require numerical inversions using Finite Element Simulations. With our directional permeability triaxial apparatus, we applied different stress paths (hydrostatic and deviatoric stress conditions) to two sandstones samples, having very different microstructures. The low permeabil-

ity Fontainebleau sandstone presents a pore structure made principally of permeable intergranular slits and the high permeability Bentheimer sandstone presents a more classical pore structure with a narrow pores sizes distribution. We performed a detailed microstructural analysis of these two sandstones using Mercury Porosimetry, Nuclear Magnetic Resonance and Microtomography Imaging. From the microscanner images we were able to reconstruct the pores networks and to determine both pores sizes distributions and throats sizes distributions. Using this poral skeleton, we performed a pore network modelling in order to calculate the absolute permeability tensors of the two rock samples. We compare these results to the experimental measurements of directional permeabilities.

Through this work, we show that directional permeability measurements are of great importance and should be incorporated in experimental transport studies. We also show that traditional permeability measurement set-ups induce serious experimental errors resulting in an under-estimation of the permeability due to both flow perturbation in the piston neighbourhood and mechanical effects at the interface rock/piston.