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Investigation of permeability anisotropy evolution of stressed reservoir

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Oil field production induces a pore pressure decrease, hence modifying the effective stress state at the reservoir scale. To optimize production and recovery rates of reservoir rocks it is of fundamental interest to understand the physical and mechanical evolutions of the host-rock and their influence on fluid transport properties. Because of reservoir boundaries conditions, the fluid pressure drop influences essentially the vertical stress. In the most cases, the recovery rate is a function of horizontal permeability, which may be influenced mostly by changes of vertical stress magnitude. In order to understand how deviatoric stresses may influence transport properties, 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 a representative geometry. Therefore, it is relevant to measure the permeability in at least two directions, along and transverse to the principal direction of stresses. For this purpose we have used a specifically designed triaxial cell operating at conditions representative of reservoirs rocks and allowing for simultaneous measurements of deformation, porosity and directional permeability evolution. Depending on rock type material, macroscopic mechanical data and stress path dependency of porosity and permeability have been recorded for pseudo elastic, brittle or compaction regimes.

We present the experimental results obtained on both low and high permeability sandstones and discuss two fundamental points. First, we show how the end effects occurring at the pistons and sample contacts affect the axial permeability evolution and second, we demonstrate the feasibility of directional permeability measurements during a single loading experiment and we present their interest to highlight the permeability anisotropies induced by large sample deformation.

Additional results have been obtained from moderately permeable carbonate rocks (Estaillades limestone), which may be described as a loose aggregate of denser carbonate clusters with two different porosities. Several compression experiments have been conducted in order to estimate the effects of the stress paths on the directional permeability evolutions. The microphysical and micromechanical phenomena linked to the evolution of the porous structure and the permeability have been identified by performing microstructural analyses of undeformed and deformed samples (post-mortem) combining Mercury porosimetry, scanning electron microscopy (SEM) and X-ray Computed Micro Tomography (CMT). On this rock we could clearly relate the most important permeability drops occurring in the compaction regime with the pore collapse mechanism.